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On the choice of reference database and calibration period of bias-corrected simulations: A case study for Hungary

Csilla SIMON[1], Csaba Zsolt TORMA[1] and Anna KIS[1]

Abstract

The aim of the present study is to investigate the accuracy of bias-adjusted regional climate model (RCM) simulations using various calibration periods, demonstrated for the region of Hungary. High-resolution (0.11°) RCM simulations of daily near-surface mean air temperature, daily minimum and maximum air temperature, and daily precipitation provided by the EURO-CORDEX community are analysed. The model ensemble consists of 5 RCM simulations driven by 4 different general circulation models for the historical time period 1976–2005. The publicly available, most accurate, measurement-based and quality-controlled HuClim is used as the reference dataset. The internationally widely used percentile-based quantile mapping method is applied for the bias-correction and it is performed on a monthly level. The novelty of the present study is that we used two different calibration periods to create bias-corrected datasets: an earlier and a more recent 30-year long period, and made these new datasets available in Zenodo. In addition to these HuClim-based bias-corrected databases, another database, containing bias-corrected RCM simulations and produced by the EURO-CORDEX community is also investigated. The assessment is carried out for the period 1993–2005, which is the overlapping time interval of the different calibration periods. According to our results, the accuracy of the bias-correction depends on the chosen calibration period and on the analysed climate index, and the choice of the validation period also affects the results. As next step, we plan to extend our research on projections under RCP4.5 and RCP8.5 scenarios.

Keywords: EURO-CORDEX, HuClim, bias-correction, calibration period, validation, Hungary

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Introduction

Climate models have become key tools for climate research, providing not only information on past and present climate, but also numerical estimates of climate change (IPCC, 2013). General Circulation Models (GCMs) operate at a coarser horizontal resolution (100–500 km), therefore, they are unable to resolve complex topographical features that vary at finer scales. Regional climate models (RCMs), in contrast, are applied only to a limited area with a higher (10–50 km) horizontal resolution, thus, representing extreme events with higher accuracy and providing added value, especially in regions with complex topography (Torma, Cs.Zs. *et al.* 2015, 2020; Di Luca, A. *et al.* 2016; Rummukainen, M. 2016; Fantini, A. *et al.* 2018; Ciarlo, J.M. *et al.* 2021).

However, it is important to keep in mind that GCM and RCM simulations are encumbered with uncertainties from a variety of sources (Giorgi, F. 2005), thus, using raw RCM simulations can lead to unrealistic results. These uncertainties can be quantified and reduced by using bias-adjusted datasets and by evaluating several RCMs together, as members of an ensemble (Beniston, M. *et al.* 2007).

[1] Department of Meteorology, Institute of Geography and Earth Sciences, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/A, H-1117 Budapest, Hungary. E-mails: csilluss58@student.elte.hu, csaba.zsolt.torma@ttk.elte.hu, kiaqagt@staff.elte.hu

The systematic bias of a climate model can be eliminated by post-processing the raw RCM data by applying a bias-correction method, which involves ensuring of equal mean values between the observation-based reference dataset and the bias-corrected climate model simulations (Déqué, M. *et al.* 2007). Previous studies have confirmed that bias-correction is required to improve the quality of RCM simulations (e.g. Ngai, S.T. *et al.* 2016; Jaiswal, R. *et al.* 2022) – it is particularly important, when RCM simulations are used for impact studies (e.g. wind energy generation: Costoya, X. *et al.* 2020; hydrology: Faghih, M. *et al.* 2022).

Several bias-correction methods have been developed to calibrate the raw RCM output against observations, and many studies have dealt with their comparison (Räty, O. *et al.* 2014; Casanueva, A. *et al.* 2020; Ji, X. *et al.* 2020; Mendez, M. *et al.* 2020). In addition to simpler approaches, including the delta method or linear scaling, there are also more complex methods that take into account the whole distribution of the meteorological variables (Themessi, M.J. *et al.* 2010). However, it is important to keep in mind that every method – even the best-estimated ones – has limitations since assumptions are made in all cases, such as the behaviour of the bias remains the same for the future with different climate conditions as it was in the past (Teutschbein, C. and Seibert, J. 2012; Van de Velde, J. *et al*. 2022). Moreover, a reliable, observation-based reference dataset of a good quality is required for a prosperous bias-correction (Casanueva, A. *et al.* 2020). The performance of the bias-correction method is sensitive to the choice of the length of the calibration period and at least a 30-year time period is recommended (Berg, P. *et al.* 2012; Reiter, P. *et al.* 2015; Ahn, K.H. *et al.* 2023).

This study focuses on the effect of the choice of calibration period on the bias-corrected RCM data. Our aim was to compare bias-adjusted databases produced by using the same method with different calibration periods, as well as using another bias-correction method with another calibration period and reference dataset (see *Appendix*, *Table A1*), and to investigate how the choice of different calibration periods affects the accuracy of the bias-correction. This is demonstrated by the validation of the different bias-corrected databases for the period 1993–2005. As far as we know, this latter aspect has never been analysed before with a special focus on the region of interest.

Data and method

Study area

Hungary, the region of interest, is located in East-Central Europe, between latitudes 45.7°–48.7°N and longitudes 15.9°–22.9°E *(Figure 1,* A*)*, surrounded by the Carpathians to the north and east, and by the Alps to the west. The Carpathians and the territory surrounded by the mountain range together form the Carpathian Basin, one of the largest basins in the world, covering an area of about 500,000 km^2, of which Hungary covers roughly 93,000 km^2. Although the Carpathian Basin has a complex topography (the elevation varies between 75 m and 2655 m), the orography of Hungary is less complex: the highest peak of the country, called Kékes, is located in the North Hungarian Mountains with an altitude of 1014 m, and the lowest point is situated in the Great Hungarian Plain (75 m a.s.l.). It is also important to note that two-thirds of the Hungarian territory lies below 200 m a.s.l. *(Figure 1,* B*)*.

The climate of the country is characterised by oceanic, continental and mediterranean effects – the features of the humid oceanic climate cause slightly varying temperatures; more extreme temperatures are the result of dry, continental air masses. The precipitation maximum occurs in May-June, and the driest season is winter. The influence of Mediterranean air masses is mainly manifested in the second precipitation maximum in autumn, which is mostly observed in the south-western part of Transdanubia (Mezősi, G. 2017). Although the Carpathians are outside of the borders of Hungary, its effect on

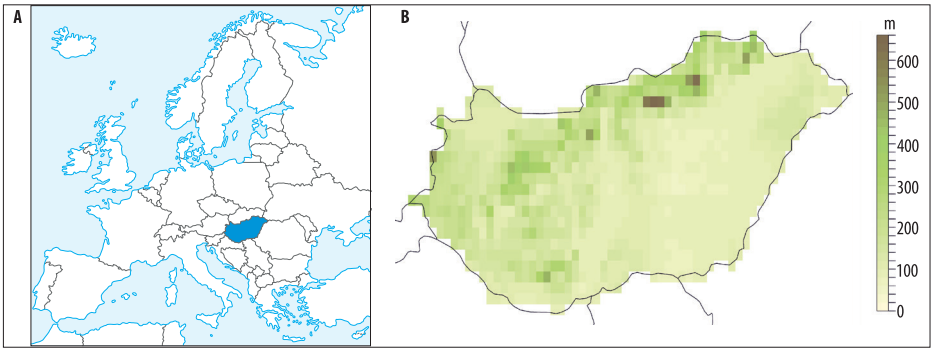


Fig. 1. The region of interest. A = Location of Hungary in Europe (filled with blue colour); B = The topography of Hungary on a 0.11° horizontal resolution. *Source*: Authors' own editing.

the climate of the country is not negligible – an important example is the blocking of cold air masses of Siberian origin (Spinoni, J. *et al.* 2014). Due to the various climatic effects, temperature and precipitation characteristics are investigated for Hungary on a yearly, seasonal and monthly scale.

Reference dataset

In this study, HuClim is used as a reference dataset for bias correction purposes and evaluation studies, which is produced by the HungaroMet Hungarian Meteorological Service and available on a daily basis and freely accessible via https://odp.met.hu/climate/. The data is available from 1971 and it is updated to the latest year (it is 2022 in the version used in the present study) for mean air temperature, maximum air temperature, minimum air temperature and precipitation. HuClim is a measurement-based dataset, which covers Hungary on a 0.1° × 0.1° horizontal grid and builds upon 500 precipitation and 112 temperature stations' data. Quality control is provided by the Multiple Analysis of Series for Homogenized Database (MASH) (Szentimrey, T. 2007) software, and the method of Meteorological Interpolation based on Surface Homogenized Database (MISH) (Szentimrey, T. and Bihari, Z. 2008) is used for gridding and interpolating the meteorological data. The importance of using HuClim data lies in the fact that this is the most accurate gridded, high-resolution, homogenized observational data currently available for the country: as it is well known that the quality of the reference database for bias adjustment is crucial (Casanueva, A. *et al.* 2020).

Model simulations and databases

Simulations of five RCMs driven by four different GCMs at a horizontal resolution of 0.11° are investigated in this study derived from the EURO-CORDEX framework (Jacob, D. *et al.* 2014). All historical simulations cover the period 1976–2005 and the projections were accomplished under the 4.5 and 8.5 Representative Concentration Pathways scenarios (RCP4.5 and RCP8.5, respectively) (Moss, R.H. *et al.* 2010). Details of the selected GCM-RCM combinations are listed in *Table 1.* During the selection procedure we focused on those RCM-GCM combinations, which were available for both RCP scenarios as well as for raw and bias-corrected versions. In addition, model performance was taken into account based on previous studies for East-Central Europe (Mezghani, A. *et al.* 2017; Torma, Cs.Zs. 2019; Lazic, I. *et al.* 2021; Simon, Cs. *et al.* 2023).

Table 1. Overview of the applied RCMs and their driving GCMs used in the present study

RCM	Driving GCM	Modelling group
CCLM4-8-17 (Rockel, B. *et al.* 2008)	MPI-ESM-LR (Jungclaus, J.H. *et al.* 2010)	Climate Limited-area Modelling Community, Germany
HIRHAM5 (Christensen, O.B. *et al.* 1998)	EC-EARTH (Hazeleger, W. *et al.* 2010)	Danish Meteorological Institute, Denmark
RACMO22E (Van Meijgaard, E. *et al.* 2012)	HadGEM2-ES (Collins, W.J. *et al.* 2011)	Royal Netherlands Meteorological Institute, The Netherlands
RCA4 (Kupiainen, M. *et al.* 2014)	CNRM-CM5 (Voldoire, A. *et al.* 2012)	Swedish Meteorological and Hydrological Institute, Rossby Centre, Sweden
REMO2009 (Jacob, D. *et al.* 2012)	MPI-ESM-LR (Jungclaus, J.H. *et al.* 2010)	Helmholtz-Zentrum Geesthacht, Climate Service Centre, Max Planck Institute for Meteorology, Germany

Four variables were used for this work: daily mean near-surface air temperature (*tas*), daily minimum near-surface air temperature (*tasmin*), daily maximum near-surface air temperature (*tasmax*), and daily precipitation (pr). Bias-adjusted model output from the EURO-CORDEX program was produced by using the MESAN reanalysis data (Häggmark, L. *et al.* 2000) for the time period 1989–2010, and a distribution scaling method (Yang, W. *et al.* 2010) was implemented for bias-correcting the RCM simulations. MESAN is an operational mesoscale analysis system developed by the Swedish Meteorological and Hydrological Institute (SMHI). The system is designed to provide high-resolution (about 11 km) analyses of meteorological variables, including precipitation and temperature. MESAN integrates various data sources such as weather radar observations, satellite data and ground-based measurements. Since climate model data and HuClim data are available on different horizontal resolutions, interpolation to a common 0.11° × 0.11° grid was performed using the CDO (Climate Data Operators; https://code.mpimet.mpg.de/projects/cdo/) software (Schulzweida, U. 2021) with a bilinear remapping method.

For the purpose of creating a new bias-corrected RCM dataset for Hungary based on the HuClim database – the use of which is not widespread, only a few studies (e.g. Kern, A. *et al.* 2024) applied it for this territory –, we have also corrected the raw EURO-CORDEX simulations (see details in section Bias correction method). This bias-adjusted RCM data produced by the use of HuClim are publicly available in the Zenodo repository (Simon, Cs. *et al.* 2024). Note that the bias-correction was implemented for the RCM simulations of the historical (1976–2005) and the scenario (2006–2099) periods, but in this study only the analysis of the historical simulations is considered.

Bias correction method

In order to correct the systematic bias present in raw RCM outputs, the internationally accepted, non-parametric, percentile-based quantile mapping method was applied, following the work of Mezghani, A. *et al.* (2017). This method is one of the most commonly used higher-skill bias-correction techniques in the climate research community (Teutschbein, C. and Seibert, J. 2013) which has been successfully applied in the East-Central European region (e.g. Torma, Cs.Zs. and Kis, A. 2022; Kern, A. *et al.* 2024). In general, the quantile mapping procedure matches the quantile-based distribution of the raw RCM simulations to that of the observed data. In the present study the bias-adjustment of the simulated time series was performed for each grid cell on the common 0.11° grid and the number of quantiles was set to 1000. In addition, the quantile mapping was performed for each month separately

with the aim of investigating the behaviour of the bias and the accuracy of the bias-correction on a finer timescale. The length and the quality of the reference dataset is also a key tool, because quantile mapping is considered to be sensitive to that (Fowler, H.J. and Kilsby, C.G. 2007). To perform the quantile mapping method, two different 30-year calibration periods were selected from the observation-based HuClim database: an earlier (1976–2005, BC-HUCLIM-1) and a more recent (1993–2022, BC-HUCLIM-2) 30-year long period with different climatic characteristics, thus, creating two different bias-adjusted databases.

Noting that using different calibration periods of the same length and the same bias adjustment procedure can highlight the effect of the choice of the calibration period. However, the most recent period has characteristics of a warmer climate relative to the earlier period, which can lead to differences in relative biases, when different datasets based on different calibration periods are investigated. HuClim was also used by Kern, A. *et al.* (2024) to construct the FORESEE-HUN v1.0 database, which contains bias-adjusted RCM projections for the period 2022–2100 for Hungary, and for which a longer calibration period (1971–2020) was chosen.

Selected climate indices

Beside the investigation of average temperature and precipitation values, a total of eight climate indices were also chosen and analysed over the region of interest. *Table A2* in *Appendix* contains the details about the set of these indices, which can be separated into two categories: (1) threshold-related indices: count the number of days when a given (precipitation or temperature) threshold is exceeded; namely, summer days (SU), frost days (FD), tropical nights (TR) and wet days (RR1); (2) extreme-related indices: i.e. the warmest day (TXx) and the coldest night (TNn) of a period, the maximum of daily precipitation amount (RX1day), and extremely wet days (R99p).

Results

In this section, the performance of the different bias-adjusted databases is investigated for the evaluation period 1993–2005, which is the overlapping time interval of the three different calibration periods (1976–2005; 1989–2010; 1993–2022) used for the bias-corrections, furthermore, it contains only historical model simulations. Different metrics were selected for the evaluation: firstly, the mean precipitation and temperature characteristics are analysed on different timescales, and then the chosen climate indices are investigated over Hungary.

Mean precipitation and temperature characteristics

First of all, relative bias was calculated as the difference relative to the climatological average (as defined e.g. in the work of Vogel, E. *et al.* 2023) of the precipitation in the reference period shown in the first column of *Figure 2*. Relative bias was obtained from average annual values over the evaluation period. In the case of precipitation, relative bias shows positive values in most of the area for the raw simulations, especially in the North Hungarian Mountains with a positive bias of 35–55 percent, whereas in the south-western part of the country a negative bias of 5–15 percent occurs. BC-MESAN shows lower relative bias in the northern area, but the negative values are more pronounced. In terms of the two HuClim-based bias-corrected datasets the relative bias is closer to zero in comparison to the above-mentioned cases, but for the BC-HUCLIM-1 a negative bias of 5–10 percent is dominant over the country, while BC-HUCLIM-2 shows the same amount of positive bias in most of the area. In summary, the warming of recent decades has also affected annual precipitation totals. For temperature (*tas*, *tasmin*, *tasmax*) absolute biases are shown (columns 2–4 of *Figure 2*), which were calculated as the difference between the simulated and the observation-based values. Absolute biases are small (around 0.5 °C) for BC-HUCLIM-1 and BC-HUCLIM-2, but with an opposite sign, which can be related to the different climatic

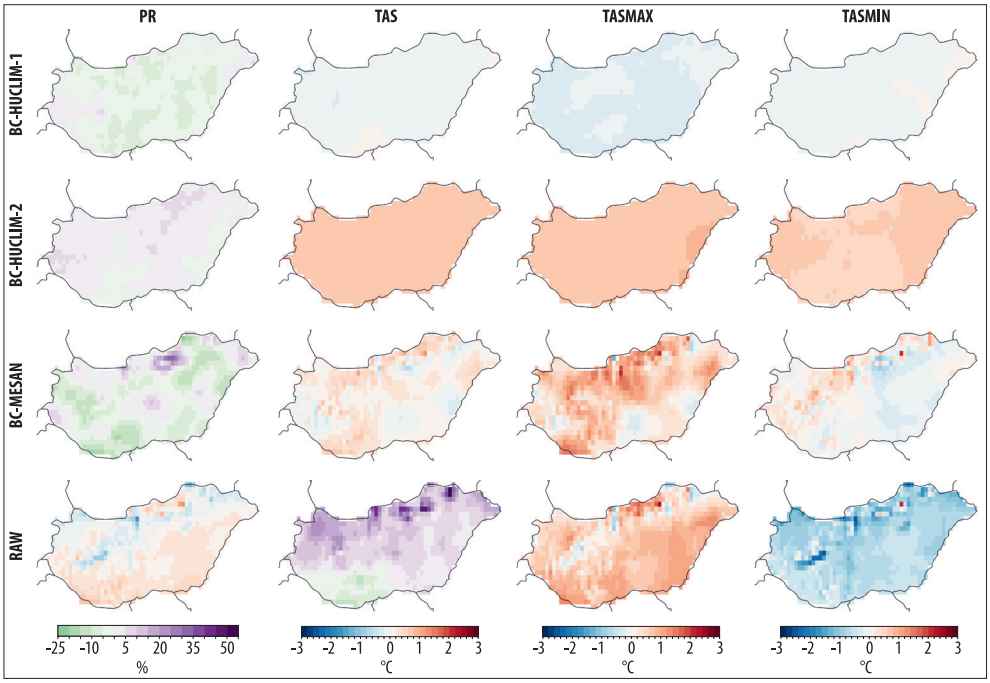


Fig. 2. Biases of the raw and bias-adjusted RCM simulations based on the multi-model ensemble mean for each variable and database for the period 1993–2005. *Source*: Authors' own editing.

conditions of the two calibration periods, i.e. while the database calibrated on the basis of a warmer climate shows an overestimation, the database bias corrected on the basis of a colder (earlier) period shows an underestimation. BC-MESAN is the most accurate for *tas* (±0.6 °C), but a relatively large bias appears in the case of *tasmin* (1–2 °C).

The performance of each RCM simulation was analysed by the difference of spatially averaged seasonal precipitation sum between the simulated values and HuClim, calculated and displayed for each database and expressed as a percentage *(Figure 3)*. The difference between the climate models is higher in all seasons for the raw simulations, while for the bias-corrected results, these differences are reduced. Most of the raw RCM simulations underestimate summer precipitation by 15–30 percent, whereas in the other seasons an overestimation by 5–30 percent is found. For the two HuClim-based bias-corrected datasets, the difference between the individual RCMs is proved to be the smallest in spring and autumn. RACMO22E was found to be the most accurate among the RCMs and the worst performing models are HIRHAM5 and CCLM4-8-17. Based on the multi-model average of the differences, the variation is negligible in autumn for BC-HUCLIM-2 (-0.3%), and BC-HUCLIM-1 shows the best performance (-4%) in the case of winter. However, for spring and summer the results most consistent with observations were found in the case of the BC-MESAN multi-model average (+4.5% and -3.9%, respectively).

The performance of the individual RCM simulations was also investigated for the temperature-related variables. The average seasonal temperature characteristics were calculated based on the RCM simulations and compared to HuClim, which served as reference

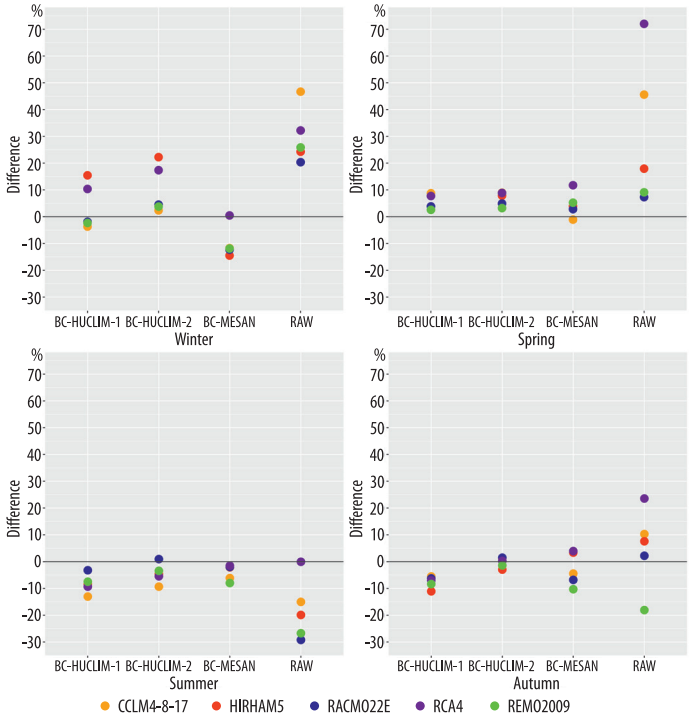


Fig. 3. The spatially averaged seasonal precipitation totals compared to HuClim for the period 1993–2005 displayed for the individual RCM simulations (indicated by different colours) and for the databases considered in this study. The differences are expressed as a percentage. *Source*: Authors' own editing.

(results can be seen in *Figure A1* in *Appendix*). The multi-model average and standard deviation of the variations have also been calculated and analysed. Similar to precipitation, raw RCM outputs show the largest standard deviation (between 0.6–2 °C), except for average summer *tasmin* (0.17 °C), which is comparable with BC-MESAN (0.15 °C). For BC-MESAN, the standard deviation is the smallest in autumn for all variables, and the most negligible for *tasmin* (0.08 °C), however, in the case of average seasonal *tas* and *tasmax*, the highest standard deviation values occur for all seasons in comparison with the other bias-corrected databases. The standard deviation is comparable for BC-HUCLIM-1 and BC-HUCLIM-2 and it ranges from 0.15 °C to 0.25 °C. Based on the multi-model average of the differences of the individual RCM simulations, BC-HUCLIM-2 shows the poorest performance characterised by a general overestimation. The best performance was found for BC-HUCLIM-1 in terms of average seasonal *tas* and *tasmin*, with an average difference of ±0.3 °C. For BC-MESAN a slight overestimation is more common for *tas* and *tasmax*. In the case of BC-HUCLIM-1 and BC-HUCLIM-2, CCLM4-8-17 was obtained to be the most accurate RCM simulation, and the performance of RCA4 was found to be the poorest in winter. For the other seasons, we cannot highlight any climate model as being the best one or an absolute outlier.

Finally, we evaluated the raw and bias-adjusted RCM data on a monthly basis. The annual cycle of the average monthly mean, minimum and maximum temperature and the average monthly precipitation sum over Hungary was investigated for the validation

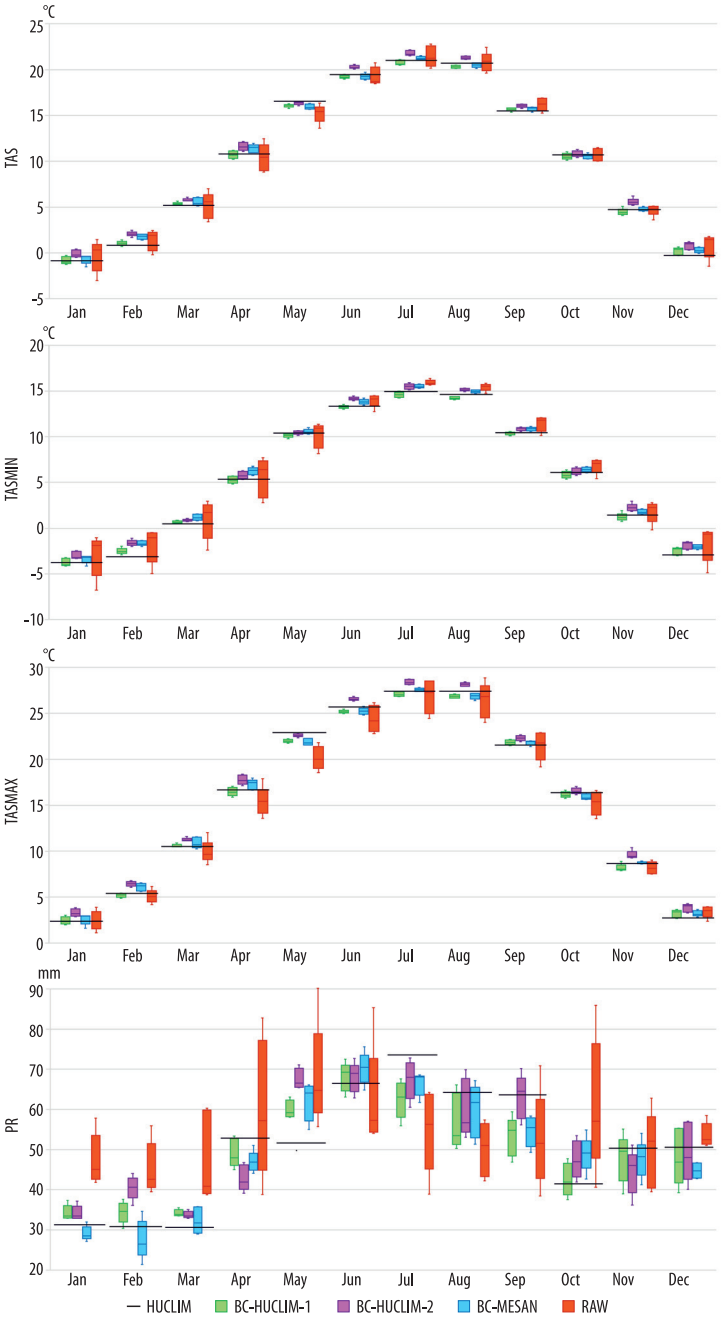


Fig. 4. The annual cycle of the average monthly temperatures (*tas, tasmin, tasmax*) and precipitation in Hungary during the period of 1993–2005 according to the raw and the different bias-adjusted RCM simulations (marked with different colours) in comparison with the measurement-based HuClim data (black horizontal lines). *Source*: Authors' own editing.

period according to the multi-model ensemble of the raw and the bias-corrected RCM simulations *(Figure 4).* In the one hand, for the temperature-related variables and for the raw RCM simulations, the spread of the models was found to be the largest (1.4–1.9 °C) in summer in the case of *tasmax*, but on the other hand, it was minimal (0.3–0.7 °C) for *tasmin*. The variance between the RCM simulations ranges between 0.6 °C and 1.7 °C for *tas*, with the greatest extent in winter and spring, and the smallest in autumn based on the raw data. The uncertainty was reduced by bias-adjustment regardless of the choice of the calibration period. The performance of BC-HUCLIM-1 was the best for temperature values in autumn and in the first part of spring (March and April), however, a general underestimation (with a median of 0.1–0.6 °C) can be observed in May and in the summer months (JJA).

In the case of BC-HUCLIM-2 an overestimation by 0.4–1.7 °C is dominant except for May and for October. BC-MESAN has the best performance in autumn and the poorest from February to April. For precipitation, a substantial overestimation (10–44 mm) was shown by the raw RCM simulations, espe-

cially in winter months, moreover, in May and October, when the uncertainty is the highest. A general underestimation of 9–35 mm was found for July, August and September based on the raw RCM simulations. After the bias-correction procedure, the variance between the RCM simulations decreased, and it was found to be the smallest in January and March in the two, HuClim-based bias-adjusted databases, but in some cases (in August and December) it remained comparable with the uncertainties of the raw simulations. The performance of the different bias-adjusted databases varies over the months: BC-HUCLIM-1 and BC-HUCLIM-2 show similar results in January, March, June, August and December, however, the boxes represent higher (lower) values for BC-HUCLIM-2 in comparison with BC-HUCLIM-1 in February, May, July, September and October (April and November). A clear overestimation (underestimation) appears in the case of May and October (July) regardless of the applied bias-correction and calibration periods.

Climate indices

This section presents the validation of the selected climate indices for Hungary. First, the spatial distribution of the annual number (amount) of threshold-based and extreme, temperature-related (precipitation-related) climate indices was investigated for the different datasets. *Figure 5* shows the results for summer days, tropical nights, frost days and wet days averaged over the period 1993–2005. The annual number of SU varies between 10–100 days over Hungary, with the minimum (10–25 days) in the mountainous areas. The highest occurrence (4–7 days per year) of the annual number of TR was observed at higher altitudes and on the southern slopes of the mountain ranges. This result can be explained by the presence of inversion stratification and as an effect of foehn wind, which occurs on the lee side of a mountain range (Brinkmann, W.A.R. 1971). The annual number of FD and its spatial distribution is also consistent with orography: over the highest peaks it reached 140–150 days, while in the southern part of Hungary it remained below 100 days per year. The annual frequency of RR1 is found to be relatively homogeneous across the country with 80–100 days.

Figure A2 in *Appendix* shows the spatial distribution of the bias fields with respect to the HuClim dataset. On the one hand, the ensemble mean of BC-HUCLIM-1 is in good agreement with the reference values for every threshold-based climate index apart from the underestimation of SU with 5–15 days in the Great Hungarian Plain and the slight underestimation of TR, especially in areas with higher altitudes. On the other hand, the average annual number of TR is overestimated by all databases except for BC-HUCLIM-1. In the case of SU, a general underestimation was found for BC-MESAN and a general overestimation appears based on BC-HUCLIM-2, especially in the south-eastern region of the target area. Raw simulations show 20–30 days overestimation for RR1 (mostly in the mountains), and the same extent of underestimation appears for FD compared to the reference values. These results are consistent with a warming trend in the region, i.e. the database calibrated to the most recent period gives an overestimation of the relevant indices compared to the earlier period.

Figure 6. compares the values of extreme-related climate indices and their spatial distribution over the period 1993–2005 based on the different databases investigated in this study. According to the reference data, the absolute minimum temperatures (around -28 °C) were detected in areas prone to frost, such as the north-eastern region and the northern valleys. Among the bias-corrected databases BC-HUCLIM-2 and BC-MESAN show relatively better agreement in terms of both spatial distribution and values. BC-HUCLIM-1 assumes lower temperatures over an extensive area. The highest temperatures (39–40 °C) occurred in the south-eastern part of the Great Hungarian Plain, while in the mountains TXx values of 30–32 °C were found. This index is best represented by BC-HUCLIM-1, however, BC-MESAN, as well as the raw simulations, overestimates TXx by 1–2 °C, mainly in the Great Hungarian Plain.

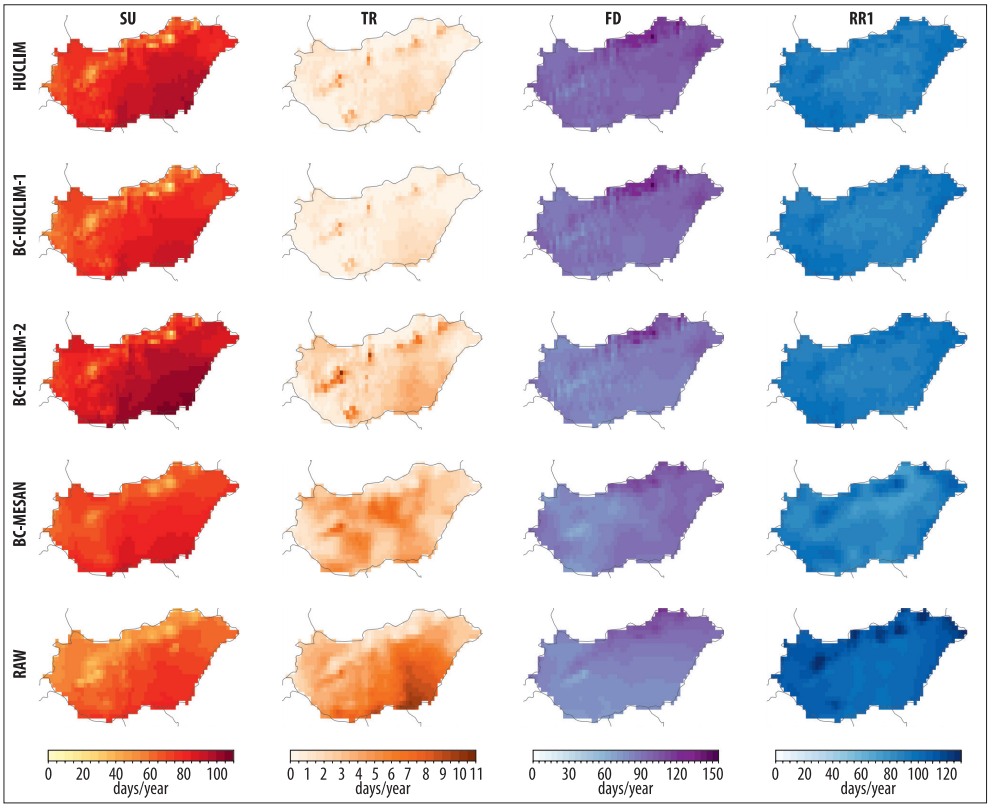


Fig. 5. Threshold-based climate indices (SU, TR, FD, RR1) over Hungary based on the multi-model averages of the different bias-corrected simulations (rows 2–4) and raw outputs (last row) in comparison with the HuClim reference data (first row) for the validation period of 1993–2005. *Source*: Authors' own editing.

Turning our attention to the extreme, precipitation-related climate indices, the highest daily precipitation sum (110–130 mm) was clearly related to Mátra mountain range, where Kékes is located. However, for R99p – which varies between 18–30 mm over Hungary –, the higher values were more prevalent in the south-western Transdanubian region and in the western border. These spatial patterns are well represented by BC-HUCLIM-1 and BC-HUCLIM-2, but according to BC-MESAN, a much more homogeneous spatial distribution appears for RX1day with a strong underestimation, especially in the mountains, where the values for this index are almost half as much as the reference. The spatial distribution of the bias fields with respect to the HuClim dataset is also shown in *Figure A3* in *Appendix*.

Normalized Taylor diagrams (Taylor, K.E. 2001) were also created in order to determine the degree of statistical similarity between the HuClim reference dataset and the various climate model simulations for each climate index. The closer a symbol is to this reference point (indicated by a black square), the better the performance of the related RCM simulation ensemble. *Figure 7* presents these statistical metrics for the average annual number of threshold-based climate indices for the target domain for the period 1993–2005. It can be

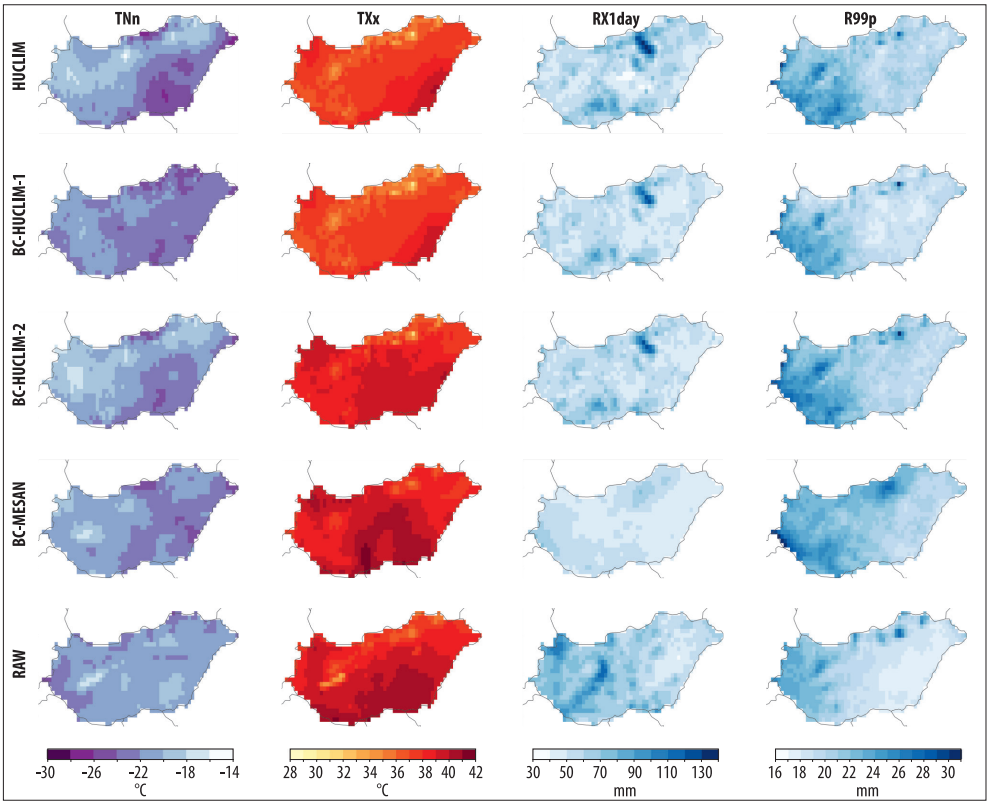


Fig. 6. The same as in *Figure 5*, but for extreme-related climate indices (TNn, TXx, RX1day, and R99p). *Source*: Authors' own editing.

seen that bias-correction based on HuClim data (regardless the calibration period) has obviously a positive effect, in addition, the two HuClim-based datasets provide similar statistical metrics, except for TR, where standard deviation values were found to be different – which means that BC-HUCLIM-2 exhibits larger spatial variability for tropical nights than BC-HUCLIM-1. These databases show the highest degree of similarity for SU and FD compared to the HuClim reference, for which the correlation coefficients are found to be above 0.99 and the RMSE values are minimal (< 1.2). It is interesting to see that the symbols of the multi-model ensemble of BC-MESAN and raw simulations are located on similar lines of correlation for each climate index.

