Hungarian Geographical Bulletin

Volume 71 Number 3 2022

Research Centre for Astronomy and Earth Sciences
GEOGRAPHICAL INSTITUTE

HUNGARIAN GEOGRAPHICAL BULLETIN

Quarterly Journal of the
GEOGRAPHICAL INSTITUTE
RESEARCH CENTRE FOR ASTRONOMY AND EARTH SCIENCES

Indexed by Elsevier-GEOBASE®, Elsevier-SCOPUS®,
EBSCO Information Services, CAB Abstracts, Current Geographical Publications,
Scimago Journal & Country Rank, Google Scholar

HUNGARIAN GEOGRAPHICAL BULLETIN 71 2022 (3)

CONTENT

Book review section

DOI: 10.15201/hungeobull.71.3.1 Hungarian Geographical Bulletin **71** 2022 (3) 213–229.

The relationship between ignimbrite lithofacies and topography in a foothill setting formed on Miocene pyroclastics – a case study from the Bükkalja, Northern Hungary

Tamás BIRÓ[1], Mátyás HENCZ[1], Tamás TELBISZ[1], Zoltán CSERI[1] and Dávid KARÁTSON[1]

Abstract

Units with extremely variable erodibility are typical in the succession of pyroclastic-dominated volcanic fields. Welded ignimbrites are usually resistant to erosion, thus, they often appear as positive landforms, i.e., mesas or tilted plateaus after millions of years of denudation. The Bükkalja Volcanic Area being part of the most extended foothill area of the North Hungarian Mountains, is composed predominantly of Miocene ignimbrites, where the frequency distributions of elevation a.s.l., slope, aspect, as well as topographic openness, were investigated using a 30 m resolution SRTM-based digital surface model at four sample areas located at different relative distances from the assumed source localities of the ignimbrites, showing both non-welded and welded facies. The degree of dissection was also examined along swath profiles. The topography of the sample area closest to the source localities is dominated by slabs of moderately dissected welded ignimbrites, gently dipping towards SE. Farther away from the source the topography is dominated by erosional valleys and ridges, resulting in a narrower typical elevation range, a higher proportion of pixels with greater than 5° slope, higher frequencies of NE and SW exposures, and more significant incision resulted in more frequent pixels with positive topographic openness less than 1.5 radians here. Higher thicknesses and emplacement temperatures of ignimbrites, often showing welded facies are more common closer to the source vent. Thus, the erosional pattern around calderas can be used to draw conclusions on the spatial extent of the most intense ignimbrite accumulation, i.e., the location of eruption centres even in highly eroded ignimbrite fields.

Keywords: Bükkalja, ignimbrite, Miocene, welded ignimbrite, SRTM, swath analysis, topographic openness, digital elevation model, differential erosion

Received July 2022, accepted August 2022.

Introduction

Pyroclastic successions developed around caldera clusters often host units showing contrasting resistance to erosion. Welded ignimbrites are usually characterized by extremely low erodibility, often forming plateaus existing for millions of years, sometimes as inverted relief (Adams, B.A. and Cooper, F.J. 2020; Van Wyk de Vries, B. *et al*. 2022). Tilted ignimbrite plateaus exceeding 10^{4-5} km^2 lateral extent dissected by canyons at their edges due to fluvial erosion are well-known landforms of many ignimbrite fields around the Earth: among others at the western edge of the Central Andes (Székely, B. *et al.* 2014), at the Taupo Volcanic Zone at the North Island of New Zealand (Leonard, G.S. *et al.* 2010) or around many calderas in the United States (e.g., the Pajarito Plateau at the eastern flank of the Valles Caldera; Crowe, B.M. *et al.* 1978). The Bükkalja study area presented in this paper does not belong to the largest ignimbrite fields in a global comparison, but its in-depth volcanological research and the long-term erosion since Mi-

[1] Department of Physical Geography, Institute of Geography and Earth Sciences, ELTE Eötvös Loránd University. Pázmány Péter sétány 1/C, H-1117, Budapest, Hungary. Corresponding author's e-mail: tamas.biro@ttk.elte.hu

ocene times makes it a perfect study area that can provide valuable results for analysing the geomorphological evolution of ancient, deeply eroded ignimbrite fields hosting plateaus of welded ignimbrites.

The Bükkalja is the most extended foothill of the North Hungarian Mountains, forming a gradually descending (from 400 to 130 m a.s.l.) hilly region between the Mesozoic carbonate block of the Bükk Mountains and the Quaternary fluvial sediments of the Great Hungarian Plain (*Figure 1*, Dobos, A. 2002; Hevesi, A. 2002). The Bükkalja exposes the thickest (often exceeding 500 m) and most complex succession of silicic pyroclastics of Miocene age in the northern part of the Pannonian Basin (Szakács, A. *et al.* 1998; Lukács, R. *et al.* 2018, 2022). Moreover, the surface occurrence of the Miocene pyroclastics at the Bükkalja is the largest in Northern Hungary, covering an area of about 10 x 40 km (Less, Gy. *et al.* 2005). Consequently, the Bükkalja has been the focus of both volcanological and geomorphological studies in recent decades: Volcanological research has explored the stratigraphic units of the Bükkalja pyroclastic succession, the character of the volcanism, as well as the spatial dimensions and age of individual eruptive events (Capaccioni, B. *et al.* 1995; Szakács, A. *et al.* 1998; Lukács, R. *et al.* 2007, 2015, 2018, 2022; Biró, T. *et al.* 2020; Hencz, M. *et al.* 2021a, b; Karátson, D. *et al.* 2022).

Geomorphological studies on the Bükkalja have been carried out in detail to investigate the connection between structural geology, lithology, landscape evolution and landforms, focussing on the following questions: how lithology is related to the drainage network (Vágó, J. 2012; Pecsmány, P. 2021), which lithological conditions enhance the preservation of relict surfaces (Vágó, J. and Hegedűs, A. 2011), how the deep structure revealed by seismic sections is reflected in the course of major fluvial valleys (Pecsmány, P. and Vágó, J. 2020), and where fault-bounded structural basins are developed in the area (Pecsmány, P. *et al.* 2021).

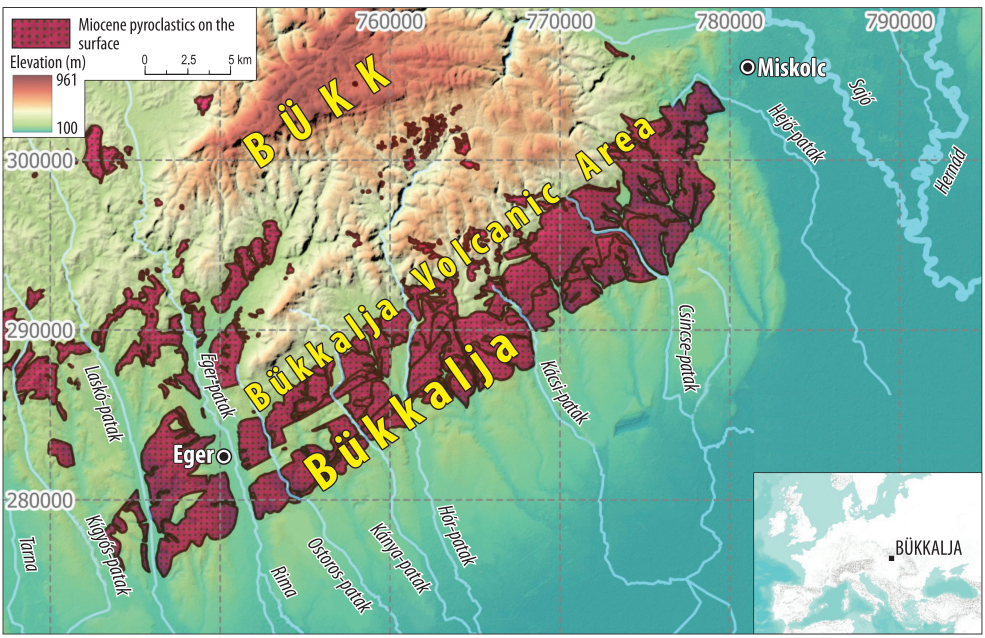


Fig. 1. Topography of the Bükkalja Volcanic Area (BVA) and its vicinities. Inset map shows the location of the Bükkalja. Coordinates are in HD 1972 EOV coordinate system.

The relation between the large-scale topography including the valley and hydrological network of the Bükkalja and the volcanological units was investigated in details by Vágó, J. (2012). However, the link between the topography and the proposed source localities of the ignimbrites (e.g., Szakács, A. *et al.* 1998; Lukács, R. *et al.* 2015; Hencz, M. *et al.* 2021a) that influence the lateral variations in thickness and lithofacies of pyroclastic units has not been investigated in-depth. Therefore, the aim of the present study is to quantify the differences in the statistical distributions of the most obvious topographic parameters of the ignimbrites such as elevation a.s.l., slope, aspect, and topographic openness, in relation to their source localities. In our analysis, special emphasis is given to the welded (i.e., closer to the source localities) or non-welded (i.e., farther to the source localities) character of the ignimbrites.

Geological background

Geomorphology and geology of the Bükkalja Volcanic Area

The Bükkalja is a hilly area between the Bükk Mountains and the Great Hungarian Plain, extending about 60 km in NE-SW and 20–30 km in NW-SE, typically with elevations between 130 and 350 m a.s.l. Its current topography, which is characterized by dips about 5° from the Bükk Mountains. towards the Great Hungarian Plain, is interpreted as a result of pedimentation in three stages, between ~20–14, ~8.0–5.5, 2.0–1.8 Ma (Dobos, A. 2002). During these periods, under typically a semi-arid climate, the slopes of the Bükkalja underwent parallel retreat due to areal water erosion. Today, only several km^2-sized patches of the 2^{nd} and 3^{rd} pedimentation periods have remained, forming an older relict surface between 243–426 m and a younger one between 151–243 m elevation a.s.l. (Vágó, J. and Hegedűs, A. 2011).

The Bükkalja exposes various Paleogene to Quaternary formations: The Oligocene Kiscelli Clay Formation is overlain by Oligocene-Lower Miocene shallow marine beds of variable grain-size belonging to the Eger Formation (Less, Gy. *et al.* 2005). The Paleogene-Lower Miocene sedimentary deposits is in turn overlain by a several 100 m-thick pyroclastic succession emplaced between ~18.2–14.3 Ma from dozens of large explosive eruptions of dominantly high-K rhyolitic magmas (*Figure 2*, Szakács, A. *et al.* 1998; Lukács, R. *et al.* 2018, 2022; Karátson, D. *et al.* 2022). The current surface occurrence of the pyroclastic succession is confined to a ~10 x 40 km region with NE-SW elongation. To keep the nomenclature simple, in this study, the term Bükkalja Volcanic Area (BVA hereafter) is used to refer to the surface occurrence of pyroclastics, which is smaller than the whole area of the Bükkalja. The Miocene pyroclastic succession is overlain by the Pannonian Edelényi Variegated Clay and the Nagyalföldi Formation, which consists of sediments deposited in shallow-sea or by fluvial processes in the gradually filling Pannonian Lake (Less, Gy. *et al.* 2005). The southernmost slopes and larger valleys of the Bükkalja are covered by loess and other Quaternary sandy sediments, which have been redeposited by fluvial processes (Less, Gy. *et al.* 2005).

From a structural geological point of view, the Bükkalja is located between the Mesozoic carbonate mass of the Bükk Mountains, characterized by intensive uplift causing removal of ca. 1 km thick Paleogene-Neogene sedimentary succession during the Pliocene-Pleistocene (between 2 and 3 Ma; Dunkl, I. *et al.* 1994), and the Vatta-Maklár Trench that is interpreted as a "transtensional half-graben" (Petrik, A. 2017) and has been subsiding from the beginning of the Miocene onwards displaying a SW-NE elongation (Petrik, A. 2017). The Bükkalja is also dominated by faults with SW-NE strike, the most significant of which being the Kőkötő Fault, which can be traced on the surface from the SW edge of Eger town to the eastern edge of Bogács village (*Figure 3*, Petrik, A. 2017). Layers of hanging wall blocks displaced along the listric faults are characterized by 2–5° dip and SE dip direction (Petrik, A. 2017).

The pyroclastic succession of the BVA consists of layers from dozens of eruptive events

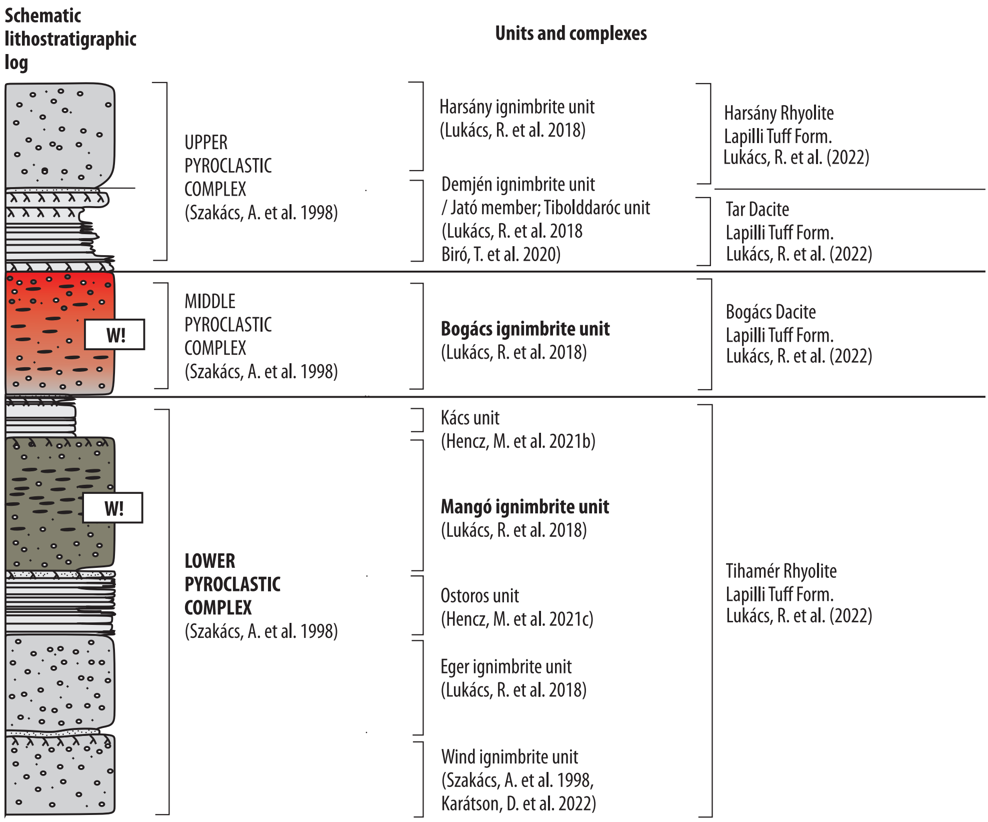


Fig. 2. Generalised lithological column of the BVA after Hencz, M. *et al.* (2021c) and Lukács, R. *et al.* (2022). "W!" marks the ignimbrites which tend to be welded. Thicknesses of stratigraphical units and symbols of components are not to scale.

(see *Figure 2*, Szakács, A. *et al.* 1998; Lukács, R. *et al.* 2018; Biró, T. *et al.* 2020), which, according to the latest stratigraphic classification, belong successively to the Tihamér Rhyolite Lapilli Tuff, the Bogács Dacite Lapilli Tuff, the Tar Dacite Lapilli Tuff and the Harsány Rhyolite Lapilli Tuff Formation (Lukács, R. *et al.* 2022). The pyroclastic deposits include layers of fallout origin, ignimbrites emplaced from pyroclastic density currents, and subordinately epiclastics formed by the resedimentation of the primary pyroclastic material mostly by fluvial processes (Capaccioni, B. *et al.* 1995; Szakács, A. *et al.* 1998; Lukács, R. *et al.* 2007, 2015, 2018; Biró, T. *et al.* 2020; Hencz, M. *et al.* 2021a, b). The pyroclastic layers deposited from distinct eruptive events are generally bounded by palaeosols, suggesting that the BVA was a subaerial region, where pyroclastic material was deposited during eruptive events punctuated by quiescence periods lasting for 10^3–10^5 years, in which soil formation may have occurred (see *Figure 2*, Biró, T. *et al.* 2020). In terms of thickness, the pyroclastic succession is dominated by ignimbrites, of which there are at least 8 in the area, each 20–50 m thick (Lukács, R. *et al.* 2018). Some of these (Wind, Eger, Harsány ignimbrite) are characterized by massive lapilli tuff facies and do not show welding or cementation, while others (Mangó, Bogács, Demjén) show welded lithofacies to some extent (see *Figure 3*).

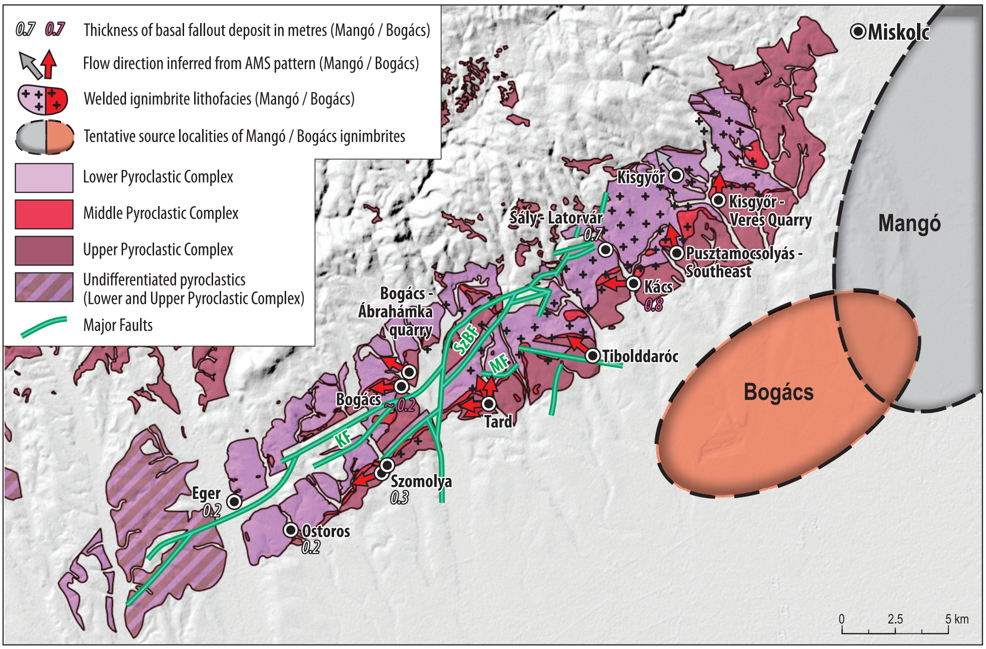


Fig. 3. Volcanological map of the BVA with assumed source localities of the Mangó and Bogács ignimbrites and indicators of source localities. *Sources:* Volcanological map – 1:100 000 Geological map of Hungary (© MBFSz Térképek – https://map.mbfsz.gov.hu/fdt100/) and Lukács, R. *et al.* (2022). Thickness data on the basal fallout deposit of the Mangó and Bogács ignimbrites – Biró, T. *et al.* (2017), Hencz, M. *et al.* (2021a, b). Flow directions based on AMS data – Szakács, A. *et al.* (1998), Cseri, Z. (2017). Source locality of the Mangó ignimbrite – Hencz, M. *et al.* (2021a). Major faults – Petrik, A. *et al.* 2016, Petrik, A. 2017. KF = Kőkötő Fault; SzBF = Szomolya–Bogács Fault; MF = Mangó Fault.

Lithofacies and source localities of the Mangó and Bogács ignimbrites

From a geomorphological point of view, it is very important that the most significant ignimbrites have a welded facies characterized by hard, high-density, erosion-resistant lithology due to compaction after emplacement as a result of >500 °C depositional temperature and significant load stress (e.g., Freundt, A. *et al.* 2000). In general, the thickness of ignimbrites is the most significant at the vicinity of the source vent and in the main valleys, which is manifested by the appearance of welded facies at such settings (Freundt, A. *et al.* 2000). Welded ignimbrite lithofacies can be extremely resistant to erosion, often forming positive/inverted landforms, e.g., mesas, due to millions of years of degradation (Adams, B.A. and Cooper, F.J. 2020; Van Wyk de Vries, B. *et al.* 2022). At the BVA, the Mangó, Bogács and Demjén ignimbrites show welded lithofacies (see *Figure 2*, Lukács, R. *et al.* 2015, 2018; Hencz, M. *et al.* 2021a).

The exact location of the eruption centres that produced the BVA pyroclastic succession is unknown for most units, as the vent areas are no longer detectable in the topography due to several millions of years of basin subsidence and sediment accumulation around the Bükk Mountains (Szakács, A. *et al.* 1998). However, the assumed location of the eruption centre of the Mangó and Bogács ignimbrites, which are characterized by extensive welded facies, thus, representing hindered erodibility, have been inferred based on multiple proxies: i) flow directions (i.e., direction of lateral shear during emplacement) (Szakács, A. *et al.* 1998), ii) the lateral variations of basal fallout deposit thickness and iii) maximum grain-size of lithics (Hencz, M. *et al.* 2021a).

The Demjén ignimbrite occurs only in the south-western area of the BVA at greater thickness (>20 m) and shows welding, while in the central and eastern areas of the BVA at Bogács and Tibolddaróc (see *Figure 3*) it is less than 10 m thick and fine-grained, discriminated as the 'Jató member' (Biró, T. *et al.* 2020). Consequently, it plays only a very minor role in affecting the topography of the BVA.

The thickening of the basal fallout layer of the Mangó ignimbrite from 0.2 m in the vicinity of Eger to 0.7 m at Sály, and the increase of the maximum lithoclast size, clearly indicate that this ignimbrite was derived from a source area located southeast of the BVA at the southern vicinity of Miskolc (see *Figure 3*, Hencz, M. *et al.* 2021a). The proximity of the eastern region of the BVA to the source locality is also confirmed by the presence of Mangó ignimbrite with a dominantly welded lithofacies in the Kisgyőr area (previously identified as the Kisgyőr Member (Less, Gy. *et al.* 2005; Hencz, M. *et al.* 2021a).

The source locality of the Bogács ignimbrite has been reconstructed from anisotropy of magnetic susceptibility (AMS) directions about 10–15 km south of Tibolddaróc, also supported by a positive Bouguer anomaly (Szakács, A. *et al.* 1998). By considering the thickness variations of the basal fallout layer of the Bogács ignimbrite which ranges from ~0.2 m to 0.8 m from Bogács to Kács (Biró, T. *et al.* 2017; Hencz, M. *et al.* 2021b) the previous localization of the source vent can be slightly shifted and the source region is detected ~10 km from Kisgyőr towards the south (see *Figure 3*).

Thus, both the Mangó and the Bogács ignimbrites are supposed to have been originated from source localities at the south-eastern vicinity of the BVA. The aim of the present study is to investigate how the topographic features of the BVA are influenced by the location of the source area of the Mangó and Bogács ignimbrites, with regard to the distribution and lithofacies variations of the two ignimbrites, in particular, welding.

Methods

The analysis of the topography was performed on the SRTM surface model with 1″ (30 m) resolution (NASA 2013) with QGIS 3.18 (QGIS Development Team 2022). A two-fold methodology was used to study the topography: 1) The frequency distributions of elevation a.s.l., slope, aspect, positive and negative topographic openness of four sample areas *(Figure 4)* differing in distance from assumed ignimbrite source localities were compared. 2) The topographical features were also investigated along swath profiles.

The four sample areas were delineated by considering the location of assumed source regions of the Mangó and Bogács ignimbrites, the distribution of the Miocene pyroclastics (map.mbfsz.gov.hu/fdt100/; © MBFSz Térképek), the welded or non-welded character of pyroclastics (Pentelényi, L. 2005), the location of the main valleys and the spatial heterogeneity of Bouguer anomaly (map.mbfsz.gov.hu/gravitacios_anomalia/; © MBFSz Térképek). This latter parameter shows the relative depth of the Mesozoic carbonatic basement (*Figure 5*, Petrik, A. 2017), i.e., the amount of Neogene-Quaternary uplift at the BVA. The north-eastern boundary of sample area 1 was set to the north-eastern limit of the LPC (Lower Pyroclastic Complex *sensu* Szakács, A. *et al.* 1998; see *Figure 2*) distribution. Further east, pyroclastic outcrops are rare, so their surface distribution is a matter of some uncertainty (Less, Gy. *et al.* 2005). The boundary between the 1st and the 2nd sample area is defined by the valley of the Kács Stream (Kácsi-patak), west of which the Bouguer anomaly changes, a positive anomaly being observed in the central part of the BVA. The boundary between the 2nd and the 3rd sample

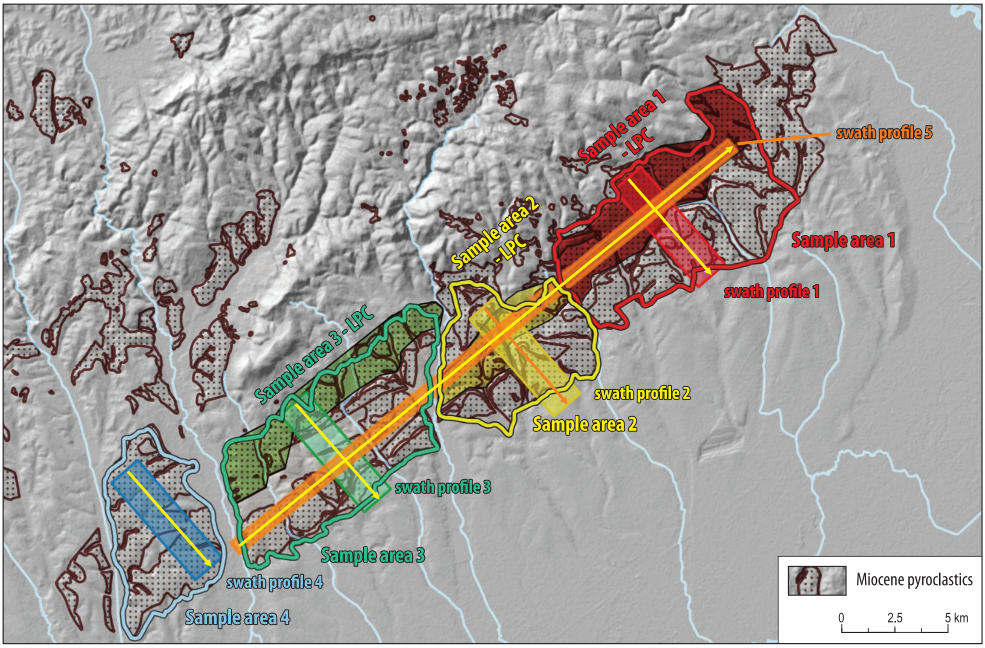


Fig. 4. Sample areas and swath profiles investigated in this study

area is located along the valley of the Hór Stream (Hór-patak). To the west of this, in the area of the 3rd sample area, a small parallel negative Bouguer anomaly is observed NW of the Vatta–Maklár Trench. Furthermore, in the 3rd sample area, the surface distribution of the pyroclastics is split into two 3–5 km wide bands, between which Oligocene and Lower Miocene sedimentary formations are exposed along the so-called Kőkötő Fault (see *Figure 3*, Petrik, A. 2017). The boundary between the 3rd and the 4th sample area is the widest stream valley in the Bükkalja, the Eger Valley. Here, the Bogács ignimbrite is not observed, and the LPC and UPC (Upper Pyroclastic Complex *sensu* Szakács, A. *et al.* 1998; see *Figure 2*) are not clearly separated (Lukács, R. *et al.* 2022; Karátson, D. *et al.* 2022). The 4th sample area is also distinct with respect to the Bouguer anomaly, because it shows a slight positive anomaly like the 2nd sample area.