Taylor diagrams for extreme-related climate indices for the period 1993–2005 can be seen in *Figure A4* in *Appendix*. In this case the effect of bias-adjustment using HuClim was also found to be favourable but less successful than for threshold-related indices. Similar statistical metrics were obtained for the HuClim-based databases in terms of extreme, precipitation-related climate indices, but more pronounced differences appeared for TNn and TXx. The degree of similarity regarding the spatial distribution of the lowest temperature was higher for BC-MESAN compared to BC-HUCLIM-1, however, BC-HUCLIM-1 showed the best performance in the case of TXx, for which the correlation coefficient is around 0.99 and the RMSE was found to be the smallest (0.15).

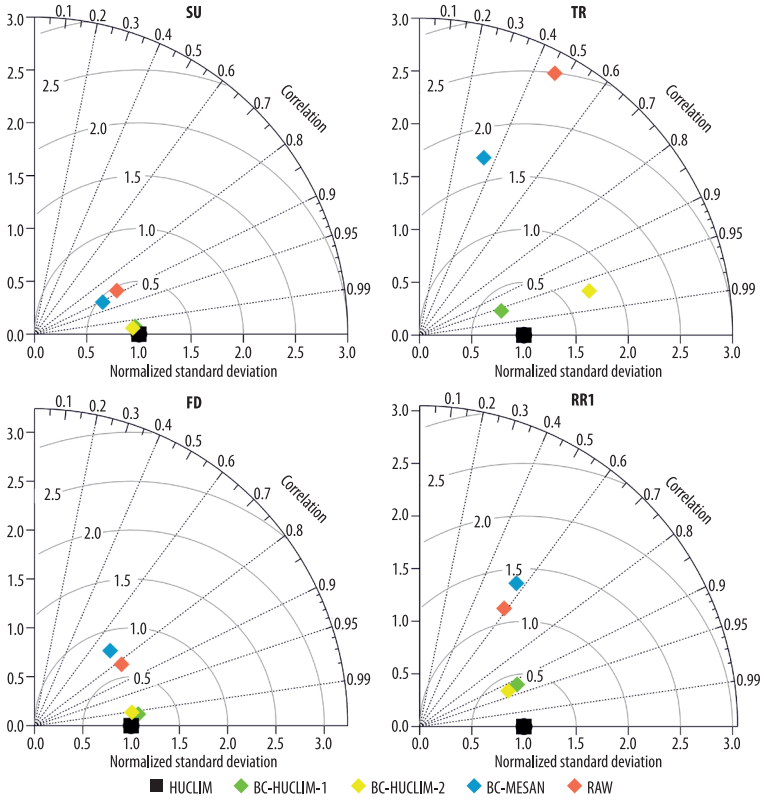


Fig. 7. Statistical characteristics summarized by Taylor diagrams for raw and bias-corrected multi-model data (coloured symbols) with respect to HuClim (black square) for the period 1993–2005. The four panels refer to the threshold based climate indices (SU, TR, FD, and RR1). *Source*: Authors' own editing.

Summary and final conclusions

The effect of the choice of the calibration period on the accuracy of the bias-correction was analysed in this study for Hungary, through the validation of three different bias-adjusted databases. Five RCMs were investigated from the framework of EURO-CORDEX at a horizontal resolution of 0.11° for the historical time period of 1976–2005 for four variables: daily mean temperature, minimum and maximum temperature, and precipitation. The percentile-based quantile mapping method was applied for the bias-correction, and was performed on a monthly scale. The observation-based HuClim dataset was used as a reference for the bias correction and the validation. Two, 30-year long time periods were selected from the HuClim database: 1976–2005 and 1993–2022, and as a result of the bias-correction, two different bias-adjusted databases were created based on these calibration periods. A third bias-adjusted database produced by the EURO-CORDEX community was also examined in this study. Two groups of climate indices were also assessed: (1) threshold-related climate indices: SU, TR, FD and RR1; (2) extreme-related climate indices: TXx, TNn, RX1day and R99p. The period 1993–2005 was selected as the

validation period, since it is the overlapping time interval of the three calibration periods and contains only historical simulations.

In the validation period, the relative bias of the mean annual precipitation was the closest to zero (5–10%) in the cases of the two, HuClim-based bias-corrected databases, but with the opposite sign. This sign of absolute bias also appears for mean annual temperatures, since BC-HUCLIM-1 (BC-HUCLIM-2) has a bias of around -0.5 °C (+0.5 °C) over Hungary. The average seasonal temperature characteristics are similarly well approximated by BC-HUCLIM-1 and BC-MESAN, but a general overestimation appears for BC-HUCLIM-2. For the annual cycle of the average monthly mean, minimum and maximum temperature, BC-HUCLIM-1 is the most accurate bias-adjusted database, especially in autumn and in the first part of spring (March and April), however, a slight underestimation (with a median of 0.1–0.6 °C) appears during the summer months (JJA). For precipitation, the performance of each database shows a large variability between seasons and months. Note that the variation between the individual RCM simulations is reduced for each bias-corrected database in comparison with the raw model simulations. The annual number of threshold-based climate indices was in good agreement with the reference values in the case of BC-HUCLIM-1. The spatial distribution of the precipitation-related climate indices (RR1, RX1day, R99p) are well represented by the HuClim-based bias-corrected datasets, however, an excessively homogeneous spatial distribution appears for RX1day with a strong underestimation according to BC-MESAN. In general, the choice of calibration period is clearly influenced by the ongoing climate change. That is, the database corrected for the warmer period overestimates the average temperature and precipitation patterns compared to an earlier (and cooler) period, while the thresholds for the cold period are underestimated.

As a final conclusion, it can be said that the performance of the bias-corrected RCM simulations clearly depends on the analysed variable and chosen calibration period, as the results of the validation reflect the different climatic conditions of the calibration periods. (For example, the overestimation of the temperature-related variables or the tropical nights when using a more recent time period with more extreme events for bias-correcting the raw RCM data.) On the other hand, the results for precipitation are less affected by the choice of the calibration period, but they are more sensitive to the reference database. This can be explained by the fact that precipitation is one of the most variable meteorological elements not only in time but also in space. It means that using a database produced by a higher number of stations' measurement data provides more accurate results for precipitation. Overall, using the earlier calibration period (1976–2005) from the HuClim database proved to be the most accurate in the most cases during the validation. The next step in our research is to analyse the different bias-adjusted RCM simulations for the future.

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Appendix

Table A1. Overview of the databases analysed in our work

Name	Type	Bias-correction method	Reference dataset	Calibration period
RAW	raw	–	–	–
BC-MESAN	bias-adjusted	distribution scaling	MESAN	1989–2010
BC-HUCLIM-1		quantile mapping	HuClim	1976–2005
BC-HUCLIM-2		quantile mapping	HuClim	1993–2022

Table A2. Description of the temperature and precipitation based climate indices used in this study

Label	Name	Category	Description	Unit
SU	Summer days	Threshold	Let TX be the daily maximum temperature on day *i* in period *j*. Count the number of days when $TX_{ij} > 25$ °C.	Days
FD	Frost days		Let TN be the daily minimum temperature on day *i* in period *j*. Count the number of days when $TN_{ij} < 0$ °C.	
TR	Tropical nights		Let TN be the daily minimum temperature on day *i* in period *j*. Count the number of days when $TN_{ij} > 20$ °C.	
RR1	Wet days		Let R be the daily precipitation amount on day *i* in period *j*. Count the number of days when $R_{ij} \geq 1$ mm.	
TXx	The warmest day	Extreme	Let TXx be the daily maximum temperature in month *k*, period *j*. The maximum daily maximum temperature each month is then: $TXx_{kj} = \max(TXx_{kj})$.	°C
TNn	The coldest night		Let TNn be the daily minimum temperature in month *k*, period *j*. The minimum daily minimum temperature each month is then: $TNn_{kj} = \min(TNn_{kj})$.	°C
RX1day	The highest daily precipitation sum		Let R be the daily precipitation amount on day *i* in period *j*. The highest daily precipitation sum over a time series is then: $RX1day = \max(R_{ij})$.	mm
R99p	Extremely wet days		Let R be a time series of the daily precipitation amount. Then R99p is the 99th percentile of the daily precipitation amount on wet days for a reference period.	mm

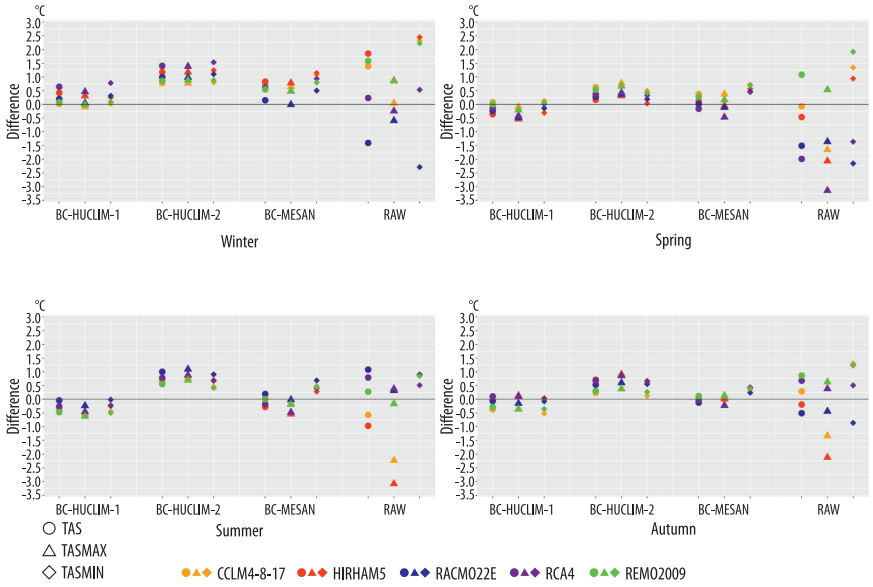


Fig. A1. The spatially averaged seasonal temperature characteristics compared to HuClim for the period 1993–2005 displayed for the individual RCM simulations indicated by different colours and for the four databases considered in this study. The differences are expressed in °C. *Source:* Authors' own editing.

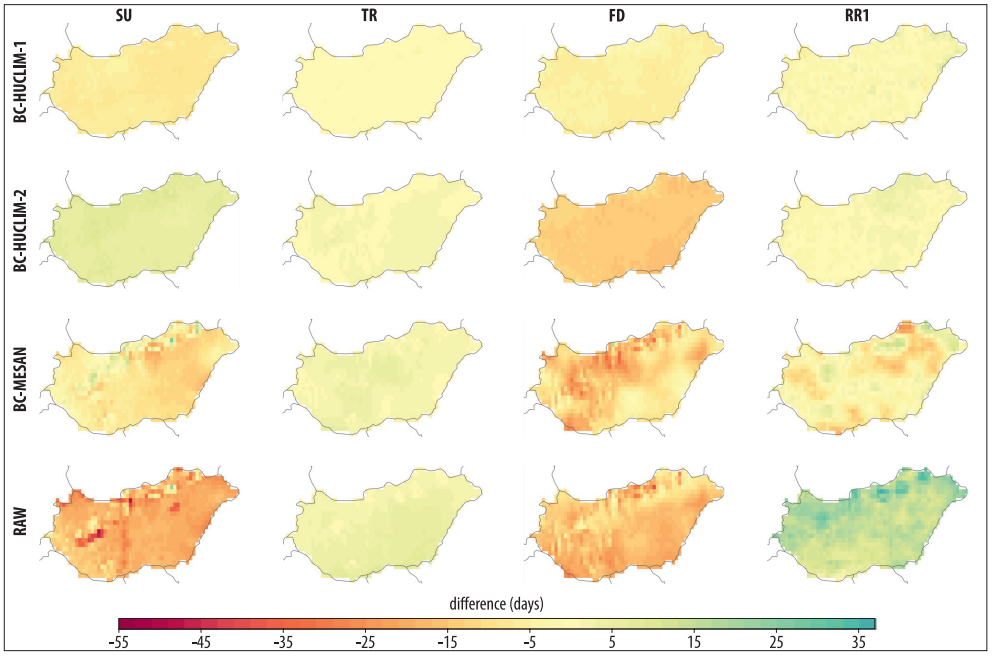


Fig. A2. Differences of threshold-based climate indices (SU, TR, FD, RR1) over Hungary based on the multi-model averages of the different bias-corrected simulations (rows 1–3) and raw outputs (last row) with respect to the HuClim reference data for the validation period of 1993–2005. *Source:* Authors' own editing.

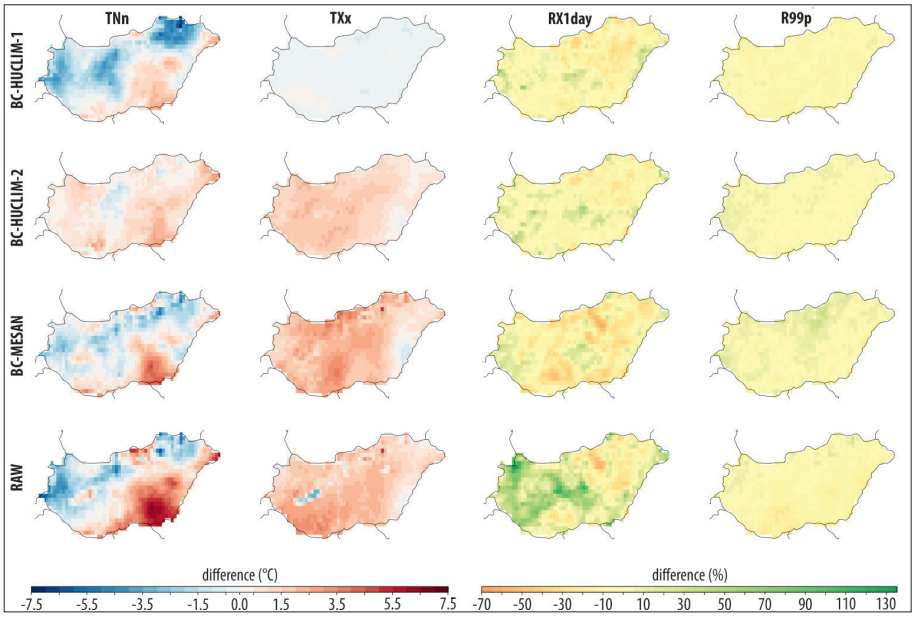


Fig. A3. The same as in *Figure A2,* but for extreme-related climate indices (TNn, TXx, RX1day, and R99p). *Source:* Authors' own editing.

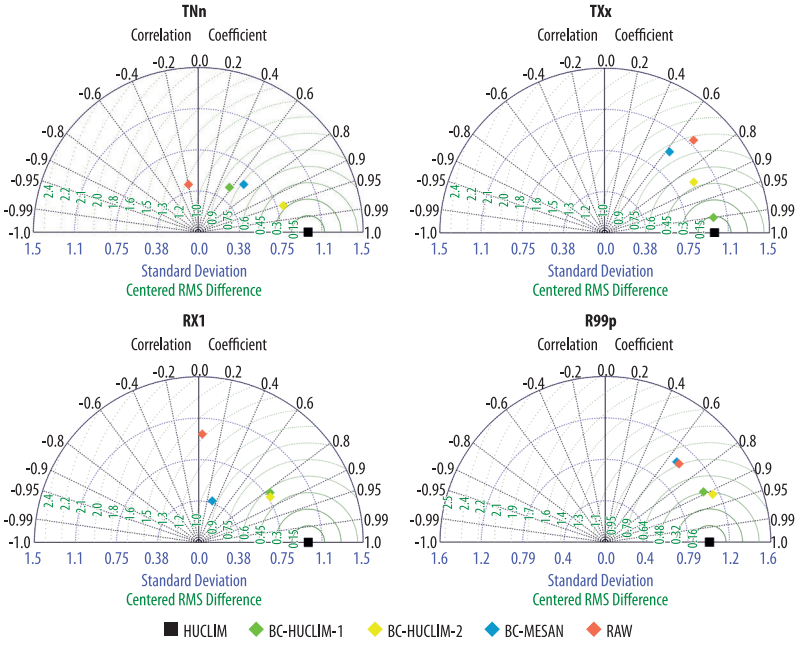


Fig. A4. Statistical characteristics summarized by Taylor diagrams for raw and bias-corrected multi-model data (coloured symbols) with respect to HuClim (black square) for the period 1993–2005. The four panels refer to the extreme-related climate indices (TNn, TXx, RX1, and R99p). *Source:* Authors' own editing.

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Border between West and East of Europe in the mental maps of European university students

Aleš NOVÁČEK[1], Jan D. BLÁHA[2] and Aneta ZAJÍČKOVÁ[1]

Abstract

The paper addresses the issue of dividing Europe into two sub-regions, West and East, which are monitored and defined through the method of cognitive mapping. The first section reviews basic approaches to this division of Europe, focusing on the concept of duality, analysing its causes, manifestations and perception in the form of the West-East division. The following empirical part presents the results of an international research conducted in the form of a questionnaire survey distributed among university students from nine European countries. Respondents were asked to define the border between the European West and East based on their subjective perceptions. The results were subsequently analysed and aggregated into map outputs using GIS tools. Although the respondents were young, the findings show that the perceived boundary between West and East still largely aligns with the Cold War-era division of Europe, with Central Eastern European countries, except Slovenia and Czechia, often classified as East. The mental maps also showed partial differences in the views of individual nations. The final part of the study is devoted to the interpretation of the results and their reflection in terms of the presented theoretical concepts and assumptions.

Keywords: Europe, West, East, mental maps, spatial perception, boundaries, delimitation, GIS analysis

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Introduction

The terms West and East are often used in the context of Europe, or even the world, but they are typically understood in varying ways, whether as historical or civilizational entities (Huntington, S. 1996; Nováček, A. 2012a; Murphy, A.B. *et al.* 2020), geopolitical groupings (Ikenberry, G.J. 2024), or socio-economic macro-regions (Cole, J. 1996; Anděl, J. *et al.* 2019). Consequently, there is a significant inconsistency in the definition and spatial delimitation of these terms and regions. In fact, the same problem occurs in many other cases of geographical regions commonly referenced in literature, media, but also people's thinking in general (Jordan, P. 2005).

One of geography's key tasks while studying regions is their definition and spatial delimitation, i.e. regionalisation. Multiple methods exist for this purpose, addressed in geography by a number of authors, such as Grigg, D. (1965), Hampl, M. and Marada, M. (2015) and others. In this regard, two basic approaches can be distinguished. The first, traditional approach defines regions *on the basis of more or less objective criteria*, such as the spatial occurrence of the phenomena in question (homogeneity principle) or spatial links between the centre and its surroundings (nodality principle). However, this method encounters limits with regions that do not form homogeneous or closed units. Hartshorne, R. (1939) argued that regions are mental constructs and

[1] Department of Geography, University of South Bohemia. Jeronýmova 10, 371 15, České Budějovice, Czechia. E-mails: anovacek@pf.jcu.cz, enet.z@seznam.cz

[2] Institute of Communication Studies and Journalism, Charles University, Smetanovo nábřeží 6. 11001 Praha 1, Czechia. E-mail: jan.d.blaha@gmail.com

that any attempt to divide the world involves subjective decisions. Ambiguously defined concepts – regions "West" and "East" – are examples of such constructs.

In response, new approaches in regional geography propose using *subjective perceptions of space* (perceptual regions) to define regions, often tied to regional identity (e.g. Siwek, T. 2011; Johnston, R. and Sidaway, J.D. 2016). These approaches can often provide a better account of the intangible and cognitive dimensions of space and regional identity, and the relationship between region and society (Paasi, A. 1986; Eder, K. 2006; Semian, M. and Chromý, P. 2014). Cognitive mapping is a key method for the delimitation of regions and studying spatial perception, where respondents transfer their cognitive experiences and ideas into a drawn map, either analogue or digital.

The authors of this study have followed this approach. The main aim was to determine where the inhabitants of Europe perceive the border dividing their territory into West and East. *The research* was carried out in the form of a questionnaire survey with the participation of 352 students from 21 universities in nine European countries (Austria, Czechia, Germany, Hungary, Lithuania, Poland, Slovakia, Ukraine, and the UK). Their task was to draw the border between the European West and East on an outline map based on their subjective perceptions, and to indicate in which sense they dominantly perceive this duality. The findings were analysed and aggregated using GIS tools into clear map outputs intended for interpretation. The interface between Western and Eastern Europe is usually referred to as the broad area of Central or Central Eastern Europe (Cabada, L. 2020, and others), and more recently, the eastern borders of the European Union. Thus, one could expect a high spatial de-concentration of the dividing lines drawn by respondents on the maps.

The main findings are based on the comparison of cognitive mapping results with existing theoretical concepts. The interpretation was focused on how much they are identical to each other and how is the influence of regional identity manifested here. Therefore, the study aimed to detect and explain differences in perceptions among respondents from different countries. Based on other studies relying on the cognitive mapping (Saarinen, T. 1999; Schenk, F.B. 2013; Bláha, J.D. and Nováček, A. 2016; Didelon-Loiseau, C. *et al.* 2018; Nieścioruk, K. 2023), it was possible to assume a significant influence of the respondent's origin or location in this respect.

West and East in the concepts of the division of Europe

The theoretical concepts dealing with the regionalisation of Europe can be divided into the following *categories based on the number of territorial parts* into which they divide its space:

The 'pluralist' view divides Europe into numerous more or less distinct regions (Jordan, P. 2005; Delanty, G. 2012). Thus, Europe tends to be divided in various parts, into Northern, Western, Southern (or Mediterranean), Central (or Central Western and Central Eastern), Eastern and Southeastern (i.e. the Balkan states). It is often used for statistical purposes (The World Factbook 2024; UNSTAT 2024) and in textbooks and school settings to simplify and clarify the teaching of the regional geography of Europe.

The 'triality' view divides the European space into three sub-regions, most often Western, Central, and Eastern Europe. This view correlates to some extent with the West–East division of Europe, but treats Central Europe as a separate and distinct entity. The triality view is especially represented in historically and (politico)geographically oriented works by authors often from Central and Central Eastern Europe, such as Naumann, F. (1915), Kundera, M. (1984), Szűcs, J. (1988), Kłoczowski, J. (2005), or Křen, J. (2005).

The third view is based on the principle of '*duality*', dividing Europe into two sub-regions: West and East, or historically also North and South. This concept represents the main theoretical basis of our research and more details about it are given in the next chapter.

Several aspects are reflected in the mentioned concepts of the divisions of Europe:

a) *The geopolitical aspect*, represented before WWII, e.g. by the German concept of 'Mitteleuropa' (Naumann, F. 1915), was completely linked to the West-East bipolar division of Europe and the world during the Cold War (e.g. Heffernan, M. 1998);

b) *The economic aspect*, on which the neo-Marxist Modern World-System (Wallerstein, I. 1974) and the associated concept of core – semi-periphery – periphery are based. In this sense, the aspect of differences in development proves to be particularly important for the regionalisation of Europe (Chirot, D. 1991);

c) *The cultural* or *historical aspect* dividing Europe into regions based on the common historical development of their territories (Szűcs, J. 1988; Halecki, O. 2000; Delanty, G. 2012; Schenk, F.B. 2013, 2017), or according to the development and occurrence of cultural phenomena and traditions (Hajnal, J. 1983; Murphy, A.B. *et al.* 2020);

d) *The physical-geographical aspect* of the west-eastern division of Europe is represented, for example, by the differences between areas with predominantly oceanic or continental climates.

In addition to these single-aspect approaches, there are several authors preferring a *more complex view* combining and interconnecting these aspects (e.g. Nováček, A. 2012b, and others).

Duality of Europe: West and East

The concept of the division of Europe into *West and East*, the main theoretical basis for our study, has been a part of geographical thinking for a long time. This idea gained importance mainly due to the geopolitical bipolarity after WWII. Although the dual vision of Europe is strongly influenced by this legacy, it is far from being a modern construct of the 20th century and has deep historical roots. Lemberg, H. (2000) notes that until the early 19th century, the contemporary perception of Europe was predominantly viewed through a North-South division over a West-East one.

The first indications of a West-East division of Europe trace back to ancient times (Latin versus Greek world). Throughout the Middle Ages, it was consistently reinforced both by the rivalry between the Frankish and Byzantine empires and, more significantly, by the division of Christianity and its associated culture (Davies, N. 2006). While the term 'Western Europe/West' began to solidify during the reign of Emperor Charlemagne in the late 8th and early 9th centuries, 'Eastern Europe/(European) East' only emerged as a designation in the early 19th century (Heffernan, M. 1998).

In the 19th and 20th centuries, Europe's awareness of the fundamental differences in values, culture and socio-economics between the West and East (historically linked to Russia and the Balkans) increased. Initially viewed as a boundary between Europe and Russia (the USSR) before WWII, the post-war division shifted westwards deep into Central Europe for four decades (Pounds, N.J.G. 1969).

The fall of the Iron Curtain and the Eastern Bloc in 1989 and the integration of Central Eastern European countries into Western European or transatlantic structures prompt questions about how these changes have affected the West-East border perception, especially among younger generations who did not experience the period before 1989. Our research aims to address this question.

Our study understands the discussed concepts of *West* and *East* in the context of duality as collective designations of two parts of Europe. They can be characterized by their identities, typical attributes (political, socio-economic, cultural or ethnic) and distinguished by their mutual polarity and difference. To define them, reference can be made to publications that have addressed this issue in the past, e.g. Maxwell, A. (2011), and Nováček, A. (2012a). Most of the above-mentioned authors understand the current form of the west as a more modern, advanced, richer, liberal, democratic region, integrated into Western European (or transatlantic) economic and military-political structures (EU and NATO) and standing on a long tradition of western values of humanism, individualism,

capitalism and free civil society. Conversely, the East is usually perceived as less developed, poorer, less free and democratic region, standing outside Western European integration structures, drawing historically on Orthodox tradition and partly on Oriental influences, along with Western influences (Chirot, D. 1991). In an extreme sense, this concept is often identified with the area of Russian civilizational influence (Neumann, I.B. 1999).

Boundary between West and East in literature

Only a few studies that have touched on the issue of the division of Europe into West and East have attempted to draw a concrete dividing line between the two regions. Mostly they do so on the basis of some selected aspect of duality.

Among the authors who have relied on *the historical and cultural aspect* are Cahnman, W.J. (1949), or Davies, N. (2014), who trace this border through the territory of the present-day states of Central Eastern Europe and Germany, highlighting its temporal variability. Rupnik, J. (1992) as well as Cox, H.E. and Hupchick, D.P. (2001) move it further east to the western borders of present-day Russia, Belarus and Ukraine and into the areas that once formed the southern border of Hungary. This aligns with the boundary between western and Orthodox civilization used by Huntington, S. (1996). Hajnal, J. (1983) provided an interesting duality example by drawing a line from Sankt Petersburg through the Baltic, Poland, Moravia, and Trieste, based on the prevailing historical model of the family.

The socio-economic aspect is often applied when defining the world's macro-regions. Within this regionalisation, De Blij, H.J. and Muller, P.O. (1988) divide the European space into two parts, with the interface running through the territory of Belarus and Ukraine. More recent studies by Anděl, J. *et al.* (2018a) or Fellmann, J.D. *et al.* (2008), shift this line to the western border of Russia, Belarus, Ukraine and Moldova.

(Geo)politically oriented works usually view the West and the East as two competing entities. Most studies based on Cold War realities accepting the Iron Curtain line as the dividing line belonged to this group (e.g. Pounds, N.J.G. 1969). More recent works then see this boundary more between Russia (and Belarus) on the one hand, and the NATO states on the other (Ikenberry, G.J. 2024). Other contemporary studies derive this division from differences in political views within the European Union (Cabada, L. 2020), or on issues of national identity and migration (Bartasevicius, V. 2022; Lewicki, A. 2023). In this context, the aforementioned authors draw attention to the dichotomy between old and new EU member states, thus, placing the boundary of duality de facto back to the line of the former Iron Curtain.

A more comprehensive view of the boundary between West and East was applied by Stehlík, J. (1996), who, in addition to the states west of the Iron Curtain, also included the territory of Czechia and Slovenia in the west. Based on a comprehensive analysis, Nováček, A. (2012a), in contrast to Stehlík, also includes the territories of the Baltic states, Poland, Slovakia and Hungary, i.e. the whole Central Eastern Europe, in the west. Hampl, M. (2009) went even further in his demarcation of global systems, leaving only Russia, Belarus and Ukraine to the east of this main dividing line.

The delimitation of the boundary between macro-regions *based on cognitive mapping* was used by Polonský, F. *et al.* (2010) or Didelon-Loiseau, C. *et al.* (2018). Both studies focused on the division of the world into macro-regions through the eyes of university students. In the first study, Czech students most often divided Europe into two macro-regions, with the dividing line running dominantly beyond the western border of Russia, Belarus and Ukraine. A slightly smaller proportion of respondents identified the interface with the eastern border of Germany and Austria. Similar to the smaller group of respondents in the first study, the respondents in the second, more internationally focused study approached the division in the same way.

These perceptual probes effectively confirm the conclusions drawn from the previous discussion of the literature. That is, that the defini-

tion of the boundary between the West and the East is not uniform, with two views prevailing. The first sees it roughly at the border between the German-speaking countries and the other Central European countries, while the second pushes it to the eastern border of the EU.

Cognitive mapping and methodology

Cognitive mapping, defined by Downs, R.M. and Stea, D. (1973, 9) as "a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in space," enables the transfer of mental models of space onto paper or other recording media. In general, the effectiveness of cognitive mapping studies relies heavily on respondent selection, task wording, the method of collecting the mental maps, and their subsequent processing, including aggregation.

With regard to the objectives of this study (an effort to collect the subjective opinions of respondents regarding regional geography), *the selection of respondents* was aimed at university students of geography or related fields, e.g. international relations. This group was chosen for their likely interest in European affairs and basic knowledge of European regional geography. It was also important that the respondents' knowledge of the history and conditions of European dualism was not too deep. For this reason, as far as possible, mainly students in their first or second year of undergraduate studies were contacted. Thus, the research serves as a probe into the views of a younger generation lacking direct experience of the era preceding the fall of the Iron Curtain.

To compare the opinions of respondents of different nationalities, the questionnaire was provided in multiple languages (English, German, Polish and Czech). The distribution of the questionnaires was carried out either personally by the authors during their numerous internships abroad or online through contacts with lecturers or students working at these universities.

The questionnaire featured an outline map of Europe with state borders and names, along with a form for collecting respondent information (age and nationality) and a task statement reading*: "According to your subjective opinion, define a line in the map dividing Europe into parts: West and East. The line does not have to follow existing state borders. If you decide to fill it out online, you may use MS Paint (or another software)."* This wording allowed respondents freedom in drawing the line, without restrictions regarding state borders or map format (analogue vs. digital).

To understand the reasoning behind the drawn boundaries, the final part of the questionnaire asked: *"On what basis did you dominantly define the line? (For example: economic, natural, political, historical, cultural, religious, complex or something else)"*.

The research included 21 institutions from 18 locations across Austria, Czechia, Germany, Hungary, Lithuania, Poland, Slovakia, Ukraine, and the United Kingdom. The locations and countries were selected to prioritize mental maps from Central Europe, supplemented by data from two western countries (Germany, UK) and two eastern countries (Lithuania, Ukraine) for comparison. The distribution method ensured that the origin of the sample was embedded in the final maps, serving as a key parameter for subsequent analysis. As shown in *Table 1*, the number of resulting maps obtained was not the same in all countries, however, previous studies by the authors (i.e. Bláha, J.D. and Nováček, A. 2016) have suggested that a sample of approximately 25 maps from each target country can be considered representative for the purposes at hand. Most of the 352 completed questionnaires were collected during the main wave of the research, i.e. from April 2021 to January 2022.

Processing of mental maps

All operations for processing the digitized mental maps were performed in ArcGIS Pro. The maps were first georeferenced and then the drawn boundaries between West

and East were vectorized. The individual boundary drawings were aggregated in two steps: 1) Based on respondents' affiliation with each of the nine states; 2) Overall for all respondents, but with relativized results for each state. This ensured equal weight for each state in the final aggregation, despite varying numbers of respondents.

To interpret the aggregated results, it was necessary to perform a spatial analysis. For the sake of clarity, the following software, i.e. tools of extended Spatial Statistics and visualization, was used to perform the analysis of perceived boundaries between Western and Eastern Europe by individual groups of respondents.

To aggregate results, contour lines marking 25, 50, 75, and 100 percent of the volume surface were used and graphically adjusted, i.e. using the Smooth Polygon tool. This approach clearly identifies territories perceived by a certain percentage of respondents as West (blue shades), East (red shades), and transitional zones (white). Additionally, the line method was applied, with lines of varying thickness corresponding to the percentage of respondents (intervals 5–20–40–60–80–100%) who drew the boundary between the West and the East of Europe in this line. This way of visualising the aggregated results in turn allows to better see the dominance of the course of each border. This is also why this visualization method was chosen for the individual national views and their effective comparison.

Results and discussion

Delimitation of the perceptual boundary between West and East

In analysing the aggregated mental maps, the authors looked at a) the degree of variability of the perceptual boundary between West and East; b) its dominant course; c) the predominant classification of a country as West or East; d) the dominant aspect for defining duality; e) the identification of "national" views and their differences.

When drawing the perceptual boundary between West and East, about two-thirds of respondents largely followed existing state borders. The others either drew the dividing line as a straight line or deliberately bisected a state whose classification they were unsure of in this way. Some accepted specific natural or historical borders (the western border of the former East Germany, the western border of Moravia, the eastern border of the German Empire, etc.). The *most cited aspects in defining the border* were economic (17% of respondents), complex (14%), and, to a lesser extent, political (11%). Cultural and historical aspects were the main factor in 8 percent of cases, while natural aspects were cited by 5 percent. A total of 29 percent of respondents did not take the opportunity to express themselves at all. This suggests that current socio-economic differences – developed West vs. underdeveloped East – are favoured over historical factors when defining the border.

The aggregated map of all respondents *(Figure 1)* shows a *high variability in opinions on the border's course, especially in the Central European region*. Conversely, in the north and partly in the south, the consensus was significantly higher. In the North, over 60 percent of respondents identified the border with the border between Finland and Russia and over 70 percent with the Baltic Sea. Similarly, in the south, the Adriatic and Ionian seas were seen as boundaries. The higher variability in Central Europe may stem from the greater number of countries and potential border options, as well as the concentration of respondents from this region. Most respondents identified the dividing line with the German eastern border (in the section with Poland about 60%, with Czechia 40%) and with the Austrian eastern (55%) and southern borders (30%). Although only a portion agreed on the entire border, it can be considered the most dominant. The reason for placing the border here likely relates to significant developmental differences, particularly felt by Central European respondents. Although this was a younger generation of people with no direct personal experience of the Cold War division

of Europe, the relic Iron Curtain effect continues to manifest itself in various forms. As Domański, B. (2004) and Lewicki, A. (2023) suggest, the influence of the political profiling of the EU's eastern wing (the Visegrad Group countries – V4) is also involved. A similar demarcation of the dividing line within Europe can be seen in a number of cultural-geographic studies (Fellmann, J.D. *et al.* 2008; partly Murphy, A.B. *et al.* 2020).

Other alternatives to the perceptual border between the West and the East have in some

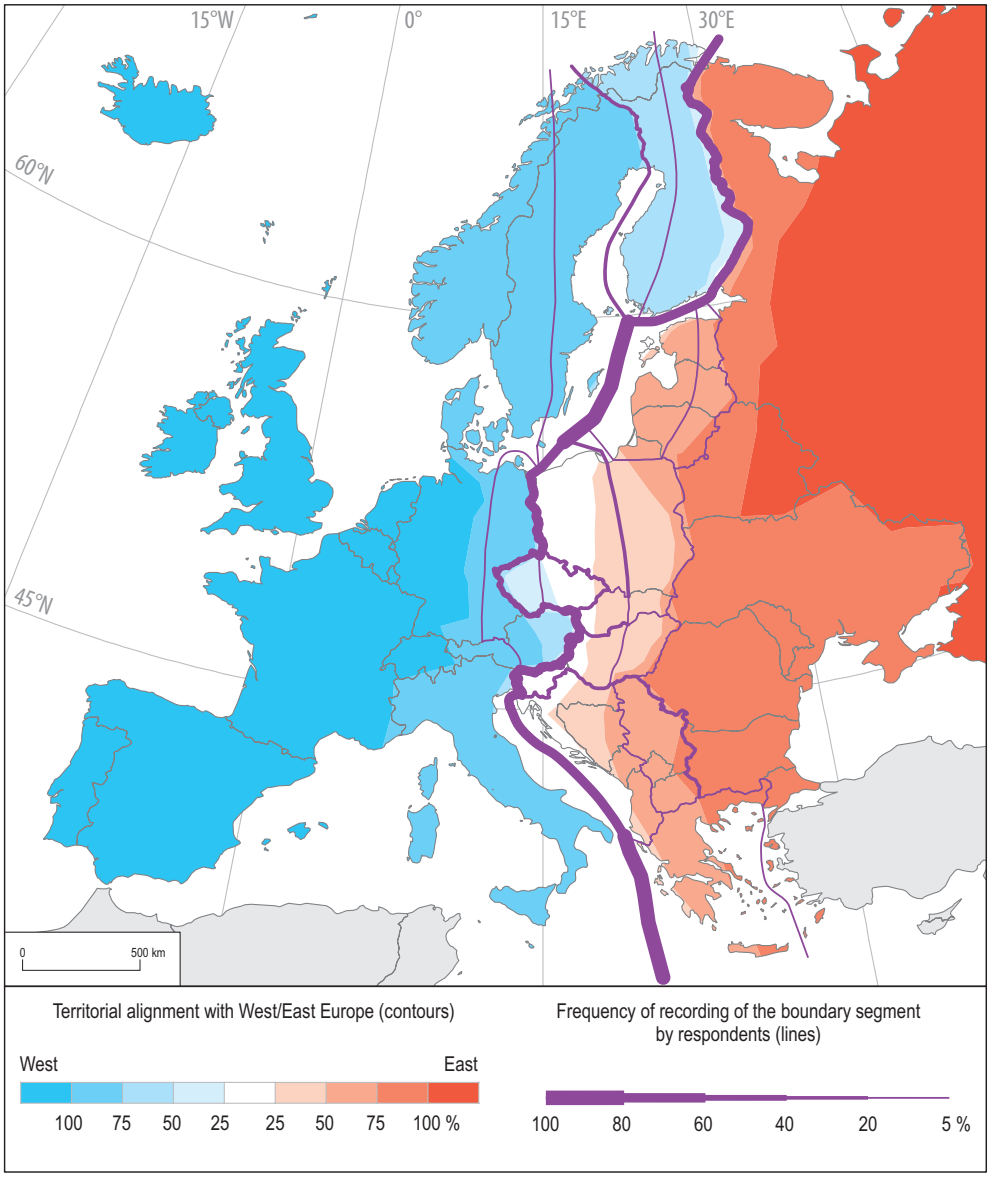


Fig. 1. Aggregation of all the respondents' mental maps. *Source:* Authors' own research and processing.

cases also included an attempt to run it in the Baltic and Central Europe along the eastern border of the EU, possibly passing through the Baltic states and the V4 countries in various ways. However, the overall consensus for these lines was only between 10 and 25 percent depending on the particular section. This delimitation can be justified on historical and cultural grounds (e.g. Western Christianity vs. Orthodoxy; Cox, H.E and Hupchick, D.P. 2001; Davies, N. 2006) as well as the current geopolitical division of the world – NATO vs. Russia (Ikenberry, G.J. 2024). A similarly localized boundary can most often be found in works devoted to the delimitation of the world's macroregions (Huntington, S. 1996; Hampl, M. 2009; Anděl, J. *et al.* 2018a, b). These results align partly with earlier cognitive mapping studies among Czech geography students by Polonský, F. *et al.* (2010). However, in contrast to our study, they found the eastern border of the EU to be the dominant dividing line of both variants.