Slope and aspect maps were generated by the 'Slope' and 'Aspect' tools located in the GDAL Dem Utility of the QGIS. Topographic openness (*sensu* Yokoyama, R. *et al.* 2002) is defined as the mean of 8 zenith (positive topographic openness) or nadir angles (negative topographic openness) within a defined horizontal distance (known as the radial limit) from each cell of a digital elevation model. Positive and negative topographic openness were calculated by the 'Topographic Openness' tool of the QGIS according to Daxter, C. (2020). The radial limit was 1,000 m, the number of sectors was 8 for each analysis. Bin sizes of histograms were specified as follows: 10 m for elevation a.s.l., 2° for slope and 0.1 radian for topographic openness. Circular frequency diagrams also known as 'rose diagrams' were produced from aspect data by using Georose program (Yong Technology 2014). Bin size was set to 10°.

In addition to the analysis of the four sample areas, the LPC areas within the 1st, 2nd and 3rd sample areas were also analysed specifically. The same topographic parameters were analysed, restricted to the surface distribu-

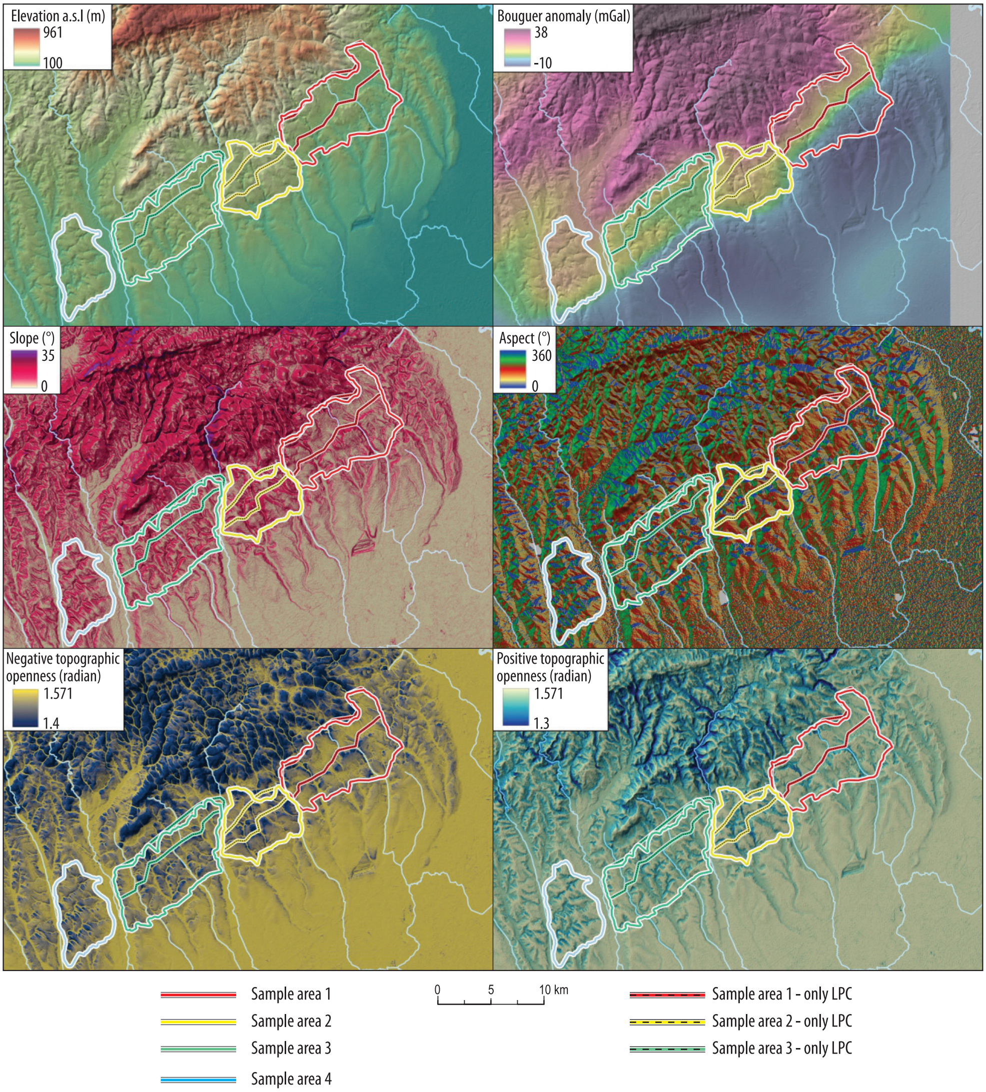


Fig. 5. Elevation a.s.l., Bouguer anomaly, slope, aspect and topographic openness map of the BVA. The Bouguer anomaly map was compiled after the 1:500 000 Bouguer anomaly map of Hungary (© MBFSz Térképek – https://map.mbfsz.gov.hu/gravitacios_anomalia/).

tion of the LPC (see *Figure 3*). In the case of sample area 3 only the northern occurrence of the LPC was considered (which is located towards the north from the Eger–Bogács line), because the southern one is rather influenced by faulting (see *Figure 3*).

Swath profile analysis – a refined version of the classic, line-based cross-section analysis – was also carried out. Swath profiles describe the topography of a greater zone by computing the average, maximum, minimum elevation a.s.l. and the 1st and 3rd quartiles of the frequency distribution constructed from the elevation values of the pixels of the surface model within a swath with known orientation (for details of the methodology consult Telbisz, T. *et al.* 2011a, 2013). The differences between the curves of the 1st and 3rd quartiles show the variability of the topography. Four of the swaths along which the analysis was carried out had an area of 1.6 x 6 km and the azimuths of their longer sides were generally 140° (clockwise). In addition, a 5th swath profile was also considered covering the LPC from the SW to the NE margin of the BVA (see *Figure 4*). Length and width of this swath profile was 30 000 and 670 m, respectively.

Results

Maps and histograms of elevation a.s.l., slope, topographic openness and aspect

The four sample areas show relevant differences for each of the topographic parameters studied, either the derived maps (see *Figure 5*) or the frequency diagrams (*Figures 6* and *7)*, or the swath profiles are considered *(Figure 8).* The differences between sample areas 1, 2 and 3 are even more pronounced when only the LPC area is considered.

For each sample area, the frequency distribution of elevation a.s.l. resulted in a single-peaked curve. For sample areas 1 and 4, most of the elevation values are between 150 and 250 metres. The average elevation value is slightly higher for sample area 3, where values are typically observed between 175 and 300 m. The highest average elevation is observed at sample area 2 with half of the values above 250 metres. If only the area of LPC is considered, the distributions are different from the previous ones. The values of LPC elevation a.s.l. are the most scattered for sample area 1. Values between 150 and 250 m are most typical, but values between 250 and 350 m are also frequent. Sample area 3, in contrast, shows a distribution characterized by a single peak, with values between 225 and 275 m being the most frequent.

For each sample area, the distribution curve of slope values is generally similar, although slight differences are evident. The most common slope value is below 10 degrees for all sample areas. However, sample area 1 has a higher relative frequency below 6° and a lower relative frequency above 6° than the other 3 sample areas. Most pixels above 10° are observed at sample area 2. The frequency distribution curves for sample areas 3 and 4 are closely similar. If only the LPC areas are considered, the individual sample areas show broadly similar distributions to the previous ones, but the differences between the sample areas are again more remarkable.

As for negative topographic openness, each sample area shows a distribution curve with an individual peak. For sample areas 2, 3 and 4, the most frequent values are closely around 1.5 radians (rad for short hereafter), while for sample area 1 the peak is slightly higher. The curve for sample areas 3 and 4 is also quite similar. In comparison, sample area 1 has more values above 1.5 rad, while sample area 2 has more values below 1.5 rad. Considering only the LPC areas, sample areas 1, 2 and 3 are quite distinct in terms of the distribution of negative topographic openness: although all three sample areas show a single-peaked distribution, the relatively smaller values (<1.5 rad) are observed for sample area 2, while the largest values (>1.5 rad) are observed for sample area 1. Sample area 3 shows a transition between these, with values around 1.5 rad being the most common.

In terms of positive topographic openness, all four sample areas show a substantially similar distribution: the most frequent value is found around 1.55 rad, but there is also a smaller adjacent peak at 1.5 rad beside the main peak. Each sample area differs in terms of the ratio of the two peaks to each other and the significance of the range below 1.45 rad. The minor peak at 1.5 rad is most pronounced for sample area 3 and least significant for sample area 1. The frequency distribution of sample area 2 differs from the other three in that the relative frequency of values below 1.45 rad is notable. The difference be-

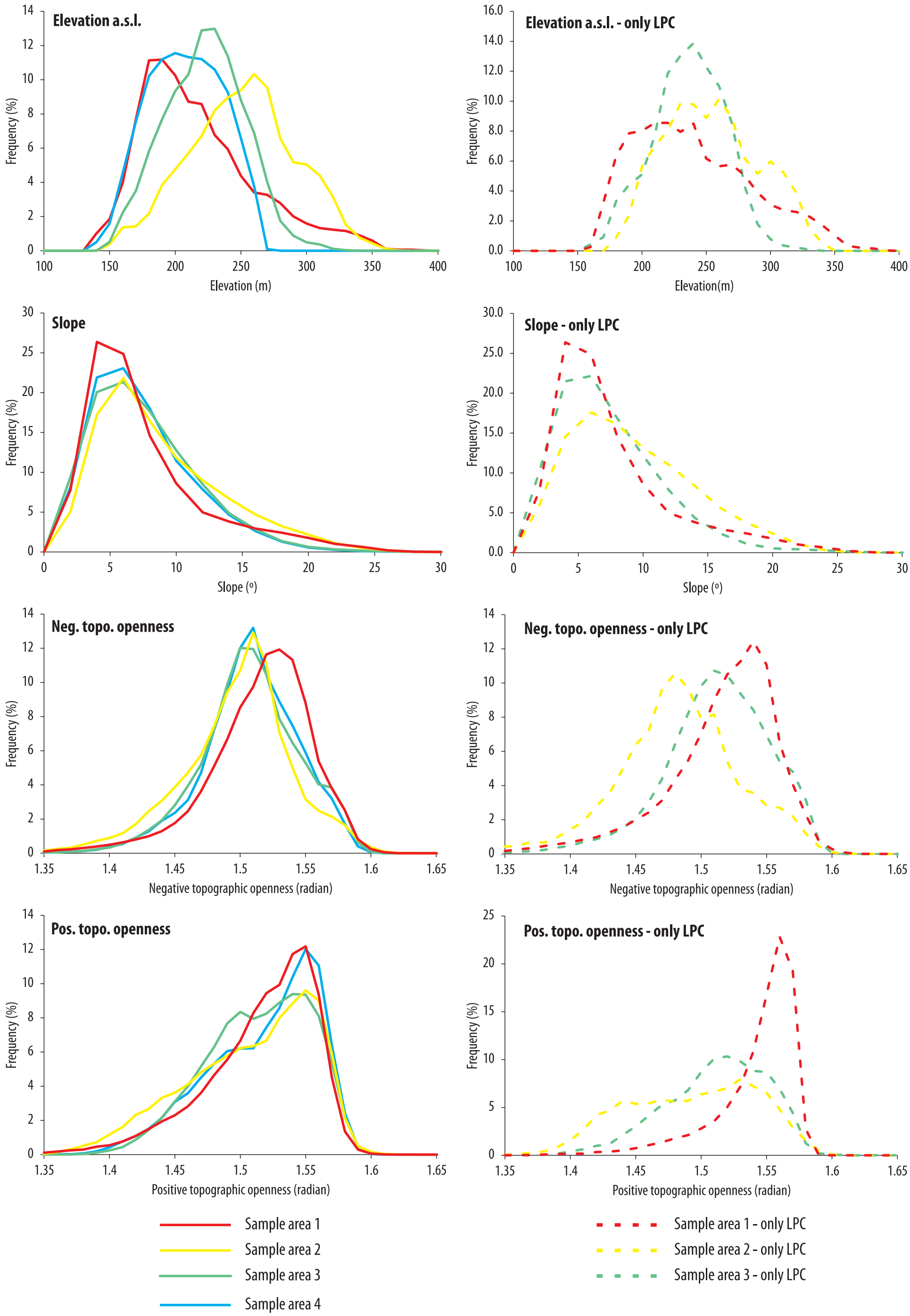


Fig. 6. Frequency distribution of topographic parameters. Note, that the dashed curves refer to sample areas restricted to the LPC surfaces only.

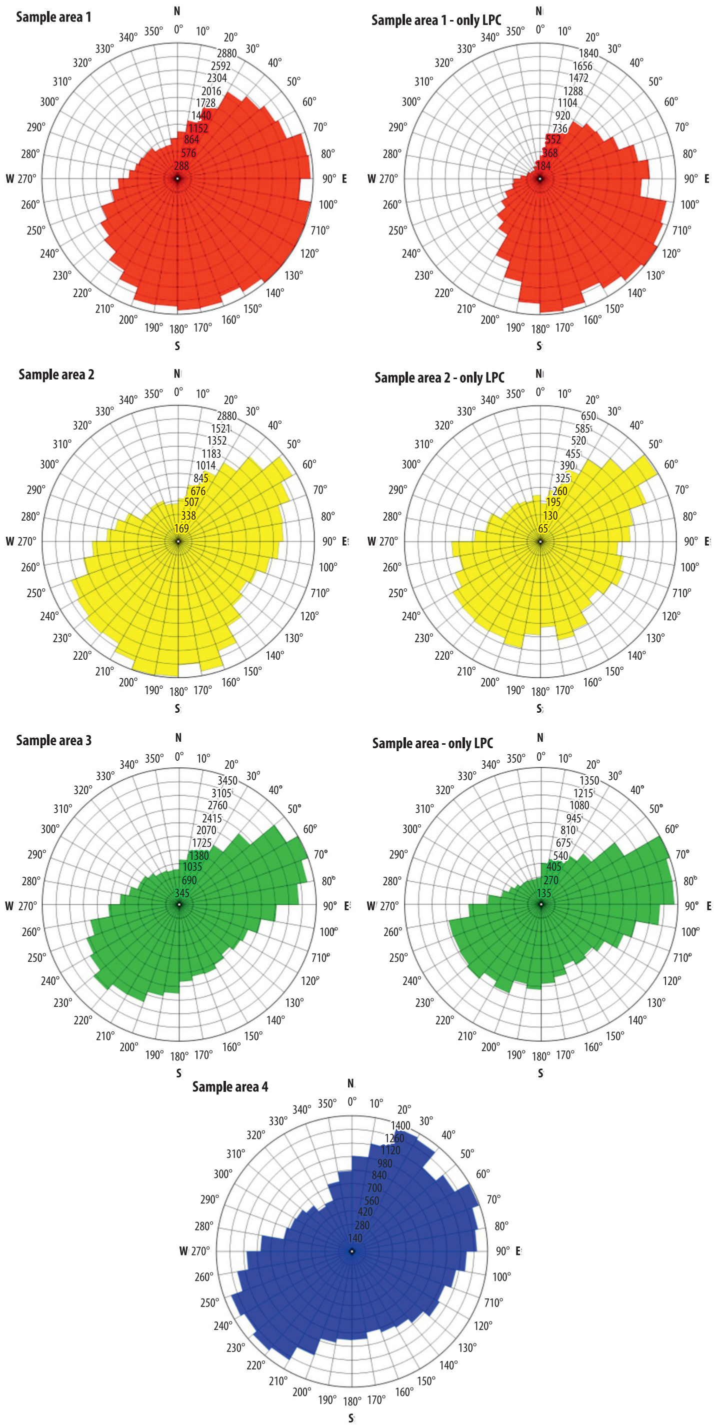


Fig. 7. Rose diagrams showing aspect distribution of the sample areas

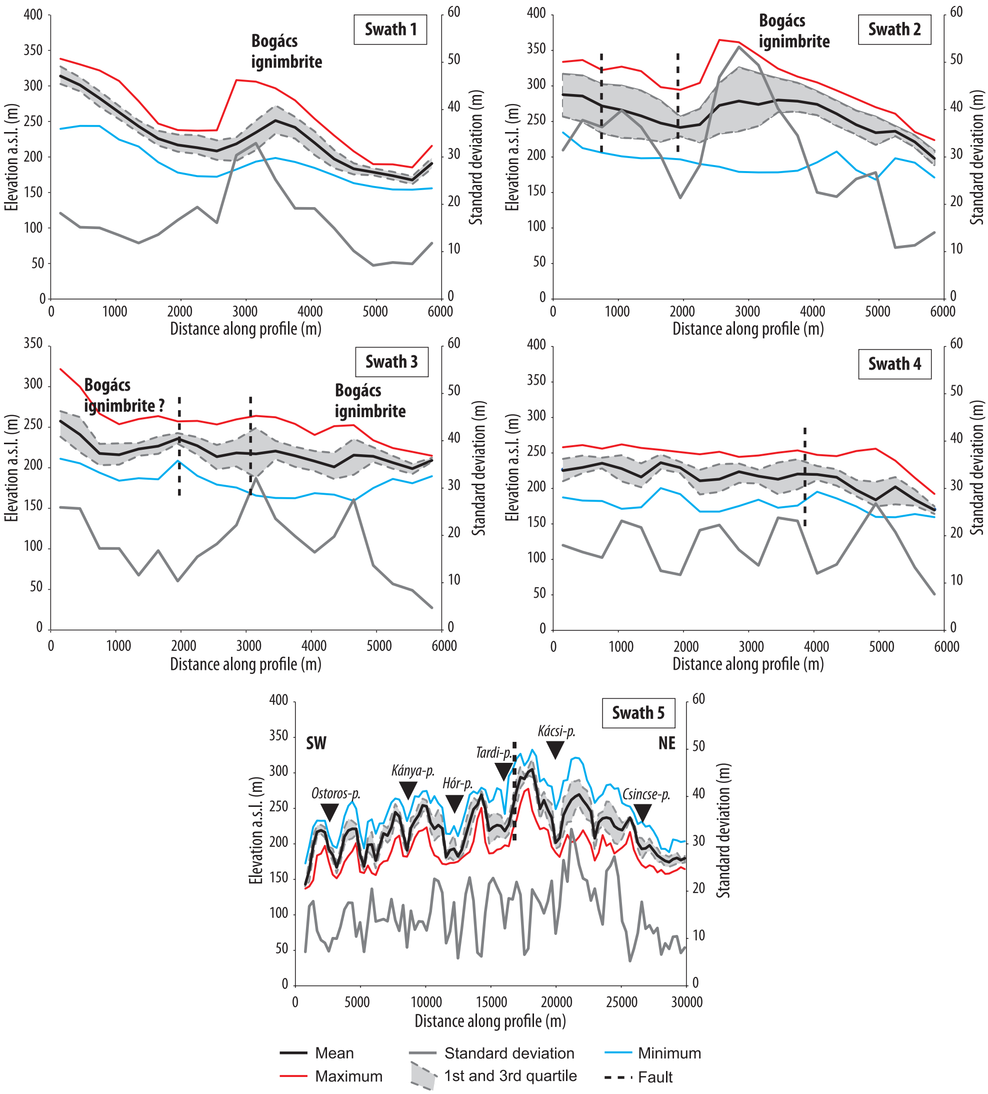


Fig. 8. Swath profiles investigated in this study. Faults are adapted from Petrik, A. (2017).

tween sample areas 1, 2 and 3 is most evident in the positive topographic openness values obtained for the LPC areas. For sample area 1, a significant peak is observed at 1.55 rad. In contrast, sample area 2 shows a flat tail, with values between 1.45 rad and 1.55 rad being virtually uniformly frequent. Sample area 3 shows a transition between the two.

Based on aspect values, sample area 1 is considered to be unimodal, dominated by aspect values between 70° and 200°. The relative frequency of pixels facing to NW is much lower here. In contrast, pixels facing NE and SW are the most prominent at the other three sample areas. It is important to note that sample area 2 differs slightly from this group, as S-facing pixels are also frequent in addition to NE and SW directions. Similarly, sample area 4 has a significant contribution of E-facing pixels in addition to the dominant NE and SW directions.

Topographic swath profile analysis

The different character of the topography of the study areas is also evident by considering the swath profiles (see *Figure 8*). The most important information that can be derived from the swath profiles is the different relative degree of dissection of the LPC surfaces in the northern and north-western forefronts of the Bogács ignimbrite occurrences along swath 1, 2 and 3. The degree of the dissection is indicated by the difference between the Q1 and Q3 curves on the one hand, and the standard deviation along the profile on the other. It is obvious that the LPC shows the smallest topographic variability along swath 1, even though this is the steepest slope. The highest variability is observed for swath 2.

Furthermore, it is also apparent that between swath 1 to 3 the relative height of the Bogács ignimbrite with respect to the LPC surface gradually decreases from ~40 m to less than 20 m. Swath profile 5 shows the topographical change of the LPC from the SW towards the NE edge of the BVA. It shows, that although the standard deviation of elevation a.s.l. is higher at the NE part of the BVA, the valleys are generally deeper at its SW part.

Discussion

Foothill geomorphology principally affected by ignimbrite lithofacies

Present results show that the elevation a.s.l., slope, aspect and topographical openness of sample areas 1 and 3, 4 show a marked difference: the dominant features of the topography of sample area 1 are the tilted slabs facing S, SE and are characterized by relatively minor fluvial dissection, while the other sample areas show a topography significantly dissected by fluvial erosion.

The frequency distribution of elevation a.s.l. at sample area 1 shows an asymmetric distribution, which is different from the other three sample areas. The distribution of elevation a.s.l. at the other 3 sample areas shows a symmetrical distribution. This type of frequency distribution is typical of the relief dissected by fluvial erosion (e.g., Telbisz, T. *et al.* 2011b). The most frequent value in sample area 1 is less than 5° in the frequency distribution of the slope, which is especially evident when considering only the LPC surface. It is worth noting that the predominant components of the valley network here are the steep-sided valleys with a NW-SE orientation, which separate the tilted slabs protected by the Mangó ignimbrite. Only in the NW vicinity of the Bogács ignimbrite surficial occurrence there are minor valleys inclined or perpendicular to this direction. Thus, the lack of well-evolved, multidirectional valley network results in the lack of abundant higher slope values compared to the other sample areas. Further on, the dominance of the tilted welded ignimbrite slabs is also reflected in the aspect distribution. The tilted slab formed by the Mangó ignimbrite is still more or less present at sample area 2, but is much more dissected due to the more intense incision resulting in the higher proportion of slope values greater than 10°. For sample areas 3 and 4, the south and southeast sloping slabs are absent and are replaced by erosional valleys with a multidirectional network having a predominant influence on aspect values, too. The difference of sample area 1 on the frequency diagram of topographic openness from the other sample areas is also due to this reason. In areas where the degree of dissection is limited, the frequency distribution of topographic openness will be dominated by a pronounced peak. On the other hand, where the topography is composed of valleys and ridges, the frequency distribution of topographic openness becomes two-peaked, i.e., the peak at lower values of negative topographic openness is typical of ridges, while the peak at relatively higher values is typical of valley bottoms (see

Figure 5 in Yokoyama, R. *et al.* 2002). In fact, sample area 1 has higher values than the other three sample areas both regarding negative and positive topographic openness, indicating that there is a relatively lower degree of erosional dissection here.

By taking into consideration the relative location of various sample areas from the source localities of the Mangó and Bogács ignimbrites, a pronounced difference between sample area 1, which is the closest to the vent area (within 10–20 km), and sample areas 3 and 4, which are further away by 30–40 km, is evident. The dominance of tilted slabs of welded ignimbrites in the topography around Kisgyőr and their absence in the SW part of the BVA has already been recognised by Pentelényi, L. (2005), Vágó, J. (2012), and Vágó, J. and Hegedűs, A. (2011). It has also become evident that the occurrences of the Bogács ignimbrite are characterized by the highest relative relief in the BVA (>100 m/km^2), and that the surface of the welded lithofacies of the Mangó ignimbrite (Kisgyőr Ignimbrite member *sensu* Pentelényi, L. 2005) typically exhibits low slope values as a consequence of the tilted plateau morphology (Vágó, J. and Hegedűs, A. 2011). However, a systematic study of the topographic features of the BVA along its NE-SW extension, taking into account that the ignimbrites of the NE areas (Mangó and Bogács), which are closer to the source localities tend to be welded, has not been carried out so far.

The stratigraphic succession of pyroclastic-dominated volcanic fields frequently contains units of extremely variable erodibility (e.g., friable vs. densely welded ignimbrites), which has a crucial influence on the extent, shape and temporal variability of both small- and large-scale landforms i.e., from river terraces to several 100 km^2-large ignimbrite plateaus (Yokoyama, S. 1999; Karátson, D. *et al.* 2009; Székely, B. *et al.* 2014; Adams, B.A. and Cooper, F.J. 2020). Present results show that the topography of the BVA is fundamentally controlled by spatial variations of the lithofacies of the Mangó and Bogács ignimbrites related to the distance from their source area. Both the Mangó and Bogács ignimbrites have their highest relative thickness, often exceeding 30 m, in sample area 1, and in the same area, both ignimbrites display a typical welded lithofacies characterized by fiamme structures and low porosity (Pentelényi, L. 2005, Hencz, M. *et al.* 2021a, b). At the western part of the BVA associated with sample areas 3 and 4 the Mangó ignimbrite is still more than 20 m thick, however, it shows non-welded, rather friable lithofacies (e.g., at the eastern vicinity of Eger; Biró, T. *et al.* 2017; Hencz, M. *et al.* 2021a). Towards SW, the Bogács ignimbrite is thickening gradually and even disappears approximately in the central part of sample area 3, east of Ostoros (see *Figure 3*). Consequently, the topography of sample area 1, which is relatively closer to the source region, is characterised by slabs tilted south-east by up to 10° dip angle, and composed of welded lithofacies of the Mangó and Bogács ignimbrites. This is particularly evident in the case of the LPC surface, which is dominated here by the welded Mangó ignimbrite, which has preserved its less dissected, slab-like appearance despite the fact that the topographic gradient, i.e., the degree of tilting from the original presumably near-horizontal bedding (Biró, T. *et al.* 2020), is the most significant here.