As shown by the values in *Table 1* and the colour shades in *Figure 1*, more than 90 percent of all respondents agreed on the inclusion of Sweden, Germany (including former East Germany), most of Italy and all countries west of these in the West. Slightly fewer agreed on Austria (88%) and the south or north-east of Italy (89%), followed by Finland (67%) and Slovenia (56%). Half of the respondents placed the Czech territory in the West and half in the East. Countries east of these were more likely classified as East (in order: Croatia, Poland, Slovakia, Hungary, Bosnia and Herzegovina) or clearly in the east (Greece, the remaining Balkan states and the rest of Eastern Europe).

Table 1. Ranking of selected territories according to respondents from each country

Country (territory)	Country of respondents*									
	UK	GE	AT	CZ	SK	PL	HU	LT	UA	*Total*
Number of respondents	32	36	24	88	68	25	31	25	23	*352*
Share of respondents who classified the country (all or most of its territory) to the West										
Territory of respondents' own country	100	100	96	50	32	36	10	28	0	*41*
East of Germany (former GDR/Bavaria)	91	89	96	94	99	100	97	92	100	*95*
Sweden	75	92	87	94	97	98	100	84	87	*91*
Italy (south/north-east)	87	92	92	94	88	96	81	88	100	*89*
Austria	66	86	96	95	91	96	90	80	74	*88*
Finland	43	78	67	70	81	68	87	52	21	*67*
Slovenia	50	19	88	61	49	68	65	72	43	*56*
Czechia	34	19	83	50	50	52	61	68	45	*50*
Croatia	31	19	79	31	31	48	35	60	35	*37*
Poland	22	6	58	34	28	36	19	44	30	*30*
Slovakia	19	0	54	31	32	32	10	48	32	*28*
Hungary	22	0	50	27	32	36	10	48	30	*27*
Bosnia and Herzegovina	22	3	67	18	18	44	10	44	35	*24*
Greece	28	6	46	13	15	20	3	40	13	*18*
Other western Balkans	16	3	38	11	13	24	3	40	30	*16*
Baltic states	6	3	54	15	15	20	6	24	0	*15*

*UK = United Kingdom, GE = Germany, AT = Austria, CZ = Czechia, SK = Slovakia, PL = Poland, HU = Hungary, LT = Lithuania, UA = Ukraine. *Source:* Authors' own research and processing.

National views

If we compare the aggregated maps produced by merging the mental maps from respondents in a given country *(Figure 2)*, we can observe both some similarities and differences between these "national views".

The greatest *variability* within national view in drawing the dividing line occurred among respondents from the UK, Austria, Poland,

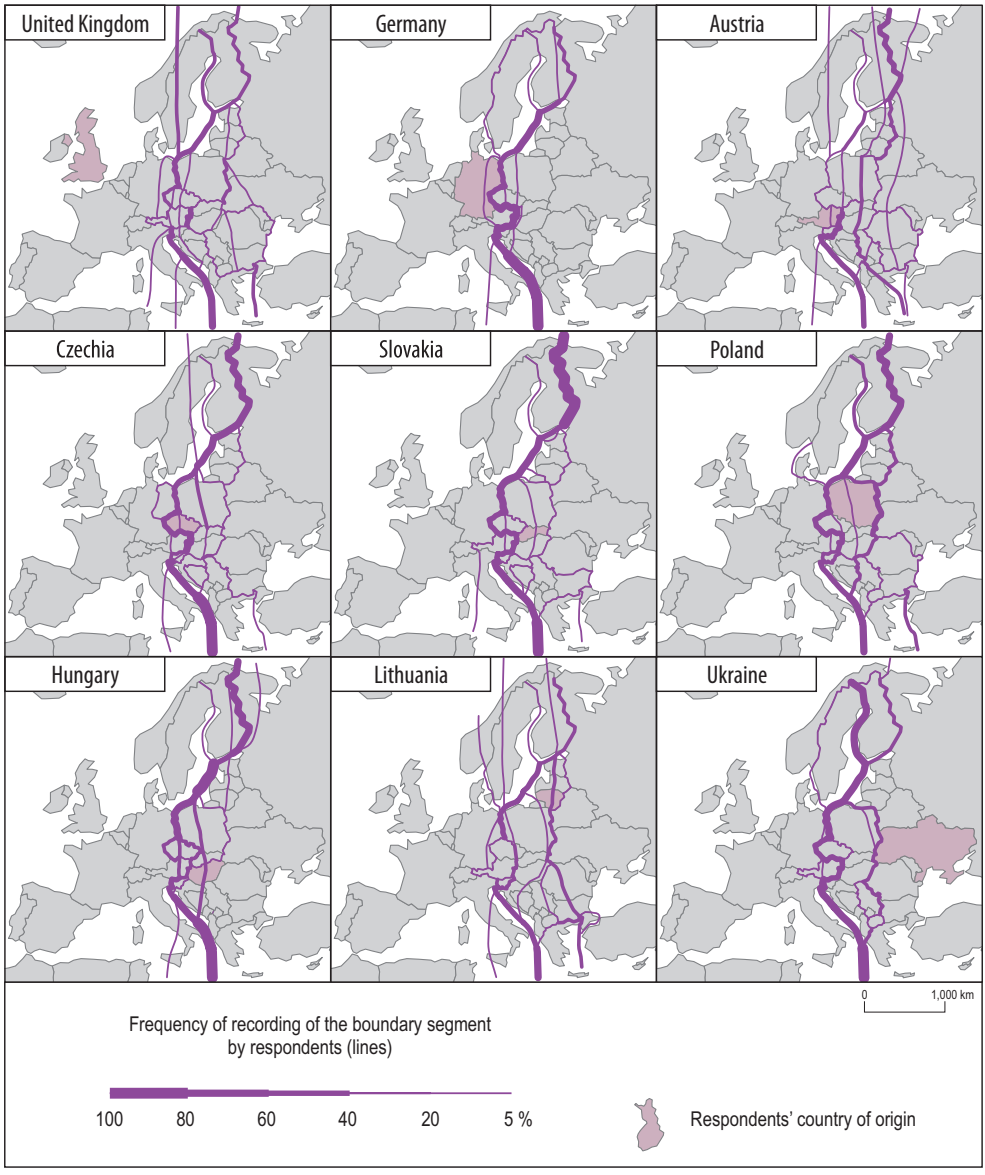


Fig. 2. Definition of the border between West and East by respondents from each country. *Source:* Authors' own research and processing.

and Lithuania. In contrast, respondents from Germany, Hungary, and Ukraine displayed the most unified views. On average, the British, Germans and, surprisingly, Hungarians placed the border the furthest west of the nations surveyed, while Poles and Lithuanians placed it furthest east. The comparison according to where the respondents predominantly *placed the territory of their own* country is also interesting (see *Table 1*). The Germans and Austrians, and unsurprisingly the British, almost unanimously placed their own country (all or most of it) as part of the West, with only 11 percent of German respondents separating the eastern areas of their state (the former East German territory) to the East. By contrast, half of Czech respondents, and only about a third of Poles, Slovaks, and Lithuanians, saw their country as part of the West. With the exception of Lithuanians, the ambivalence of opinion can be partly attributed to their inclination towards Central Europe as a distinct sub-region (Kłoczowski, J. 2005; Bláha, J.D. and Nováček, A. 2016). While it is unsurprising that Ukrainians identified with the East, the strong identification of Hungarians with the East is somewhat striking.

Clear *differences between the different national views* appear in the inclusion of the territories of Finland, the Baltic states, the V4 countries, Slovenia, Croatia, or the Western Balkan countries (see *Table 1*), as noted in various theoretical works (e.g. Cahnman, W.J. 1949; Jordan, P. 2001; Todorova, M. 2009).

Despite these differences, several national views show *notable similarities*. The aggregated *maps from United Kingdom and Germany*, for example, are highly similar, reflecting a typical Western European view. These nations tend to perceive Central Eastern Europe as part of the East, sometimes looking down on them (Domanski, B. 2004). Accordingly, they shift the West-East boundary westward, often aligning it with the former Iron Curtain or the eastern borders of present-day Germany and Austria.

The Czech and Slovak respondents also displayed significant similarity, with two main dividing lines dominating. The more common one follows the eastern borders of Finland, Germany, and Austria, reflecting persistent developmental differences (Stehlík, J. 1996). This economic aspect by Slovak respondents mentioned as the main dividing basis. The other runs along the eastern borders of the Baltic states, Poland, Slovakia, Hungary and Croatia. Interestingly, respondents from eastern Slovakia often drew the dividing line through their country, reflecting the long-standing dichotomy in maturity within (Matlovič, R. *et al.* 2018). The high similarity between Czech and Slovak views can be attributed to a shared tradition of geographic education, media, and awareness of a common history dating back to the Czechoslovak state.

A third significant similarity emerged between *respondents from Poland and Lithuania*. Like the Czechs and Slovaks, the same two conceptions dominated their views. However, Poles and Lithuanians showed a greater tendency to integrate the Baltic states and some Balkan areas into the West. This view may stem from a similar historical experience marked by antagonism toward both Russia, identified here with the East, and Germany, identified with the West, leading to a dilemma about their European classification. In contrast to a number of renowned works by Polish authors who emphasize more on the political and cultural aspects of duality (e.g. Solarz, M.W. 2022), the Polish respondents themselves preferred a border defined by economic differences reminiscent of the Iron Curtain. While the Polish respondents derived their division mainly according to economic aspects, their Lithuanian colleagues do it based on cultural, historical and also natural ones.

The Austrian view can be considered a kind of intersection of all three previous groups. Due to their location and history, the Austrians feel closer to the nations of Central Eastern Europe than Germans do. This may explain their tendency to push the West-East boundary further east, even more so than V4 countries' respondents themselves. The high variability of marked lines also corresponds to the fact that none of the mentioned aspects of duality significantly prevailed among the Austrian respondents.

Hungarian respondents demonstrated a relatively specific and homogeneous view. Like others, they mainly referenced the Iron

Curtain, but they more frequently classified Czechia and Slovenia as Western, thus, agreeing with Stehlík, J. (1996). Although Hungarian respondents often mentioned historical and cultural aspects as the main basis of duality, they almost exclusively referred to their own country as a part of the East, a distinction from other V4 countries. This may be due to Hungary's noticeable developmental gap with neighbouring Austria and Slovenia, a sense of belonging to the Danube region of historical Hungary (Rupnik, J. 1992), or domestic media portraying Hungary as politically distancing itself from the EU and the West (Cabada, L. 2020; Bartasevicius, V. 2022).

Ukrainian respondents did not show any ambition to place their state in the West, furthermore locating the duality border as far west as the border of Germany and Austria and even Sweden, i.e. further west than the Central Eastern European nations. The Ukrainian point of view corresponds to the fact that cultural-historical and political aspects were mentioned as the most common reason for the division. Their geographical distance from the perceptual border, like the British, may have allowed for a less subjective view than the Central European nations. However, this research was conducted just before Russia's 2022 invasion of Ukraine, raising questions about how the conflict may have subsequently altered Ukrainians' views.

Conclusions

The initial discussion of the literature highlighted inconsistencies in the regionalisation of Europe, particularly in the perception and spatial delimitation of West and East. This study, using cognitive mapping, confirmed these inconsistencies. Aggregating mental maps from a larger number of respondents helped objectify individual opinions and enabled comparison across groups, demonstrating the effectiveness of this method applicable in the context of regional and cultural geography.

Most mental maps showed a strong correlation between the West-East boundary and current state borders. Despite considerable variability and spatial dispersion of the marked border lines, the greatest consensus emerged on a line dividing Europe along the eastern border of Finland across the Baltic Sea, along the eastern borders of Germany, Austria and Italy, crossing the Adriatic and Ionian Seas. Although the respondents were young, this result reflects a continuity of perspective reminiscent of the Cold War division of Europe. Most respondents, including those from the V4 countries, thus, perceived the countries of Central Eastern Europe, with the partial exception of Slovenia and Czechia, primarily as part of the East. This finding partly contrasts with the popular claim, narrated in the media especially in the 1990s in post-socialist Central Eastern Europe, that "with the collapse of the Eastern Bloc in 1989, they are once again returning to the West of which they used to be a historical part" (Rupnik, J. 1992). The second highest consensus was on a line running through the Baltic and Central Europe along the eastern border of the EU.

Other marked boundaries mostly fell in the zone between these two lines, creating a space understood as an interpenetration and overlap between West and East (Kundera, M. 1984; Halecki, O. 2000; Jordan, P. 2001; Meinhof, U.H. 2002). The data from the respondents further show that they preferred to look at the current reality of socio-economic differences (more advanced West vs. the lagging East) rather than historical factors when defining the border.

Aggregated results for the states revealed both differences and similarities between different "national" views. Respondents generally tended to push the boundary close to their own country, with those from western states locating it further west and those from eastern states locating it further east. This could possibly happen because of certain tendency of nations clearly identified with the West (respondents from United Kingdom and West Germany) to perceive the East as a less developed and less civilized region (Said, E.W. 1978) and to define themselves against it may play a role in this. On the

contrary, the surprisingly high proportion of respondents from Eastern and Central Europe who assigned their own country to the East may indicate self-deprecation and frustration with their more economically advanced western neighbours. While intra-state differences in views were generally minimal, aggregate views differed for geographically close locations located in different states (such as Passau and České Budějovice, or Vienna and Bratislava). This highlights the strong influence of an individual's origin on the perception of space and the definition of regions. As Saarinen, T. (1999) suggests, these differences can stem from variations in educational systems, i.e. textbooks and atlas conceptions, different historical experiences, politics, and media portrayals of the countries concerned. All of these shape the individuals' cognitive maps and their own subjective regional identities (Paasi, A. 1986).

The authors of the research acknowledge that the results may be influenced by the specific survey conditions, such as the strict requirement to define a single line and the fact that only young geography enthusiasts participated. The results, thus, represent a specific probe that may not fully reflect the views of the general population. It can be assumed that different age groups, influenced by memories of other geopolitical realities and schooling, might produce different results. As a study relying on the cognitive mapping method, it brings a new perspective to the debate on delimitation of regions. The insights generated here may inspire further similar research at different levels of regions.

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Territorial identity of a region: A review of data collection techniques

Martin BARTŮNĚK[1] and Petr MAREK[2]

Abstract

This scoping review focuses on methodological approaches and, in particular, data collection techniques, for investigating part of the identity of a region – the territorial identity (boundaries) – within the field of new regional geography. The paper builds on a continuously expanding compilation of studies from academic databases and supplementary reference searches in geographically oriented journals. Reviewing 76 articles, it identifies the principal data collection techniques, including the utilisation of secondary sources (e.g. literature and maps or databases of place names) and strategies for obtaining primary data with questioning. These represent two analytical perspectives: indirect (secondary data) and direct (primary data) identification of territorial identity. The techniques are analysed concerning methodological approaches, including the use of territorial identity markers or territorial identity perception, as well as in terms of various scales and research character (single or multiple regions examination). The findings demonstrate that secondary data are predominantly used for delimiting regions through territorial identity markers whereas primary data are employed mainly to delimit regions reflecting territorial identity perception. Furthermore, the choice of data is not inherently dependent on region scale, as even world regions can be studied using questioning. Additionally, the absence of temporal analysis and the under-representation of mixed research designs in the studies suggest avenues for future research. Integrating diverse data collection techniques and methodological approaches might capture the concept of the region better, offering valuable insights for theoretical advancement and practical applications.

Keywords: new regional geography, territorial identity, territorial shape, delimitation of region, border, boundary, identity of region, data collection techniques

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Introduction

Boundaries, delimiting the territorial shape of a region, have attracted the attention of geographers for a long time (see Minghi, J.V. 1963). Recognised as an essential component of the identity of a region (Paasi, A. 1986), they have also been studied from the perspective of new regional geography, in which this paper is anchored. While this study engages with scholars explicitly aligned with this field, it also draws on earlier works (e.g. Brownell, J.W. 1960; Reed, J.S. 1976) predating its formal establishment in the 1980s (a detailed overview of regional geography evolution provide, e.g. Kasala, K. and Šifta, M. 2017) and incorporates insights from related sub-disciplines in linguistics (e.g. Preston, D.R. 2010). Historically, many studies aimed to delimit particular regions (Zelinsky, W. 1980), with potential for applications in education (e.g. Alderman, D.H. and Good, D.B. 1996) or regional development (e.g. Stoffelen, A. *et al.* 2024). Recently, however, research has increasingly shifted towards redefining the concept of a region (e.g. Vukosav, B. and Fuerst-Bjeliš, B. 2016). Ad-

[1] Jan Evangelista Purkyně University in Ústí nad Labem, Faculty of Science, Department of Geography. Pasteurova 3544/1, 400 96 Ústí nad Labem-město, Czechia. E-mail: martin.bartunek@ujep.cz

[2] Masaryk University, Faculty of Social Studies, Department of International Relations and European Studies. Joštova 218/10, 602 00 Brno, Czechia E-mail: petrmarek@mail.muni.cz

ditionally, some point out that *where* (and *how*) people perceive regions can influence their identification with those regions as well as regionalism (Jordan, T.G. 1978; Marek, P. 2023).

Despite long-standing interest in the territorial shape (boundaries) of a region, the methods employed for delimiting regions often receive insufficient attention. This scoping review employs a content analysis of existing literature to address the following goals: first, to classify and discuss the techniques employed to collect data; second, to examine their interrelationship with methodological approaches used to delimit regions' territories/boundaries (the territorial identity of a region); and third, to analyse how the scale of a region influences the choice of data collection techniques. The study highlights research gaps, proposes future directions and offers recommendations for advancing boundary research.

Territorial identity as seen by new regional geography

New regional geography explores the concept of the region theoretically, as a social construct, spatial structure and dynamic process (Thrift, N. 1983; Paasi, A. 1986; Gilbert, A. 1988; Jonas, A. 1988; Pudup, M.B. 1988; Murphy, A.B. 1991). The region as a social construct implies it is created and exists primarily in people's minds as a perceptual region (Zimmerbauer, K. 2011; Vukosav, B. and Fuerst-Bjeliš, B. 2016; Marek, P. 2020, 2023). Conversely, the region as a spatial structure influences people and may be an important source of, among other things, their identification with a certain spatial unit, as well as a driving engine of regionalism (Keating, M. 1998; Paasi, A. 2009a; Zimmerbauer, K. 2011; Marek, P. 2023). Paasi, A. (1986, 2002) and the previously mentioned authors conceptualised/classified regional identity into three dimensions. An instrumental dimension, that is, regionalism (regional activism), is reached by the smallest number of regions, while more regions attain an affective dimension – people's identification with the region and/or regional community (the regional identity of people). Ultimately, all regions have a cognitive dimension, that is, their identity (the identity of a region). These dimensions are in continuous change/development, as regions (and generally regional identities) are dynamic processes that are "constantly becoming" (Pred, A. 1984, 279). Region (and regional identity) not only emerges but also reproduces, transforms and may eventually disappear (Paasi, A. 1986; Raagmaa, G. 2002), as evidenced, for example, by Chromý, P. *et al*. (2009), studying the reproduction of several Czech historical regions, by Konopski, M. (2021), investigating the transformation of a Polish region of Podlasie, and by Simon, C. *et al*. (2010), exploring a Dutch disappearing region of Noordoostpolder.

The identity of a region (cognitive dimension) is categorised into two types: (1) "objective" formal and functional regions, based on objective criteria, and (2) subjective images of the region, based on perception, that is, perceptual regions (Paasi, A. 1986; Marek, P. 2023). According to Paasi's institutionalisation of regions theory, all regions (including formal, functional and perceptual regions) have three "shapes" that give identity to the region: (1) its territorial shape delimited by boundaries, (2) its symbolic shape, mainly its proper name (a choronym) and (3) its institutional shape (Paasi, A. 1986, 2002).

This article focuses on the territorial shape of a region, referred to as its territorial identity. Although the relational view of the region questions the territorial approach, downplaying boundaries (e.g. Allen, J. *et al.* 1998), the territorial approach, as well as boundaries, remain relevant (Paasi, A. and Zimmerbauer, K. 2016; Zimmerbauer, K. *et al.* 2017) and widely studied to the present.

Methods for studying territorial identity in new regional geography differ in (1) data collection techniques and (2) methodological approaches, although Peng, J. *et al.* (2020, 11–12), for example, do not distinguish them. Although the result section details data collection techniques, their close interrelation-

ship with methodological approaches used to delimit regions' territories/boundaries requires attention. Therefore, an overview of these approaches is provided; their more profound conceptualisation (as well as related data evaluation and interpretation techniques) should also be discussed closely, but this is out of the scope of this article.

Some authors (e.g. Lowry, J. 2013; Melnychuk, A. *et al.* 2014) note that territorial identity can be studied (and delimited) in two major ways. The first examines people's perceptions (*territorial identity perception*), as apparently initiated by Brownell, J.W. (1960). The second focuses on *territorial identity markers,* attributed within new regional geography to Reed, J.S. (1976), however, defining regions based on various ethnographic characteristics, for example, was already established among ethnographers much earlier (see Drápala, D. and Pavlicová, M. 2014). Melnychuk, A. *et al.* (2014, 159) propose a third methodological approach involving an analysis of historical-geographical conditions of *territorial identity development*. Finally, a fourth methodological approach can be identified as the *territorial identity discourse,* which should precede the previous one since the region is a dynamic process and it is beneficial to understand its current shape before proceeding with its development. This approach, apparently initiated by Sinnhuber, K.A. (1954), focuses on analysing territorial identity through the subjective perceptions of various experts, who define these regions using a scientific methodology. Nevertheless, territorial identities can also be approached based on objective criteria (the formal and functional regions mentioned above) within new regional geography (e.g. Staut, M. *et al.* 2007; Marek, P. 2023).

Methodology

This study employed an initial compilation of 59 published articles obtained from the Web of Science and Scopus databases, along with other sources, intending to identify data collection techniques for the identification of territorial identity. The compilation, developed during the authors' previous years-long interest through the "snowball" technique, revealed significant methodological challenges related to the ambiguity of keyword definitions *(Figure 1,* A*)* for subsequent supplementary reference searches. This issue, previously highlighted by Kitchin, R. (1994), for example, may be attributed to the absence of a sophisticated theory of boundaries (Paasi, A. 2009b), which significantly limits the precision of a systematic search process within the context of a "scoping review" (Tricco, A.C. *et al.* 2018).

To identify other relevant sources, the search in the Web of Science database relied on a combination of keywords such as (vernacular or perceptual) region, mental map, identity, border, territorial, perception, marker, delineation and their synonyms (e.g. boundary, cognition, spatial). Conducted in mid-September 2024, this search yielded additional potential articles to enhance the compilation *(Figure 1,* B*)*. However, four inclusion and exclusion criteria were chosen: (1) only articles were included, excluding books and other sources; (2) the focus was narrowed to geographically oriented journals, excluding those focusing on medicine or engineering; (3) only English-language publications were considered due to language barriers; (4) duplicates and incomplete citations (without abstracts) were removed.

The review selection process comprised four additional stages. Initially, abstracts lacking terms "*border, boundary, zone, frontier, area, territory, space (spatial), delimit (delineat), percept* or *vernacular*" were excluded, as these terms broadly reflect the concept of delimiting regions. Concurrently, the aforementioned keywords encompassed studies from the initial compilation and, thus, were subsequently excluded from the subsequent compilation. An analysis of keyword frequency in abstracts facilitated the identification of relevant studies, which were then subjected to a cross-check screening by the authors based on the article title. Ultimately, only those studies that addressed the delimitation of regions under the conceptual framework of new regional geography were selected following a com-

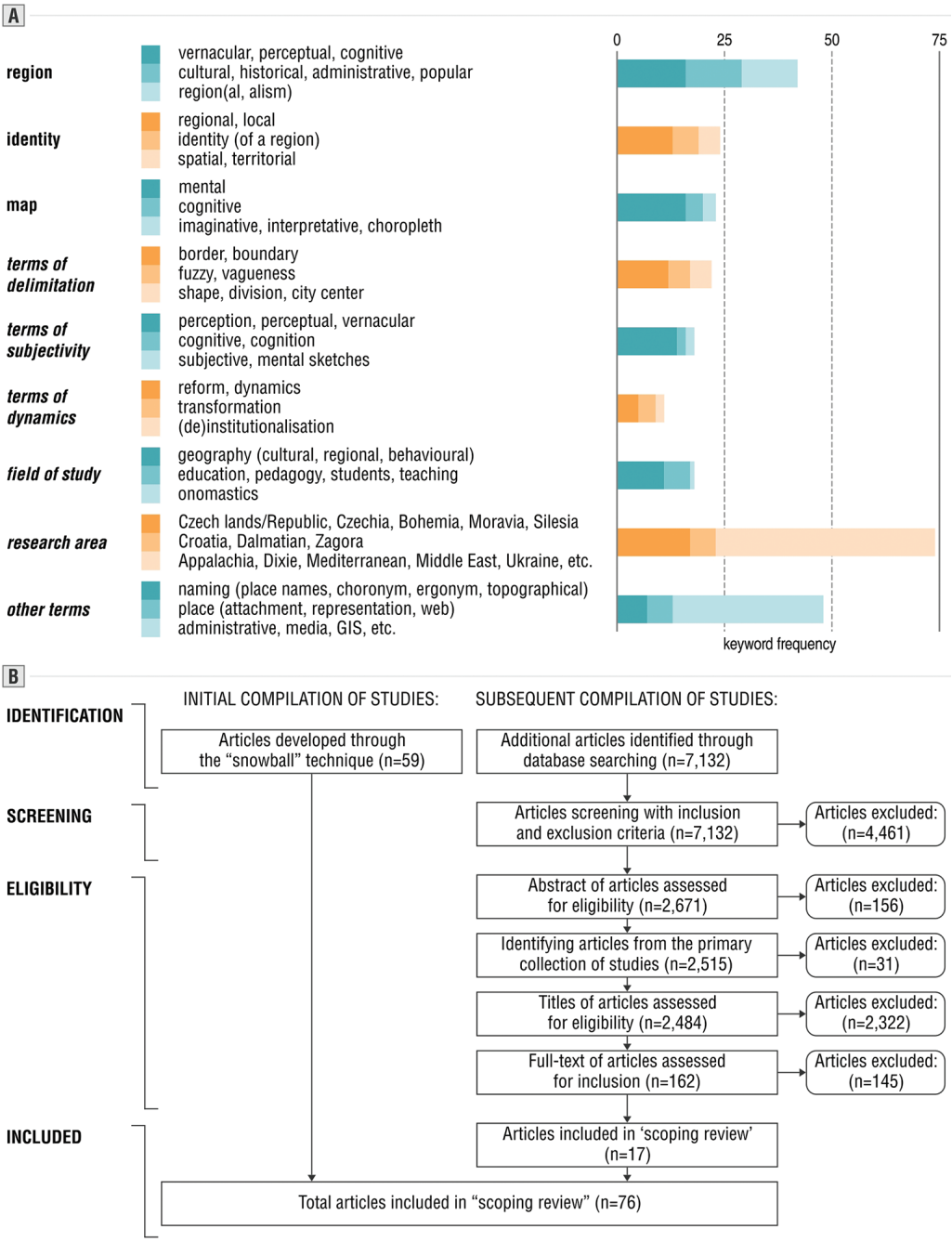


Fig. 1. List of the most frequent keywords in the initial compilation of studies (A), and the process of identifying studies for the subsequent compilation of studies (B). *Source*: Authors' own elaboration.

prehensive review of the articles' full texts. As a result, 17 more studies were added. It is important to acknowledge the inherent subjectivity of this selection process, as well as its potential limitations, particularly the reliance on a single database and the exclusive focus on English-language studies, which may not fully capture the width of relevant studies. In the latest modifications, mainly English texts were selected from the initial compilation (with three exceptions from the Czech environment due to their exceptional specificities in data collection), and when several articles of the same author(s) were written from one data collection only one representative study was selected.

The data collection techniques and their details are outlined in the result section. While only a few selected studies showcase their use, these techniques are commonly applied in other research context as well. Moreover, the identified studies sometimes combine various methodological approaches to delimit the region, using a combination of data collection techniques. All the techniques identified in the studies are analysed in terms of the methodological approaches used, and their connection to the regions being studied.

Identified data collection techniques to delimit a region

This chapter reviews data collection techniques employed in past research. Each subchapter addresses distinct techniques and the sources of data for analysis. Two principal techniques may be recognised in the research of territorial identity: (1) techniques relying on secondary sources, and (2) techniques generating primary data. Despite efforts to structure data collection techniques under the identified methodological approaches to delimit a region, overlaps among them complicate this structuring, as certain data collection techniques are linked to multiple methodological approaches *(Figure 2).*

Literature, spatial Information and researchers' field notes analysis

A comprehensive review of the literature is crucial for understanding any research (Clifford, N. *et al.* 2010), including territorial identity. This technique involves investigating the current boundaries of a region, that is, the territorial identity discourse, through analysis of

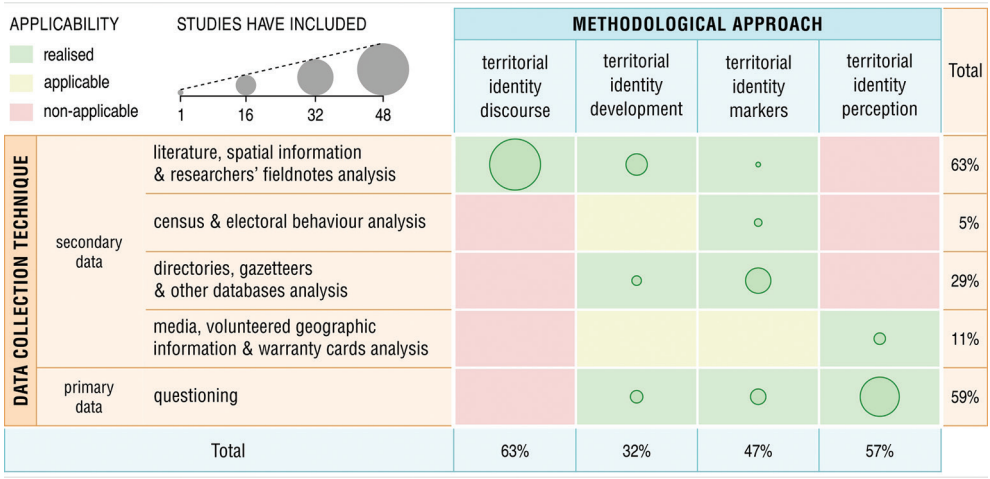


Fig. 2. Interrelationship of techniques and approaches and their frequency of usage in the compilation of studies. *Source*: Authors' own elaboration.

regional geography textbooks, cartographic documents, GIS databases, laws or academic and popular literature in general. This initial step provides insight into a region's contemporary territorial identity, guiding subsequent evaluation and interpretation of data obtained through other techniques. Furthermore, some authors employ this technique to investigate territorial identity development, as literature and maps provide both contemporary and historical perspectives.

Numerous authors have drawn upon the aforementioned sources of information, particularly in studies on (de)institutionalised regions, where the current or past state of the region's borders serves as a research foundation (e.g. Bartůněk, M. and Bláha, J.D. 2023; Marek, P. 2023). However, some researchers compare the territorial shape of the same region across several studies, highlighting variations in boundaries influenced by different geographical aspects, as demonstrated by Hale, R.F. (1983), and Tandarić, N. *et al.* (2013). Other studies explore varying boundaries based on the geographical location of the study, such as Bláha, J.D. and Nováček, A. (2016), or Pánek, J. and Šenkeříková, M. (2018), who employ a systematic description accompanied by an analytical map.

Temporal approaches to boundary evolution are exemplified by Vukosav, B. (2015), who analysed the boundaries through cartographic representations and Semian, M. (2012), who examined evolving discourses on delimitation of the region by various authors and institutions.

Finally, the analysis of researchers' field notes offers additional insights, such as the documentation of cultural traits (Štika, J. 1961), which are methodologically classified under territorial identity markers.

Census and electoral behaviour analysis

Processing secondary data from government sources, particularly census records, allows the identification of territorial identity markers by providing insights into socio-cultural characteristics of the population such as language, religion and nationality/ethnicity, which, in some countries, can assist in defining boundaries.

Illustrative studies include those conducted by Vaishar, A. and Zapletalová, J. (2016), and Siwek, T. and Kaňok, J. (2000), which examine nationality data to inform further research. Although Bartos-Elekes, Zs. (2019) also employs ethnicity as a variable, the ethnic group under examination exhibits a wide range of distinct socio-cultural characteristics, including language and religion. Phillips, D.W. and Montello, D.R. (2017) adopt a more comprehensive approach, incorporating a wider range of demographic data and applying geodemographic classification.

In addition, Weakliem, D. and Biggert, R. (1999) propose using political preferences derived from election results to determine the territorial distribution of regional identity.

Directories, gazetteers and other databases analysis

The use of symbolic shape elements (proper names, emblems, logos, etc.) in cultural landscapes reflects the perception of the inhabitants who belong to that particular area (Melnychuk, A. *et al.* 2014). Accordingly, the identification of territorial identity markers or territorial identity development can be achieved through the utilisation of secondary data from (government) directories, gazetteers and other databases. For more details on proper names, see their categorisation in ICOS Terms (2023), or for symbolic elements in general, refer to Šifta, M. and Chromý, P. (2017).

A common technique in the reviewed studies is delimiting regions through institutions (businesses, educational, governmental and non-profit organisations) using choronyms in the institutions' names, that is, chrematonyms. This application can be demonstrated in the context of a single region (e.g. Colten, C.E. 1997; Vukosav, B. and Fuerst-Bjeliš, B. 2016; Sublett, M.D. 2021), or two overlapping regions (e.g. Reed, J.S. 1976; Ambinakudige, S.

2009; Andrews, J.R. and Finchum, A. 2020). Other authors concentrated on the potential for regionalisation within an administrative unit, that is, on the scale of a state (e.g. McEwen, J.W. 2014; Liesch, M. *et al.* 2015) or even a continent (e.g. Zelinsky, W. 1980). Additionally, some scholars (e.g. Weaver, R. and Holtkamp, C. 2015; Holtkamp, C. *et al.* 2018) have traced the characteristic appellatives for the region in toponyms or urban place names (e.g. hodonyms) and the occurrence of regions' names within them (Melnychuk, A. *et al.* 2014). In addition, some authors (Konopski, M. 2021; Marek, P. 2023) have identified, although through a distinct data collection technique, that territorial identity is shaped by settlement names, indicating an additional data source.

Authors addressing temporal aspects in their research either track the evolution of business names by repeating studies after several years (Reed, J.S. *et al.* 1990) or compare results with earlier studies (Alderman, D.H. and Beavers, R.M. 1999). Alternatively, they analyse the current use of business and institution names to observe transformations of the territorial identity from the previous state (Gnatiuk, O. and Melnychuk, A. 2019).

It is evident that proper names represent the most prevalent source of data within this category. However, as Gnatiuk, O. and Melnychuk, A. (2021) have demonstrated, the utilisation of other symbols representing the region, such as emblems and flags, has the potential to contribute to the definition of territorial identity as well.

Media, volunteered geographic information and warranty cards analysis

Unlike previous expert-based/government data, the data used in this technique emphasises subjective attitudes and utilises quantitative methods to analyse patterns of ordinary people's perceptions. Several authors have used newspaper articles, language corpora, and the media in general (Vukosav, B. and Fuerst-Bjeliš, B. 2015). A further example is *volunteered geographic information* (VGI) utilising the web, where the content is generated by internet users themselves (Goodchild, M.F. 2007). From a methodological perspective, all this represents an indirect approach to *territorial identity perception*.

In content analyses conducted by Vukosav, B. (2011), or Vukosav, B. and Fuerst-Bjeliš, B. (2015), newspapers were analysed to examine the relationship between municipalities and regions of interest, specifically looking at which municipalities are linked to which regions and how frequently these associations occur.

Within VGI, two principal aspects of data collection can be identified: first, trigger phrase searches are utilised (e.g. Jones, C.B. *et al.* 2008; Reinbacher, I. *et al.* 2008), as websites frequently link specific locations, such as cities, with the region's name; second, the use of geotags from platforms like Flickr, Instagram, Twitter and Wikipedia helps delimit a region (e.g. Gao, S. *et al.* 2017). A notable example is Shortridge, J.R. (1987), who used warranty cards in a case study specific to the United States.

Questioning

A survey is a key method for collecting primary data on territorial identity, capturing attitudes across large populations (Babbie, E. 2007) and allowing the direct exploration of territorial identity perception, and even territorial identity development and territorial identity markers. It encompasses research design elements like sampling and analysis (for further details on sampling see, e.g. Clifford, N. *et al.* 2010; for guidance on wording of questions see, e.g. Flowerdew, R. and Martin, D. 2005). This subchapter focuses on a questionnaire as the data collection technique (Gregory, D. *et al.* 2009) and emphasises differences across the reviewed studies, particularly in the formulation of questions, strategies employed throughout the questionnaires and the inclusion of a base map, all in relation to different attributes of regions.