Although the distinct topography of the SW and NE parts of the BVA can be explained by the lateral facies variations of the Bogács and Mangó ignimbrites, the results suggest that the topography of the BVA is also influenced by the total amount and direction of vertical movements.

The effect of vertical movements on fluvial dissection at the BVA

The degree of dissection does not vary unidirectionally between sample areas 1 and 4. Instead, it was observed that sample area 2 has a greater relative depth of valleys than sample areas 3 and 4, despite the fact that here the Mangó ignimbrite still has a welded facies (Pentelényi, L. 2005). Sample area 2 has the highest average elevation a.s.l. and shows a positive Bouguer anomaly compared to the other sample areas (see *Figures 6* and *8*). Both the higher average elevation a.s.l. and the positive Bouguer anomaly suggest a more intense uplift here than at all other sample areas. As a consequence, valley incision is also most intense here and both the LPC outcrop and the Bogács ignimbrite are the most intensively dissected here. This is probably also in relation to the fact that this is the region of the BVA where the largest number of fairy chimneys (tent rocks or beehive rocks) carved by water erosion from unconsolidated ignimbrite occur (Borsos, B. 1991). The formation of the fairy chimneys in this region was probably facilitated by the more intense uplift and related effective fluvial incision.

Conclusions

The frequency distributions of elevation a.s.l., slope, aspect as well as positive and negative topographic openness were investigated at the Bükkalja Volcanic Area (BVA) using a 30 m resolution SRTM-based digital terrain model at four sample areas located at different relative distances from the assumed source localities of the ignimbrites showing welded facies. At these sample areas we also investigated the degree of dissection along swath profiles. Based on the results obtained, the following conclusions can be drawn:

All morphometric parameters investigated show a remarkable difference between sample areas located closer and further away from the source localities. The topography of the sample area closest to the source localities (i.e., the eastern part of the BVA) is dominated by slabs of moderately dissected welded ignimbrites, gently dipping towards SE. This topography appears as an asymmetric curve in the frequency distribution of elevation a.s.l., showing a slight overplus for the higher values, increasing the frequency of less than 5° slope values and SE-facing pixels, and resulting in a distribution of single-peaked positive and negative topographic openness with higher frequencies for larger values than in case of the other sample areas. The topography of the sample areas farther away from the source localities (i.e., in the western part of the BVA) is dominated by erosional valleys and ridges, resulting in a narrower typical elevation range, a higher proportion of pixels with greater than 5° slope compared to sample area 1, and higher frequencies of NE and SW exposures. At these sample areas, the more significant incision has resulted in more frequent pixels with positive topographic openness less than 1.5 radians.

The increasing dissection of the BVA from NE towards SW is principally controlled by the change in the lithofacies of the Mangó and Bogács ignimbrites, via the dominance of welded facies within sample areas 1 and 2, the decrease in thickness, and the disappearance of welded lithofacies in the SW direction.

In addition to the location of the ignimbrite source regions, the degree of dissection at the BVA is also influenced by the relative amount of vertical uplift, as the most dissected sample area coincides with the region with the largest positive Bouguer anomaly and average elevation a.s.l.

The overall implication of the present study is that the degree of dissection of millions of years old ignimbrite fields is fundamentally determined by the thickness and lithofacies (welded vs non-welded) of the ignimbrites that may show a large lateral variability. Since higher thicknesses and temperatures, and consequently welded facies, are more common closer to the source vent, the erosion pattern can be used to draw conclusions on the spatial aspects of the most intense ignimbrite aggradation, i.e., the location and vicinity of eruption centres in deeply eroded ignimbrite fields.

Acknowledgement: Present research was supported by the ÚNKP-21-4 New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund (ÚNKP-21-4-II-ELTE-382; ÚNKP-21-4-I-ELTE-63) and by the Hungarian National Fund (NKFIH-OTKA K131894). We thank Károly Németh and Zoltán Pécskay for fruitful discussions on the landforms of ignimbrite-dominated landscapes.

REFERENCES

Adams, B.A. and Cooper, F.J. 2020. *The importance of ignimbrite armour on mountain range evolution.* American Geophysical Union. Fall Meeting Abstracts, EP031-0019. Available at https://ui.adsabs.harvard.edu/abs/2020AGUFMEP0310019A/abstract

Biró, T., Kovács, I.J., Karátson, D., Stalder, R., Király, E., Falus, Gy., Fancsik, T. and Sándorné, J.K. 2017. Evidence for post-depositional diffusional loss of hydrogen in quartz phenocryst fragments within ignimbrites. *American Mineralogist: Journal of Earth and Planetary Materials* 102. (6): 1187–1201.

Biró, T., Hencz, M., Németh, K., Karátson, D., Márton, E., Szakács, A., Bradák, B., Szalai, Z., Pécskay, Z. and Kovács, I.J. 2020. A Miocene phreatoplinian eruption in the north-eastern Pannonian Basin, Hungary: the jató member. *Journal of Volcanology and Geothermal Research* 401. Doi:10.1016/j.jvolgeores.2020.106973

Borsos, B. 1991. A bükkaljai kaptárkövek földtani és felszínalaktani vizsgálata (Geological and geomorphological investigation of the beehive-rocks of the Bükkalja). *Földrajzi Közlemények* 115. (3–4): 121–137.

Capaccioni, B., Coradossi, N., Harangi, R., Harangi, Sz., Karátson, D., Sarocchi, D. and Valentini, L. 1995. Early Miocene pyroclastic rocks of the Bükkalja Ignimbrite Field (North Hungary) – A preliminary stratigraphic report. *Acta Vulcanologica* 7. (2): 119–124.

Crowe, B.M., Linn, G.W., Heiken, G. and Bevier, M.L. 1978. *Stratigraphy of the Bandelier Tuff in the Pajarito Plateau. Applications to waste management.* Report no. LA-7225-MS. Los Alamos, New Mexico, USA. Los Alamos Scientific Laboratory. Doi:10.2172/6870764.

Cseri, Z. 2017. *A bükkaljai ignimbritek mágneses szuszceptibilitás anizotrópiájának jellemzői.* (Features of anisotropy of magnetic susceptibility of ignimbrites at the Bükkalja). MSc Thesis, Budapest, ELTE Faculty of Science, Department of Physical Geography.

Daxter, C. 2020. *Topographic Openness Maps and Red Relief Image Maps in QGIS.* Innsbruck, University of Innsbruck, Institute of Geology.

Dobos, A. 2002. A Bükkalja II. felszínalaktani leírás. (The Bükkalja II. geomorphological description). In *A Bükki Nemzeti Park.* Ed.: Baráz, Cs., Eger, Bükki Nemzeti Park Igazgatóság, 217–228.

Dunkl, I., Árkai, P., Balogh, K., Csontos, L. and Nagy, G. 1994. A hőtörténet modellezése fission track adatok felhasználásával – a Bükk hegység kiemelkedéstörténete (Thermal modelling based on apatite fission track dating – the uplift history of the Bükk Mountains). *Földtani Közlöny* 124. (1): 1–24.

Freundt, A., Wilson, C.J.N. and Carey, S.N. 2000. Ignimbrites and block-and-ash flow deposits. In *Encyclopaedia of Volcanoes*. 1st edition. Ed.: Sigurdsson, H., New York, Academic Press, 581–599.

Hencz, M., Biró, T., Cseri, Z., Karátson, D., Márton, E., Németh, K., Szakács, A., Pécskay, Z. and Kovács, I.J. 2021a. A Lower Miocene pyroclastic-fall deposit from the Bükk Foreland Volcanic Area, Northern Hungary – clues for an eastward-located source. *Geologica Carpathica* 72. (1): 26–47.

Hencz, M., Biró, T., Cseri, Z., Németh, K., Szakács, A., Márton, E., Pécskay, Z. and Karátson, D. 2021b. Egy összetett kitörési eseménysorozat nyomai a Bükkalján (Észak-Magyarország): a Kács Egység (Signs of complex eruption events at the Bükk Foreland [Northern Hungary]: the Kács Member). In *22nd Mining, Metallurgy and Geology Conference. Abstracts.* Cluj, Hungarian Technical Scientific Society of Transylvania. 71–75.

Hencz, M., Biró, T., Kovács, I.J., Stalder, R., Németh, K., Szakács, A., Pálos, Z., Pécskay, Z. and Karátson, D. 2021c. Uniform "water" content in quartz phenocrysts from silicic pyroclastic fallout deposits – implications on pre-eruptive conditions. *European Joural of Mineralogy* 33. (5): 571–589.

Hevesi, A. 2002. Fejlődéstörténet II. Felszínfejlődés (Surface evolution II. Surface development). In *A Bükki Nemzeti Park.* Ed.: Baráz, Cs., Eger, Bükki Nemzeti Park Igazgatóság, 83–108.

Karátson, D., Telbisz, T., Székely, B. and Wörner, G. 2009. *Style, rate and pattern of erosion on stratovolcanoes and ignimbrite surfaces in the Central Andes.* EGU General Assembly Conference. Geophysical Research Abstracts, Vol. 11. 10547-1.

Karátson, D., Biró, T., Portnyagin, M., Kiss, B., Jean-Louis, P., Cseri, Z., Hencz, M., Németh, K., Lahitte, P., Márton, E., Kordos, L., Józsa, S., Hably, L., Müller, S. and Szarvas, I. 2022. Large-magnitude (VEI ≥ 7) 'wet' explosive silicic eruption preserved a Lower Miocene habitat at the Ipolytarnóc Fossil Site, North Hungary. *Scientific Reports* 12. Article number 9743.

Leonard, G.S., Begg, J.G. and Wilson, C.J.N. 2010. *Geology of the Rotorua Area. Institute of Geological and Nuclear Sciences 1:250 000 geological map 5.* Lower Hutt, New Zealand, GNS Science.

Less, Gy., Kovács, S., Pelikán, P., Pentelényi, L. and Sásdi, L. 2005. *Geology of the Bükk Mountains. Explanatory book to the geological map of the Bükk Mountains (1:50 000).* Budapest, Hungarian Institute of Geology and Geophysics.

Lukács, R., Harangi, Sz., Ntaflos, T., Koller, F. and Pécskay, Z. 2007. A Bükalján megjelenő felső riolittufaszint vizsgálati eredményei: a harsányi ignimbrit egység. (The characteristics of the Upper Rhyolite Tuff Horizon in the Bükkalja volcanic field: The Harsány ignimbrite unit). *Földtani Közlöny* 137. (4): 487–514.

Lukács, R., Harangi, Sz., Bachmann, O., Guillong, M., Danisik, M., Buret, Y, von Quadt, A., Dunkl, I., Fodor, L., Sliwinski, J., Soós, I. and Szepesi, J. 2015. Zircon geochronology and geochemistry to constrain the youngest eruption events and magma evolution of the Mid-Miocene ignimbrite flare-up in the Pannonian Basin, eastern-central Europe. *Contributions to Mineralogy and Petrology* 170. Article number 52.

Lukács, R., Harangi, Sz., Guillong, M., Bachmann, O., Fodor, L., Buret, Y., Dunkl, I., Sliwinski, J., von Quadt, A., Peytcheva, I. and Zimmerer, M. 2018. Early to Mid-Miocene syn-extensional massive silicic volcanism in the Pannonian Basin (East-Central Europe): Eruption chronology, correlation potential and geodynamic implications. *Earth Science Reviews* 179. 1–19.

Lukács, R., Harangi, Sz., Gál, P., Szepesi, J., Di Capua, A. and Fodor, L. 2022. Formal definition and description of lithostratigraphic units related to the Miocene silicic pyroclastic rocks outcropping in Northern Hungary: A revision. *Geologica Carpathica* 73. 137–158.

NASA 2013. *Shuttle Radar Topography Mission (SRTM) Global.* Distributed by OpenTopography.

Pecsmány, P. and Vágó, J. 2020. A mélyszerkezet és a domborzat közötti kapcsolat a Bükkalja területén (Relationship between geological structure elements and topography in the Bükkalja). *Műszaki Földtudományi Közlemények* 89. (1): 29–34.

Pecsmány, P., Hegedűs, A. and Vágó, J. 2021. DEM based morphotectonical analysis of the Kisgyőr Basin (Bükk Mountains, Hungary). *Acta Montanistica Slovaca* 26. (2): 364–374.

Pecsmány, P. 2021. A Bükkalja völgyhálózatának rendűség szerinti iránystatisztikai vizsgálata (Quantitative analysis of drainage network direction in the Bükkalja). *Multidisciplináris Tudományok* 11. (2): 9–16.

Pentelényi, L. 2005. A bükkaljai miocén piroklasztikum összlet (The Miocene pyroclastic assemblage of Bükkalja). In *A Bükk hegység földtana. Magyarázó a Bükk-hegység földtani térképéhez (1:50 000).* Ed.: Pelikán, P., Budapest, MÁFI, 110–125.

Petrik, A., Beke, B., Fodor, L. and Lukács, R. 2016. Cenozoic structural evolution of the southwestern Bükk Mountains and the southern part of the Darnó Deformation Belt (NE Hungary). *Geologica Carpathica* 67. (1): 82–104.

Petrik, A. 2017. *A Bükk déli előterének kainozoós szerkezetalakulása* (Cenozoic structural evolution of the Southern Bükk foreland). PhD Thesis, Budapest, ELTE Faculty of Science.