Important factors within this technique are (1) the number of regions studied, and (2) their scale, as these elements influence the questionnaire design, strategy and interpretation, in other words, the presentation of the region's territorial shape. Regarding the number of regions, territorial identity can be investigated by focusing on (a) a single region (e.g. Pleić, T. *et al.* 2021), or a partial shape of one region through complementary studies (e.g. Staut, M. *et. al.* 2007; Tandarić, N. *et al.* 2013); (b) a border between neighbouring regions (e.g. Šerý, M. and Šimáček, P. 2012), or (c) multiple regions (e.g. Good, J.K. 1981). Regarding the scale of regions, questionnaires are typically used for (a) smaller regions within a single state (e.g. Heath, D.E. 1993; Semian, M. 2012); however, some studies focus on (b) regions that extend beyond a single state (e.g. Shortridge, J.R. 1985; Bláha, J.D. and Nováček, A. 2016), or even (c) regions on a global scale (e.g. Polonský, F. *et al.* 2010; Didelon, C. *et al.* 2011).

In designing questionnaires, two key aspects must be considered: (1) the formulation of questions by the researcher and (2) how respondents can answer. Questions may include requests to (a) "draw the boundary on a map" (e.g. Geršič, M. 2017), (b) "rate each cell in a polygon grid" (Montello, D.R. *et al.* 2014), (c) "include/exclude your local area in/from the region" (e.g. Brownell, J.W. 1960), or (d) "name local areas in the region" (e.g. Schlemper, M.B. and Panozzo, K.A. 2020). The nature of these questions depends on the ability to record the answer: for instance, (a) closed-ended questions can be used (e.g. Konopski, M. 2021), (b) multiple-choice questions allow respondents to select from multiple regions (e.g. Lamme, A.J. and Oldakowski, R.K. 1982), or (c) open-ended questions can be used, enabling respondents to identify their region without prompts (e.g. Jordan, T.G. 1978; Hale, R.F. 1984).

Questionnaires enable the implementation of opposite strategies: (1) in-person interaction with the respondent, or (2) avoiding such interaction. Face-to-face questioning represents an in-person strategy (e.g. Marek, P. 2023); one may also consider incorporating elements of interviews (e.g. Marek, P. 2020) or focus groups (e.g. Edmondson, D. 2018). In contrast, impersonal strategies include (a) telephone calls (e.g. Lamme, A.J. and Oldakowski, R.K. 2007), (b) sending the questionnaire to respondents by post (e.g. Zdorkowski, R.T. and Carney, G.O. 1985), or (c) using internet-based forms (e.g. Pánek, J. and Šenkeříková, M. 2018).

Special attention should be given to the base maps possibly used for recording regional boundaries concerning (1) their form and (2) their content. While most authors rely on (a) printed base maps (e.g. Ulack, R. and Raitz, K. 1981), the use of (b) online base maps has recently gained prominence (e.g. Pánek, J. and Šenkeříková, M. 2018). It is not always necessary for the map content to be displayed at all, as shown by the use of (a) blank paper (e.g. Kaisto, V. and Wells, C. 2021); conversely, (b) map content can abound with various topography elements (e.g. Marek, P. 2020), but frequently (c) it is reduced to representations of states with cities (e.g. Lowry, J. *et al.* 2008; Konopski, M. 2021). The topography elements and their lettering should be carefully considered especially for printed base maps, taking into account scale and map sheet size (Zaga, M. and Waisel, T.Y. 2023). Although many authors use base maps, the map content is often insufficiently considered, despite its influence on the results (see Stachowski, K. 2017). Perceptual dialectology, while focusing on language and linguistic region's delimitation (e.g. Bounds, P. 2015; Alhazmi, J. 2017), places greater emphasis on map content (e.g. Bounds, P. and Sutherland, C.J. 2018; Cramer, J. 2021; Jeszenszky, P. *et al.* 2024), a practice that should be more aligned with geographic studies.

The investigation of the distribution of language and dialect through questionnaires and the adaptation of standalone sociolinguistic interviews (e.g. Fotiou, C. and Grohmann, K.K. 2022) within perceptual dialectology represents a direct approach to territorial identity markers. A comparable

approach is implied in a study conducted by Lowry, J. (2013), which asked respondents to identify symbols associated with the region that could serve as indicators of its boundaries, effectively linking the territorial and symbolic shapes of the region. Finally, some authors (e.g. Miroševič, L. and Vukosav, B. 2010; Melnychuk, A. and Gnatiuk, O. 2018) use the regional identity of people as a marker of territorial identity, similar to how census data is analysed in relation to nationality (although nationality represents only a part of the affective dimension).

Territorial identity development can also be investigated through questioning. Marek, P. (2020) and Konopski, M. (2021) demonstrate this in the case of historical regions, whose initial perceptual delimitation can be expected to align with the historical boundary. Kaisto, V. and Wells, C. (2021) explicitly asked their respondents how the current region's boundaries changed according to their opinion in a certain period. Similarly, questioning can also address temporal factors by comparing generational perspectives or adopting (semi-)longitudinal study (Lamme, A.J. and Oldakowski, R.K. 2007).

Conclusions and future research recommendations

This scoping review analysed 76 studies on the delimitation of territorial part/shape of the identity of regions, sourced through the "snowball" technique and targeted Web of Science searches. The paper classified data collection techniques in territorial identity research and demonstrates their integration within broader methodological approaches extensively used in new regional geography, emphasising the need for further investigation into these methods.

In general, secondary data sources (including literature with spatial information, maps, census data, place names databases) provide indirect, expert-based/government indicators for boundary identification. Conversely, the direct gathering of primary data through questionnaires, in conjunction with the retrieval of secondary data through media or VGI analysis, provides insights into the perceptions of ordinary people. *Figure 2* illustrates the interdependence of these techniques with methodological approaches, highlighting their (in)occurrence in analysed studies and presenting key patterns – especially secondary data being used predominantly for delimiting regions through territorial identity markers whereas primary data being employed mainly to delimit regions reflecting territorial identity perception.

First, in realised studies, the most prevalent technique is the analysis of literature and spatial information, as it is frequently combined with other techniques in a single study. These data are typically linked to territorial identity discourse, which may involve the integration of previous delimitations of the region by the researcher or an administrative boundary. Alternatively, the data inform research on territorial identity development, particularly when historical boundaries are utilised. A further substantial proportion of the secondary data comprises a variety of database analyses incorporating proper names to identify territorial identity markers. Of these, the most frequently used are chrematonyms, also known as ergonyms. The aforementioned secondary data are considered to be easily adaptable to other regions, whereas others, like warranty cards, are limited to specific countries due to their (non-) availability. The utilisation of VGI analysis has not been extensively employed, apparently due to the higher demand for computer skills; nevertheless, there exists a significant potential for its application. In general, the use of primary data is constrained by its lack of availability and the fact that it takes longer and costs more than using already existing secondary data; despite this, questioning is employed in a substantial proportion of studies. This challenge was frequently addressed by recruiting (geography) students as respondents, though some authors acknowledge the limitations of unrepresentative sampling (Lowry, J. 2013; Bláha, J.D.

and Nováček, A. 2016). A study's reliability may be enhanced by asking the general population, although this may be limited by a lack of geographical education among the respondents. To eliminate these difficulties, real-time (face-to-face or telephone) questioning includes the possibility of guidance for the respondent (which is often needed particularly when utilising a base map). However, this strategy may affect/manipulate resulting data – so it is double-edged.

Second, other techniques, particularly those related to territorial identity markers and territorial identity development, are infrequently applied or may be classified only as applicable. For instance, territorial identity markers combined with media or VGI analysis may serve as alternatives to researchers' field notes, documenting cultural traits in the perceptions of ordinary people. The choice of techniques, however, often depends on the type of secondary data used; in cases involving census data or proper names that can be extracted from various databases, alternative techniques may be more appropriate. A more significant gap in the studies is the lack of attention to temporal dimensions within territorial identity development research – an oversight that hinders building the theory of region as a dynamic process. To address this, future research should emphasise examining the evolution of the population's socio-cultural characteristics, for example, through the analysis of census data. Media and VGI analysis also holds the potential for investigating temporal aspects by filtering data from specific periods.

Third, disconnections exist between data collection techniques and methodological approaches, suggesting that not all techniques can be integrated into all approaches.

Concurrently, this study relates the findings to regions of varying scales demonstrating the applicability of techniques and approaches, whether in the context of a single region or multiple regions (regionalisation) research (see *Figure 3*, or a list of all the regions studied in *Appendix*). First, research on single or multiple regions is balanced, particularly evident below the state scale. At the state scale, existing research slightly favours multiple regions studies, whereas above state scale research tends to focus on single regions. This is related to the fact that research on the de jure territorial shape of a single region such as a state may appear redundant, but this may not always be the right assumption. In terms of techniques, a higher proportion of single region studies occurs at below state scale with the use of directories, gazetteers and other databases analysis, whereas media and VGI analysis and questioning are more frequently applied in multiple region research.

Second, conversely, there is a notable discrepancy in the extent of research conducted on regions of varying scales. The regions that have been the subject of the greatest number of studies are those that are below state scale, with the remaining studies distributed evenly between research on regions at the state scale and on regions above state scale. Similarly, all techniques exhibit an identical representation across scales. However, it is noteworthy that research on regions above state scale employs a greater proportion of primary data than secondary data, although primary data are typically less available. The discrepancy may be attributed to the fact that the utilisation of secondary data necessitates the integration of foreign data sources, which may present linguistic barriers for a researcher, or that the secondary data for above state scale regions may not exist at all. In contrast, collecting primary data may, in fact, be less challenging. For instance, (geography) students may be involved (see above), or collaborations between foreign research institutes may be realised.

This study is intended to encourage the implementation of triangulation design in the social sciences, wherein multiple research methods converge in a single study (mixed research designs) to provide a more nuanced and multifaceted comprehension of territorial identity. The findings demonstrate that many techniques are complementary and, in some cases, methodological approaches

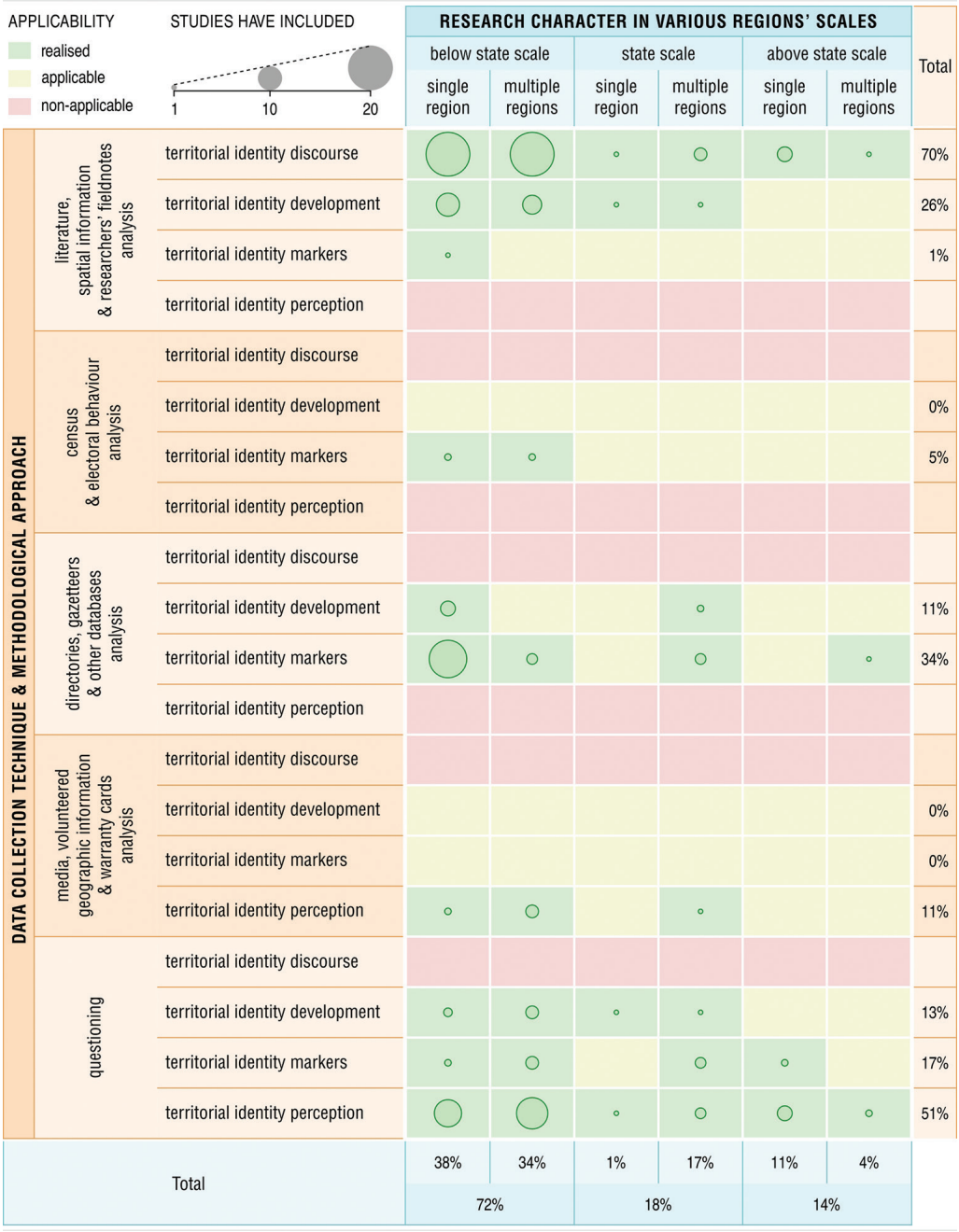


Fig. 3. Interrelationship of techniques with regions under study. *Source*: Authors' own elaboration.

are effectively combined – particularly with a territorial identity discourse (in 59% of all studies). Despite this, the combination of methodological approaches, such as the integration of territorial identity markers with territorial identity perception or territorial identity development, remains a relatively uncommon practice. An exception is, for example, the study by Homanyuk, M. (2019), employing various methodological approaches and data collection techniques for the same research subject (although without a clear description of the research methodology), which helps to put the pieces together into a comprehensive picture of the territorial shape of the region. Upon subtraction of territorial identity discourse, 25 percent of the studies employ two methodological approaches, while all methodological approaches are employed in only 4 percent of the studies. Future research should focus on combining techniques within various methodological approaches while critically examining the interconnectedness of findings. This will help advance both theoretical understanding of territorial identity and its potential applications in fields such as education or regional development.

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Appendix

Name of the region (research area) with country/continent code	Research character in various regions' scale*	Data collection technique combined with methodological approach**	Publications
Kibera city – KEN / AF	∘∘∘	1–A, 4–D	Aadland, M. *et al.* (2016)
Middle East – – / AF, AS, EU	O	1–A, 5–D	Pánek, J. and Šenkeříková, M. (2018); Zaga, M. and Waisel, T.Y. (2023)
Western Saudi Arabia – SAU / AS	∘∘∘	5–C	Alhazmi, J. (2017)
Cyprus – CYP / EU	ooo	1–A, 5–C	Fotiou, C. and Grohmann, K.K. (2022)
Bohemian Paradise – CZE / EU	∘	1–A, 1–B, 5–D	Semian, M. (2012)
Czechia – CZE / EU	∘∘∘ | ooo	1–A, 1–B, 2–C, 5–B, 5–C, 5–D	Chromý, P. *et al.* (2009); Šerý, M. and Šimáček,, P. (2012); Vaishar, A. and Zapletalová, J. (2016); Marek, P. (2020, 2023); Bartůněk, M. and Bláha, J.D. (2023)
Silesia – CZE / EU	∘	1–A, 1–B, 2–C, 5–B, 5–D	Siwek, T. and Kaňok, J. (2000)
Wallachia – CZE / EU	∘	1–A, 1–C	Štika J. (1961)
Southeast Saxony – DEU / EU	∘∘∘	1–A, 1–B	Bartůněk, M. and Bláha, J.D. (2023)
Finland – FIN / EU	o	1–A, 1–B, 5–B, 5–D	Kaisto, V. and Wells, C. (2021)
Midlothian region – GBR / EU	∘	1–A, 3–C	Alani, H. *et al.* (2001)
United Kingdom – GBR / EU	∘∘∘	1–A, 4–D	Jones, C.B. *et al.*(2008); Reinbacher, I. *et al.* (2008)
Croatia – HRV / EU	∘∘∘	1–A, 1–B, 3–C, 5–C, 4–D	Miroševič, L. and Vukosav, B. (2010); Vukosav, B. and Fuerst-Bjeliš, B. (2015, 2016)
Zagora – HRV / EU	∘	1–A, 1–B, 3–C, 4–D	Vukosav, B. (2011, 2015); Vukosav, B. and Fuerst-Bjeliš, B. (2016)
Hogeland – NLD / EU	∘	1–A, 5–D	Stoffelen, A. *et al.* (2024)
Podlasie – POL / EU	∘	1–A, 1–B, 5–B, 5–C, 5–D	Konopski, M. (2021)
Poland – POL / EU	ooo	5–C	Bounds, P. (2015); Stachowski, K. (2017)
Slovenia – SVN / EU	ooo	5–D	Geršič, M. (2017)
Székely Land – ROU / EU	∘	1–B, 2–C	Bartos-Elekes, Zs. (2019)
Podolia – UKR / EU	∘ | ∘∘∘	1–A, 1–B, 5–B, 5–C	Melnychuk, A. and Gnatiuk, O. (2018)
Tavria/Tauride – UKR / EU	∘	***1–A, 1–B, 3–B, 3–C, 4–D, 5–C, 5–D	Homanyuk, M. (2019)

Appendix continued

Name of the region (research area) with country/continent code	Research character in various regions' scale*	Data collection technique combined with methodological approach**	Publications
Ukraine – UKR / EU	ooo	1–A, 1–B, 3–B, 3–C	Melnychuk, A. *et al.* (2014); Gnatiuk, O. and Melnychuk, A. (2019, 2021)
Balkans – – / EU	O	1–A, 5–D	Pleić, T. *et al.* (2021)
Central Europe – – / EU	O	1–A, 5–D	Sinnhuber, K.A. (1954); Bláha, J.D. and Nováček, A. (2016)
Danube – – / EU	O	5–C	Padło, T. *et al.* (2021)
Mediterranean – – / EU	O	1–A, 5–C, 5–D	Staut, M. *et. al.* (2007); Tandarić, N. *et al.* (2013)
Alberta – CAN / NA	∘∘∘	5–D	Montello, D.R. *et al.* (2014)
Appalachia – USA / NA	∘	1–A, 3–C, 5–D	Ulack, R. and Raitz, K. (1981); Weaver, R. and Holtkamp, C. (2015)
Arkansas – USA / NA	∘∘∘	5–D	Good, J.K. (1981)
California – USA / NA	∘∘∘	1–A, 4–D, 5–D	Montello, D.R. *et al.* (2014); Gao, S. *et al.* (2017)
Corn Belt – USA / NA	∘	1–A, 1–B, 3–C	Sublett, M.D. (2021)
Dixie – USA / NA	∘	3–B, 3–C	Reed, J.S. (1976); Reed, J.S. *et al.* (1990); Alderman, D.H. and Beavers, R.M. (1999); Ambinakudige, S. (2009); Andrews, J.R. and Finchum, A. (2020)
Florida – USA / NA	∘∘∘	1–A, 5–B, 5–D	Lamme, A.J. and Oldakowski, R.K. (1982, 2007)
Kansas – USA / NA	∘∘∘	3–C, 5–D	Shortridge, J.R. (1980)
Lehigh Valley – USA / NA	∘ | ∘∘∘	1–A, 5–D	Heath, D.E. (1993)
Louisiana – USA / NA	∘∘∘	1–A, 3–C	McEwen, J.W. (2014)
Michigan – USA / NA	∘∘∘	3–C	Liesch, M. *et al.* (2015)
Midwest – USA / NA	∘	3–C, 5–D	Brownell, J.W. (1960); Shortridge, J.R. (1985)
New England – USA / NA	∘	1–A, 5–D	Lowry, J. (2013)
North America – – / NA	∘∘∘	3–C	Zelinsky, W. (1980)
Northwest – USA / NA	∘	5–D	Lowry, J. *et al.* (2008)
Oklahoma – USA / NA	∘∘∘	5–D	Zdorkowski, R.T. and Carney, G.O. (1985)

Appendix continued

Name of the region (research area) with country/continent code	Research character in various regions' scale*	Data collection technique combined with methodological approach**	Publications
Rocky Mountains – USA / NA	∘	1–A, 3–C	Holtkamp, C. *et al.* (2018)
Santa Barbara city – USA / NA	∘∘∘	1–A. 2–C, 5–C	Phillips, D.W. and Montello, D.R. (2017)
South – USA / NA	∘	3–B, 3–C	Reed, J.S. (1976); Reed, J.S. *et al.* (1990); Ambinakudige, S. (2009)
Southwest – USA / NA	∘	1–A, 3–C	Holtkamp, C. *et al.* (2018)
Texas – USA / NA	∘∘∘	1–A, 5–D	Jordan, T.G. (1978)
The Land of Lincoln – USA / NA	∘	3–C	Colten, C.E. (1997)
Unied States of America – USA / NA	ooo	3–C, 4–D, 5–D	Good, J.K. (1981); Hale, R.F. (1984); Shortridge, J.R. (1987); Alderman, D.H. and Good, D.B. (1996); Edmondson, D. (2018)
Wisconsin – USA / NA	∘∘∘	1–A, 5–D	Hale, R.F. (1983)
Wisconsin's Holyland – USA / NA	∘	5–D	Schlemper, M.B. and Panozzo, K.A. (2020)
Venezuelan Andes – VEN / SA	∘	1–A, 1–B	Price, M.D. (1996)
The World– – / –	OOO	1–A, 5–D	Polonský, F. *et al.* (2010); Didelon, C. *et al.* (2011)

*Research character in various regions' scale: ∘ = below state scale; o = state scale; O = above state scale; ∘ = single region; ooo = multiple regions (regionalisation). **Data collection technique combined with methodological approach: 1 = literature, spatial information and researchers' field notes analysis; 2 = census and electoral behaviour analysis; 3 = directories, gazetteers and other databases analysis; 4 = media, volunteered geographic information and warranty cards analysis; 5 = questioning. A = territorial identity discourse; B = territorial identity development; C = territorial identity markers; D = territorial identity perception. ***Assumed methodology.

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Human and demographic capital in peripheral and core municipalities and regions and its development (northwest Bohemia)

Vlastimil VESELÝ[1] and Jan KUBEŠ[2]

Abstract

The paper compares the human and demographic capital of central, suburban, semi-peripheral and peripheral municipalities of the Karlovy Vary Region and also the regions of Czechia and neighbouring regions in Germany. Peripheral municipalities are considerably distant from meso- and micro-regional towns in terms of time spent on public transport. The demographic capital of municipalities is assessed according to indicators of population development, natural and migration balance, and age structure. In the evaluation of human capital, indicators of education, unemployment, foreclosures, entrepreneurship, and housing construction are used. The assumption of low human capital in peripheral municipalities compared to more geographically exposed municipalities was not confirmed. Suburban municipalities have the highest human and demographic capital. Although the studied region borders the developed regions of Germany, it has the least favourable values of human and demographic capital of all Czech regions and neighbouring German regions. This is a consequence of the complete population exchanges after World War II, the existence of the Iron Curtain on the region's borders with the West during the socialist (communist) period, the peripheral location of the region within Czechia, the inappropriate development of industry under socialism, and the problems of this sector and weak cross-border cooperation in the post-socialist period. The paper also presents strategies and measures to support human capital in the types of municipalities of the region and throughout the region.

Keywords: Human capital, regional development, settlement centres, periphery, semi-periphery, small towns

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Introduction

The Karlovy Vary Region is located in the very west of Czechia, on the borders with the developed Bavaria and with Saxony in Germany. It has a peripheral location within Bohemia and Czechia and is part of one of the inner peripheries of Central Europe. The region has great internal socio-geographic heterogeneity due to physical-geographical conditions and specific and problematic political, ethnic, economic and social developments (Hampl, M. 2003; Lipovská, Z. *et al.* 2012). These characteristics of the region are then reflected in its current level of development and in the demographic and human capital of its municipalities and the region as a whole (also Wielechowski, M. *et al.* 2021). For these reasons, it is important to recognize, understand and positively direct its demographic and human capital.

The *aim of the paper* is to identify and explain differences in human capital (in people's abilities, skills and activity) and in demographic capital (in demographic stability and development of population structure) in peripheral, semi-peripheral, suburban and central municipalities (meso- and micro-

[1] University of West Bohemia, Faculty of Economics, Department of Geography, Univerzitní 2732/8, 301 00 Plzeň, Czechia, E-mail: vesely.vlastimil@email.cz

[2] University of South Bohemia in České Budějovice, Department of Geography, Branišovská 1645/31A, 370 05 České Budějovice 2, Czechia, E-mail: kubes@pf.jcu.cz, ORCID: 0000-0001-7929-4539

regional towns) of the Karlovy Vary Region, sub-regions of this region, and also between this region and other Czech and neighbouring German regions. It also includes the proposal of strategies and measures for the further development of human capital in the region and its municipalities.

As for the research questions, the first is auxiliary – it asks about the distribution of higher and lower settlement centres, suburban zones, semi-peripheries and peripheries of the region, the second is the main one and is aimed at identifying and comparing human and demographic capital of types of municipalities and sub-regions on the territory of the region, and the third is focused on comparing the region with other Czech regions and neighbouring German regions.

The introduction of the paper is followed by a theoretical part defining the issue of human and demographic capital and their development effect and also the issue of peripherality. The next part of the paper presents the specifics of the Karlovy Vary Region. In the methodological part of the paper, the procedure for defining settlement centres and other types of municipalities is given, and the human and demographic capital indicators used are defined here. A comparison of the human and demographic capital of the monitored types of municipalities, sub-regions and regions is made in the results part of the paper. This is followed by a Discussion with proposals for strategies and measures for the development of human capital in the region and a Conclusion.

Theoretical background

American economist Gerry Becker defined *human capital* as the sum of people's abilities and skills and the application of those abilities and skills, and also pointed out the importance of education and health in human capital (Becker, G. 1964). The concept of human capital was then often used by sociologists (e.g. Coleman, J.S. 1988) and also human geographers in studies devoted to the new economic geography, regional disparities and regional development (Krugman, P.R. 1991; Elhorst, J.P. 1998, and others). Some developmental elements of social capital were also included in human capital (Svendsen, G. and Sørensen, J.F. 2006; Weaver, R.D. and Habibov, N. 2012). In developed countries, developed or stable *demographic capital* (Sagan, I. and Masik, G. 2014; Wieczerzak, J. 2018) can be considered such a natural and migratory balance of the population that leads to long-term stability in the number of the population and the balance of its structure. The question is whether to consider demographic capital as part of human capital or as a separate issue.

Investments and other supports in youth and adult education contribute to economic growth (Mincer, J. 1984; Blundell, R. *et al.* 1999 and many recent studies). Growth in education benefits the entire country, its regions and their communities (Agarwal, S. *et al.* 2009; Weaver, R.D. and Habibov, N. 2012, and others). Also, in the business and employer sphere, the state and development of working knowledge, abilities and skills is important (Bontis, N. and Serenko, A. 2007; Ployhart, R.E. *et al.* 2014). In countries, regions and municipalities of developed countries with low birth rates, high emigration and a high proportion of elderly people, strategies and measures to gradually improve these unfavourable demographic characteristics must be sought (Sleebos, J. 2003; Adsera, A. 2004; Lutz, W. 2006).

The literature lacks a unified view of *"periphery"* in the territory. According to some authors, it is the socio-economically underdeveloped part of the region (Leimgruber, W. 2004), according to others, it is a part of the area quite distant from the city or town (this paper), or it may be a combination of both views (Agarwal, S. *et al.* 2009; Bernard, J. and Šimon, M. 2017). In the peripheries, weak human capital is usually assumed (Musil, J. and Müller, J. 2008; Novotná, M. *et al.* 2013). However, some peripheral municipalities far from larger towns can benefit from their location near a border crossing,

near an important road, in an area with significant tourism or high cultural capital and identity (Kubeš, J. and Podlešáková, N. 2021; PRKK, 2021). In this paper, human capital will be evaluated on the continuum: micro-regional towns – suburban – semi-peripheral – (remote) peripheral municipalities.

The Karlovy Vary Region

The Karlovy Vary Region is one of the 14 territorial-administrative regions of Czechia. It is located in the westernmost Bohemia, on the border with Bavaria (Upper Franconia and Upper Palatinate regions) and Saxony (Chemnitz region) in Germany. The region has a peripheral location within Bohemia and Czechia and is part of one of the inner peripheries of Central Europe. The border area with Saxony is mountainous with narrow valleys, in the central part there is an elongated west–east basin with the Ohře river flowing through it, and in the southern and south-eastern parts there are highlands.

The region has a population of just under 300,000 (in 1930 it was 500,000). The regional (meso-regional) centre is the city of Karlovy Vary, with only 50,000 inhabitants, larger towns are Sokolov (centre of the brown coal area) and Cheb. There are a total of 134 municipalities of various population sizes in the region. In this paper, municipalities are divided into meso- and micro-regional towns (10), (very) small towns (11), townships (11) and functionally less significant municipalities (see the methodological and results part of the paper).

In the 19th century, world-famous spa towns developed near mineral springs, especially Karlovy Vary and Mariánské Lázně. During the industrial revolution, brown coal mining and related industries developed in the heart of the region. Based on coal mining and related industries, smaller towns and townships were established here, supplemented by panel housing estates during the socialist period. The southern and south-eastern parts of the region had and still have a rural character. The almost complete removal of the German-speaking population from the region after World War II and the insufficient settlement of the region by Czech people is still evident today. During the socialist period, an impenetrable Iron Curtain existed on the border with Bavaria. Post-socialist public administration representatives are trying to restore cross-border relations with neighbouring German regions, but so far not very successfully (Teufel, N. *et al.* 2022). The region's post-socialist economy is suffering from the end of coal mining and the problems of the local textile, glass and porcelain industries.

Research methodology

When delimiting the peripheries, it is first necessary to define the higher settlement centres. According to Hampl, M. and Marada, M. (2015), the 50,000-person city of Karlovy Vary is a meso-regional city, albeit a very weak one. Micro-regional towns are one hierarchical level lower. In their micro-region, they have a relatively closed daily commute to work and services. In the environment of Czechia, a micro-regional town should have a gymnasium or another high school for pupils aged 15–18, at least 10 specialist doctors, a food supermarket, 2000 occupied jobs, 1000 commuters for work and study (verified on the territory of the Pilsen Region – Kubeš, J. and Podlešáková, N. 2021) and at least 5,000 inhabitants (Hampl, M. and Marada, M. 2015). The ranking of micro-regional towns (and also lower settlement centres) was created using four indicators – number of inhabitants, number of types of services (the presence of thirty administrative, school, health, purchasing, financial and cultural services), number of people commuting to work or study, and the number of bus and train connections arriving on a working day. The numerical data are then converted to point values, where the data for the city of Karlovy Vary represent 100 points. The last two interrelated indicators have half the weight,

as they are interconnected. Lower settlement centres are (very) small towns and townships with low point values.

In the second step, peripheral municipalities need to be defined. In this paper they are delineated in the territory behind the 30-minute isochrone when travelling by bus or train to the time-nearest meso- or micro-regional town in working days. If the journey to the stop and the journey from the stop to work are added to the half hour and the return journey is also included, then this commute is at the limit of long-term endurance. If clusters of neighbouring peripheral municipalities have at least three municipalities and an area of more than 50 km^2, they form a peripheral area at the micro-regional level. Two types of these peripheral areas can be distinguished – state-border (outer) and between Czech meso-regions (inner). Suburban municipalities are characterized by a large presence of houses of a suburban character, they are located in the immediate hinterland of larger towns. Semi-peripheral municipalities lie between peripheral and suburban municipalities. In addition to the above, the territory of the Karlovy Vary Region was divided into 9 sub-regions.

In the third step, 6 demographic-capital and 6 human-capital indicators for the level of municipalities are used *(Table 1)*. Municipalities should not have a population decline, they should have a zero or positive natural and migratory population balance, a sufficient proportion of children and a not too high proportion of elderly people*. Residents of municipalities should be educated and active in business, should build (finance) new housing and should not be in debt and unemployed. Indicator values in the first quartile of descending values are considered favourable, values in the last quartile as unfavourable.

Table 1. Used indicators of demographic and human capital

Code	Indicators
	Indicators of demographic capital
LD	Index of long-term population development 2022/1991[1,2,3]
SD	Index of short-term population development 2022/2018[1,2,3]
NT	Average annual natural balance of population per 1000 inhabitants 2017–2021[1,2,4]
MT	Average annual migration balance of population per 1000 inhabitants 2017–2021[1,2,4]
CH	Percentage of children under 14 in 2022[1,2]
SE	Percentage of seniors aged 65+ in 2022[1,2]
LEM	*Life expectancy at birth in years in 2022*[2,3]
	Indicators of human capital
EE	Percentage of the population over 15 years of age with at most elementary education in 2021[1,2,5]
UE	Percentage of inhabitants older than 15 years with tertiary education in 2021[1,2]
NA	Number of new apartments 2018–2022 per 1000 inhabitants in 2022[1,2]
NE	Number of business entities per 1000 inhabitants aged 15 and over in 2022[1,2]
EX	Percentage of inhabitants in foreclosure in 2022[1,2]
UN	Percentage of unemployed inhabitants older than 15 years in 2022[1,2]
MSC	*Average gross monthly salary in thousands of CZK in 2022*[2]
SAR	*Number of people working in science and research per 1000 economically active people in 2022*[2]
GDP	*GDP in purchasing power standard (in thousands of EUR) in 2023*[2,3]
UEX	*Percentage of inhabitants aged 25–64 years with tertiary education in 2022*[3]
HTS	*Percentage of employment in high-technology sectors in 2022*[3]

[1]Indicator used for comparison types of municipalities of Karlovy Vary Region. [2]Indicator used for comparison of Czech regions. [3]Indicator used for comparison of neighbouring German and Czech regions. [4]The year 2022 was affected by arrival of Ukrainian refugees. [5]It includes primary and lower secondary education.

At the level of regions of Czechia, indicator of life expectancy, gross monthly wages and employment in science and research were added to the above indicators (LEM, MSC and SAR

* In Czechia, these parameters may not be favourably evaluated in municipalities with large socially excluded localities.

in *Table 1*). The comparison of the Karlovy Vary Region with neighbouring German and Czech regions is limited due to the unavailability and incomparability of some data. It includes these indicators – LD, SD, LEM, GDP (GDP in purchasing power standard), UEX (percentage of inhabitants aged 25–64 years with tertiary education) and HTS (percentage of employment in high-technology sectors) (see *Table 1*).

Data and indicators for assessing the demographic and human capital should be contextual (associated with these capitals), complete (covering all components of these capitals), representative (indicators should be constructed to produce values close to reality), and correct (also actual) – see Chytil, M. K. (1982). Ensuring "completeness" at the municipal level is difficult due to the unavailability of some data at this level. Creating a summary indicator that would include the values of individual indicators is not appropriate, because both the demographic and human capital of a municipality or region are complex and multidimensional concepts, the individual dimensions of which need to be expressed by separate indicators (Hendrick, R. M. 2004). Therefore, a separate assessment of demographic and human capital and their individual aspects was carried out in the paper.

Results

The meso-regional city, micro-regional towns, (very) small towns and townships of the Karlovy Vary Region are shown in *Figure 1* and *Table 2*. The map also shows suburban, semi-peripheral and peripheral municipalities. Peripheral municipalities create two state-border peripheral areas ("a" and "b") and two larger peripheral areas between meso-regions ("α" and "β" in *Figure 1*). The peripheral areas α and β extend beyond the borders of the region into neighbouring Czech regions and, thus, co-create an extensive inner rural periphery in the west of Czechia (Kubeš, J. and Podlešáková, N. 2021).

Table 3 shows the situation with demographic and human capital in higher and lower settlement centres, other types of municipalities and in nine sub-regions of the Karlovy Vary Region. Meso-, micro- and small towns are losing residents mainly due to low birth rates and migration to the suburbs of the region and to other regions of Czechia (see LD, SD, NT, MT). Of the sub-regions, those adjacent to advanced Bavaria had a more favourable population development. They have important border crossings and roads that help with commuting to work to Bavaria. The urbanized sub-regions of Sokolov and Kraslice, heavily affected by deindustrialization, had a greater relative decrease in population than rural peripheries α and β. The balance of migration (MT) over the past few years indicates a strong suburban migration and documents the decline of the population in towns. The high migration loss of the Ostrov nad Ohří sub-region can be attributed to the loss of the population of mountain settlements of this sub-region. The city of Karlovy Vary has the oldest population (CH, SE), even among all cities in Czechia. So far, the suburban municipalities have a young population, because mainly young families with children moved there from the relevant town and other towns.

In the next part of *Table 3*, the human capital of types of municipalities and sub-regions is compared. The values of the education level indicators (EE, UE) are particularly favourable for the meso-regional city of Karlovy Vary, where university-educated medical doctors (including spa doctors), various managers, teachers and key public administration employees are concentrated. However, the city has the second lowest value of university education among cities in Czechia (after the industrial city of Ústí nad Labem) (see also Minařík, B. and Borůvková, J. 2014). Due to the arrival of young educated suburbanites, some of the suburban municipalities in the vicinity of the city of Karlovy Vary achieve a higher level of education than the city. The construction of apartments (NA) stands out in suburban municipalities (mainly apartments in family houses) and in some mountain municipalities with the construction

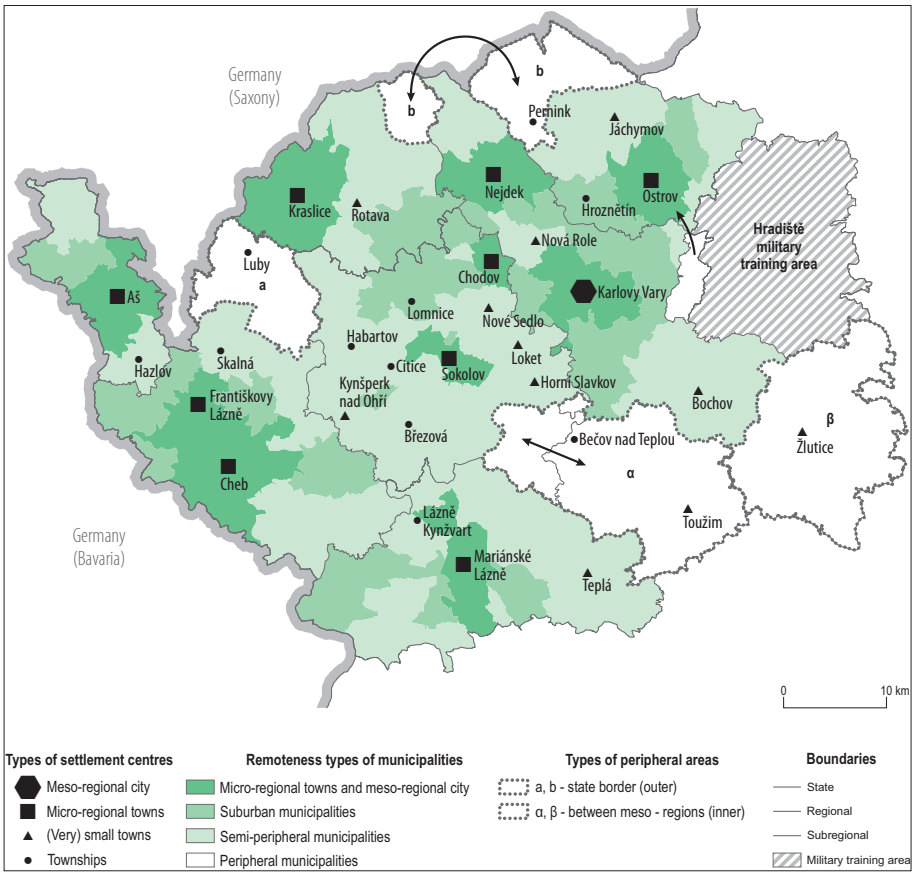


Fig. 1. Settlement centres, peripheral areas and sub-regions of the Karlovy Vary Region, 2022. *Source*: Authors' own processing based on the procedure in the research methodology (GIS by Křenek, P.).

Table 2. Definition of higher settlement centres of the Karlovy Vary Region, 2022

Settlement centres	Population in 2023* persons	Number of types of services, 2023	Number of commuters, 2021*	Number of bus and train connections, 2023**	Weighted average score	Strength of higher settlement centre
Type: meso-regional city						
Karlovy Vary	52,081	55	15 055	362	100.00	very strong
Type: micro-regional town						
Cheb	31,954	41	5432	249	62.78	strong
Sokolov	26,211	37	8078	234	58.92	strong
Ostrov nad Ohří	15,894	29	3622	177	39.91	medium strong
Mariánské Lázně	16,591	30	3522	133	38.82	medium strong
Chodov	13,157	15	1996	198	28.84	weak
Aš	12,804	24	792	55	26.15	weak
Františkovy Lázně	5,707	11	1315	230	22.36	very weak
Nejdek	7,772	15	1494	69	18.90	very weak
Kraslice	6,614	16	694	68	17.83	very weak

Sources: *Databases of the Czech Statistical Office, **IDOS timetables.

Table 3. Human and demographic capital in types of municipalities and sub-regions of the Karlovy Vary Region, 2022

Types of municipalities Sub-regions	Values of demographic capital indicators						Values of human capital indicators					Fourth/*first* quartiles[1]
	LD	SD	NT	MG	CH	SE	EE[2]	UE[2]	NA	NE	EX	UN	
Types of municipalities – average values													
Meso-regional city (Karlovy Vary)	0.88	1.01	-4.93	0.50	14.0	24.2	*12.3*	*15.8*	11.6	*448*	9.1	5.2	5/3
Micro-regional towns	0.94	0.99	-3.90	-2.02	14.8	21.5	17.0	8.8	6.4	292	10.5	4.0	2/0
Suburban municipalities	1.80	1.06	-1.74	15.97	16.0	17.7	15.0	10.6	28.5	342	6.5	2.5	0/4
Semi-peripheral municipalities	1.13	1.01	-2.79	1.55	15.8	19.0	19.7	7.1	12.7	293	10.3	4.0	0/0
Peripheral municipalities	1.09	1.01	-1.86	1.28	16.5	20.2	19.8	6.4	22.2	335	11.8	4.8	1/1
Small towns	0.94	0.98	-2.91	-3.96	15.4	20.3	19.9	6.8	7.4	264	11.3	4.8	2/0
Townships	1.04	1.00	-5.86	4.94	15.1	20.9	18.6	7.8	13.1	276	9.7	3.5	1/0
Sub-regions – total values													
Aš sub-region	1.04	0.97	-3.73	1.64	15.7	19.5	21.3	5.9	5.2	268	13.2	2.4	2/0
Cheb sub-region	1.04	1.00	-3.78	1.43	15.0	19.8	16.8	9.3	15.3	304	10.5	3.2	0/0
Mariánské Lázně sub-region	0.98	*1.05*	-4.24	2.64	14.9	22.7	15.2	*11.0*	13.7	*394*	8.4	5.2	2/3
Sokolov sub-region	0.92	1.00	-3.25	-2.40	15.5	19.8	18.9	7.7	6.9	234	9.0	5.4	4/0
Kraslice sub-region	0.91	0.98	-4.16	-1.14	15.5	22.3	18.7	5.9	6.3	262	14.0	6.5	4/0
Nejdek sub-region	1.01	1.00	-4.14	3.15	14.6	20.8	17.1	7.2	10.6	262	7.8	3.4	0/0
Karlovy Vary sub-region	0.96	1.02	-3.86	2.57	14.7	23.0	*12.8*	*14.9*	14.7	*428*	8.1	4.7	1/3
Toužim-Žlutice sub-region	0.95	0.98	-2.03	-2.28	15.5	21.1	19.8	6.5	5.7	286	10.3	5.2	2/0
Ostrov nad Ohří sub-region	0.96	0.96	-3.45	-5.12	15.1	21.3	17.8	9.00	10.4	306	9.1	4.1	2/0

Notes: Description of indicator codes are in *Table 1*. Underlined value: the value lies in the fourth quartile in terms of values sorted in descending order; Value in italics: the value lies in the *first* quartile. [1]Number of values in the fourth/*first* quartile. [2]Data from the 2021 Census. *Sources:* Databases of the Czech Statistical Office, but EX: data are from the Executor's Chamber of the Czech Republic. Authors' own calculations.

of apartments intended for recreation. The incidence of business entities (SV) is high in Karlovy Vary (economic centre of the region, business in the care of spa guests), Mariánské Lázně (care for spa guests) and in suburban municipalities (immigration of entrepreneurs from towns). The assumption of the highest incidence of foreclosures (EX) in the predominantly working-class settlements of the Sokolov sub-region was not confirmed. The most foreclosures are in the state-border Aš and Kraslice sub-regions. Unemployment (UN) is low and not very different, it is higher only in the deindustrialized Kraslice sub-region.

In the last column of *Table 3*, an attempt is made to provide an overall assessment of demographic and human capital. The meso-regional city of Karlovy Vary has no good values of demographic capital, but it has predominantly favourable human capital. The collapse of a number of industrial enterprises in micro-regional and small towns has an adverse impact on the human and demographic capital in these towns, also suburbanization negatively affects the demographic capital of these towns. Suburban municipalities enriched by younger, educated and well-earning people have favourable demographic and human capital values. Individual semi-peripheral and peripheral municipalities are different in terms of the values of the monitored indicators. If they have quality lead-

ership and no environmental burden, they can have favourable values. The sub-regions of Karlovy Vary and Mariánské Lázně have the most favourable values for sub-regions, also thanks to their spa character.

The Karlovy Vary Region did not fare well in the comparison of human and demographic capital of 14 (territorial-administrative) regions of Czechia, despite the fact that it borders developed Bavaria. According to the average ranking of the values of 7 demographic indicators, the region ranked last with an average of 12.5 (*Figure 2*). The region was placed in the top ten regions of Czechia only in the case of the representation of senior citizens (SE). The Karlovy Vary Region also finished last in the evaluation of human capital using 8 indicators (average ranking 12.9) *(Figure 3)*. The region has particularly unfavourable values in the indicators of the level of education (EE, UE), gross monthly salary (MSC) and employment in science and research (SAR). Close behind the monitored Karlovy Vary Region is the Ústí Region (average rank in human capital 12.6), which is also struggling with the post-socialist transformation of its brown-coal industry. Žítek, V. and Klímová, V. (2016), Wielechowski, M. *et al.* (2021) or Hamplová, E. *et al.* (2021) confirm the poor position of the Karlovy Vary Region among Czech regions.

A somewhat simplified comparison of the demographic and human capital of the Karlovy Vary Region and neighbouring regions in Bavaria, Saxony, and Bohemia is offered in *Table 4*. The Karlovy Vary Region is losing population slightly, but the population development in the eastern German region of Chemnitz is significantly worse due to the departure of young people to the western parts of Germany. The relatively advanced Czech healthcare system contributes to the small differences in life expectancy between Czech and German regions. However, there are fundamental differences in the wealth (GDP) of the Bavarian regions on the one hand and the Saxon and mainly Czech regions on the other, especially in the case of the Karlovy Vary Region. The need to retain university graduates, create a university, and develop science, research, and high-tech industries in the studied region is documented by the unfavourable values of the UEX and HTS indicators for the region.

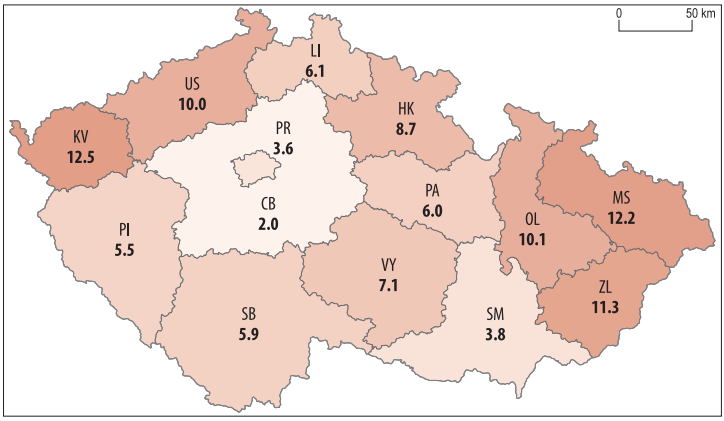


Fig. 2. Average order of indicator values of demographic capital in the regions of Czechia, 2022. The list of indicators is in *Table 1*. Region codes: PR = Prague; CB = Central Bohemia Region; SB = South Bohemia Region; PI = Pilsen Region; KV = Karlovy Vary Region; US = Ústí Region; LI = Liberec Region; HK = Hradec Králové Region; PA = Pardubice Region; VY = Vysočina Region; SM = South Moravian Region; OL = Olomouc Region; ZL = Zlín Region; MS = Moravian-Silesian Region. *Sources*: Databases of the Czech Statistical Office, and authors' own calculations.

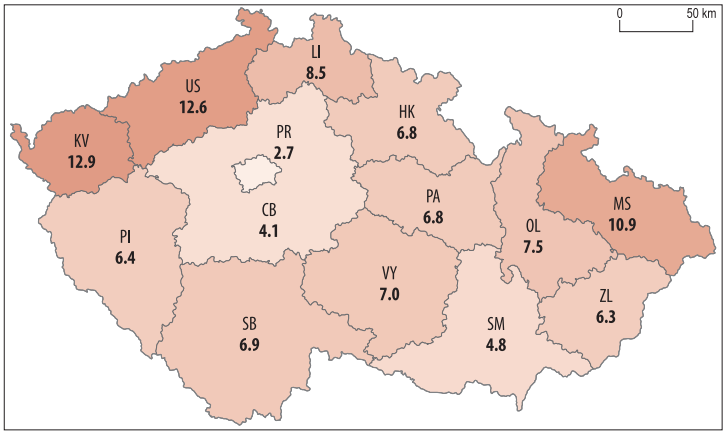


Fig. 3. Average order of indicator values of human capital in the regions of Czechia, 2022. For explanations and sources see *Figure 2*.

Table 4. Human and demographic capital in the Karlovy Vary Region and neighbouring Bavarian, Saxon and Czech regions according selected indicators, 2022

Region, country	NUTS EU region	Values of demographic capital indicators			Values of human capital indicators		
		LD	SD	LEM	GDP	UEX	HTS
Chemnitz (Saxony, Germany)	NUTS2	0.76	0.98	80.3	29.6	25.1	3.4
Upper Franconia (Bavaria, Germany)	NUTS2	1.07	1.00	80.0	38.8	27.5	3.8
Upper Palatinate (Bavaria, Germany)	NUTS2	1.12	1.00	80.5	43.7	30.6	5.0
Germany	*NUTS0*	*1.04*	*1.01*	*81.5*	*48.6*	*32.0*	*5.3*
Karlovy Vary Region (Bohemia, Czechia)	NUTS3	0.97	1.00	78.1	19.3	14.0	1.5
Ústí Region (Bohemia, Czechia)	NUTS3	0.99	0.99	77.5	23.5	16.2	2.9
Pilsen Region (Bohemia, Czechia)	NUTS3	1.08	1.04	79.6	26.2	23.6	4.7
Czechia	*NUTS0*	*1.05*	*1.02*	79.7	27.6	*26.7*	*5.1*

Note: Description of indicator codes are in *Table 1*. *Sources*: Databases of the Czech Statistical Office and Eurostat. Authors' own calculations.

Discussion and strategies and measures for the development of human capital

The above-mentioned unfavourable demographic-capital and human-capital values of the Karlovy Vary Region are the result of a number of factors operating both in the past and in the present. Immediately after World War II, there was a population exchange – the displacement of the vast majority of German-speaking residents and the arrival of mostly poor Czech and Slovak new settlers without ties to the local settlements and landscape. This non-rootedness and residential instability of the region's inhabitants is now no longer as strong, but it still exists. The region's human capital was subsequently adversely affected by the political, social and economic measures of the socialist (communist) governments between 1948–1989. The Iron Curtain of barbed wire with high electric voltage built near the border with Bavaria prevented

cross-border relations. The problematic post-socialist development and subsequent not very successful post-socialist transformation of the brown-coal, textile, glass and porcelain industries in the region led to low wages, job losses and the departure of many young and educated residents from the region.

Economic transformation and further economic development in the post-socialist countries of Central Europe led to an intensification of economic, social and demographic contrasts between the cores and the peripheries within regions and on the east-west gradient within these countries, with more positive developments in the cores (including their suburban zones) and in the western regions of the countries (while eliminating the influence of the capital cities) (Downes, R. 1996; Blažek, J. and Csank, P. 2005; Matlovič, R. *et al*. 2018). However, this may not be the case for those regions that entered the post-socialist transformation with the significant weight of coal mining and processing, textile and metallurgical industries, as these sectors have been going through crises here since the 1990s. In Czechia, this applies to the Ústí and Karlovy Vary regions located in the west of the country.

The Karlovy Vary Region and the neighbouring regions in Bavaria and Saxony (Upper Franconia, Upper Palatinate and Chemnitz) have a peripheral location within Central Europe, as they are far from large settlement agglomerations and economic cores and axes of Czechia and Germany (it is a "macro-regional" periphery). This peripherality leads to the migration of young and educated people to the aforementioned major agglomerations, cores and axes, where they find interesting and well-paid work (Brixy, U. *et al*. 2022), diverse services and culture. If the municipalities of these regions are also characterized by meso-regional and micro-regional peripherality (they are located far from the meso-regional city and micro-regional towns), then this migration is even stronger. However, we cannot forget the not yet very strong migration counter-current – counter-urbanization, which in recent years has been bringing some people from towns and agglomerations to rural and ecologically valuable areas (Šimon, M. and Bernard, J. 2016 in Czechia, Steinführer A. *et al.* 2024 in Germany).

The key strategy for developing human capital in the Karlovy Vary Region is to develop the education of the population, including *university education*. There is no public university here, but its establishment is being prepared. The organizational form of the planned school is now being decided – whether it will be a full-fledged university or polytechnic college, or just a separate faculty of a university located outside the region, in Pilsen or Prague. The school's focus should respect the specifics of the region and the needs of employers in the region. So far, economic, ICT, public administration, balneology and rehabilitation fields are planned. It would be good to add bachelor's degree technical fields that would support the maintenance and development of mechanical engineering in the region (Gál, Z. and Páger, B. 2017). This is what representatives of these companies in the region want (PRKK, 2021). A problem can be the region's small population base (300,000 inhabitants), which affects the number of potential students and the variety of potential fields of study.

The region has a sufficient network of schools providing diverse *upper secondary education* (for students aged 15–18) in micro-regional towns, the exception is the peripheral Toužim-Žlutice sub-region in the south-east of the region. Manufactory factories producing unique, world-renowned products in the region for more than 100 years – musical instruments, unique and serial porcelain and glass products – should retain the relevant craft disciplines and lecturers. A greater expansion of dual education can be recommended – education in schools and at the same time directly in industrial companies, as proposed by local industrialists (Vaishar, A. *et al.* 2012).

Primary and lower secondary education ("elementary education" in Czechia) in the region should be of high quality and accessible even

in rural peripheries and in socially excluded localities. In the rural periphery of the central, southern and south-eastern parts of the Karlovy Vary Region, where there are mainly small rural settlements without schools, commuting pupils to distant schools is difficult, time-consuming and dangerous. This may be the reason for the departure of young families with children from rural peripheries (Kubeš, J. and Podlešáková, N. 2021).

Insufficient qualifications and insufficient language skills of *representatives and employees of public administration* in the region is one of the reasons for the still weak cross-border cooperation with neighbouring Bavaria and Saxony and within the cross-border Euregio Egrensis. According to Welter, F. *et al.* (2007), and Stoffelen, A. *et al.* (2017) the development of cooperation is hindered by the lack of initiative and impulsiveness of the Czech partners, insufficient language skills of partners on both sides of the border, reminiscences of residents on both sides of the problematic stages of the development of Czech-German relations in the 20th century, and persistent socioeconomic differences. Lipovská, Z. *et al.* (2012) recommend expanding and intensifying cooperation between schools (including regional universities) on both sides of the border in education and getting to know each other. Daily or weekly commuting of Czech workers to neighbouring German regions for work is not the form of interstate cooperation.

The Karlovy Vary Region is struggling with a *shortage of medical doctors* in its hospitals and polyclinics, and in the peripheral countryside. Many doctors have aged or left for better-paid work in Germany (Mareckova, M. 2004), and young doctors do not want to go to this peripheral region. State, regional and municipal financial and other incentives for doctors and medical students are already being implemented.

World-famous spas are concentrated in the region – in Karlovy Vary, Mariánské Lázně, Františkovy Lázně, Jáchymov. Around 650,000 guests use them annually, of which 70 percent are foreign (Vystoupil, J. *et al.* 2017). Balneology, accommodation, catering and other services come together in this spa industry (Speier, A.R. 2011). These spas have many employees, but they often lack the necessary education (including language skills) (Bolelоucka, E. and Wright, A. 2020). It is therefore necessary to establish a spa tertiary education system in the region and strengthen the relevant secondary education system as well as a balneological research institute.

After 1989, especially near the highway near Cheb, Sokolov and Karlovy Vary, large *halls of logistics and assembly plants*, mostly owned by foreigners, were created. They mainly employ cheap and poorly qualified Czech workers here. Now the leadership of the region and the state should rather support the development of modern and high-tech industry associated with a qualified workforce (Žítek, V. 2010). It is also important to preserve the production of original, internationally recognized glass and porcelain products, musical instruments and some food products requiring special craftsmanship. If a regional innovation centre were to be established in the region, it could support these higher production activities more, support start-ups, overall technical development and, thus, improve the human capital of the workforce.

In the Sokolov sub-region, surface mining of brown coal took place and to a lesser extent is still taking place, which is provided by workers living mainly in local towns and townships. The management of the *Sokolovská uhelná company* (regional brown-coal company), representatives of the towns and the Karlovy Vary Region, and local labour authorities come up with a series of measures related to the gradual reduction of brown coal mining and related energy and with a plan to end mining by 2035 (see Lipovská, Z. *et al.* 2012). The Sokolovská uhelná company wants to focus on new carbon-free energy, other new technologies and on the reclamation and revitalization of the landscape destroyed by surface mining (Frantál, B. *et al.* 2024). This will require a skilled, partly new workforce. Laid-off workers from brown-coal mining and processing

should undergo retraining, which will also contribute to the growth of human capital in the region. Similar problems are faced by the Most brown-coal area (Ústí region, Czechia) and brown-coal areas in Hungary (Salgótarján – Horváth, G. and Csüllög, G. 2012) and in eastern Germany (Lusatia – Matern, A. *et al*. 2023).

Conclusions

Favourable demographic capital and the growth of human capital are key factors for the further development of the Karlovy Vary Region as a whole, sub-regions of the region and individual municipalities located both in the peripheral, semi-peripheral and core areas of the region. The paper uses a settlement-geographical approach – first, the higher and lower settlement centres of the region are defined, and based on the time distance from micro-regional towns, the semi-peripheries and remote peripheries of the region are delimitated. Using the indicators, the paper then evaluates and compares the demographic and human capital of the types of municipalities and sub-regions of the Karlovy Vary Region, as well as this region and other regions of Czechia and neighbouring regions in Germany.

The meso-regional city of Karlovy Vary has a weaker demographic capital influenced by the aging of the local population and the departure of suburbanites to suburbs. Its human capital is favourable. Meso- and micro-regional towns are losing residents primarily as a result of suburbanization, which enriches their nearby suburban hinterland in terms of population and human capital. The municipalities in the semi-peripheral and peripheral rural areas of the region are diverse as a whole. If they have quality management and a good location, their capital values can be favourable.

In the case of the Karlovy Vary Region, located in the west of Czechia, on the border with developed Germany, the east-west gradient of human capital development within Czechia has not been confirmed. The Karlovy Vary Region is not doing well in comparison with other regions. It is in last place among Czech regions and lags even further behind neighbouring regions in Bavaria. The reason is primarily the specific development of the region after World War II, its peripheral position within Czechia, and the problematic post-socialist transformation of its economy until recently based mainly on brown coal.

The paper also includes strategies and measures to increase human capital in the Karlovy Vary Region and its municipalities. The key is the retention of university graduates and the establishment of a university or polytechnic college in the region. The development of upper secondary education, including dual training in companies, is also important.

Another significant benefit to the human capital of the region should be high-quality and affordable retraining of laid-off workers from the ceasing brown coal mining and from other declining industries, and the support of industrial enterprises with higher added value and high-tech production. The qualification development of workers in the region's world-famous spas is also important. Intensifying real (not paper) Czech-German cross-border cooperation would bring development incentives, improved language skills, and mutually beneficial economic and cultural cooperation to the region, its public administration, associations, schools, and businesses.

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How to develop the creative milieu and physical resources of the university campus into a sustainable innovation zone – The case of Morasko-Poznań, Poland

Michał MĘCZYŃSKI[1], Przemysław CIESIÓŁKA[1], Marc A. WEISS[2] and Tamás EGEDY[3]

Abstract

This article evaluates the development of the Morasko Campus of Adam Mickiewicz University (AMU) in Poznań, one of Poland's leading academic centres, in relation to its alignment with the Sustainable Innovation Zone (SIZ) concept. This concept refers to urban districts that concentrate sustainable innovation activities within an attractive, creative milieu. The study draws on model solutions from the literature on creating city innovation districts, focusing on some physical assets considered to be sustainable innovations. The findings indicate that the Morasko Campus has begun to integrate elements of the SIZ concept, particularly in selected public spaces and university building courtyards. Initial pilot projects have been launched to incorporate sustainable innovations, such as green roofs, green walls, and solar energy photovoltaic panels, into the campus buildings. As sustainability becomes a central focus of the University's development policy, it is anticipated that these initiatives will increase in the near future.

Keywords: Sustainable Innovation Zone (SIZ), university campus, creative milieu, innovation district, sustainable innovation, Poznań, Poland

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Introduction

In today's turbulent economic, political, and social landscape, academic institutions face new challenges. They play a crucial role as driving forces in the knowledge economy, fostering intellectual growth, driving innovation, and addressing societal changes. Amidst climate challenges, universities have an emerging role in educating and developing new solutions to mitigate these changes. Their efforts should focus more on developing clean and green technologies, digital solutions, academic creativity, entrepreneurship, and start-up creation (Fastenrath, S. *et al.* 2023). The physical space of the university, where all knowledge functions are generated, is the university campus. Some of these campuses are anchors for the development of innovation districts. They help create flourishing, sustainable and creative milieu, social inclusion, good quality of space, and fostering of innovations (Tremblay, D.G. and Battaglia, A. 2012). They are also key elements of global strategy for cities wanting to become leaders in the knowledge-based economy (Oinas, P. *et al.* 2018). Finally, they reflect the development of urban geography

[1] Faculty of Human Geography and Planning, Adam Mickiewicz University in Poznań, Krygowskiego 10, 61-680 Poznań, Poland. E-mails and ORCIDs: michal.meczynski@amu.edu.pl, ORCID 0000-0001-8064-2879; przemyslaw.ciesiolka@amu.edu.pl, ORCID 0000-0001-9478-0500

[2] Institute of Urban and Regional Development, University of California, 316 Wurster, Berkeley, CA 94720 – 1870, USA. E-mail: marcweiss@globalurban.org, ORCID 0009-0008-8776-6223

[3] Department of Tourism, Budapest University of Economics and Business. Markó u. 29–31. H-1055 Budapest, Hungary; Geographical Institute, HUN-REN Research Centre for Astronomy and Earth Sciences. Budaörsi út 45. H-1112 Budapest, Hungary. E-mail: egedy.tamas@uni-bge.hu, ORCID 0009-0003-3929-8425

and place-making associated with the generation of innovations in cities (Fastenrath, S. *et al*. 2023). In turn, these innovation districts are mainly developed in the vicinity of university campuses that concentrate high-quality human capital and scientific research infrastructure, and green spaces that stimulate the exchange of information, knowledge development, and the creation of innovations while maintaining high environmental standards (Finlay, J. and Massey, J. 2012; Turk Cerovečki, M. and Stiperski, Z. 2024).

A concept that well describes the way of shaping university campus is the Sustainable Innovation Zone (SIZ), that was proposed by Weiss, M.A. *et al*. (2015) for the economic growth and development strategy of the state of Rio Grande do Sul in Brazil, known as the Leapfrog Economic Strategy. This term was related to the idea of a technological leap for companies located in this region, and the goal of the strategy was to create the most sustainable and innovative place in Latin America by 2030 (Weiss, M.A. *et al*. 2015; Weiss, M. 2016; Angoneze-Grela, E. 2021; Męczyński, M. *et al.* 2024). The author of the concept assumes that in SIZs, research and academic institutions generate innovations, including so-called sustainable innovations that help conserve and reuse renewable resources much more efficiently (Weiss, M. 2016, 2023). In this case, the term sustainable innovation refers to the development of products and services to meet the goals of sustainable development, considering economic, social, and environmental factors (Mazaheri, M. *et al.* 2022). This theoretical concept enabled the continuation of research by Meusburger, P. (2009), and Amcoff, J. (2020), related to the quality of the university environment, but also defining a new path of research on developing a creative milieu at the university campus in the face of sustainable development challenges, and implementing policies focused on the mitigating climate change and reducing GHG emissions. This new approach builds upon previous research related to the Morasko Campus of Adam Mickiewicz University (AMU) in Poznań, one of the leading academic institutions in Poland (e.g. Konecka-Szydłowska, B. 2020; Kulczyńska, K. *et al.* 2020).

The article focuses on identifying and analysing the physical resources that influence the development of a SIZ, using the Morasko Campus as a case study. The campus, recognized as one of the most modern and dynamically evolving in Poland, serves as an example to evaluate how its design, resources, and creative milieu align with the principles of SIZs and their role in promoting sustainable innovation and inclusive prosperity. The research questions of this study are as follows: 1) What are the possibilities for adopting the SIZ concept at university campuses in Central and Eastern Europe? 2) How do physical resources and the built environment influence the development of a creative milieu at Morasko Campus and contribute to the creation of an SIZ? 3) What type of the university campus-based SIZ is developing at the Morasko Campus? 4) What are the key elements of the SIZ concept identifiable at Morasko Campus?

The analysis emphasizes physical (material) resources, such as public spaces, buildings, and the campus's connectivity to the broader Poznań metropolitan region. The findings aim to verify a concept originating in the 1970s, observed in both capitalist and communist countries, that advocated for constructing new campuses in city outskirts. At Morasko Campus, the original architectural vision by Fikus, M. and Gurawski, J. (1978) sought to create a space fostering integration across university activities and life, both within the campus and its interaction with the city. Today, this idea aligns with the global trend of higher education institutions becoming experimental "living laboratories" for sustainable development. Examples include the University of California campuses (San Diego and Irvine), which focus on creating sustainable infrastructure, reducing carbon emissions, and advancing green initiatives. The authors highlight the critical role of higher education in driving societal transformation, using campuses as prototypes for green infrastructure transformation (Arnaud, B.St. *et al.* 2009).

The structure of this article reflects the achievement of its stated goal. The introduction presents the research problem, outlining its purpose and scope. The second section focuses on the evolving role of university campuses, based on a literature review. This is followed by a review of the literature on the formation of innovation districts and the development of a creative milieu, with particular emphasis on the new approach introduced by the SIZ concept. Next, the article provides an overview of the innovative potential of AMU in Poznań, including key faculty building characteristics on the Morasko Campus. The subsequent section presents research findings about the campus, assessing buildings and land use in relation to the creative milieu and SIZ development. Finally, the article concludes with a discussion and key findings drawn from the research.

Changing role of university campuses

Intensive research on the role of university campuses in the local economy has gained momentum in academia over the past quarter century. Studies have highlighted significant variations in the impact of university campuses on local economies and societies, depending on: a) the university's location (e.g. rural campuses with a strong social role vs. full-service research universities in core regions, see Benneworth, P. 2019), and b) the university's characteristics (e.g. innovative university, see Clark, B.R. [2001]; engaged university, see Breznitz, S.M. and Feldman, M.P. [2012]; entrepreneurial university, see Guerrero, M. *et al.* [2014]; or civic university, see Goddard, J. *et al*. [2016]). Research by Benneworth, P. *et al.* (2022) shows that university campuses in rural areas play a crucial role in local socio-cultural infrastructures, mobilizing local social capital and fostering community development. Meanwhile, university campuses with a regional role – both urban and metropolitan – are not just passive knowledge brokers but actively contribute to economic development through knowledge spill-overs and partnerships with regional and local stakeholders (e.g. spin-offs). Korotka, M.A. (2015) emphasizes that university campuses help develop new infrastructures through spill-over effects, while Cooke, P. (2005) highlights their role in advancing regional innovation systems. Additionally, university campuses can host firms that collaborate with universities, particularly those with research and development centres, as well as other public research institutions. However, their influence extends beyond shaping the hard factors of the local economy (e.g. new firm creation based on innovative ideas); they also significantly impact soft factors (e.g. cultural and creative development), enhancing regional attractiveness and quality of life (Boschma, R. 2015).

University campus activities can be grouped into three main areas: 1) research (e.g. technology transfer and innovation), 2) teaching (e.g. lifelong learning/continuing education), and 3) university engagement in the economic, social, cultural, and environmental development of the region (Mora, J.G. *et al.* 2015). Over the past decade, the third mission of universities – their role in societal engagement – has grown in importance (Trencher, G. *et al.* 2014; Compagnucci, L. and Spigarelli, F. 2020). As a result, the traditional view of university campuses as solely educational institutions is fading, while their role as hubs for creativity and cultural development is becoming more prominent. A key question in our study is how university campuses are transforming into institutions that foster a creative milieu and support sustainable development and innovation. This is not a new debate – since the 1960s, scholars have examined how universities adapt to societal expectations and evolving needs (Kerr, C. 1963). According to Jäger, A. and Kopper, J. (2013) this transformation depends on three interrelated factors: 1) the configuration of activities within a university, 2) the degree of its territorial embeddedness, and 3) the institutional frameworks in which it operates. Corresponding to these factors, it is critical to assess the role of university

campuses in sustainable local economic development and in creating a creative milieu that fosters sustainable innovations. In light of climate change and shifting stakeholder priorities, universities must also contribute to climate mitigation policies and support the development of SIZs.

The role of the creative milieu in fostering sustainable innovation zones at university campuses

The new challenges the university campuses have to face are the problems among other of the climate changes, rapid technological changes and social exclusion. The creation of a SIZ should be analysed as a multi-stage process in the evolution of university campuses that includes these challenges *(Figure 1).* This transformation begins with a shift in focus: beyond location and accessibility, the *quality of place* becomes essential (Boix, M. *et al.* 2015; Mateos-Garcia, J. and Bakhshi, H. 2016). The concept of "quality of place" emphasizes that living and working environments significantly impact quality of life. Thoughtful design and planning can enhance it, yielding environmental, social, and economic benefits (Burton, M. 2014). Richard Florida's creative class theory (2002) aligns with this idea, linking quality of place to quality of life and economic growth. He highlights key social and cultural factors – such as diversity, vibrancy, creativity, tolerance, aesthetics, and safety – as crucial for attracting the creative, educated individuals who drive the growth and competitiveness of places (Trip, J.J. 2007).

Moreover, in creating attractive, high-quality public spaces, Gehl, J. (2010) emphasizes supporting both necessary activities (e.g. commuting) and optional ones (e.g. strolling, sitting, pausing). He argues that the liveability of public spaces extends beyond aesthetics to include scale, safety, sensory engagement, comfort, and functional diversity. As a result, these spaces tend to attract a broader range of users participating in diverse activities and encourage more extended visits (Gehl, J. 1986; Carmona, M. 2019). Likewise, on university campuses, people gravitate toward spaces that foster social interaction, academic pursuits, and creative activities. Such environments should offer comfort, protection from the elements, shaded seating areas, options for dining, and spaces dedicated to cultural and artistic experiences (O'Rourke, V. and Baldwin, C. 2016). Most aspects of the quality of place refer to tangible (e.g. buildings, pathways, benches) and intangible (e.g. social interactions, emotions) assets of public spaces. These assets create a vibrant, liveable, and creative atmosphere for knowledge and information exchange.

The role of the place in the creation and exchange of information is well presented by Törnqvist, T. (1983) creative milieu idea. He

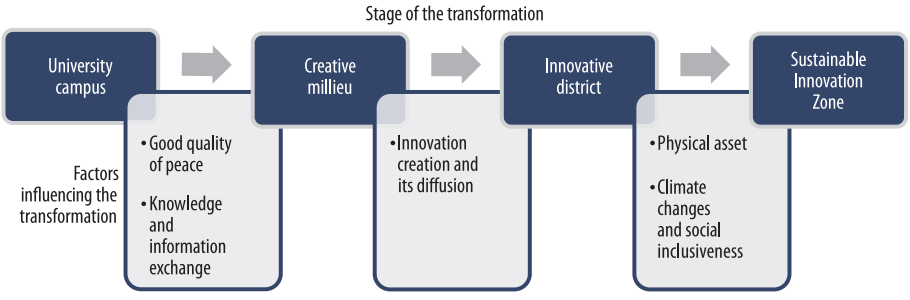


Fig. 1. The process of the university campus transformation into a sustainable innovation zone.
Source: Authors' own compilation.

argued that a creative milieu emerges when four key features are present: 1) information, which must be exchanged and shared, 2) knowledge, including bodies of work and databases, 3) competence in specific activities, and 4) creativity, which integrates with the first three features to generate new products, ideas, and processes. Törnqvist, G. (2004) emphasizes the role of various relationships in knowledge creation, including formal and informal networks of individuals and connections between local and regional institutions. In light of these concepts, university campuses are supposed to offer an ideal setting to provide a creative milieu.

However, creative places on university campuses combine characteristics that usually take a long time to evolve and develop. Building up libraries, archives, databases, and traditional skills takes time. Such places come to have a recognized set of creative specializations, which act as a magnet to attract talented and creative people. Therefore, in creating the *university's creative milieu,* it's vital to combine the perspective of the separated area with the broader viewpoint of more considerable structures such as the surrounding district and the entire city. Moreover, in the minority of research, especially related to the university public spaces, authors underline the tangible creative outcome of the university-built environment (Soares, I. *et al*. 2020; Rafiei, S. and Gifford, R. 2023). Therefore, it is important to focus on the university campus as a part of the city district and its role in urban transformation. Innovation districts are an example of such areas, with universities serving as anchor institutions that stimulate innovation. They are well-accessible places for generating innovations and providing a good quality place that reflects the idea of a creative milieu. For cities seeking to transform and repurpose aging industrial buildings, innovation districts present a valuable opportunity (Katz, B. and Wagner, J. 2014). They are increasingly integrating into the urban fabric, developing alongside nearby enterprises (including start-ups), institutions that support entrepreneurship and knowledge transfer (such as innovation and technology transfer centres), and research and development units that drive innovation (Katz, B. and Wagner, J. 2014).

According to Morrison, A. (2022) the development of innovation districts represents a place-based urban strategy aimed at transforming underperforming, centrally located neighbourhoods into vibrant hubs for innovative and creative companies and professionals. Within this framework, innovative districts serve as a catalyst for urban regeneration. However, it must also tackle pressing contemporary challenges, including climate change, social exclusion, the demand for sustainable innovations, and the pursuit of new avenues for economic growth (Vanolo, A. 2017). One of the responses to the new challenges that meets the criteria of a well-designed innovation district and creative milieu that effectively addresses sustainable development challenges and advances social inclusion is the SIZ concept founded by Weiss, M. (2023). It provides a specific example of the functionality of innovation. The SIZ is the one of the successful outcomes of introducing sustainable economic development strategies for cities and regions that drive new employment creation and economic growth, fostering sustainable businesses and communities.

These strategies also promote renewable energy, clean technologies, environmental quality, and climate change mitigation in cost-effective ways defined by the "Four Greens" approach: 1) Green Savings; 2) Green Opportunities; 3) Green Talent; 4) Green Places (Cristophers, B. and Riofrancos, T. 2024). According to Weiss, SIZ should emerge at university campuses around technology parks and business incubators, where renewable resources are reused. This new type of innovation district creates an urban "Innovation Ecosystem" focused specifically on sustainable innovations. All of the products, services, technologies, and talent within an SIZ are designed to make the area more environmentally sustainable and climate-resilient within a circular

economy that dynamically save money and grows businesses, jobs, incomes, and assets. Additionally, SIZ is inclusively oriented, actively involving social entrepreneurs, sustainability activists, creative design experts, and others, all empowered by a grassroots movement, in addition to actively involving technologists and investors. SIZs essentially are a model for community economic development (Fitzgerald, H.E. *et al.* 2019), with a greater focus on business and employment development than related community sustainability initiatives such as Ecodistricts, or Transition Towns (Barry, J. and Quilley, S. 2008). The essential principles on which the development of SIZs can be based are included in this general slogan: "Getting Richer by Becoming Greener" (Weiss, M. 2016).