QGIS Development Team 2022. *QGIS Geographic Information System*. Open Source Geospatial Foundation. URL http://qgis.org

Szakács, A., Márton, E., Póka, T., Zelenka, T., Pécskay, Z. and Seghedi, I. 1998. Miocene acidic explosive volcanism in the Bükk Foreland, Hungary: Identifying eruptive sequences and searching for source locations. *Acta Geologica Hungarica* 41. (4): 413–435.

Székely, B., Koma, Zs., Karátson, D., Dorninger, P., Wörner, G., Brandmeier, M. and Nothegger, C. 2014. Automated recognition of quasi-planar ignimbrite sheets as paleosurfaces via robust segmentation of digital elevation models: an example from the Central Andes. *Earth Surface Processes and Landforms* 39. (10): 1386–1399.

Telbisz, T., Kovács, G. and Székely, B. 2011a. Sávszelvények készítése és elemzése (Creating swath profiles and swath analysis). In *Lehetőségek a Domborzatmodellezésben. A HunDEM 2011 Kerekasztal és Konferencia Közleményei.* Ed.: Hegedűs, A., Miskolc, Miskolci Egyetem Földrajz Intézet, 1–8.

Telbisz, T., Mari, L. and Szabó, L, 2011b. Geomorphological characteristics of the Italian side of Canin Mountains (Julian Alps) using digital terrain analysis and field observations. *Acta Carsologica* 40. 255–266.

Telbisz, T., Kovács, G., Székely, B. and Szabó, J. 2013. Topographic swath profile analysis: a generalization and sensitivity evaluation of a digital terrain analysis tool. *Zeitschrift für Geomorphologie* 57. (1): 485–513.

Van Wyk de Vries, B., Karátson, D., Gouard, C., Németh, K., Rapprich, V. and Aydar, E. 2022. Inverted volcanic relief: Its importance in illustrating geological change and its geoheritage potential. *International Journal of Geoheritage and Parks* 10. (1): 47–83.

Vágó, J. and Hegedűs, A. 2011. DEM based examination of pediment levels: a case study in Bükkalja, Hungary. *Hungarian Geographical Bulletin* 60. (1): 25–44.

Vágó, J. 2012. *A kőzetminőség szerepe a Bükkalja völgy- és vízhálózatának kialakulásában* (The effects of rock quality on the valley and drainage network of Bükkalja). PhD Thesis. Miskolc, University of Miskolc.

Yokoyama, S. 1999. Rapid formation of river terraces in non-welded ignimbrite along the Hishida River, Kyushu, Japan. *Geomorphology* 30. (3): 291–304.

Yokoyama, R., Shirasawa, M. and Pike, R.J. 2002. Visualizing topography by openness: a new application of image processing to digital elevation models. *Photogrammetric Engineering and Remote Sensing* 68. (3): 257–266.

Yong Technology 2014. *GeoRose*. Edmonton, CAN, Yong Technology Inc. Available at http://www.yongtechnology.com/download/georose

Web sources:

1:100 000 Geological map of Hungary. Available at https://map.mbfsz.gov.hu/fdt100/

1:500 000 Bouguer anomaly map of Hungary. Available at https://map.mbfsz.gov.hu/gravitacios_anomalia/

DOI: 10.15201/hungeobull.71.3.2 Hungarian Geographical Bulletin **71** 2022 (3) 231–247.

Trends in extreme precipitation events (SW Hungary) based on a high-density monitoring network

Gabriella SCHMELLER[1], Gábor NAGY[2], Noémi SARKADI[1], Anikó CSÉPLŐ[1], Ervin PIRKHOFFER[1], István GERESDI[1], Richárd BALOGH[1], Levente RONCZYK[1] and Szabolcs CZIGÁNY[1]

Abstract

Climate change is commonly associated with extreme weather phenomena. Extreme weather patterns may bring prolonged drought periods, more intense runoff and increased severity of floods. Rainfall distribution is extremely erratic both in space and time, particularly in areas of rugged topography and heterogeneous land use. Therefore, locating major rainfall events and predicting their hydrological consequences is challenging. Hence, our study aimed at exploring the spatial and temporal patterns of daily rainfall totals of R ≥ 20 mm, R ≥ 30 mm and R ≥ 40 mm (extreme precipitation events, EPE) in Pécs (SW Hungary) by a hydrometeorological network (PHN) of 10 weather stations and the gridded database of the Hungarian Meteorological Service (OMSZ). Our results revealed that (a) OMSZ datasets indicated increasing frequencies of EPEs for the period of 1971–2020 in Pécs, (b) the OMSZ dataset generally underestimated EPE frequencies, particularly for R ≥ 40 mm EPEs, for the period of 2013 to 2020, and (c) PHN indicated a slight orographic effect, demonstrating spatial differences of EPEs between the two datasets both annually and seasonally for 2013–2020. Our results pointed out the adequacy of interpolated datasets for mesoscale detection of EPE distribution. However, topographically representative monitoring networks provide more detailed microscale data for the hydrological management of urban areas. Data from dense rain-gauge networks may complement interpolated datasets, facilitating complex environmental management actions and precautionary measures, particularly during weather-related calamities.

Keywords: rainfall pattern, extreme precipitation events, monitoring, rainfall frequency, Pécs

Received March 2022, accepted September 2022.

Introduction

Climate change is not only associated with higher temperatures but also involves the changes of the temporal and spatial pattern of precipitation and particularly the dynamics of severe weather phenomena, including extreme precipitation events (EPE) (Lovino, M. *et al*. 2014; Grazzini, F. *et al*. 2019; Jakab, G. *et al*. 2019; Balatonyi, L. *et al*. 2022). EPEs, defined as daily precipitation totals higher than 20 mm by the Hungarian Meteorological Services (OMSZ), are commonly associated with low pressure systems of either Atlantic or Mediterranean origin (Maheras, P. *et al*. 2018).

Orographic and topographic barriers, as well as large inland water bodies often influence precipitation regimes and patterns (Roe, G.H. *et al*. 2003; Roe, G.H. 2005; Pavelsky, T.M. *et al*. 2012; Veals, P.G. *et al*. 2018; Napoli, A. *et al*. 2019; Schnek, T. *et al*. 2021). The dynamics as well as the microphysical and thermodynamical properties of convective clouds, combined with the

[1] Institute of Geography and Earth Sciences, Faculty of Sciences, University of Pécs. Ifjúság u. 6. H-7622 Pécs, Hungary. Corresponding author's e-mail: sarkadin@gamma.ttk.pte.hu

[2] South Transdanubian Water Management Directorate. Köztársaság tér 7. H-7623 Pécs, Hungary. E-mail: gabor.nagy.84@gmail.com

physical attributes of the surface (e.g., elevation, land use and aspect) distinctly influence the spatial distribution of rainfall totals and intensity (Kunz, M. and Kottmeier, C. 2006; Malby, A.R. *et al*. 2007; Houze, R.A. 2012; Scaff, L. *et al*. 2017; Geresdi, I. *et al*. 2017, 2020; Kirshbaum, D. *et al*. 2018).

Knowledge on the spatial pattern of precipitation is critical in terms of many practical applications (Minder, J.R. *et al.* 2008; Houze, R.A. 2014). A strong correlation between erosion rate, morphological evolution and the spatial distribution of precipitation was revealed in the Olympic Mountains (State of Washington, US). The geographical pattern of precipitation is particularly important when the hydrological consequences of extreme rainfall events are considered, e.g., in the case of intense runoff and flash floods (Pirkhoffer, E. *et al.* 2009; Czigány, Sz. *et al.* 2010a; Hanel, M. *et al.* 2012; Karlsson, I.B. *et al.* 2016; Kis, A. *et al.* 2020), soil erosion (Pásztor, L. *et al.* 2016) and mass movements (Kovács, I.P. *et al.* 2015, 2019a, b; Józsa, E. *et al.* 2019). Varied topography, combined with the dense stream networks and the large areas of silty loam, relatively low-coherence soils of South Transdanubia of Hungary, necessitates knowledge on rainfall patterns in this region with high erosion rates (Waltner, I. *et al.* 2020).

Due to its topography, Hungary is only moderately affected by surplus orographic precipitation. Only the northern mountains, the Bakony, the Sopron and the Kőszeg Mountains as well as the Mecsek Hills in the south are affected by thunderstorms and EPEs of partly orographic origin (Kovács, A. and Kovács, P. 2007; Kovács, E. *et al*. 2018; Lakatos, M. *et al.* 2020). Southern Transdanubia is especially prone to extreme precipitation and its vulnerability is large because of multiple aspects (Kovács, I.P. *et al.* 2015). Where rugged topography is associated with a high percentage of impervious surfaces, like in the urban area of Pécs and on the southern slopes of the Mecsek Hills, appropriate water management is crucial (Ronczyk, L. *et al.* 2012).

The intensity and frequency of observed EPEs have markedly changed over the past decades not only globally but also in the Carpathian Basin. Observed data revealed increasing frequency of EPEs for the period of 1946 to 2001 while annual precipitation totals decreased over this time (Bartholy, J. and Pongrácz, R. 2007) and also since 1901 (Kocsis, T. and Anda, A. 2017). Similarly, Berényi, A. *et al.* (2021) found that during the period of 1951–2019 the frequency and the intensity of the extreme precipitation events has been increased, such as the extreme weather events. In accordance with the latter trend, but based on climate model simulations, drying of the climate of Hungary, particularly for summer, was simulated for the 21st century with large uncertainties in rainfall pattern and seasonal distribution (Pieczka, I. *et al.* 2011; Kovács, A. and Jakab, A. 2021). Bartholy, J. and Pongrácz, R. (2007) demonstrated the change of the seasonal pattern of precipitation. According to Bötkös, T. (2006), who also used OMSZ dataset for Pécs, from 1951 to 2005, no marked changes were observed in the frequency of EPEs in Pécs-Pogány but he found slightly increasing annual totals with a decreasing annual number of rainy days with < 10 mm daily totals. The return periods of EPEs demonstrated a decreasing trend in Pécs-Pogány, SW Hungary by Lakatos, M. and Hoffmann, L. (2019). Climate simulations projected diminishing return periods of EPEs by a factor of 1.2 to 2.0 by the end of the 21st century for Hungary (Pongrácz, R. *et al.* 2014; Breuer, H. *et al.* 2017). Cheval, S. *et al.* (2017) predicted steady aridification for SE Europe and specifically for the Carpathian (Pannonian) Basin over the period of 1961 to 2050. For the better understanding of urban hydrodynamics, and the management of surplus water, or in contrast, the shortage of soil moisture, smart city concepts and dense hydrometeorological monitoring networks may prove adequate solutions. Spatially dense rain-gauge networks do not only provide high-resolution data on the elements of the hydrological cycle but may also be useful for the verification of numeric models (e.g., Sarkadi, N. *et al.* 2016) and, thus, may increase the accuracy of weather forecasts and improve nowcasting.

Hence, our study aimed at providing additional pieces of information on the spatial and temporal patterns of EPEs in Pécs. Our findings fill in a significant research gap, as in absence of a dense ground rain-gauge network, no spatial precipitation data of high resolution had been available for Pécs until 2012. Our specific objectives were threefold: (i) mapping of EPEs for the period of 2013 to 2020 and (ii) to validate the OMSZ interpolated data with the ground measured rainfall data; (iii) to analyse the temporal variability of the frequencies of EPEs compared to corresponding OMSZ data for the period of 1971 to 2020.

Materials and methods

Study site

The city of Pécs covers an area of 167 km^2 and is located on the southern slopes of the Mecsek Hills, the Pécs Basin and the northern margin of the Baranya Hills. The highest point within the administrative border of the city is the Tubes Hill (612 m), while the lowest point is in the Pécs Basin (Megyeri út, 103 m). The Mecsek Hills is a low-mountain range that spans for about 45 km in an ENE-WSW direction and has a width of about 10 km (Lovász, Gy. 1977) *(Figure 1).*

The study area lies in the south-eastern Transdanubian Hills macroregion (Dövényi, Z. 2010). The region is located in the temperate climatic zone, fully humid with hot summers and Mediterranean and arid continental influences (Lovász, Gy. 1977; Péczely, Gy. 1981). The long-term average annual temperature is 11.5 °C (1991–2020 in Pécs-Pogány) with markedly higher values in the past few years (12.66 °C at the Ifjúság Street campus of University of Pécs for the period of 2009 to 2021). The mean temperature of the coldest month (January) is -0.39 °C, while the warmest month is July with a mean temperature of 22.06 °C for 1991–2020 at Pécs-Pogány. The average annual precipitation total is around 680 mm in the region. The 30-year average value is 672 mm in Pécs (1991 to 2020 data, source: Hungarian Meteorological Services). Based on the 1991 to 2020 meteorological data in average January was the driest month (31 mm), while the highest 30-year averaged precipitation was recorded in June (83 mm). According to Ács, F. *et al.* (2015) the climate of the Transdanubian Hills region can be characterized with the combination of four climatic types: moderately cool/cool and moderately dry/moderately moist in the period of 1901–1930. These climatic zones shifted toward the moderately cool/moderately dry category over the period of 1971–2000 (Ács, F. *et al.* 2015). However, Breuer, H. *et al.* (2017) demonstrated that the change of the climatic classification of this region was mainly manifested in drying with minimal or no alterations in categorical changes related to temperature.