In many aspects, the concept of SIZ also refers to other contemporary approaches to the sustainable development of innovation districts, i.e. creative districts (Richards, G. 2020), ecological districts (Ecodistrict – Reynolds, J. 2019), or transition towns (Transition Towns – Kenis, A. and Mathijs, E. 2014). Most of these concepts point to the functioning of scientific or educational institutions, e.g. universities, around which it is possible to "anchor": start-ups, international enterprises, or public institutions supporting innovative activities. In this approach, the university campus becomes not only a place for creating and transmitting knowledge, but also a place for concentrating business activities (e.g. Cambridge Research Park, University of Sheffield Innovative District).

The creation of a creative milieu on a university campus, as a key element of the SIZ, requires high-quality public spaces, mixed land use, sustainable transportation systems, urban greenery, and functional urban layouts with sustainable architecture (see e.g. Jenks, M. and Jones, C. 2010). In particular, the development of renewable energy resources follows principles aligned with green infrastructure – defined as an interconnected network of vegetated areas that preserve natural ecosystems while benefiting residents (Benedict, M.A. and McMahon, E.T. 2006; Barrios-Crespo, E. *et al*. 2021). Regarding layout and architecture, Weiss's concept of SIZ is closely linked to sustainable construction, which emphasizes the use of environmentally friendly materials and construction technologies, natural ventilation and heating systems, as well as green facades and roofs (Besir, A.B. and Cuce, P.M. 2018).

The characteristics discussed in relation to the creation of SIZ at university campuses can be summarized into three spatial models of the SIZ, reflecting the typology of innovation districts of Katz's and Wagner's (2014): 1) Anchor Plus Zone – this area is centred around leading institutions in the city, usually large economic entities, along with a public institution that "anchors" other economic entities; 2) Re-imagined Urban Zone – this area often features historic waterfronts or degraded post-industrial/warehouse spaces, as these types of older and neglected urban areas are transformed into new growth hubs based on innovations; 3) Urbanized Science Park – this type of zone integrates isolated, autonomously functioning suburban science and technology parks into the urban fabric by providing public transport and multi-family housing developments.

The above models indicate the formation of SIZs at university campuses, based on the presence of three types of resources: 1) physical, 2) economic, and 3) networking (Katz, B. and Wagner, J. 2014). Physical assets constitute public and private spaces with buildings, parks, streets and information and communication infrastructure that stimulate cooperation based on modern technologies (including those beneficial from the point of view of environmental protection) and serve to generate innovations. Economic assets are *companies, institutions* and *organizations* that drive, cultivate or support the innovation environment. Finally, the third type of resource is networking, based on relationships between actors (e.g. individuals and companies), enabling the transformation of ideas into inventions and innovations. In our study, we focus on analysing the physical (built) environment that serves as the foun-

dation for a creative milieu and a SIZ at the Morasko Campus, part of AMU in Poznań – one of Poland's leading academic institutions. In light of these concepts, the following key questions arise: What is the process of SIZ development at the Morasko Campus? How does this process differ from that of other university campuses in Western Europe?

Source materials and research methods

This article attempts to use the SIZ concept to analyse the Morasko Campus of AMU in Poznań. In this respect, reference was also made to the model solutions proposed in the work by Katz, B. and Wagner, J. (2014). The research process consisted of two stages.

In the first stage of the research, the method of analysing existing data (desk research) was used to collect and analyse information from secondary sources. In this way, data on the conditions and directions of spatial development of the Morasko Campus, included in strategic documents prepared by the municipal authorities and the university were studied. The focus was primarily on the spatial plans for the development of the Morasko Campus. Separate attention was given to the university's innovation reports, which gathered information on the current status and plans in this area. The conclusions drawn from the analysis of the above data were supported by qualitative content analysis, which envisages drawing inferences based on certain features of the message and involves extracting from the sources written extracts, quotes or examples to support an observation or relationship (Buttolph Johnson, J. *et al.* 2010). The second stage of the research incorporated the urban inventory method to gather background information on the current state of land use and development.

The above research at the Morasko Campus was carried out as part of student work in the academic year 2022/2023 and then collected, aggregated and completed by the authors of this article in early 2024. The urban inventory work concerned in particular: 1) assessment of the implementation of sustainable development principles conducive to innovation in the Morasko Campus space, 2) assessment of the introduction of ecological solutions in the Campus buildings, 3) transport connections of the Campus with the rest of the city and the entire metropolitan area.

The article uses the case study method, which involves an in-depth characterization of a selected example, the analysis of which allows concluding as to the causes and results of a given phenomenon (Stake, R.E. 1995). Thanks to the use of this method, it was possible to relate the theoretical concept of SIZ to real phenomena that develop in practice (Flyvbjerg, B. 2006). The empirical case study method is used mainly in descriptive research issues (Fidel, R. 1984). The research area chosen was the Morasko Campus, because of its physical conditions. It is a compact complex of academic buildings belonging to one of the most prestigious universities in Poland. An attempt was also made to verify the original idea of building a campus from the 1970s *(Figure 2).* It assumed that the Morasko Campus would be well connected to the rest of the city, via fast-track roads and high-speed rail. Internally, however, pedestrian traffic would dominate, which would be surrounded by greenery. This will promote the integration of students and academics from all Poznań universities (Fikus, M. and Gurawski, J. 1978).

Physical resources at the Morasko Campus important for sustainable innovation zone development

The Morasko Campus covers an area of approximately 300 hectares and includes over 20 buildings, and its spatial structure comprises two locations for research and teaching buildings. These are the western areas, where most of the faculties and buildings associated with them are located; and the north-eastern areas, which include two faculties and the buildings of the Physical Education and Sports Centre. The dominant

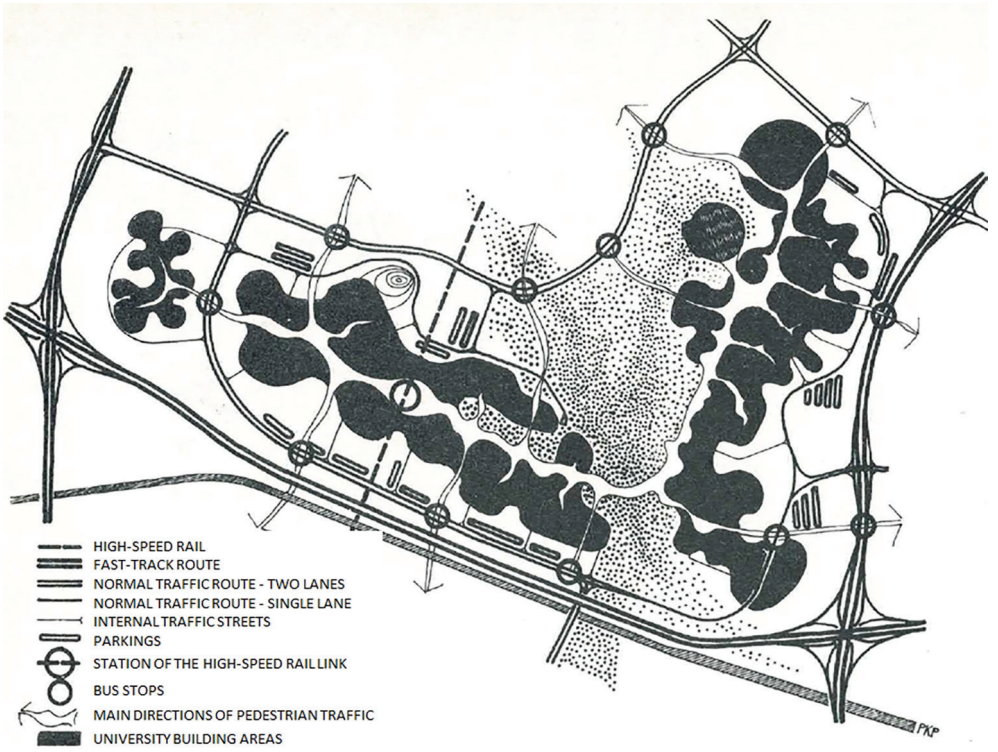


Fig. 2. Original concept for the construction of the Morasko Campus. *Source*: Authors'own compilation based on Fikus, M. and Gurawski, J. 1978.

academic function of the campus is complemented by recreational, sports, and residential functions.

The valuable natural environmental resources existing in the university's surroundings and the climate protection measures taken by the university's authorities have resulted that in 2023 AMU in Poznań was ranked 339th in the GreenMetric World University Rankings, and third among all Polish universities. AMU's high position in the university's environmental and climate rankings makes the development of an SIZ on its premises both feasible and attractive. However, this development should not only be based on the application and imitation of innovative solutions but also on their creation. For the Morasko Campus, this is made possible by technology transfer through the University Centre for Innovation and Technology Transfer (UCITT), and the particular purpose vehicle of AMU innovations, established in 2023. The latter venture enables the university to hold its shares in spin-off companies based at the university, and the first spin-off companies with university participation already have been established. Examples of such spin-offs at the university are in artificial intelligence, Laniqo, and the area of biotechnology, SpinBionic (Banaszak, M. 2023). Other important innovation development facilities located on campus are: Greater Poland Centre for Advanced Technologies, and NanoBioMedical Centre *(Figure 3)*. These ventures are good examples of linking scientific activity with the economy and creating relationships through which the SIZ can be developed.



Fig. 3. Selected spaces for Innovation Development in Poznań. *Source*: Authors' own elaboration.

In their work, Katz, B. and Wagner, J. (2014) divided the physical resources present in innovation districts into: 1) those occurring in public space, 2) those occurring in private space, and 3) those connecting innovation district to other parts of the city. With regard to the Morasko Campus, private resources were omitted from the analysis as they were not considered to be essential for developing the SIZ. Our attention was focused on the two remaining physical resources, i.e. 1) those occurring in public spaces, and 2) those connecting the zone to other parts of the city.

Physical resources present in public space

With regard to the first resources present in public space, they were analysed, taking into account the impact on the sustainability of the Morasko Campus and the possibility of creating innovation based on: 1) the green public spaces occurring between the buildings, and 2) the courtyards of the university buildings *(Figure 4)*. In both cases they can be regarded as those tangible assets that will have a major influence on promoting a creative milieu at the Morasko Campus.

In relation to the first of the highlighted public spaces, namely the green spaces that occur between buildings, only part of them have been developed in a way that promotes interaction, making connections, where "people collide with each other" (Katz, B. and Wagner, J. 2014). This is fostered by well-developed areas that provide variety and richness of experience, encourage walking or cycling, and invite people to linger longer in the space by shielding them from noise and other unpleasant sensations. As a result, social balance and a sense of security can be achieved (Gehl, J. and Svarre, B. 2013). Among the

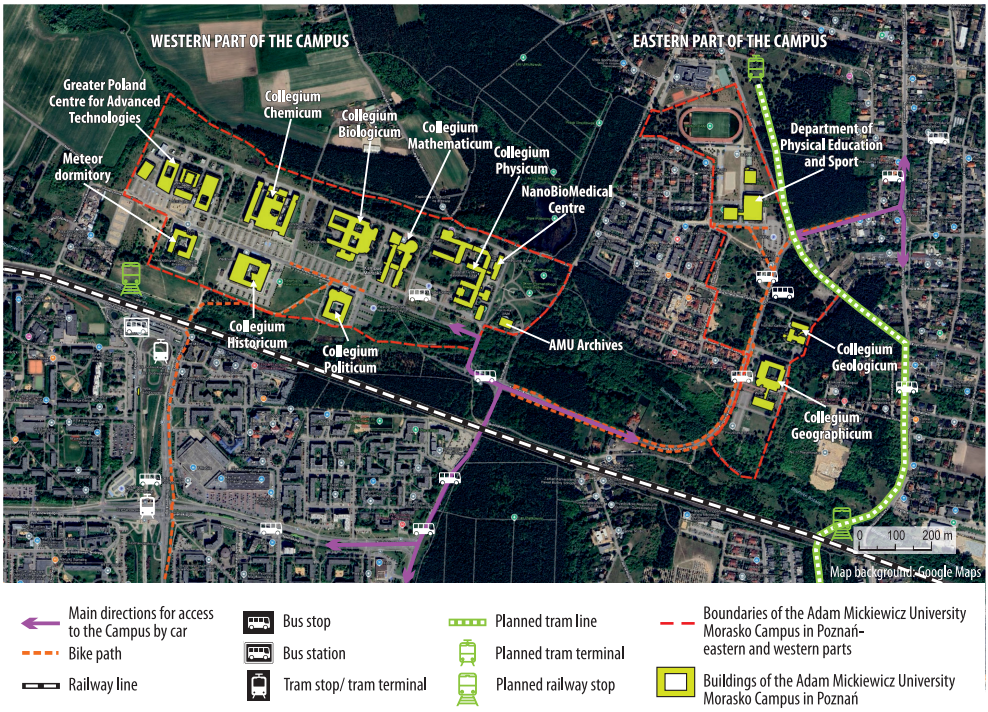


Fig. 4. Physical resources in public space influencing sustainable development of innovation at the Morasko Campus in Poznań. *Source*: Authors' own elaboration based on results of field inventory.

inventoried areas, the Skwer Poznański Towarzystwa Przyjaciół Nauk (Square of the Poznań Society of Friends of Science) located in the western part of Morasko Campus, fits best into these assumptions. It is a place with varied terrain height, isolated by greenery from the surrounding traffic areas, where there are both shaded and open spaces possible to use for more active recreation. It is an example of a modern solution and proper natural development combining nature with neighbouring facilities belonging to the university.

In areas on the north-eastern side of the Campus, in the vicinity of some faculty buildings, the Demonstration Climate Garden was built *(Photo 1)*. It is isolated from traffic, which reinforces its social function. This construction is a good example of sustainable innovation. It not only represents a new eco-product, but also the inclusive process of designing that involved many representatives of academia. Because it is open to the public people from nearby neighbourhoods, visitors can rest on the sun-chairs, feel fresh air, chat and laugh together, exchange information, or simply relax. This sustainable innovation is the result of the international project TeRRIFICA – Territorially Responsible Research and Innovation Fostering Innovative Climate Action (Horizon 2020). The Climate Garden is located in the vicinity of the sports hall and swimming pool belonging to the University, in the eastern part of the Campus. This sports complex area provides welcoming inclusiveness for the students and people living nearby. Unfortunately, the remaining public spaces of the Morasko Campus hardly meet the criteria for sustainable public spaces.



Photo 1. Demonstration Climate Garden located between Collegium Geographicum and Collegium Geologicum

They are dominated by spaces designed for motor vehicle traffic, including car parks. They will require a strategic plan for future development, including the introduction of sustainable innovations.

The second of the distinguished public spaces that can influence the development of innovation, which was taken into account in our research, is the space of the courtyards of university buildings. This represents a unique idea for the development of social life. Courtyards are found in the vicinity of almost all buildings located on the Campus, but only in individual cases do they fulfil the main role assigned to them, that of meeting places (Wittmann, M. *et al*. 2018). According to the research carried out, the courtyards of the Meteor dormitory, as well as those of the Collegium Politicum building *(Photo 2),* were found to be particularly suitable for social interaction. These are areas where benches and other elements of small architecture (including fountains) and greenery activate the local academic community. The enhancement of 'urban furniture' with good local materials, and the humanly adapted height of the walls enclosing these spaces, help make them places that stimulate creativity (Askarizad, R. and He, J. 2022). The courtyards of the buildings seem to offer great potential for the development of academic life that has not yet been fully utilized on the Morasko Campus. The space of these courtyards supports the creation of creative milieu, for the exchange of knowledge and information among students and academics. Eventually, it creates new possibilities for developing sustainable innovations (Törnqvist, G. 1983).

Physical resources connecting innovation district with the city

The second physical resource analysed, based on Katz, B. and Wagner, J. (2014), pertains to its role in connecting the innovation district with other parts of the city. Accord-



Photo 2. Courtyard of the Collegium Politicum (Faculty of Political Science and Journalism building) in the western part of the campus. (Photos taken by Ciesiółka, P.)

ing to development plans drawn up in the 1970s, the Morasko Campus area was to form part of the so-called Northern Development Belt of Poznań. The planning assumption for the area of the current Morasko Campus was to create just a university cluster, bringing together Poznań's universities. However, during the 1980s. due to economic challenges, excessively high construction costs, and inflated demographic forecasts for the city, plans for the strip development were abandoned. As a consequence, the route of the fast tram, which was intended to run through the Morasko Campus, was shortened. Accordingly, the Morasko Campus has become a peripherally located area, spatially separated from other parts of the city by a railway line and by forests and green space. The Campus has been isolated from the central fabric of city life. It is worth noting that the location of the Morasko Campus on the periphery of the city shows some similarities with the recent American model of a university campus development as newly designed districts far from the central urban area (Caldenby, C. 2008). In addition to the Morasko Campus, the key example of locating this type of university activity in Poland on the outskirts of a city is the Pychowice Campus of Jagiellonian Universit in Kraków (Rewers, R. 2016), and the Campus of the Kielce University of Technology (Pachowski, J. 2014).

Good transport links in the SIZ concept are an important development incentive for the university campus (Banet, K. 2018; Nayum, A. and Nordjærn, T. 2021). However, the Morasko Campus *still suffers from the problem of isolation* from the rest of the city. Currently, the main public transport connection for the area with other parts of Poznań and the metropolitan region is provided by bus lines. This is particularly true of the north-eastern

part of the Campus. The nearest tram line, on the other hand, is located a few hundred metres from the western part of the Campus. The inconvenience of the distance from the tram line, as well as the need to change means of transport, and its limited capacity, make the car the dominant means of getting to this part of the city, especially for university employees (Zhou, J. 2012). Evidence of the dominance of this mode of transport can be seen in the extensive parking areas that predominate in the public spaces around the Morasko Campus. In recent years, however, initiatives have been implemented to improve the transport accessibility of the Campus. Pedestrian and bicycle paths are being built, linked to the tram lines. There are plans to extend the tram line in the eastern part of the city. In addition, an extension of the metropolitan railway is currently underway, two stops of which will be located relatively close to the Morasko Campus (Poznań-Piątkowo and Poznań-Naramowice) (Bul, R. 2016). This should enhance accessibility to the area for both the residents of Poznań and the entire metropolitan region. The development of a metro train station near the University Campus could have a similar economic impact to that of the NoMa–Gallaudet U station in Washington (Green, M.N. *et al.* 2014; Weiss, M. 2016).

Discussion

Both the research presented in the literature review and our own empirical results show that the development of creative milieu and sustainable innovation zones are processes that can be understood at the level of space and place. According to the seminal work of Tuan, Y.E. (1977), space can be described primarily in abstract and objective terms, while place can be described in concrete and subjective terms. Space creates the framework of human existence in the form of physical and virtual space allowing something to exist, accommodate or represent itself. At the same time, the inseparable attributes of place are human actions and human connections, thoughts, emotions and feelings. Thus, for a place to exist, there is need for a space and a human being attached to it (Relph, E. 1976; Mierzejewska, L. 2015; Wideström, J. 2020). The creative milieu can be understood at both the physical and virtual levels, encompassing both the built environment and the social sphere (Kotus, J. 2024).

Although our study focuses on the physical aspects of the creative milieu (i.e. the physical environment and resources), we cannot overlook the social and economic dimensions of the process (i.e. the local community, academia, and business networks as part of the virtual space and place). Given the complexity of a university campus – where tangible elements (e.g. faculty buildings, commuting infrastructure) intertwine with intangible aspects (e.g. knowledge exchange, information flow, and formal and informal relationships) – this integrated perspective seems particularly relevant. In the discussion section, we will examine some of the spatial and place-related determinants of this issue in the context of SIZ development at the Morasko Campus.

Previous studies on the emergence of innovation have highlighted their concentration in specific places and time periods. University campuses, particularly those with a well-developed academic environment and strong ties to the economic sector, have been identified as key places for fostering innovative activity (e.g. Finlay, J. and Massey, J. 2012). In such areas, innovation districts – or specific forms such as the SIZ proposed by Weiss, M. (2023) – can emerge. A potential example of this development is the Morasko Campus of AMU in Poznań.

The social, economic and, more recently, climate changes taking place in large cities are triggering transformations of the university campus functions and spatial structures (Gasper, R. *et. al.* 2011). These processes are conducive to the emergence of innovations, which is due to their nature and their appearance in moments of socio-economic turbulence (Schumpeter, J.A. 1960). In the face of accelerating climate change, sustainable innovations play an increasingly

crucial role in socio-economic development. Their emergence depends not only on human creativity, existing knowledge resources, and entrepreneurship, but also on the specific environment in which they are created. Törnqvist, G. (1983) refers to such an environment as a "creative milieu" (Męczyński, M. 2021).

This article examines how the creative milieu and physical resources at the Morasko Campus of AMU in Poznań contribute to its transformation into a SIZ. The conclusions are based on an analysis presented in part four, which explores the Campus's origins and contemporary development, and part five, which examines its physical resources. The study evaluates the extent to which the Campus can evolve into an SIZ, applying the assumptions of Weiss's concept *(Table 1)*.

One of the key assumptions of the SIZ concept is the creation of a physical environment that fosters the development and implementation of sustainable innovations within the area. An analysis based on the GreenMetric World University Rankings revealed a high level of environmentally friendly technological solutions in the buildings of the Morasko Campus. In this regard, a crucial prerequisite for SIZ development has been met. Moreover, it is important to note that this progress is driven by the creation of sustainable innovations rather than merely adopting outsourced solutions. This approach aligns with successful international examples, such as the Eindhoven High Tech Campus (HTCE), which relies on geothermal energy for heating and is nearly self-sufficient in electricity production. Notably, many of these innovations were developed on-site at HTCE itself (www.hightechcampus.com/sustainablecampus/).

Table 1. Development of the Morasko University Campus towards the Sustainable Innovation Zone (SIZ)

Assumptions of the SIZ concept	Demonstration of the fulfilment of the SIZ concept at the Morasko Campus
Sustainable innovation and modern technology	– Third place for Adam Mickiewicz University in Poznań among Polish universities in GreenMetric's World University Rankings. – Creating green walls and roofs (buildings: Collegium Geographicum, Collegium Biologicum, Collegium Phisicum, AMU Archives). – Installation of PV panels (Collegium Chemicum). – Planned installation of special roof windows to absorb solar energy and produce electricity from it (Collegium Geographicum).
Public transport operating based on the principles of sustainable development	– Transport peripherality of the Campus. – Planned and partially implemented solutions to improve transport connections with the city centre.
Creative milieu fostered by the business environment and technology transfer	– University Centre for Innovation and Technology Transfer. – Special-purpose company AMU Innovations. – Spin-offs in areas such as: artificial intelligence – Laniqo, biotechnology – SpinBionic. – Greater Poland Centre for Advanced Technologies. – NanoBioMedical Centre.
Creative milieu development based on the local (academic) community engagement in pro-environmental activities	– Extensive public spaces can promote social integration and communications. – The partially enclosed spaces found in the vicinity of the Meteor dormitory and faculty buildings play an important role in the innovation process: Collegium Biologicum, Collegium Geographicum (Climate Garden) and Collegium Geologicum (Lapidarium).

Source: Authors' own elaboration.

In the process of development of the creative milieu there is a clear link between the level of innovation and entrepreneurship. Pre-entrepreneurial academic activity is increasingly developing on the Morasko Campus. Numerous AMU employees work in spaces specially prepared for scientific and research activities geared towards commercialisation (e.g. the Greater Poland Centre for Advanced Technologies, and the NanoBioMedical Centre). It should be noted that the formation of entrepreneurial attitudes among scientists is progressing quite dynamically, not only at AMU but also on a national scale in Poland. Participation in special programmes aimed at learning how to commercialise research plays an important role in this respect. An example of such a programme is Top 500 Innovators, thanks to which representatives of Polish science, including AMU employees, were able to participate in workshops and several-week internships expanding the commercialisation of knowledge. These classes took place, among others, at Stanford University and the University of California, Berkeley, in the USA (www.top500innovators.org/).

The development of SIZs and creative milieus requires strong institutional support. The University Centre for Innovation and Technology Transfer, located on Morasko Campus, serves as a bridging institution, fostering a business-friendly environment and promoting a high management culture that facilitates the transfer of technology from academia to business and the economy. However, despite the growing intensity of knowledge and technology transfer at the Morasko Campus, it has not yet reached the scale observed at leading Western European universities, such as those in Copenhagen, Eindhoven, and Helsinki. These universities operate within innovation districts featuring so-called living labs (https://edisonda.pl/wiedza/living-lab-czym-jest-laboratorium-innowacji/). Although innovation activities at AMU are not yet based on a living lab model, the university's support for entrepreneurial development has already yielded results. In 2023, the first spin-off companies were established through AMU Innovations, a special-purpose vehicle created to facilitate commercialization efforts.

As Weiss, M. (2023) points out, the efficient use of physical resources is essential for establishing the SIZ. One key example is the development of public transport within such zones. In this regard, the original planning assumption from the 1980s – to create a functional link between the Morasko Campus and the neighbouring city to the south – has not been fully realized. This has led to both external and internal isolations from the city, as the significant distance between the western and eastern parts of the Campus hinders connectivity. This challenge is not unique to Morasko Campus. Even renowned innovation districts like Silicon Valley, developed around Stanford University, have been criticized for their relative isolation from the surrounding urban environment (Katz, B. and Wagner, J. 2014). A similar situation exists in innovation hubs such as Sophia Antipolis in France, where employees typically reside in surrounding municipalities like Antibes, Nice, Grasse, Cannes, and Mougins. While the technology park is regarded as a prestigious workplace, it lacks the urban amenities needed to attract permanent residents (Barbera, F. and Fassero, S. 2013).

In Poland, the links between the Morasko Campus and its surrounding neighbourhoods are not so long-lasting, and they may limit the possibility of developing a SIZ at Morasko. The resource identified by Weiss, M. (2023) on the SIZ is the local community, which is made up of faculty, staff, and students engaging in pro-environment and sustainable economic and community development activities. On the Morasko Campus, mainly, the enclosed spaces in the vicinity of the Meteor dormitory and the faculty buildings have a positive impact (Collegium Biologicum, Collegium Geographicum with the Climate Garden, and Collegium Geologicum with the Lapidarium). Positive "people clashes" (Katz, B. and Wagner, J. 2014) can occur in these spaces, which contribute to the creation of new and fertile ideas. In this respect, it is worth noting the example of the Milla Digital neighbourhood in Zaragoza, Spain, where a space

was created based on historical squares and buildings for the interaction of employees of ICT companies (Joroff, M. *et al*. 2009). As a conclusion, we have collected information on the most important linkages between the Morasko Campus and the SIZ-concept, especially the factors and developments that play a crucial role in the transformation of the campus into a SIZ.

Conclusions

In our study, we have identified and analysed the physical resources that influence the development of creative milieu and a SIZ, using the Morasko Campus as a case study. In this sense we explored how the university campus and its associated initiatives contributes to its transformation into a creative milieu and, ultimately, a SIZ. The concentration of creative knowledge and workforce on a university campus plays a key role in triggering this process, as it facilitates the development of a creative milieu and is generally open to the adaptation of innovative architectural and technological solutions (see the role of place). In addition to the presence of a creative milieu, the physical environment and the physical characteristics of the campus play a crucial role in the development of Weiss's SIZ strategy, and, in the longer term, in the development of a sustainable and high-quality environment (see the role of space). Previous research has also shown that a creative milieu and high-quality (working) environment clearly contribute to the development of the creative economy and local economies and clusters (Egedy, T. and Kovács, Z. 2010).

Our pilot research aimed to examine the relevance of the SIZ theory in a Central and Eastern European context by analysing the creative milieu, physical resources and innovations development at the Morasko Campus of the Adam Mickiewicz University in Poznań. specifically exploring the potential role of sustainable and innovative solutions in urban development. Examples from North America and Western Europe show that this idea can indeed contribute to improving a creative and innovative milieu for cities. Our empirical results demonstrate that the SIZ theory's methodology provides a good starting point for developing sustainable innovation zones in Central and Eastern Europe. The investments and innovative developments on the Morasko Campus can be well identified and classified according to the key elements of the Katz-Wagner idea.

Based on the Katz and Wagner's concept of innovation district and its types, we defined our own classification of the Sustainable Innovation Zones (SIZ) concept. We distinguished three models of zones: 1) Anchor Plus Zone; 2) Re-imagined Urban Zone; 3) Urbanized Science Park. These models indicate the formation of SIZs at university campuses, based on the presence of three types of resources: 1) physical, 2) economic, and 3) networking (Katz, B. and Wagner, J. 2014). The research carried out in this article concludes that the development of the Morasko Campus seems to meet the requirements of the anchor-plus zone model. The innovation zone develops around the city and is linked with major academic institutions. In addition, the Morasko Campus fulfils selected aspects of the urbanised science park model. The area has been isolated from the rest of the city for years and has functioned autonomously. The initiatives taken recently and planned for the coming years to improve public transport should connect the campus much more closely with city centre in the future.

The analysis of the creative milieu and physical resources has shown that these factors actively contribute to the development of the social and economic environment, facilitating the transformation of the area into a SIZ. The physical resources provide the necessary infrastructure for technology and knowledge transfer. Key institutions driving this process include the University Centre for Innovation and Technology Transfer, the Wielkopolska Centre for Advanced Technologies, and the NanoBioMedical Centre. Additionally, AMU Innovation – a special-purpose vehicle established by AMU to support indirect commercialization

through the creation of employee spin-off companies—plays a crucial role. These elements lay the foundation for attracting additional business entities in the future and fostering a network of relationships that will enhance the area's potential as a hub for sustainable innovation and inclusive prosperity. Moreover, the possibility of social integration between students and academics is supported by the physical infrastructure of the relatively modern AMU faculty buildings. Adequate infrastructure related to enhancing creative human interaction ('people clashes'), including the new dormitory building and consumption spaces, is gradually being created. The complexity of the built environment at the Morasko Campus is being completed by the good landscape and proximity to the natural environment of the green belts in the northern part of Poznań. Further research should be concentrated on the network development and the inclusiveness of the campus, which will provide evidence that implementing the SIZ concept is possible at one of the leading academic institutions in Poland.

The added value of our study in the context of Central and Eastern Europe is mainly to highlight the links between the creative milieu and the development of a high-quality, sustainable and innovative environment. Through the creation of these development links, university campuses can step out of their role as mere educational institutions and successfully fulfil their so-called third mission, i.e. to promote local social, cultural and economic development.

The methodology and results presented in the article and pilot study can also serve as a good starting point for a comparative study of university campuses in Poland, and Central and Eastern Europe. The research results can be used to further analyse how university campuses can become SIZs supporting sustainable, innovative, inclusive, and prosperous urban development in the medium and long term. They also highlight the importance of developing an innovative and creative milieu over the long term to help transform these campuses into truly sustainable and innovative districts.

This study provides a good example of a modern university campus that reflects the transition to a new and more advance way of thinking about these vital elements. Starting out as a remotely isolated campus, the result of political decisions taken by the central government during the communist years, then evolving through the moderated development during the country's socio-economic transformation in the 1990s, until the recent times when concerns related to climate change started to play an essential role in the redesign and redevelopment of the city's urban structure.

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Geographical space and service use in agriculture: The view from the perspective of multilayer networks

László KOVÁCS[1] and Viktória SZŐKE[1]

Abstract

Location theory has shown that the location of businesses follows specific patterns: primarily, the site of production, transportation costs, markets, and workforce are considered the main factors influencing business location. However, less research focuses on the spatial distribution of service use of actual businesses. Based on empirical data collected in the Hungarian counties Vas and Zala, the paper shows how the service use of agricultural producers is distributed in space. Using a questionnaire, we show that services are primarily used in nearby towns, although in some exceptional cases, small villages can also function as service providers to agribusinesses. Based on the results, we argue that agricultural producers' business connections are best described as multilayer networks in which layers are interconnected. We assume, based on a shift towards more intensive service use of agricultural producers due to the advances in agriculture 4.0, that on these layers, physical roads will maintain their importance; parallel, however, the weight of digital connections will increase.

Keywords: agricultural services, service use, spatial distribution of service use, multilayer network

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Introduction

Business activities and business connections both shape and are influenced by geographical space. On the one side, geographical proximity may influence which business actors a given business interacts with: it is more likely that a business uses, for example, a banking service with a bank branch in the same city/town. On the other side, business relations may also shape geographical space: transporting raw materials or energy carriers ends in building roads, harbours, or settlements.

Classic location theories start from transport costs: the physical distance of consumers, producers and available workforce define the location of businesses (Laulajainen, R. and Stafford, H.A. 1995). In the case of services, however, transport costs are irrelevant since, in most cases, no physical transportation of goods or raw materials takes place (Cuadrado-Roura, J.R. 2013). This is especially true for online service providers. Since services' main function is not the transport of physical goods, the distribution and use of services cannot be described by traditional location theories. Network theories and network representations, however, offer a suitable method to capture the distribution of service use in space.

The paper examines the service use through the lens of networks: we argue that business networks are multilayer networks consisting of several layers. We show on the example of agricultural producers why the networks may be considered as multilayer networks.

Agricultural producers are an especially interesting subject in three respects: First, in most cases, the location of the agricultural producer is given since it is connected to the land it uses.

[1] Institute of Economics, Faculty of Social Sciences, Eötvös Loránd University Savaria University Centre. Károlyi Gáspár tér 4. H-9700 Szombathely, Hungary. E-mails and ORCIDs: kovacs.laszlo@sek.elte.hu, 0000-0003-0641-811X; szoke.viktoria@sek.elte.hu, 0000-0003-0445-6438

Second, the importance of agricultural producers is increasing, since the stability of food supply chains is paramount for society (Rosol, M. 2019; Moragues-Faus, A. *et al.* 2020). Food chain stability is closely connected to sustainability and climate change: climate change forces us to rethink agricultural production (Conte, B. *et al.* 2021), and new approaches to agricultural products foster innovation in food production (Mouat, M.J. *et al*. 2019). Food supply chains can function, however, only if the agricultural producer is able to produce agricultural products, which implies it must rely on a large number of services in its own supply chain: for example, on forecasting, plant service, or machine service.

Although agriculture has been gaining importance in recent days, and although it relies on several services, research has not analysed how these services are distributed in space. The first research question, thus, tackles the problems of service use of agricultural producers: RQ1) How does the spatial proximity of traditional service providers influence the service use of agricultural businesses? By analysing how services connected to agriculture are distributed in space, we may shed light on the dynamics of how agricultural producers choose services. On the other hand, the results may help to plan the location of services connected to agricultural producers.

The third peculiarity of agricultural producers is due to recent advances in technology: an increasing turn towards digital services in agriculture is observable resulting in agriculture 4.0 (Singh, S. *et al.* 2020). These digital services can help to mitigate or overcome the negative effects of climate change (O'Grady, M. *et al.* 2021).

Since service use has undergone a change due to the pandemic and since future agriculture is relying increasingly on digital, online services, which also influence local service use, a shift towards online service use can be anticipated. The second research question seeks an answer to the question: RQ2) What are the possible impacts of digital agriculture and online service use on agricultural producers in the future?

The theoretical goal of the paper is, to show through the example of agricultural producers, that network science can be used to describe service use of businesses and that multilayer networks provide a theoretical framework to describe business connections of agricultural producers. The third research question is connected to the overall goal of the paper: RQ3) How can business connections be described within the framework of network theory?

The paper analyses the spatial distribution and the network structure of services connected to agricultural producers. In the case of service networks, we show that at least two layers exist: a layer which needs physical connections to agricultural producers and physical movement of people providing or using service at physical places and another layer for online services, where service use means only data exchange. We argue that the second layer is likely to become more important in the future due to recent shifts in service behaviour and due to the advance of agriculture 4.0. We also show that connected to agricultural producers more network layers exist.

In the first part of the paper, we summarize the factors influencing the location of agricultural producers, then describe how agricultural producers use services. In the second part we analyse based on empirical data – collected via a questionnaire from a small sample of agricultural producers in West Hungary – the interconnectedness of agricultural producers and service providers. In a last step we discuss findings in light of network theory and of recent and upcoming changes in agricultural service use.

Throughout the paper, we will use two notions: agribusinesses and agricultural producers. The notion of agribusiness itself is rarely defined in scientific literature (Grigg, D. 2005): it is often used in a wider sense for the whole agribusiness sector, including input suppliers, agricultural producers, merchandisers, processors, and retailers (e.g. Gunderson, M.A. *et al.* 2014; Leitão, F.O. *et al.* 2024), but also in a more restricted sense as a business producing

agricultural products in the primary sector (e.g. Mariyono, J. 2020). In order to avoid confusion, we use in the paper two notions: we use agribusiness in the former meaning as a comprehensive concept for businesses in the agribusiness sector. In the case of individual businesses producing agricultural products, we use the notion of agricultural producer.

Geographical space and agribusinesses

The interconnectedness of geographical space and business activities is a long-studied subject in geography (Ponsard, C. 1983; Wallace, I. 1985; Colombo, S. 2020). In the classic location theory, transport costs are the decisive factor in business site selection: costs of overcoming geographical distance is the central driving force behind location choice and the geographical differentiation of economic activities (Glückler, J. and Panitz, R. 2021).

Von Thünen used concentric circles to describe the relationship between land rents, product prices, and the location of agricultural production, considering transportation costs and the quality loss of perishable goods during the transport (Prykhodko, I. 2017; Szőke, V. 2023). The general idea of Thünen has been used and refined by several scholars (e.g. O'Kelly, M. and Bryan, D. 1996).

Weber's model assumes that the location of raw materials is given, the spatial distribution of consumption is known, and transport costs depend on weight and distance. According to his model, three factors determine the business location: transport costs, labour costs, and agglomeration effects (Heineberg, H. 2007; Szőke, V. 2023).

Christaller's central place theory focuses on city-region relationships and the connections between central places (Heineberg, H. 2001): in his model, he examined settlements in a given area according to their size and function while assuming their cooperation. In his theory, he distinguishes between settlements with different central roles: *Oberzentrum*, *Mittelzentrum*, *Unterzentrum* and *Kleinzentrum*, where each level of centres has different functions, providing different services at each centre role (Gebhardt, H. 2011).

Location theories, however, must also consider the characteristics of the given sector or business to choose the best location: R&D companies may, for example, consider knowledge flow (Colombo, L. *et al*. 2024), entrepreneurs may prefer to locate their business close to other entrepreneurs (Schäfer, S. and Brenning, A. 2024) while gold mines prefer locations with less corruption and security (Tole, L. and Koop, G. 2011).

Which factors influence, however, the location of agribusinesses? These spatial economic models all included agriculture explicitly or implicitly in their considerations. Lucas, M.T. and Chhajed, D. (2004) point out focusing on agricultural location theory, that in the middle of the 20th century, planar models (space is a continuous phenomenon), discrete models (number of locations for facilities is finite) and network models (transportation networks influence location) existed. They argue that agricultural location is complex: production (farm), processing facilities, and transportation to the consumer must be all included in the equation while deciding on location. Geographical proximity to other actors played an essential role in the business activities of agribusinesses until the middle of the 20th century (Molema, M. *et al.* 2016). Today, it is observable that the proximity to the consumer is the most crucial factor: since infrastructure and demand do not exist in sufficient quantity and/or quality at agricultural areas, food processing is located near the consumer (near cities) and not in agricultural areas (Cohen, J.P. and Paul, C.J.M. 2009). Thus, transportation plays a relevant role in agriculture.

Overall, connected to transportation, a dual process is observable (Shih, W.C. 2022). On one side, from the late 19th century to the late 20th century, the importance of proximity decreased as technical advancement first enabled the transport of goods over longer distances and later contributed to decreasing transportation costs (Nichols, T.E. 1969), which again led to a change in

agricultural production (O'Kelly, M. and Bryan, D. 1996). As a result, in the 21st century, extended supply chains and global connectedness lead to a complex approach to agri-food business, including agricultural production and food industry (De Backer, K. and Miroudot, S. 2014).

On the other side, in recent years, we experienced three new barriers connected to distance and the transportation of agricultural goods: first, the coronavirus pandemic showed us that borders function as real obstacles, making impossible or slowing down the movement of persons and goods (Hamid, S. and Mir, M.Y. 2021). Second, the war in Europe showed how fragile agriculture-connected supply chains are: not only crops themselves but for crop production essential goods such as fertilizers or even diesel fuel are in shortage (Ekin, E. 2022). Finally, a third factor influencing agricultural transportation and product demand is the increasing consumer demand for local products (Marino, D. *et al*. 2018). Agricultural location theories of the future have, thus, to consider not only advances but also new challenges caused by recent events and consumer trends and expectations.

Besides the above-mentioned location-connected contexts, a less researched factor is connected to agribusinesses: agricultural producers' service use. Agricultural producers today must rely on a wide range of specialized and general services for production and administration. Therefore, the geographical distribution of services may be relevant since service use, as shown below, will increase in the future.

Service use and agribusinesses

As we have seen, spatial proximity and transport costs influence agricultural production. Since the share of used services in agricultural production is increasing in all countries of the European Union (Kolodziejczak, M. 2018), research connected to service use in agriculture can contribute not only to agribusiness theory but can also have real-world implications, for example, to choosing locations for service providers.

Molema, M. *et al*. (2016) recommend thinking of agricultural producers as parts of networks: the network view enables one to see the interdependencies of the actors of networks. They argue, that in an agribusiness network, the main actors are: (1) farmers, (2) suppliers (machinery, seedlings), (3) food processing industry, (4) financiers, (5) knowledge institutions, (6) consumers and consumer organizations, (7) distributors and (8) governmental organizations, where financiers, knowledge institutions and governmental organizations are service providers for agriculture. These actors' interrelationships and functions are complex and change over time.

Similarly, Sonka, S.T. and Hudson, M.A. (1989), and also Gunderson, M.A. *et al.* (2014) name besides genetics and seed stock, input suppliers, agricultural producers, merchandisers, processors, retailers, and consumer services (in general), and finance and R&D as part of the agribusiness sector. Edwards, W. and Duffy, P. (2014) name several farm-related services in their chapter, grouped into finance-related services (e.g. bookkeeping and tax preparation, farm accounting, insurance) and production-related services (e.g. machinery services, crop scouting, veterinary services). Besides these services, a turn is observable in agriculture: more and more services – partly digital – are offered for agricultural producers (Klerkx, L. *et al.* 2019).

Used, available, and future services appear often connected to the 4.0 turn in agriculture (Winter, J. [2020] connected to industry 4.0). Since the beginning of the 21st century, we can speak of agriculture 4.0 (or smart farming or digital agriculture, Klerkx, L. *et al.* 2019): with the development of information technologies, sensors have become cheaper and more advanced, agricultural (soil-, weather-, plant- and machinery-related) data can be collected and processed quickly, in real-time. Agriculture 4.0 (or agri-food 4.0; e.g. Arora, C. *et al.* 2022) uses many data sources, connects data intelligently, makes

forecasts based on the data – it can even collect and process data and find solutions for an individual plant or animal (Klerkx, L. *et al.* 2019).

In this new agriculture, an increasing role of and the demand for non-physical services – which enable accurate data collection, data processing, and data analysis – is observable. A lot of these new technologies are connected to communication services, for example, mobile phone services (Baumüller, H. 2017), or cloud-based services (Eastwood, C. *et al*. 2019). For a recent overview of the technologies, challenges, and solutions, see, for example, Klerkx, L. *et al.* (2019) or Debauche, O. *et al.* (2021).

The digital transformation in general (Rha, J.S. and Lee, H.-H. 2022), the transformation to digital agriculture, and the recent advances in technology and society make it evident that connected to agriculture, more and more services will be provided online. The use of services in agriculture, thus, will be both offline and online: on the one hand, services that call for physical presence, like physical repair of machines or calibrating new equipment, will be done on-site. On the other hand, it can be presumed that services that do not call for physical proximity will be used more and more online.

In order to see the service use and the spatial distribution of service use, it is essential to collect and analyse empirical data connected to agricultural producers. Next, we analyse data collected from agricultural companies in West Hungary, in the counties Vas and Zala.

Research materials and methods

A survey was conducted between late 2019 and early 2021 in West Hungary, in the counties Vas and Zala, to analyse the service use of agricultural businesses.

The county of Vas covers an area of 3336.1 km^2 (HCSO 2016), of which 49.94 percent is agricultural land (43.46% arable) (HCSO 2023). 3.3 percent of the agricultural, forestry and fishing enterprises in the country are located in the county (AKI 2021a). Zala county covers an area of 3783.87 km^2 (HCSO 2016), of which 40.65 percent is agricultural land (34.57% arable) (HCSO 2023). 4.2 percent of the agricultural, forestry and fishing enterprises operating in the country are located in the county (AKI 2021b). The agricultural land of the counties is 260,000 hectares for Vas and 274,000 hectares for Zala county (Szőke, V. 2023). Agriculture was important for Vas county in the last two centuries, and even today agriculture adds more to the GDP (7%) of the county as the Hungarian average (5%; Lenner, T. and Palkovits, I. 2014). In Vas county, wheat, maize, sunflower, and rapeseed are the main crops; sugar beet and spring barley are also cultivated. In Zala county, wheat and maize are the most produced crops. The agricultural land of both counties is characterized by a fragmented structure (Szőke, V. 2023). *Figure 1.* shows the map of the two counties.

The questionnaires consisted of 14 questions, partly business-related (for example, the number of employees and machines used on the farm) and partly connected to the business connections of the agricultural producers. In addition, we asked from where (which settlement/ foreign country) the agricultural producers



Fig. 1. Geographical position of Vas and Zala counties in West Hungary. County seats: Szombathely and Zalaegerszeg. *Source*: OpenStreetMap.

regularly bought products or raw materials, where (which settlement/foreign country) agricultural products were sold (Szőke, V. and Kovács, L. 2023), and on which settlements services were used. Connected to services, we asked for service frequency and place of service use of the following services: machine service, accounting, financial auditing, bank, legal services (lawyer, notary), and plant expert. Although the questionnaire contained empty lines for participants, where they could have written other used services, no other services were named. Questionnaires were distributed online based on the recommendation of agricultural experts (snowball sampling).

In the current results section, we analyse only connections between settlements based on the service use of agricultural producers.

Data analysis

To see the connections between service providers and service users, we construct networks between settlements where the agricultural producer is situated and where it uses a given service (e.g. accounting is done on the settlement where the accounting firm is situated). For analysing, grouping, and cleaning data, Microsoft Excel, for network analysis Gephi 0.9.7 on Windows was used.

To use networks describing business relations is obvious: networked structures have been assumed and analysed since the mid-20th century (e.g. Uitermark, J. and van Meeteren, M. 2021; Barthélemy, M. 2022). In geography, network analysis started in the 1960s (Haggett, P. and Chorley, R.J. 1969) and was resurrected with the emergence of network science at the end of the 20th century (Barabási, A.-L. 2016). For an actual, detailed overview of geographical network use, see Barthélemy, M. (2011, 2022), Glückler, J. and Panitz, R. (2021) or Uitermark, J. and van Meeteren, M. (2021), for a special geographical context, for example, transportation see Derudder, B. *et al.* (2008) or Derudder, B. and Neal, Z. (2018) or network theory can also be used to identify the boundaries of a smaller touristic region (Madarász, E. and Papp, Z. 2013) or describe tourist movements in a given region (Nod, G. and Aubert, A. 2022).

The general character of network theory enables its use in economics and business theory (e.g. Easley, D. and Kleinberg, J. 2010). Network approaches may be used, for example, to analyse the connections between different industries (Cortinovis, N. *et al*. 2020; Turkina, E. *et al.* 2021), to analyse the impact of transportation networks on employment (Koster, H.R.A. *et al.* 2022), to show how strong links are connected to economic performance and weak links to growth (Zhu, S. *et al.* 2021) or to analyse regional economic resilience (Tóth, G. *et al.* 2022).

Research results

Business-related data is not easily collected from agricultural companies: agricultural producers in Hungary are often unwilling to give data connected to business activities. They fear that providing information about business connections and about confidential, business-related data can be used by their competitors and by official authorities since – although data collection is anonymous – some agricultural producers may be easily identified based on a small number of facts (Szőke, V. 2023). This is why, for data collection, we had to use the snowball method: Familiar agricultural producers were contacted, we collected data, and the businesses helped contact new businesses. In the end, we managed to collect data from 30 businesses. *Table 1* shows a detailed summary of the main characteristics of the businesses.

Due to the small number of analysed businesses the data collection cannot be representative: the goal of the empirical data collection was to show on the example of a small number of agricultural producers the real, existing connections to service providers. The collected data and the diversity of the agricultural producers (larger and smaller producers, diversity of activities, spatial distribution) make it possible, how-

Table 1. Distribution of agricultural producers who completed the questionnaire by county and by activity

Distribution of agricultural producers	Number of businesses, pieces
By agricultural sector	
Crop production	Vas 15, Zala 2: *total 17*
Animal husbandry	Vas 2, Zala 4: *total 6*
Crop production and animal husbandry	Vas 4, Zala 3; *total 7*
Number of employees (persons)	
1–2	17
3–5	5
6–10	4
11–15	1
16–20	0
20 <	3
By area (crop production; crop production and animal husbandry, ha) (together ca. 6200 ha cultivated)	
0–10	4
11–20	1
21–50	7
51–100	2
101–200	2
201–500	5
1000 <	3
By number of animals (pieces)	
0–10	1
11–50	3
51–100	5
101–200	1
201–500	0
501–1000	0
1000 <	3

Cultivated plants

Crops	Proportion of area, %	Estimated area, ha
Arable crops		
Wheat	32	2020
Rapeseed	21	1330
Maize	21	1290
Soy	13	815
Barley	9	550
Sunflower	1	85
Other non-arable crops		
Apple	0.6	40
Evergreens	0.2	10
Ornamental plants	0.1	5

Animals

Sort of animals	Number of farmers breeding the animal	Number of animals
Poultry	2	74 500
Pig	4	6570
Cattle	5	400
Beehive	2	200
Mangalica*	1	10
Others**	1	24

*Specific Hungarian pig. **Horse, goat, alpaca, sheep. *Source*: Authors' own editing.

ever, to see the dynamics of service use in the given smaller areas. Since – to the best of our knowledge – service use of agricultural producers was not analysed previously, each result can provide new insight into how agricultural producers choose and use services.

The questionnaire asked the businesses about service use, the most common services, and the actual place of service use (settlement). *Figure 2* shows the most important services the agricultural producers use. The analysis of services is not exhaustive. On the one hand, we asked just for the most common services used by agricultural producers; on the other hand, the services provided by agricultural producers (e.g. tillage and harvest provided for other agricultural producers) are not analysed. The reason for latter is that during the pilot survey, we got negative feedback connected to our planned questions on the services provided by farmers: they reasoned that the information was confidential and essential for their business. This question was, therefore, deleted from the final questionnaire.

In the next step, we analysed where (on which settlement) these services are used. *Figure 3* shows the network structure according to the number of connections between services. The network is a directed network; the arrows point from the service-providing settlement to the settlement where the agricultural producers are located.

The most central settlements providing services are towns: Szombathely and Zalaegerszeg are the county seats of Vas and Zala counties, Körmend and Sárvár are smaller towns. Egyházasrádóc and Rádóckölked are villages with large (over 1000 ha) agricultural producers. Austria is in the network because two agricultural producers have bank accounts not only in Hungary, but also in Austria – they sell crops to Austria, Italy, and Slovenia and purchase input material and machinery from Austria and Germany. The network characteristics of the constructed network of service use were analysed by network-specific metrics *(Table 2).*

The γ-index – a density index that characterizes the degree of network complexity (Barabási, A.-L. 2016) – takes the value $\gamma = 0.5490$, which indicates a moderately complex network (Dusek, T. and Kotosz, B. 2016). A value of modularity indicates that clear communities are formed – in our case, 5 – and a value of 0.4 < indicates that these communities are well separated.

The data shows that service use is connected to nearby, mostly larger settlements that provide the service. For the most common services, it is crucial to have – when needed – physical contact, for example, in a bank when withdrawing cash. As we see from the network, most agricultural producers are part of the same network because the crucial services are provided in larger or smaller towns, necessarily connecting the agricultural producers to these cities. As some services are available only in towns – or are available in towns in a larger variety – the central elements are larger towns. Smaller agricultural producers may, however, use a smaller number of services: an agricultural producer in Tótszerdahely manages to use all necessary services in the immediate vicinity (within 10 km) of the agricultural producers.

Smaller towns and settlements (e.g. Hegyfalu, a village with less than 800 inhabitants) can also function as central elements. These settlements are central because they accommodate companies providing specialized services for agricultural producers.

Most of the analysed services have a dual character: an offline and an online component. For example, actual bank visits are seldom needed; online banking activity is, however, regular. The same is true for accounting: scanned versions of invoices are sent to the accounting firm regularly; paper versions, however, only once a month. Although service use is partly online, an actual spatial proximity is called for. These are services that are accessible and provided in every larger settlement.

In the case of new digital services for agriculture, the picture may be completely different. As we pointed out, solutions enabling smart farming and using the latest technology

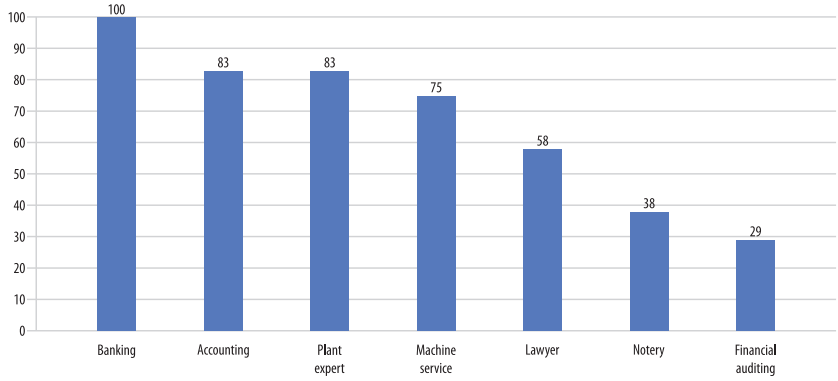


Fig. 2. Use of primary agricultural services of the companies in percent. *Source*: Authors' own editing.

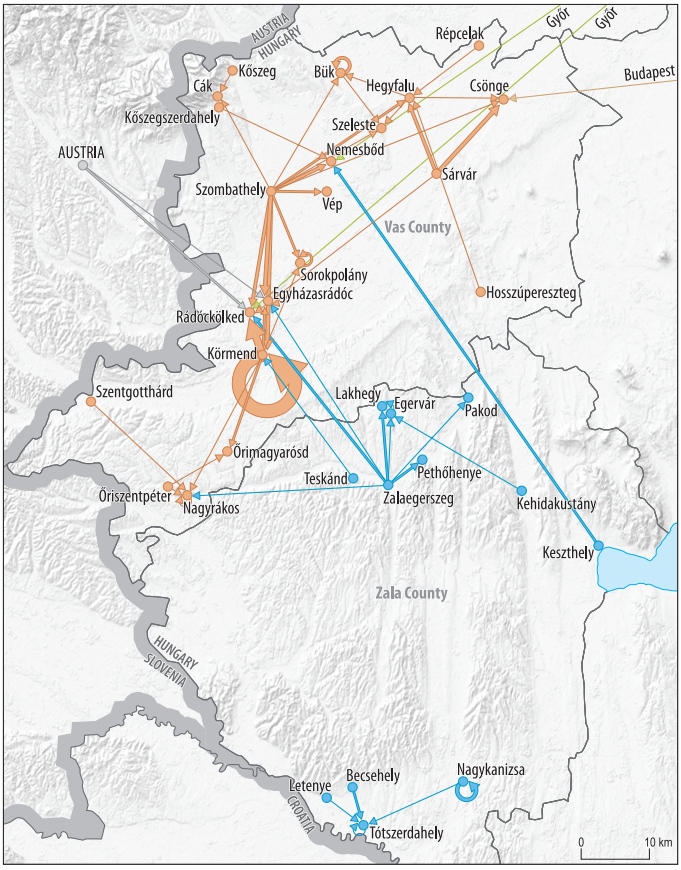


Fig. 3. The network representing the connectivity of service use, weighted by the number of connections. Thicker line marks the settlement from where more services are used. Settlements of Vas (brown coloured) and Zala (blue coloured) counties are placed according to their actual geographical location. (Győr and Budapest are out of Vas or Zala counties.) *Source*: Authors' own editing based on Szőke, V. 2023.

*Table 2. Network indicators on the use of services by agricultural producers**

Indicators	Hungarian settlements + *Austria*	*Value* (pc)
Outdegree (k_i^{out}):	Szombathely	*11* (1)
	Zalaegerszeg	*7* (1)
	Körmend	*6* (1)
	Hegyfalu, Sárvár	*3* (2)
	Austria, Bük, Győr, Nagykanizsa, Őriszentpéter	*2* (5)
	Becsehely, Budapest, Egyházasrádóc, Hosszúpereszteg, Kehidakustány, Keszthely, Kőszeg, Kőszegszerdahely, Lakhegy, Letenye, Nagyrákos, Répcelak, Sorokpolány, Szentgotthárd, Teskánd, Tótszerdahely	*1* (16)
Indegree (k_i^{in}):	Rádóckölked	*6* (1)
	Egyházasrádóc, Nagyrákos	*5* (2)
	Csönge, Hegyfalu, Nemesbőd, Tótszerdahely	*4* (4)
	Bük, Egervár, Körmend, Sorokpolány, Szeleste	*3* (5)
	Cák, Őrimagyarósd	*2* (2)
	Lakhegy, Nagykanizsa, Pakod, Pethőhenye, Vép	*1* (5)
Total degree of nodes (k_i): ($k_i = k_i^{in} + k_i^{out}$)	Szombathely	*11* (1)
	Körmend	*9* (1)
	Hegyfalu, Zalaegerszeg	*7* (2)
	Egyházasrádóc, Nagyrákos, Rádóckölked	*6* (3)
	Bük, Tótszerdahely	*5* (2)
	Csönge, Nemesbőd, Sorokpolány	*4* (3)
	Egervár, Nagykanizsa, Sárvár, Szeleste	*3* (4)
	Austria, Cák, Győr, Lakhegy, Őrimagyarósd Őriszentpéter	*2* (6)
	Becsehely, Budapest, Hosszúpereszteg, Kehidakustány, Keszthely, Kőszeg, Kőszegszerdahely, Letenye, Pakod, Pethőhenye, Répcelak, Szentgotthárd, Teskánd, Vép	*1* (14)
β Index / Average Degree	1.5556	
Average Weighted Degree**	3	
γ Index	0.5490	
μ Index	20	
π Index	28	
Network Diameter**	2	
Graph Density**	0.044	
Modularity**	0.478	
Number of Communities**	5	

*Number of nodes (N): 36, number of connections (E): 56. **Calculated by Gephi 0.9.7. *Source*: Authors' own editing based on Szőke, V. 2023.

are necessarily partly or wholly online services. For example, a weather forecast using no on-site devices is an online service, farmers can subscribe to (e.g. FarmCast). Similarly, services using satellite services are also online providers, like SkyWatch. These service providers are globally active, with no actual office in a given settlement or even in a given country. In Hungary, these services are used today not frequently, although the usage frequency is increasing.

Discussion

Spatial proximity and service use

Service as knowledge

In the first research question we searched for an answer to the following question: How does spatial proximity of traditional service providers influence the service use of agricultural businesses?

Business services form a subgroup of services: they show a large spatial concentration, both inside and outside of cities (Cuadrado-Roura, J.R. 2013). In the case of business services, a dual character is observable: for routine services and for Knowledge-Intensive Business Services (KIBS) (e.g. accountancy), proximity is relevant, for other services less so, since either the service provider travels to the service user, or telecommunication is used for services (Cuadrado-Roura, J.R. 2013). Thus, service providers of routine services often open offices in places where the service may sough after, while service companies without client contact are mostly situated near large cities with relevant infrastructure and qualified workforce (Cuadrado-Roura, J.R. 2013).

To be able to compare the network structures of different types of services, we draw networks to different services separately *(Figure 4).* The networks represent the connectivity of service use, weighted by the frequency of service use. Thicker lines mark the service used more often. Settlements of Vas (purple coloured) and Zala (green coloured) counties are placed according to their actual geographical location. As we can see from the results, different kinds of settlements function as nodes, depending on which services are analysed.

In the case of *plant experts and veterinarians* (see *Figure 4*, A), spatial proximity is an important factor: these services are sought after at the same settlement or nearby settlements (approx. 10 km). In this regard, smaller settlements are also central: in several cases, these experts are in the same settlement as the agricultural producers. Plant expert/veterinarian services can be regarded as Knowledge-Intensive Business Services, thus, the proximity is in line with previous findings (Cuadrado-Roura, J.R. 2013).

In the case of *machinery services* (see *Figure 4*, B), new settlements are central: the service providers are not in close vicinity; they are 20 km or even 100 km away. Central nodes are smaller settlements and towns. In these cases, service providers travel to the agricultural producer, for example, to repair machines. Since, however, these services are used less frequently, proximity is not important (Cuadrado-Roura, J.R. 2013).

When we look at services connected to administrative tasks, we see different structures again. In the case of *legal services* (see *Figure 4*, C), these services are seldom sought after, and service providers are mostly in larger cities. *Accountancy services* (see *Figure 4*, D), are again provided from larger settlements. *Banking services* (see *Figure 4*, E), are used primarily in larger towns, sometimes in smaller towns. Banking services are, however, often used online. These services can be considered as routine services or Knowledge-Intensive Business Services, thus, proximity is important (Cuadrado-Roura, J.R. 2013).

Results are also in line with Shearmur, R. and Doloreux, D. (2020), who show on the example of vine production, that specialized services connected to specific knowledge are mostly used close to the production site, while less-specific services like logistics or marketing are used from towns. As Shearmur, R. and Doloreux, D. (2020) point out, knowledge for some services is not necessarily located in towns: specific knowledge may be located near to producers. We confirm these findings: specific knowledge may be located in smaller settlements, and the most specific knowledge for agricultural producers – plant experts/veterinarians – is sought after from the close vicinity of the producer. The findings also confirm that knowledge must not only be associated with and located in towns or cities (e.g. De Ávila Serrano, R.V. 2019): knowledge is industry-specific, and specific knowledge may be produced on smaller settlements (Shearmur, R. and Doloreux, D 2020).

Online vs. offline services

In the case of services, in general, a shift towards more online service use can be anticipated. The second research question – RQ2) What are the possible impacts of digital agriculture and online service use on agricultural producers in the future? – seeks to analyse online and offline service use.

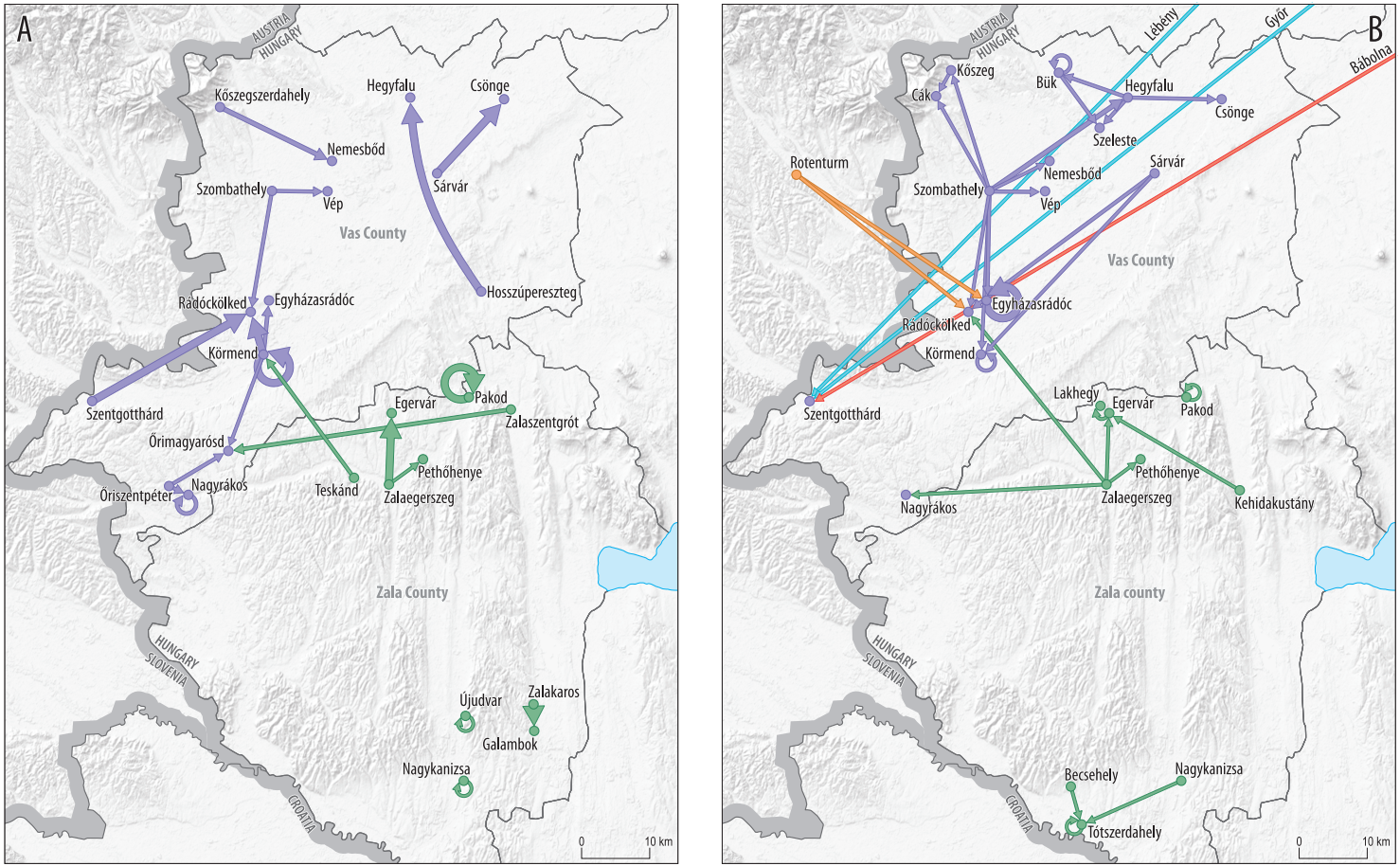


Fig. 4. The network structures of different types of services. Content of the lines and colours: explanations are in the text. A = Plants experts and veterinarians; B = Machinery services (Lébény, Győr and Bábolna are out of Vas or Zala counties; Rotenturm is settled in Austria.) *Source*: Authors' own editing based on Szőke, V. 2023.

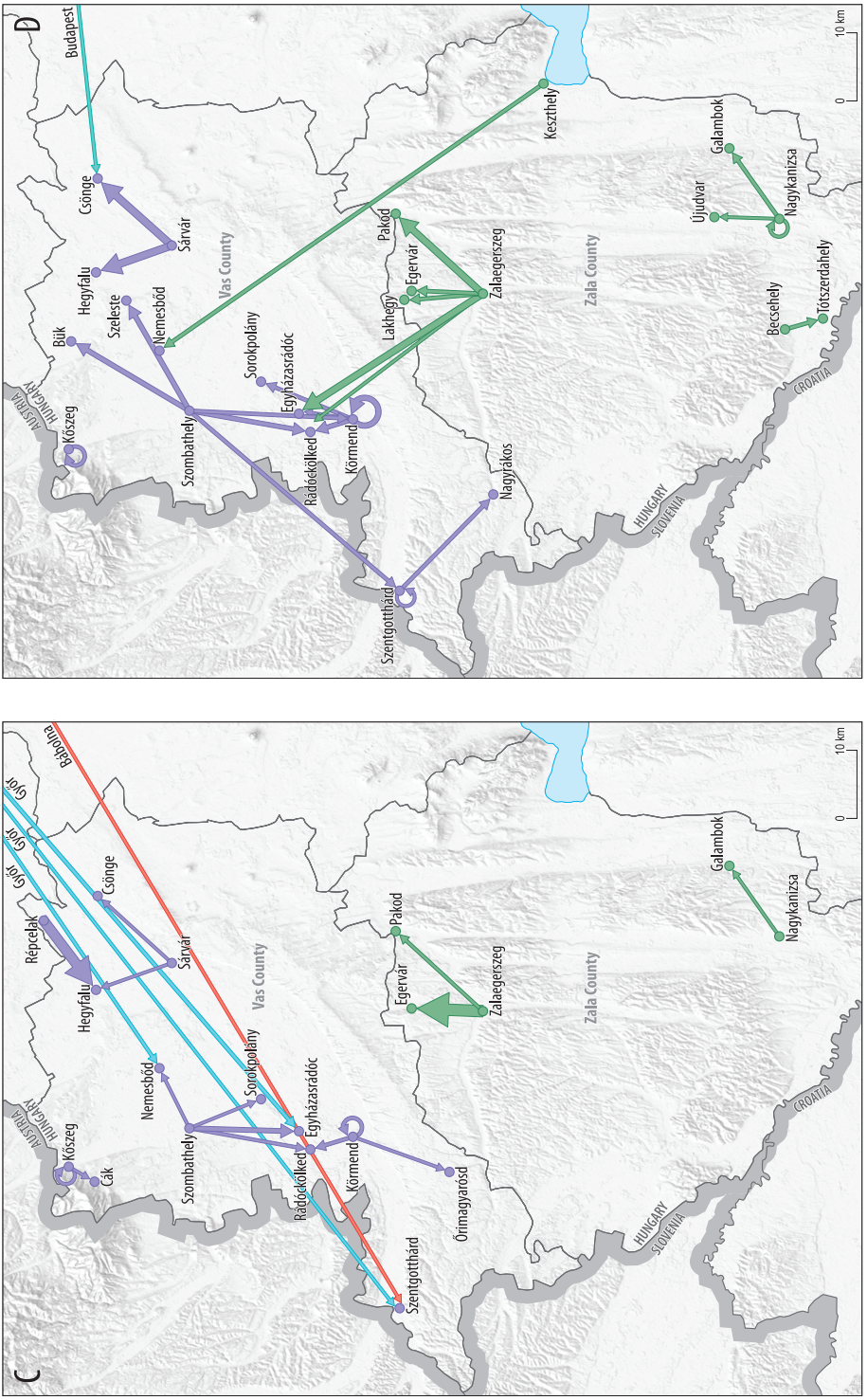


Fig 4. (Continued). The network structures of different types of services. Content of the lines and colours: explanations are in the text. C = Legal services (Győr and Bábolna are out of Vas or Zala counties); D = Accountancy-related services. *Source:* Authors' own editing based on Szőke, V. 2023.

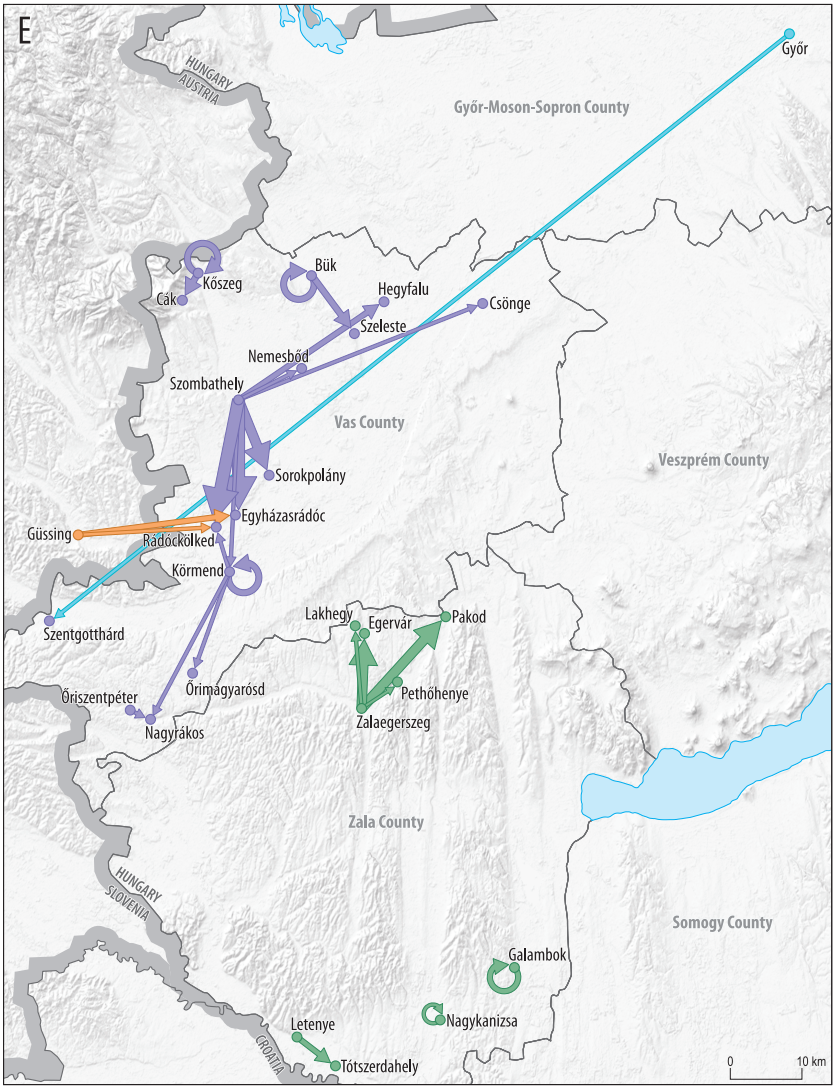


Fig 4. (Continued). The network structures of different types of services. Content of the lines and colours: explanations are in the text. E = Banking services (Győr is out of Vas or Zala counties; Güssing is settled in Austria.) *Source*: Authors' own editing based on Szőke, V. 2023.

The above data collection occurred partly during the pandemic; therefore, the initial questionnaire contained no questions connected to the change in service use habits; it only analysed service use at a given time. After seeing the results, however, we conducted short questionnaires with selected agricultural producers, explicitly asking for long-term changes in their service use habits. The goal of the new questionnaire was to see how service use changed after the pandemic. We collected data from six companies situated in Vas and Zala counties. Data collection was online in August and September 2022.

The respondents were chosen from the businesses filling out the original questionnaire.

Surprisingly, answers indicated that physical distance to the service provider became more critical during the pandemic. However, at the same time, all agricultural producers indicated that for most services (financial auditing, accounting, legal services, banking, meteorological services, government-related service use), either the online-offline service ratio remained the same over time or changed slightly or to a large extent in favour of online service use *(Figure 5)*.

For testing, we performed a hypothesis test to confirm whether there was a significant difference in the pre- and post-coronavirus values.

We hypothesised H_0: $\mu_1 = \mu_2$; H_1: $\mu_1 \neq \mu_2$ as an alternative hypothesis, and then used Student's t-test to test which services showed a difference at the 5 percent ($\alpha = 0.05$) significance level between pre- and post-coronavirus service use. To test the equality of variances, we used an F-test, and we accepted the H_0 hypothesis (H_0: $\sigma_1 = \sigma_2$; H_1: $\sigma_1 \neq \sigma_2$, with the exception of machine service). In the case of machine service, the equality of variances could not be proved by an F-test, so instead of Student's t-test, we performed Welch's t-test, in which case the equality of variances need not be satisfied. As a result of the t-tests, we could not accept H_0 for banking services because the t-value was outside the acceptance range, so the alternative hypothesis H_1 was accepted. Thus, for banking services, there is a significant difference ($\alpha = 0.05$) for the increase in the use of online services after the coronavirus pandemic.

The analysis also included correlations analysis between the pre- and post-coronavirus service use for each service.

- Very strong correlation (±0,8 to ±1): auditing, legal services, notary, IT services, occupational safety and health, plant expert government-related services, land-registry services, training, online purchasing and commerce;
- Strong correlation (±0,6 to ±0,79): machine service, postal/parcel services, fire protection services;
- Moderate correlation (±0,4 to ±0,59): accounting services;
- Weak correlation (±0,2 to ±0,39): banking services.
- Correlation cannot be computed due to a constant value: meteorological services.