The hydrometeorological monitoring network

In the current paper precipitation data from the 10 stations of the Pécs Hydrometeorological Network (hereafter: PHN) were analysed. Eight stations of the PHN were manufactured by Boreas Ltd. (Érd, Hungary) using BES-06 automated rain gauges of 0.1 mm resolution[3]. The network of the Boreas stations has been jointly operated by the Tettye Forrásház Ltd. (Water Supplying and Water Management Company of Pécs) and the Institute of Geography and Earth Sciences of the University of Pécs since 2012. The weather station at the Ifjúság Street Campus of the University of Pécs, operated by the national weather network of the Hungarian Meteorological Services, is equipped with a Lambrecht 15188 rain gauge (Lambrecht GmbH, Göttingen, Germany) as well as with a manual Hellmann rain gauge. The latter provided data for this study. The 10[th] station of the manual Hellmann rain gauge used in the analysis is

[3] www.boreas.hu

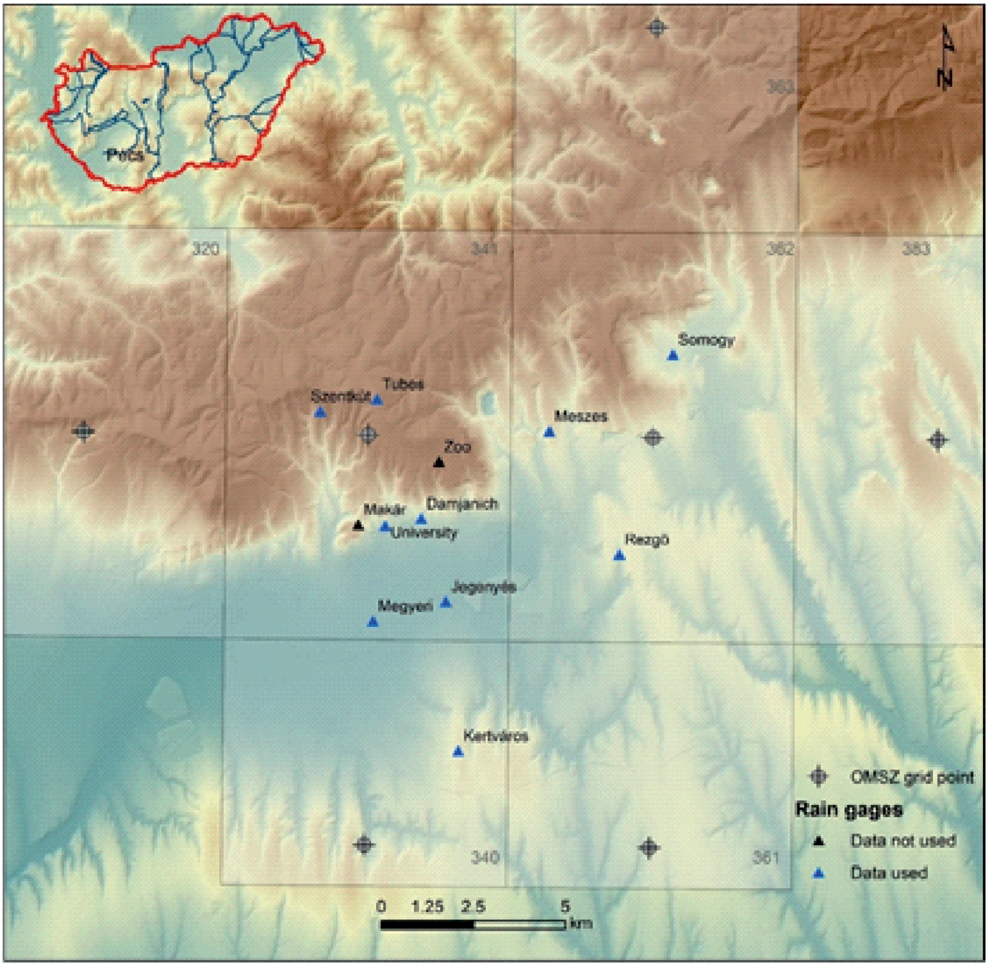


Fig. 1. Location of the study area and the PHN stations (black and blue triangles). The crossed circles show the OMSZ grid data points. The transparent squares indicate the area which we assumed to be representative for the OMSZ grid data points.

located in Jegenyés, central Pécs. It was used to double-check the manually and automatically measured rainfall data and its data were also used in the analyses. Missing data were either replaced by PHN daily mean precipitation (usually non-precipitating days) or, if found substantial, the station or period was omitted from the calculations (see *Appendix* for incorrect or missing data periods).

Due to the rugged topography and higher frequency of flash floods (Czigány, Sz. *et al.* 2013) more rain gauges were installed in the northern side of the city. A secondary aspect of the installation was the maintenance of appropriate operation (safety and access to power supply network) of the instruments whereas, thirdly, stations were installed according to the distribution of the sewage-sheds of the Tettye Forrásház Ltd. A fourth aspect of the Boreas rain gauge distribution was to detect the impact of topography on rainfall distribution within the administrative borders of Pécs.

Temporal changes in the frequency of extreme rainfall events

Gridded climatological rainfall data of 0.1° resolution was downloaded from the website of the OMSZ[4]. The precipitation data for each grid point were calculated by the OMSZ by homogenizing and interpolating measured data using the MASH (Multiple Analysis of Series for Homogenization) and MISH (Meteorological Interpolation based on Surface Homogenized Data Basis) method (Szentimrey, T. and Bihari, Z. 2007). We assumed that the OMSZ grid point values are representative for the grid box depicted in *Figure 1.* Although, this can result some biases on spatial investigations due to for instance the under-represented terrain conditions. PHN data of the rain gauges located within the boundaries of the specific OMSZ grid were compared to the gridded rainfall data *(Table 1).* Seven grids cover the entire administrative area of the City of Pécs. However, rain gauges of the PHN are only found in three grid points, numbered 340, 341 and 362 in the OMSZ database (see *Figure 1*, and *Table 1*). Due to their spatial influence, grid points 320, 361, 363 and 383, partially covering the city of Pécs, were also considered in our calculations.

Table 1. Distribution of PHN rain gages according to the OMSZ grids

Grid name	Name of PHN rain gages within the given HMS grid
NW grid (gp 341)	Szentkút, Tubes, Zoo, University, Makár, Damjanich, Jegenyés, Megyeri út
NE grid (gp 362)	Somogy, Meszes, Rezgő út
SW grid (gp 340)	Kertváros (Garden City)

Temporal changes of the annual frequency of the OMSZ EPEs were also determined for all OMSZ grid points for the period of 1971–2020. Linear trends were calculated for each of these grid points.

[4] https://odp.met.hu

PHN's EPE frequencies of mm daily rainfalls were also compared with the corresponding OMSZ grid point data for the period of 2013–2020 dataset. We also analysed the type of precipitation activity that generated the EPEs of the PHN. Climatological data of precipitation type were obtained from the Hungarian Meteorological Service. The following categories are defined in the OMSZ dataset: drizzle, rain, sleet (freezing rain), shower, snow, snow shower, hail, thunderstorm, snowstorm, thunderstorm with hail, thunder.

Spatial distribution of annual and seasonal OMSZ and PHN data for extreme precipitation events

Due to the relatively low number of weather stations available (10) to determine the spatial distribution of PHN precipitation events for the period of 2013 to 2020, Thiessen polygons were generated in ArcGIS 10.4 software environment. The general pattern of the gridded OMSZ data (Ch. 2.4) and the Thiessen polygons of the PHN data set were compared for the comparative spatial analysis of the two datasets.

The same spatial interpolation with Thiessen polygons was performed for the R ≥ 20 mm events for winter (December to January), spring (March to May), summer (June to August) and fall (September to November) and for the R ≥ 40 mm frequencies for summer and fall. Spring and winter had negligibly low frequencies hence their data are not shown.

Results

Temporal changes of the OMSZ data

The annual number of OMSZ-registered EPEs only slightly increased over the period of 1971 to 2020 with a mean slope of 0.0237, i.e., 2.37 EPE events per 100 years (*Table 2*, *Figures 2*, *3* and *4*). The R ≥ 20 mm EPEs of grid 340 demonstrated the highest increase with a slope of 0.04274 (4.274 events per 100 years).

Table 2. Slopes of the changes of the annual frequencies of EPE for OMSZ grids 340, 341 and 362 for the period of 1971 to 2020

Daily precipitation, mm	340	341	362	Mean
R ≥ 20	0.04274	0.02468	0.04010	*0.03580*
R ≥ 30	0.02699	0.02555	0.02463	*0.02570*
R ≥ 40	0.01176	0.00797	0.00922	*0.00960*

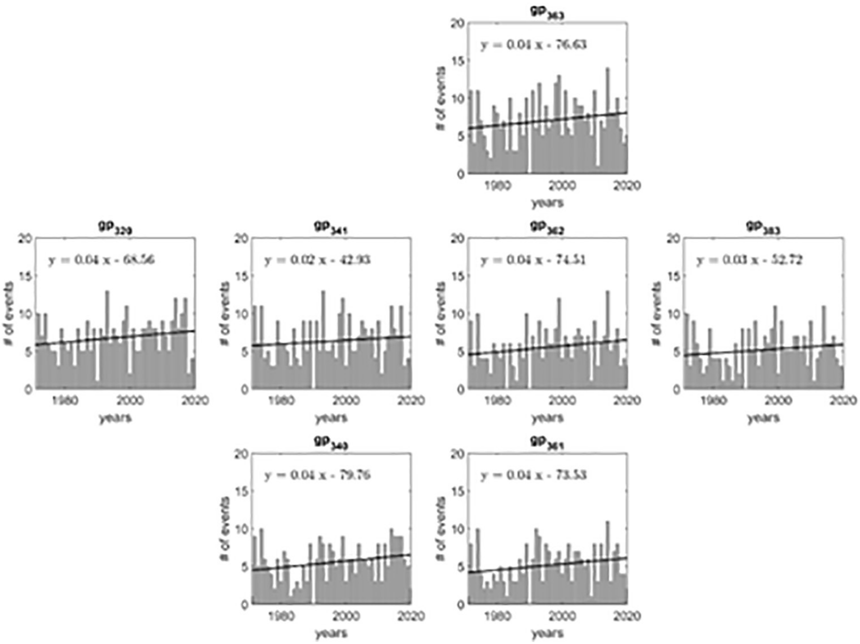


Fig. 2. Temporal changes in the annual number of the R ≥ 20 mm OMSZ's EPE observed daily precipitation totals for the period of 1971 to 2020 at all OMSZ grid points (gp).

In general, the lowest increase was observed for the R ≥ 40 mm EPEs with a mean slope of 0.0096 (0.96 events per 100 years).

In terms of grid point location, the values of grid points 340 (SW grid) and 362 (NE grid) indicated similar increase with slopes of 2.72 and 2.47 events per 100 years, respectively, while grid point 341 showed markedly lower slope (1.94 events per 100 years) for the same period.

Spatial comparison of the PHN and the OMSZ data for the period of 2013 to 2020

Marked differences were revealed in the frequencies of the EPEs between OMSZ and PHN datasets. Typically, the annual number of extreme events recorded by the PHN network was slightly higher than the annual numbers based on the OMSZ gridded dataset at most stations (*Figures 5, 6* and *7*). When

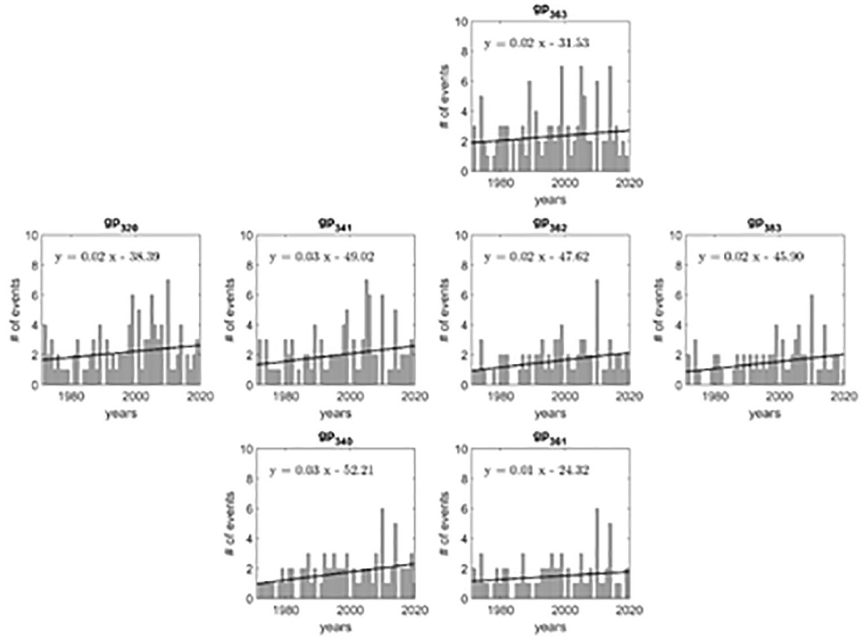


Fig. 3. Temporal changes in the annual number of the R ≥ 30 mm OMSZ's EPE observed daily precipitation totals for the period of 1971 to 2020 at all OMSZ grid points (gp).