For banking services, we see that there is a weak correlation. The variances are the same in the pre- and post-coronavirus data series,

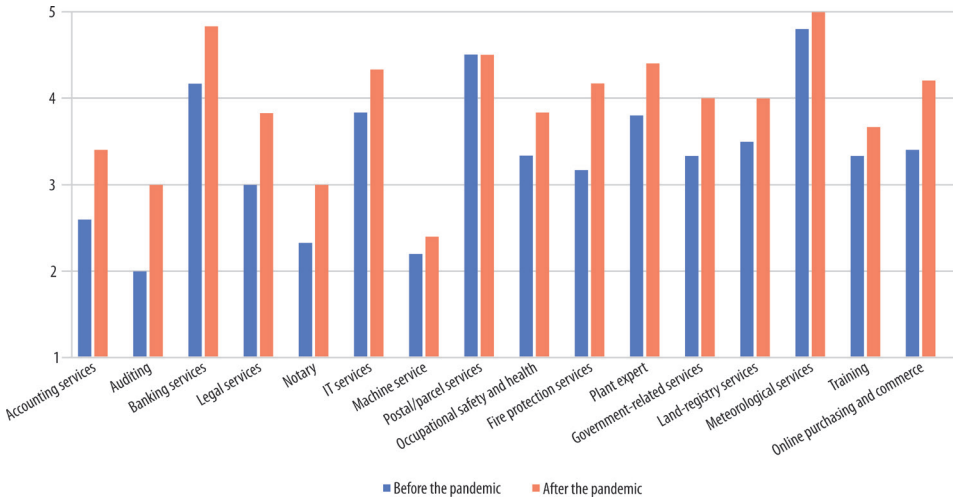


Fig. 5. Change in online service use between 2020 and 2022. Scores on Y axis: 1 = do not use / not used; 2 = only offline; 3 = rather offline, partly online; 4 = rather online, partly offline; 5 = only online. *Source*: Authors' own editing.

so the difference is not due to the difference in variances, but presumably to the fact that the surveyed firms have increased their use of online services to different degrees.

No participant indicated that the offline service use ratio increased during the given period. Results align with the increased use of digital and online technologies in all contexts of small businesses (e.g. Akmaeva, R.I. *et al*. 2020).

In the future, online services may increase since there is both a demand for and supply of these services (Gray, R.S. and Torshizi, M. 2021). Online service increase is also connected to the digital transformation of agriculture: digital transformation is taking place today, enabling more efficient production and more sustainable solutions (Rijswijk, K. *et al.* 2021; Mendes, J.A.J. *et al.* 2022). The pandemic also influenced digitalization and digital service use in agriculture (Avalos, E. *et al.* 2023). Thus, in agriculture, digitalization will likely increase, which implies more online service use (Lioutas, E.D. and Charatsari, C. 2021; Porciello, J. *et al.* 2022).

Layers of networks

Different purposes – different networks

The second part of the discussion tries to answer the third research question: RQ3) How can business connections be described within the framework of network theory?

In the case of services, a dual character is observable. On the one hand, physical movement is relevant for some services: For example, plant experts or veterinarians may travel to the agricultural producer to provide their services. On the other hand, for example, in the case of banking, services may be provided both online and at the office of the service providers: some banking services can be done via home banking (e.g. bank transfer), while others require personal presence, like cash withdrawal.

As we can see, we could assume two different networks for service providers: one that provides services for agricultural producers, where spatial proximity is relevant. In the analysed data, spatial proximity was the most important factor in the case of plant experts and veterinarians. In the case of other services, however, spatial proximity seems to be less important; nonetheless proximity is important, since physical movement is needed. In this networks information and people are traveling.

In the case of emerging digital services, however, no physical movement is necessary since data is sent online or stored and used in the cloud (Lezoche, M. *et al*. 2020; Panetto, H. *et al*. 2020). When we consider online networks of service providers, information travels on digital networks, and the service itself can be described as data exchange (and processing). Since data is exchanged on this network, no proximity – and no roads – are needed, just digital connections between the farm and the service provider.

Add to these networks further networks of agricultural producers: the network of suppliers of physical goods and the network of buyers of the agricultural products. These networks are very different from the above networks: transportation times and costs play an important role in these networks.

In a foregoing paper (Szőke, V. and Kovács, L. 2023), we analysed the purchase (supply network) and selling (sales network) relationships of the same agricultural producers we analyse in current paper. In the supply network, Hegyfalu (a small village) was the most central node, with 9 (outgoing) connections, followed by Szombathely and Sárvár with 7–7 and by Vasvár and Zalagerszeg with 5–5 connections (thus, settlements that provided supply for the analysed agricultural producers). In the case of sales networks, central nodes were Austria (7 connections), Italy (5) and Egyházasrádóc (3). These were the main settlements (countries) where the most produced agricultural goods were transported. In the case of the supply network, we identified 54 nodes with 86 connections, and in the sales network, 28 nodes with 37 connections (in comparison above, the service network for the same producers has 36 nodes and 56 connections; see *Table 2*).

Multilayer networks

From a network point of view, these different networks can be characterized as multilayer networks. Multilayer networks consist of networks on different layers, where nodes on different layers may connect the layers (Boccaletti, S. *et al.* 2014; Kivelä, M. *et al.* 2014). Multilayer networks exist in many contexts: connected to geography in city transportation, they can consist of layers according to different means of mass transportation (e.g. tram, bus) (Aleta, A. and Moreno, Y. 2019). Maritime connections (Ducruet, C. 2017) and human mobility (Belyi, A. *et al.* 2017) can be described also as multilayer networks.

We assume that the connection of businesses – in our case, agricultural producers – can be described by multilayer networks. Based on the results, we argue, that agricultural producers are the hubs of at least five different network layers:

1) a layer for suppliers of agricultural producers,
2) a layer for purchasers of goods produced by agricultural producers,
3) a layer of agricultural producers,
4) a layer for offline service providers,
5) a layer for online service providers.

All these layers have connections on the layer itself, but also between layers *(Figure 6).*

We describe the layers and connections between the layers from the perspective of agricultural producers (Layer 3).

On the layer of suppliers (Layer 1), businesses of the agribusiness sector are situated, providing supplies for the producers (Layer 3). The connections between these two layers represent roads. Movement is less frequent, but the transportation of goods suggests a good road infrastructure. Connected settlements are small settlements (producers) and settlements with relevant agribusiness supply businesses (larger, but also smaller settlements).

On the layer of purchasers (Layer 2) purchasers of agricultural goods are situated, which are part of the agribusiness sector. The connections between Layer 2 and Layer 3 represent again roads. Movement is less frequent, but the transportation of goods suggests a good road infrastructure. Connected settlements are small settlements (producers) and – mostly small – settlements, where agribusiness products are stored (traders) or processed.

Different services are situated on the layer for offline service providers (Layer 4): agriculture-specific and general services. The

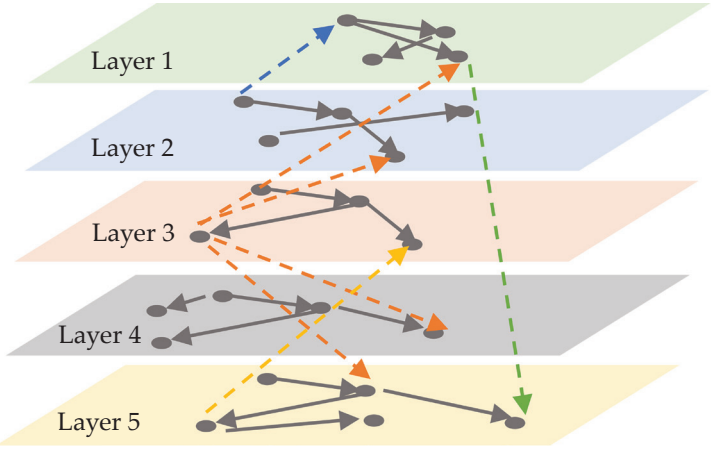


Fig. 6. A multilayer network of agricultural producers. Different colours represent different layers. Connections on layers are depicted grey, connections between layers are coloured. *Source:* Authors' own editing.

connections between Layer 4 and Layer 3 represent roads and/or digital connections. Physical movement was more frequent in the past, now physical movement is decreasing and online traffic is increasing. Connected settlements are small settlements (producers) and nearby small, middle or larger settlements, depending on the provided service.

On the layer for online service providers (Layer 5) businesses are situated, which provide almost exclusively online services, connected mostly to the digital turn in agriculture. The connections between Layer 5 and Layer 3 represent mostly digital connections. Connected settlements are small settlements (producers) and all kinds of other settlements (Layer 5). Here, we will find settlements with state-of-the-art knowledge: large or international metropolises, settlements with cloud computing, and international service providers.

Connections on the layers also exist: for example, nearby agricultural producers often cooperate, they help each other, for example, with contract work, or they may cooperate by purchasing supplies together. We may also propose a Layer 6 for employees (here not analysed). Employees also move between settlements: their home and the location of the agricultural producers are also connected via roads.

By changing the viewpoint, the above considerations indicate that successful agricultural enterprises of the past were those that had important physical connections (roads) to transport goods. These connections remain paramount since goods still need to be transported to the agricultural producer (e.g. input materials), and agricultural products need to be transported from the producer. The recent advances in technology and in behaviour connected to the pandemic, however, make digital connections more and more important.

Today and future agricultural producers need both networks: they need their physical network to transport supplies and products and for employees to move. They need, however, to be part of a similarly complex virtual network where data is moved. New technologies presented by agriculture 4.0 will work with the help of the digital network – failing to be part of this network means a future agricultural company may be less effective and competitive, since missing infrastructure connected to data-intensive solutions may slow down or block the implementation of agriculture 4.0 (Da Silveira, F. *et al.* 2023).

We also argue, that in the following years a shift between layers will be observable: as more and more digital services are (and will be) used in agriculture, the importance of Layer 5 increases. The importance of Layer 4 may decrease, but just slightly: one part of the new (online) services may decrease the importance of Layer 4; it cannot, however, vanish, since – as we have seen – in the case of a lot of services, physical proximity is relevant. The increasing importance of Layer 5 and of the formed long-distance connections are recent developments: the new layer emerged in the 1990s and is getting increasingly important as new technologies advance.

Describing business connections with different network layers adds to the researchability and to a more nuanced understanding of these connections. With different layers, layer structures, and different connections, business connections of agricultural producers may be quantifiable and describable in network terms and with network indexes and metrics. The use of the same indices and metrics can allow us to compare layers, connections, and whole structures more precisely and compare, for example, network dynamics or make suggestions where new nodes (e.g. a service provider) need to be placed.

Limitations

There are two limitations of the research. First, the collected data comes from a small part of Hungary (only two counties), representing the agribusinesses in the given counties. A second limitation comes from the fact that in the research snowball sampling was used, which means that the collected data is not independent: some of the agribusinesses providing data are closely connected.

These limitations are partly due to the fact mentioned above that data collection connected to actual business activities is not accessible. Thus, on the one hand, results connected to increased online service use based on current data collection may not be generalizable. On the other hand, the digital transformation of agriculture is described in many contexts; thus, a digital turn is taking place today, which implies the increased use of digital and online infrastructure (e.g. De Queiroz, D.M. *et al.* 2022; Kadry, S. *et al.* 2024). This turn and its implications allow for the more general discussion described above.

Conclusions

The paper analysed the spatial characteristics of service use of agribusinesses. Based on empirical data, we have shown that traditional services (such as banking or accounting) are used in smaller or larger settlements near agribusiness; towns function as service hubs for agribusinesses. We also pointed out that not only towns but also villages may function as hubs, assuming they provide at least one crucial service connected to agribusiness. We showed that business connections around agricultural producers may best described as multilayer networks, where network layers interact with each other.

As seen from the above considerations, online service use will likely increase in the future: the role of and the demand for non-physical services is advancing. As we have seen in our results, traditional services are also likely to be used more online due to the effects of the pandemic. This increase in online service use will result in several changes connected to geographical space. In the next session, we summarize how the digital turn may impact geographical space use connected to agriculture.

1) Transport and travel connected to agricultural service use will decrease. As more services are provided online and new services are partially or wholly online services, this will result in a decrease in the actual physical movement of both agribusiness employees and employees of service providers. The result will be less emissions and a slightly smaller road traffic load.

2) In cyberspace, however, agribusiness "space use" and network use will increase. Since agriculture 4.0 is about live and connected data and cloud computing, all this data needs to be transferred between the actual equipment and a central farm computer and between the farm and distant service providers. Thus, geography-related analysis of cyberspace structures must consider a shift to more extended use of cyberspace by agribusinesses (Batty, M. 1997).

3) The increased need for data transfer and processing will have physical results: a supporting infrastructure must be developed, either on single farms or in smaller regions. Since wireless data transfer is a key factor for agriculture 4.0, sufficient internet bandwidth is essential (Debauche, O. *et al.* 2021). Connected to this demand, new equipment and infrastructure (e.g. towers, relay stations) are needed.

4) As results indicate, for essential services, it is vital to maintain physical service access points as physical spaces or via mobile advisors. This is essential for agriculture service providers: as opposed to the assumption, the need for physical contact did not decrease.

5) Centres for more traditional agricultural services will be towns near agribusinesses. In contrast, centres for new, digital services will be located in knowledge-intense, primarily urban, large city areas, where service providers operate mainly globally.

Thus, recent changes in agricultural service use will have a double impact: while the use and need for physical space and structure will remain the same or slightly decrease, the infrastructure connected to digital agriculture – both in physical space and cyberspace – will increase, generating much more online traffic in and around agribusinesses.

Future research may analyse, through interviews, how location influences the choice of service providers connected to agribusinesses. The results would not only shed light on the underlying decision processes but also provide

valuable information on how service providers may best choose a location for their services. Another research direction is carrying out detailed interviews connected to existing or planned digitalization in given agribusinesses. Results could show how future developments of a given agribusiness will impact the digital infrastructure around agribusinesses.

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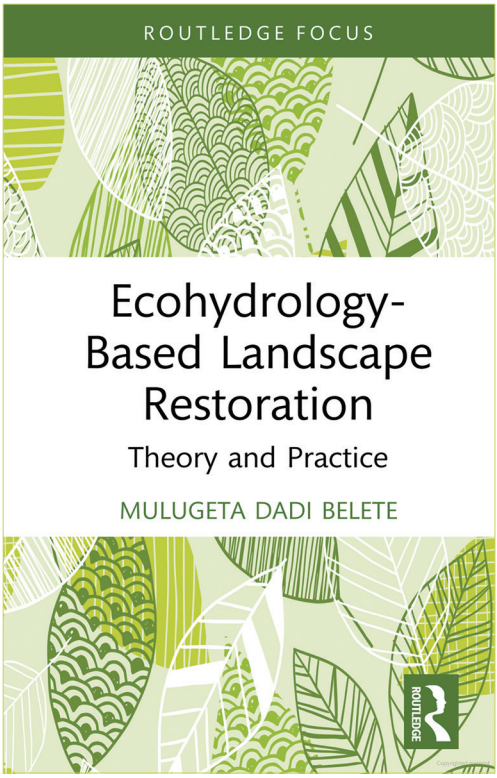
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BOOK REVIEW SECTION

Belete, M.D. (ed.): Ecohydrology-Based Landscape Restoration. Theory and Practice. Abingdon–New York, Routledge, 2024. 180 p.

Managing, maintaining and restoring natural landscapes is challenging worldwide, as human activity has significantly altered our environment. Efforts to restore natural conditions and conserve biodiversity and ecosystems are increasing. However, the effectiveness of these activities is always a key question. Efficient solutions require a holistic approach and a comprehensive understanding of how our environment operates. As the environment is a complex system, a systems approach and collaboration between different disciplines can help to find appropriate solutions for its conservation and sustainable use. The growing trend towards applying nature-based solutions is certainly a way forward in this respect.

The present book contributes to this problem by presenting the EcoLAR (Ecohydrology-Based Landscape Restoration) approach, which provides a solution for sustainable natural resource management and landscape rehabilitation. This concept was developed by Ethiopian researchers who recognised that integrating the ecohydrological approach is essential for effective landscape management. They intended to develop a new methodology to address Africa's growing and unsolved problem of landscape degradation. Accordingly, the book focuses on typical African landscapes in water-limited regions and provides practical suggestions for their management.



And why ecohydrology? Ecohydrology combines ecology and hydrology to understand water-biota interactions and to use this knowledge for environmental management. As water and ecosystems are determining part of the landscape their impact on the landscape cannot be neglected. Considering the combined role of ecosystems and water is forward-looking in landscape management and can lead to more efficient solutions.

The reviewed book is edited by Mulugeta Dadi Belete, the sole author of eight chapters of the nine. He is an Ethiopian university professor and a practitioner. His co-authors in Chapter 4 are university researchers from Ethiopia, while the main author of the chapter, Johannes Zerihun Negussie has a government background. Their various backgrounds influence the book's content and structure. The book contains both a theoretical approach and a description of the related practical solutions. The first three chapters present the EcoLAR approach, explain its theoretical background, and provide a possible workflow and a decision tool for different landscape types. The last chapters focus on solutions for different landscape types and case studies from Ethiopia illustrating the methods and demonstrating their applicability. Therefore, the book can be useful for practitioners, especially in African countries, but academics may find it also interesting, as the concept is well applicable to other regions.

The first chapter is about the „philosophical background" of the concept. It starts with a literature review summarising the main challenges in terms of landscape restoration, including the actual management strategies and solutions. According to the description, the concept of landscape restoration is continuously evolving from a mechanistic, engineering approach towards a more ecological concept. However, there are still some limitations to these ap-

proaches, and to fill this gap, the author and his contributors tried to find a complementary method to the existing „mechanical" practices to „ecologically re-engineer" them into a more efficient solution. The main idea involved ecohydrological consideration and the use of water-biota interactions to rehabilitate the landscapes more effectively.

The concept is fundamentally rooted in the ideas of previous researchers (e.g. Zalewski, M. *et al.* 2003) and it is a combination of existing methods and principles. The main theory is based on the following four statements: (1) hydrological and ecological processes follow the Trigger-Transfer-Reverse-Pulse logical framework (Ludwig, J.A. *et al.* 2005), so they influence each other in a circular system, (2) regulation of hydrological systems can control biological processes, (3) ecosystems can impact and regulate water conditions, and (4) at landscape scale the regulating effect of water and biota on one another is an effective tool to establish or maintain good conditions („dual regulation"). These statements are aligned with the principles of ecohydrology. In the EcoLAR concept, the first task is the regulation of the water flow (abiotic component – achieved by hydromechanical solutions), after the water availability facilitates the establishment of the biotic ecosystems (biotic component – achieved by „place-based and used inspired plantation"), which feeds back into the water flow component. Finally, the whole system can maintain itself. The construction of this system follows the green-(semi)grey infrastructure concept, where the grey component is the engineering solution, and the green component is the ecohydrological factor. The practice follows the engineering design principles (Bergen, S.D. *et al.* 2001), complemented by new elements such as minimum earthwork, use of local materials and application of indigenous knowledge. According to the author, this new approach can give answers to the limitations of the existing conventional methods, e.g. over-engineering of the environment, lack of system approach, and lack of consideration of dual regulation of water and ecosystems on the landscape.

Having established the need for the concept, Chapter 2 summarises the main principles of it from planning to realisation. Seven guiding principles were set up, which relate to the planning phase (1), the target-setting (2–3), management (4–6) and implementation (7) of the theory. The first principle states that hydrological and ecological systems need to be considered as basic management units of the concept. The second principle emphasises the need for local stewardship building to involve local people, stakeholders and actors in the activities. The third principle states that the parameters of the WBSRCE (water, biodiversity, ecosystem services, resilience, culture and education) system need to improve simultaneously by the regulation of ecohydrological parameters, using nature-based solutions and circular and bio-economic considerations. The fourth principle points out that regulating hydrological features is the first task, and then ecosystem restoration can begin once an adequate water supply has been established. Principle five says that the involvement of ethno-engineering solutions (local indigenous solutions) is highly recommended during the management phase. Principle six states that building a green-(semi) grey infrastructure (planned network of natural and seminatural features) as an „eco-hydrological systemic solution" is the way to reach the dual regulation of water and ecosystems in the landscape. Principle seven emphasises the need for adaptive learning, replication and up-scaling of successful actions to further improve the practice and concept. At the end of the chapter, the new concept was compared to the existing approaches to represent its wider scope.

Chapter 3 describes the conceptual plan for the proposed green (semi-)grey infrastructure construction based on ecohydrological considerations and presents the possible implementation of the concept in different landscapes. The conceptual plan was elaborated for a sloping environment, where the first objective is to regulate the hydrological factor which can be achieved by increasing water retention. Water retention can be realised in many ways depending on the conditions of the area. The author focused on capturing surface runoff, as it is the main water source under the Ethiopian climatic and topographical conditions. In the given example, surface runoff is controlled by semi-permeable wooden barriers in a gently sloping environment. This solution allows water retention and ensures water and nutrient cycling for ecosystems. The processes involved in the intervention will firstly regulate overland flow to ensure a more stable water supply to vegetation and improved infiltration. The second step is to plant vegetation in the area adapted to the water availability and local conditions. As a final step, the dual regulation of the water system and ecosystem can build up. This process can also work in different environments and landscapes. The book considers those, which are typical in Ethiopia, as hillslopes, sloping farmlands and gullied landscapes. To find the possible solution for these environments, a decision supporting flowchart was compiled.

In the following chapters from 4 to 8, the implementation of the concept is presented in the abovementioned landscapes. In Chapter 4 Negussie, J.Z. and his collaborators summarise the experiences of the application of the green-(semi)grey infrastructure in a hillslope environment. The applied practice follows the run-off-run-on theory of Ludwig, J.A. *et al.* (2005) where the surface runoff is controlled to retain and conserve water and nutrients on the hillslope. It is solved by wooden structures with bamboo mats

(grey infrastructure) constructed along the topographical contours. This way water is captured in run-on patches, where vegetation is planted (green infrastructure) and the established ecosystems will be able to regulate the surface runoff and increase infiltration. The effectiveness of this solution was proved by a case study from Ethiopia with a landscape functionality analysis.

Chapter 5 focuses on the sustainable management of farmlands with the EcoLAR approach. In this case, the basis of the solution is the sustainable land management (SLM) concept, which is combined with the terrestrial ecohydrological principles. The system has two elements, the physical structure – bamboo matted wooden cross-slope barriers – as in the conventional solutions and the place-based and need-driven plantation. First the biota benefits from the structure, later – when the plantation overtakes the regulation role of the physical barriers – dual regulation will form. The solution is presented in a case study, where the appropriate distance between the physical structures was calculated based on the shear strength, slope length and seepage saturation.

Chapter 6 concentrates on gully networks, gully erosion and landslide problems in gullied landscapes. Gully head, gully bed and gully bank are proposed to be treated differently. In the case of the gully head, a plunge-pool system is suggested, where the energy dissipation and the vegetation growth are happening together – it can be implemented by bamboo-matted plunge-pool construction and vegetation planting. In gully beds, a step-pool system is proposed, which operates as a spontaneous, self-organized system of high stability in the stream bed environment – check dams in stream beds try to simulate this natural phenomenon. In the case of curving systems, spurs (dykes, groynes) can rehabilitate the sharp curves to decrease erosion, control flow direction, create an erosion-free zone, and help biota establishments. In the case of wide gullies in-stream plantations are proposed to narrow the gully and the gully bank becomes a plantation site.

Chapter 7 is a literature study on the role and possible use of vegetated riparian buffer zones as the „last line of defence" regarding water resources in landscape management. The benefits and optimal design of these zones are detailed from different perspectives. Based on the proposal, the main elements of the system, i.e. the width of the area and the vegetation zonation need to be adapted to the investigated area and the objectives to be achieved.

Chapter 8 deals with wetlands and wetland ecosystems as parts of the landscape. Wetland protection, management and restoration is a key activity worldwide. As several concepts and proposals exist in the literature, a comprehensive wetland management framework was established to characterise and synthesise wetland management strategies and actions. This is the PREE (Preservation, Restoration, Enhancement, Establishment) framework, where different stages of wetland management and the connected activities are distinguished. It provides help for actors, especially in developing countries, to find the most appropriate solution or combination of solutions for sustainable wetland management.

Chapter 9, the final chapter, summarises the whole content of the book and the EcoLAR approach and methodology highlighting its novelty in landscape management.

In summary, the book provides a detailed insight into the problem of landscape degradation and possible solutions in water-limited African landscapes, where surface runoff is the most important source of water. The authors place great emphasis on explaining the theoretical background of their new concept and demonstrating the significance of the ecohydrological approach. This part seems a bit long and detailed compared to the chapters on case studies, which are more focused and illustrate the proposed interventions well. In my view, the proposed EcoLAR concept is a synthesis of existing theories and methodologies rather than a completely new approach, however, it offers a novel combination of existing concepts. The application of ecohydrological knowledge in the rehabilitation of water-dependent ecosystems or wetlands is a well-known practice (e.g. Wassen, M.J. and Grootjans, A.P. 1996). Still, for water-limited degraded landscapes, the involvement of ecohydrology, in particular, the dual regulation effect of water and ecosystem in landscape management is novel and forward-looking. The practical solutions presented in the book are based on these considerations, illustrated in a variety of African landscapes. It would have been interesting to read more about the sustainability of the proposed systems, especially the long-term maintenance of water supply under changing climatic conditions, which is necessary for the survival of ecosystems. Although the proposed practices have been developed in typical arid environments in African countries, the theory can be applied to other climatic and environmental conditions. Nevertheless, in humid climates, the groundwater conditions need to be better considered, and the main water-related challenges are also different.

Overall, the book is highly recommended for both scientists and practitioners who are interested in landscape restoration, as this combined methodology can provide good ideas for comprehensive and effective solutions in every part of the world.

Szilvia Simon[1]

[1] ELTE Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Geology, József and Erzsébet Tóth Endowed Hydrogeology Chair. Budapest, Hungary; E-mail: szilvia.simon@ttk.elte.hu

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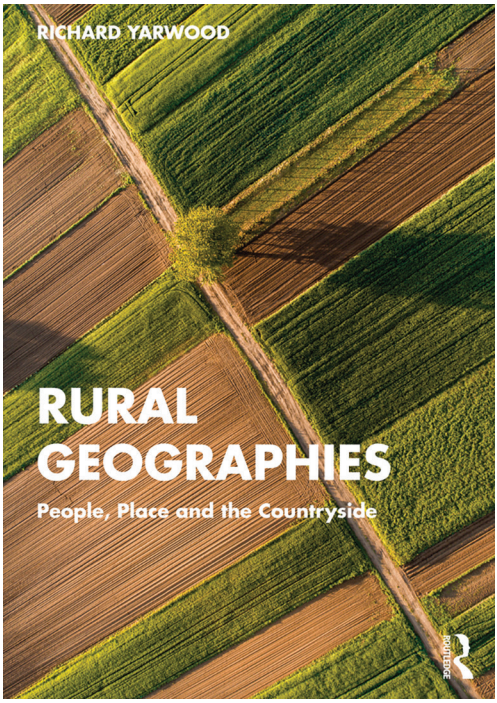
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Yarwood, R.: Rural Geographies: People, Place and the Countryside. London–New York, Routledge, 2023. 265 p.

We live in turbulent times. Geopolitics (Brexit, the Russian invasion of Ukraine), the ecological crisis, including biodiversity loss, pandemics and diseases (COVID-19, avian flu, BSE, foot and mouth disease), climate change and its impacts, such as the historic European-wide drought in 2022, all affect Social-Ecological Systems (SES), including rural areas we study or live in. *Rural Geographies: People, Place and the Countryside,* written by Richard Yarwood, a professor of Human Geography and the director of the Doctoral College at the University of Plymouth, UK, takes an interdisciplinary approach to reflect on how these events affect the countryside. The book introduces complex theoretical approaches that are useful in the study of the countryside, and it does so in a language that is widely accessible. The key ideas and concepts of the book are consistent with SES thinking, planning, and analysis, as they embody an integrated view of people and their environment. The SES approach allows us to consciously confront the prevailing view since the Enlightenment, which wrongly separates society and nature and reconstructs their relationship in a hierarchical form, where nature is not the fundamental context of existence for society, but a set of resources to be dominated and exploited. This perspective is also one of the foundations of the ecological crisis that has emerged in recent decades. In accordance with the principles of SES research, the book equips undergraduate students with the necessary tools to analyse the ongoing transformations in rural space. Richard Yarwood has extensive experience in both teaching (over 30 years) and research in rural geography. It is evident that the author has a consistent publication history in prominent journals specialising in rural geography. Notable examples include the *Journal of Rural Studies*, *Progress in Human Geography*, *Geoforum*, and *Geography Compass.* The breadth of his research interests, encompassing housing, policing, population change, service provision, volunteering, and animal geographies, reflects an integrated perspective on nature–society relations.



The book is divided into four main sections: 'Contexts', 'Changes', 'Contests', and 'Cultures'. 'Contexts' introduces the different approaches through which the countryside has been studied. It shows how our positionality influences the way we study rural areas. It provides a concise introduction to detailed community studies, scientific and radical approaches, and recent interests in cultural and post-structural geographies. The structured summary of the advantages and disadvantages of each paradigm helps the reader to position him/herself in rural geography and to find the right approach to the study of rural change. For Hungarian readers interested in delving deeper into contemporary spatial theories from a Central and Eastern European perspective, the book edited by László Faragó (2018) could be a useful resource.

The second part of the book deals with 'changes' in time and space. Keith Halfacree's (2007) threefold model, inspired by Henri Lefebvre, provides the organising logic for the subchapters. In terms of *rural localities,* agricultural change (productive) and economic restructuring (post-productive change) are discussed. In terms of *representations of the rural,* the focus is on how these representations reflect and drive rural change at different geographical scales. The final section considers the *lived experiences* of social change in the countryside.

Rural change has been characterised by various conflicts. The third part of the book, on 'contests', examines how rural places are contested in different ways and what these tensions reveal about rural society. Poverty and social exclusion remain pervasive challenges in the Global North, but often go unaddressed because of the neoliberal expectation that people and communities should help themselves. Within the eastern, Baltic, or southern member states of the European Union poverty or social exclusion is more characteristic in rural areas, while in western and northern member states it is more prevalent in cities. What a Central and Eastern

European perspective can add to the book's argument is that, in contrast to the experience of the Global North, poverty in rural areas of Central and Eastern Europe (CEE) is not hidden. The emergence of racialisation is intertwined with spatial marginalisation and segregation, but while this marginalisation is more specific to cities in the Global North, it occurs in highly deprived, often rural, areas in the Global East (Müller, M. 2018). In contrast to the experience of the Global North, where the phenomenon of a 'rural ghetto' hardly exists, processes of socio-spatial polarisation, economic decline, and racialisation-based ethnic exclusion produced contagious 'ghettos' in Central and Eastern Europe over the past three decades (Mihály, M. 2022).

In the next section, Yarwood makes the important point that rural policy and governance, and its potential to empower people to address inequality in rural areas, is limited. The reason for this lies in the institutional background of rural policy. Rural development in the European Union is rooted in the EU's most expensive and extensive common policy, the Common Agricultural Policy (CAP), which is still dominated by the productivist paradigm. As a result, the CAP continues to favour large farms and only a minority of the CAP budget is devoted to rural development and post-productivist purposes.

The chapter on housing explores these issues further by examining how access to home reflects and perpetuates socio-spatial inequalities in the countryside. In the case of the UK, Community Land Trusts (CLTs) are presented as a promising example of building housing alternatives. CLTs are locally run, democratic, non-profit organisations that own and develop land for the benefit of the community. CLTs are a form of shared equity ownership and use public and private investment funds to acquire land on behalf of a specific community. In terms of building housing alternatives, there is a huge difference in where one is located in the global economy. While in many places in Western Europe and North America, such projects have become attractive to investors and ethical banks, the financial products needed for alternative housing development are not available in CEE – and, like mainstream commercial banks, these supposedly ethical financial actors also consider CEE to be riskier (Gagyi, Á. *et al.* 2023).

The next section on mobility draws attention to the ways in which the countryside is shaped by movement. As well as highlighting problems of inaccessibility, the chapter also draws attention to the interdependence of the rural places with other, often distant, places. Migration of agricultural labour is highlighted as an important feature of the global countryside. The disparities between old and new EU member states, together with the right to work and move as EU citizens granted by the Maastricht Treaty in 1992, prompted migration to take up work in a range of jobs that offered relatively high wages, including manual agricultural work associated with the harvesting and processing of food (Yarwood, R. 2023, 127). Cheap Eastern European labour increased the production of labour-intensive crops in certain Western European countries, such as asparagus, cherries, and strawberries in the UK.

As the final section of this part of the book shows, global perspectives are needed to ensure a sustainable and resilient future for the countryside. Windfarms are used to illustrate some of the complexities associated with sustainability. Although windfarms help to reduce carbon emissions and generate renewable energy, they provide little social or economic benefit locally (Yarwood, R. 2023, 144). Continuing on Yarwood's line of thought, a concern about the renewable energy boom can be that it may result in green grabbing, through which former public or agricultural land is appropriated to meet the territorial demands of renewable energy development. The phenomenon was also studied from CEE by Katja Müller and Marieke Pampus (2023). The scarcity of resources available to social movements, coupled with the highly polarised political environment within CEE, serves to impede the development of large-scale renewable energy projects. This, in turn, hinders the establishment of democratic control over climate policy.

The 'cultural turn' has had profound impact on the way rural geography is studied and the issues it focuses on. As the fourth part of the book on 'cultures' outlines, it led to a growing interest in landscape, hidden others, and human-nature relations. National parks are presented as an example of landscape designation in the chapter about rural landscapes. The idea of a national park was linked to an idyllic image of the rural (Lake District, England) by the poet William Wordsworth in 1810, and it became manifest in the USA with the foundation of Yellowstone National Park in 1872. The profound environmental impact of the industrial revolutions drove conservation efforts in the Global East too. Dedicated primarily to scientific research, a system of nature reserves ('zapovedniki') were established in the steppe region of the Russian Empire in the 1890s. In order to gain stronger support from government officials, supporters of 'zapovedniki' increasingly accommodated limited tourism between the 1930s and 1960s (Roe, A. 2020). By the late 1960s, growing damage caused by tourists in the 'zapovedniki' increased the sense of urgency for the Soviet Union to establish Western-type national parks and again direct tourist traffic away from 'zapovedniki' (Roe, A. 2020). Several Soviet republics established national parks in the 1970s (e.g. Lahemaa National Park in Estonia in 1971, Hortobágy National Park in Hungary in 1973). An intriguing point made in the chapter is that the designation and location of national parks reflects dominant, but contested, ideas about what kinds of landscapes are valued, what kind of activities should be allowed in them, and who they are for (Yarwood, R. 2023, 158).

This line of thought is unfolded in the chapters on rural others. The call to study rural others widened the

scope of rural geography and opened the discipline to new methodologies and new, critical ways of thinking (Yarwood, R. 2023, 187). Intersectionality, developed by black feminists, recognises that social characteristics, such as class, race, ethnicity, sexuality, or gender, are not independent of each other but, rather, are 'mutually transformative and intersecting, each altering the experience of the other' (Ruddick, S. 1996 in Yarwood, R. 2023, 184). As the study of or with rural others is largely undertaken by privileged academics, Yarwood encourages us geographers to pay more attention to our positionality and backgrounds, when studying other groups of people. Moving on to human-nature relations, the chapter on 'More Than Human Ruralities' emphasises the role of animal geography to interrogate people's ethical relationships with animals and how these shape rural places. Donna Haraway's socialist feminist cyborg approach is proposed to grasp how animals are incorporated into global capitalism as elements of productivist agriculture (Haraway, D. 2013). Beyond animal geography, Haraway's cyborg approach can fruitfully be combined with James O'Connor's relational political ecology to study landscape transformations (Rudy, A.P. 2005).

An important point made in the concluding section is that although rural areas are often presented as being affected by exogenous change, they also offer the possibility of radical, far-reaching change from within. The spatial evolution of society often starts in peripheral rather than core areas. Rural places can provide spaces for new, more radical forms of citizenship to emerge. The connections created by a global countryside offer the possibility for radical and transnational politics and resistance to emerge from rural places (Woods, M. 2016 in Yarwood, R. 2023). The food sovereignty movement led by 'La Vía Campesina' is presented as an example of emancipatory rural politics. However, as a transnational movement, rooted in countries of the Global South, it reflects only to a limited extent on the political context of post-state-socialist CEE and the everyday experiences of the people living there. CEE is characterised by widespread disillusionment with politics, opposition to socialism and cooperativism. The communist legacy influences societal attitudes towards capitalism and socialism, making the adoption of the anti-capitalist pro-socialist ideology of 'La Vía Campesina' problematic in CEE (Hajdu, A. and Mamonova, N. 2020). Nevertheless, food self-provisioning through backyard farming, small-scale farming, and local markets, are a few typical Central and Eastern European practices that are crucial for the realisation of food sovereignty and alternative food systems (Mendly, D. and Mihály, M. 2024).

The literature of rural geography by, from, and about the Global North has been criticised not only from the Global South, but from CEE too (Timár, J. 2007; Jehlička, P. 2021). For a Central and Eastern European reader, it can be appreciated that in line with the global perspective of the book, various examples are taken from CEE, such as land grabbing in Romania, or migrant workers of CEE representing cheap workforce for labour-intensive agricultural work in Western Europe. However, apart from these examples, the book has little to say about the specific, (semi-)peripheral perspectives on rural change from the Global East.

The post-socialist transformation of CEE economies implied their integration into global capitalism as dependent market economies, which are dominated by foreign direct investment and have only a limited degree of economic sovereignty. This development was accompanied by internal polarisation, with some regions being transformed into important hubs of global capitalism and others (mainly rural peripheries) losing economic relevance. Inhabitants of peripheralised rural areas have a feeling of abandonment and political discontent (Mihály, M. 2022). Small-scale farmers are the losers of the globalisation of food systems in CEE too. After the rapid privatisation of state-socialist agricultural cooperatives, the further modernisation of the agro-industry that came with EU membership has created significant costs and administrative burdens for small-scale producers in CEE (De Master, K. 2013). Since the change of regime, the concentration of the retail sector, which has intensified with EU membership, has significantly reduced the prices that can be demanded for the crops produced. As a result of these processes, both in Poland (De Master, K. 2013) and in Hungary (Inzsöl, R. 2021), political discontent among small-scale farmers has increased and many are abandoning farming due to livelihood challenges. The political discontent resulting from the globalisation of the food system in Central and Eastern Europe has so far been mobilised by right-wing populists rather than transnational food sovereignty movements (De Master, K. 2013; Szombati, K. 2018). Therefore, I agree with the author that future work in rural geography should be by, rather than of or about, those from the Global South (and Global East).

Rural geography, as this book emphasises, is part of the broader discipline of geography. In line with Social-Ecological Systems research, geography is able to provide a holistic vision of the world in a way that shows awareness of society and the environment. This unique approach makes the book a valuable resource not only for undergraduate students and teachers of rural geography and rural studies, but its accessible language also makes it relevant to rural development practitioners in the Global North and beyond.

Melinda Mihály[1]

[1] HUN-REN Centre for Economic and Regional Studies, Institute for Regional Studies, Békéscsaba, Hungary; ELTE Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Social and Economic Geography, Budapest, Hungary. E-mail: mihaly.melinda@krtk.hun-ren.hu

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