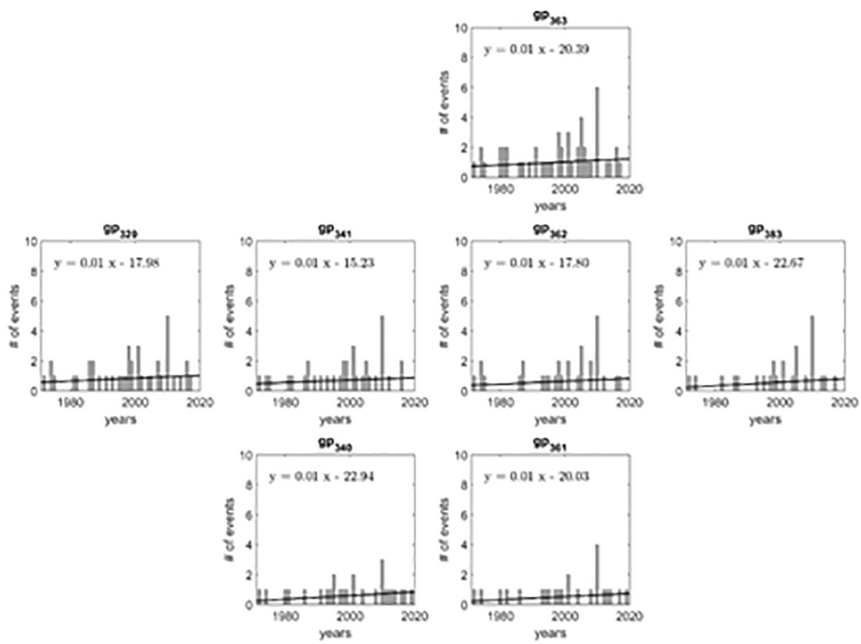


Fig. 4. Temporal changes in the annual number of the R ≥ 40 mm OMSZ's EPE observed daily precipitation totals for the period of 1971 to 2020 at all OMSZ grid points (gp).

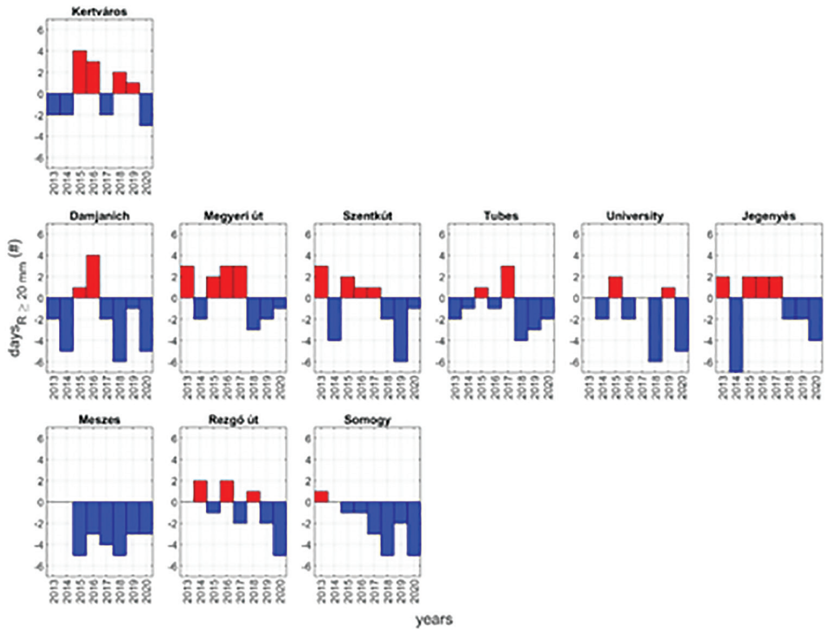


Fig. 5. Difference between the annual number of events of R ≥ 20 mm EPEs compared to the OMSZ dataset (baseline) at each PHN station for the period of 2013 to 2020. Calculation basis: OMSZ – PHN, hence blue columns show higher PHN frequencies, red colours higher OMSZ frequencies; top: grid point 340, centre: grid point 341, bottom: grid point 362).

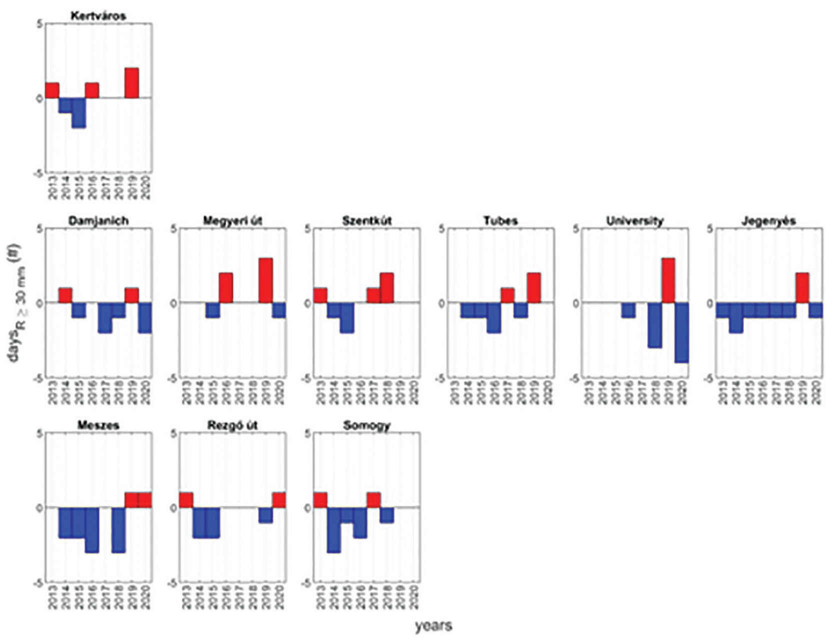


Fig. 6. Difference between the annual number of events of R ≥ 30 mm EPEs compared to the OMSZ dataset (baseline) at each PHN station for the period of 2013 to 2020. For further explanations see *Fig. 5*.

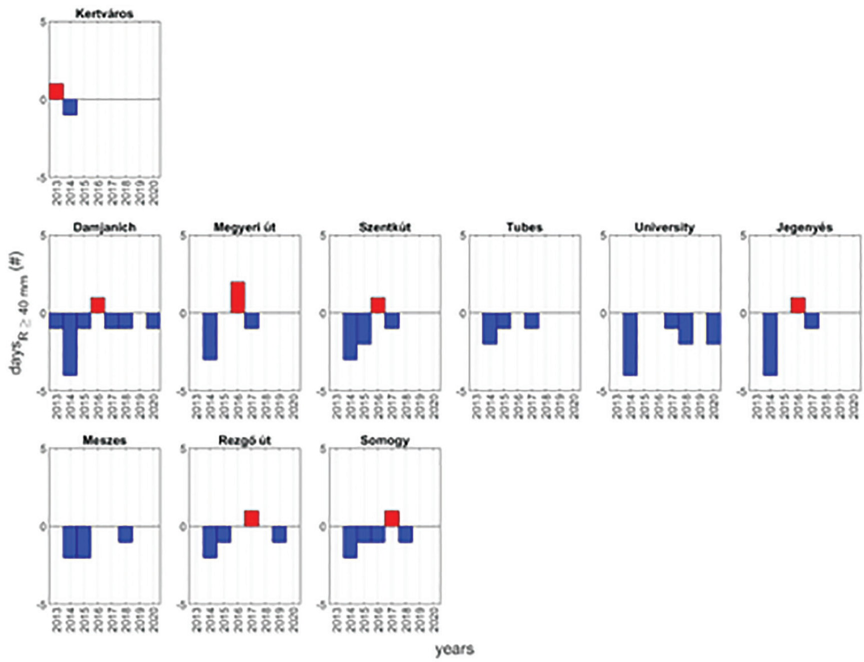


Fig. 7. Difference between the annual number of events of R ≥ 40 mm EPEs compared to the OMSZ dataset (baseline) at each PHN station for the period of 2013 to 2020. For further explanations see *Fig. 5.*

the total number of events was considered, marked differences were found among the three EPE categories.

Due to their higher number, the largest differences were observed for the R ≥ 20 mm EPEs. However, the relative differences were higher for the annual frequency of R ≥ 40 mm events than for the other two EPE frequencies. Nonetheless, the difference for the R ≥ 20 mm events was not distinctive and showed a rather equivocal pattern. The highest discrepancy of the R ≥ 20 mm events was found for the Damjanich station, while for the R ≥ 30 mm and the R ≥ 40 mm events the University station showed the greatest differences.

OMSZ frequencies were typically, but non-uniformly lower than the PHN frequencies at the studied grid points (see *Figures 5, 6* and *7*). At grid point 340, the number of R ≥ 20 mm events in PHN station, Kertváros (Garden City) were higher than the OMSZ dataset. In the years of 2013, 2014, 2017, 2018 and 2020, but were lower in the years of 2015, 2016 and 2018. The number of R ≥ 20 mm events of the PHN stations was higher than the OMSZ dataset in the year of 2013 at Damjanich and Tubes; in the year of 2014 at Damjanich, Jegenyés, Megyeri út and Szentkút; in the years of 2018 and 2019 all PHN stations registered higher number of events compared to the OMSZ data and in the year of 2020 at Damjanich, Jegenyés, Szentkút and Tubes. In the years of 2015, 2016 and 2017 all PHN stations registered a lower or equal number of events as the OMSZ.

At grid point 362, the number of R ≥ 20 mm events of the PHN stations was higher than the OMSZ dataset in 2015 at Meszes; in the year of 2017 at all stations; in the year of 2018 at Meszes and Somogy; in the years of 2019 and 2020 at all stations. In the years of 2013, 2014 and 2016 all PHN stations registered a lower or equal number of events compared to the OMSZ.

Opposed to the R ≥ 20 mm and R ≥ 30 mm events, significantly higher PHN frequencies were observed for the R ≥ 40 mm EPEs at all stations *(Figure 8).*

Therefore, when the PHN data were included in the temporal analysis, the increase of the frequency EPEs was even more pronounced than solely based on the OMSZ interpolated dataset.

Non-convective precipitation (rain, snow or sleet) and thunderstorms were found to be responsible for EPEs in Pécs over the studied period, assuming that the precipitation type of the Pécs-Pogány OMSZ station is representative for all PHN precipitation events. In some cases, however, the Pécs-Pogány station did not report any precipitation, whereas rainfall was detected by the PHN. These cases are represented by the category called 'not specified' in *Figure 8*. Non-specified events were classified as convective cases based on the observed amount and intensity of precipitation for analysation of occurrence of frequency in different categories. The frequency of non-convective rainfall events were a few percent higher than that of the convective cases. A slight gradient with decreasing differences from north (62–38%) to south (50–50%) is observable in the studied area. Minor differences were detected in an east-west direction with a slightly increasing gradient from west to east.

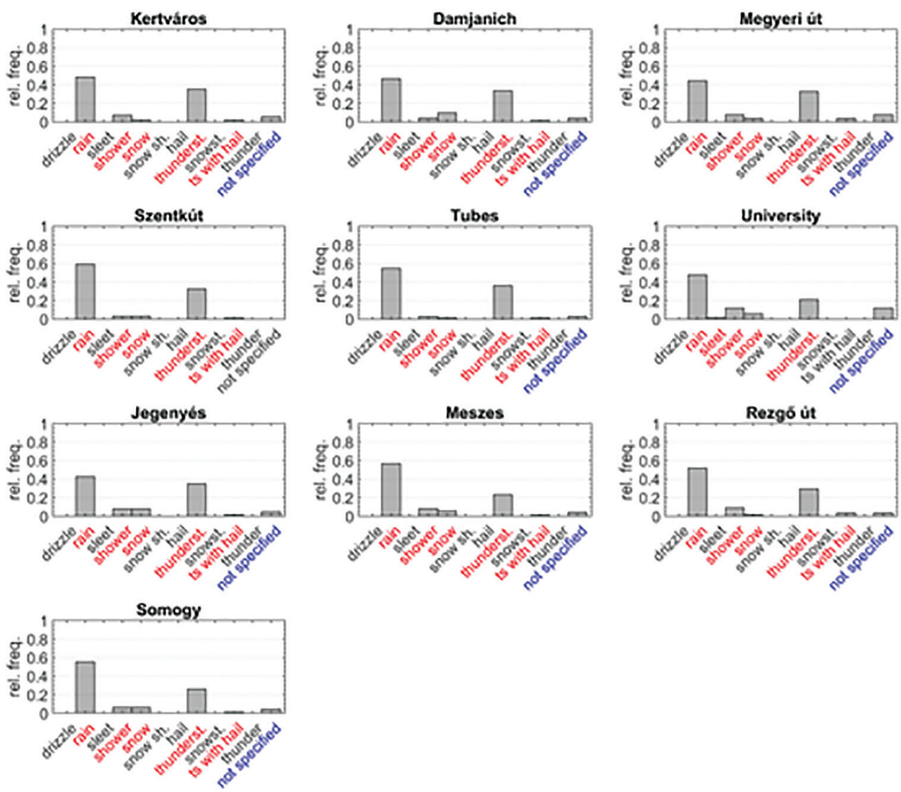


Fig. 8. Relative frequencies of the type of extreme precipitation events (R ≥ 20 mm) at different locations, for the period of 2013-2020. Red fonts highlight the events that occurred at the stations based on the reported type of precipitation at OMSZ Pécs-Pogány station. Blue fonts highlight non-specified events (the occurrence of EPE at PHN station, but OMSZ data did not report precipitation on the same day).

Spatial pattern of annual mean extreme rainfall events

The spatial distribution of the R ≥ 20 mm EPEs markedly differed between the two datasets *(Figure 9).* Firstly, as it was already claimed in chapter 3.2, in general, the PHN dataset indicated higher mean annual frequencies of EPEs than the OMSZ data for the period of 2013 to 2020. Secondly, contrast to the higher frequencies in the western and northern part of the city and the OMSZ dataset, the PHN dataset indicated the highest frequencies in the north-central part of Pécs along a SW-NE axis with an annual frequency of 8 to 9 events (see *Figure 9*, A and B). This frequency decreased to a minimum of 6.5 events yearly in the Pécs Basin (lowest

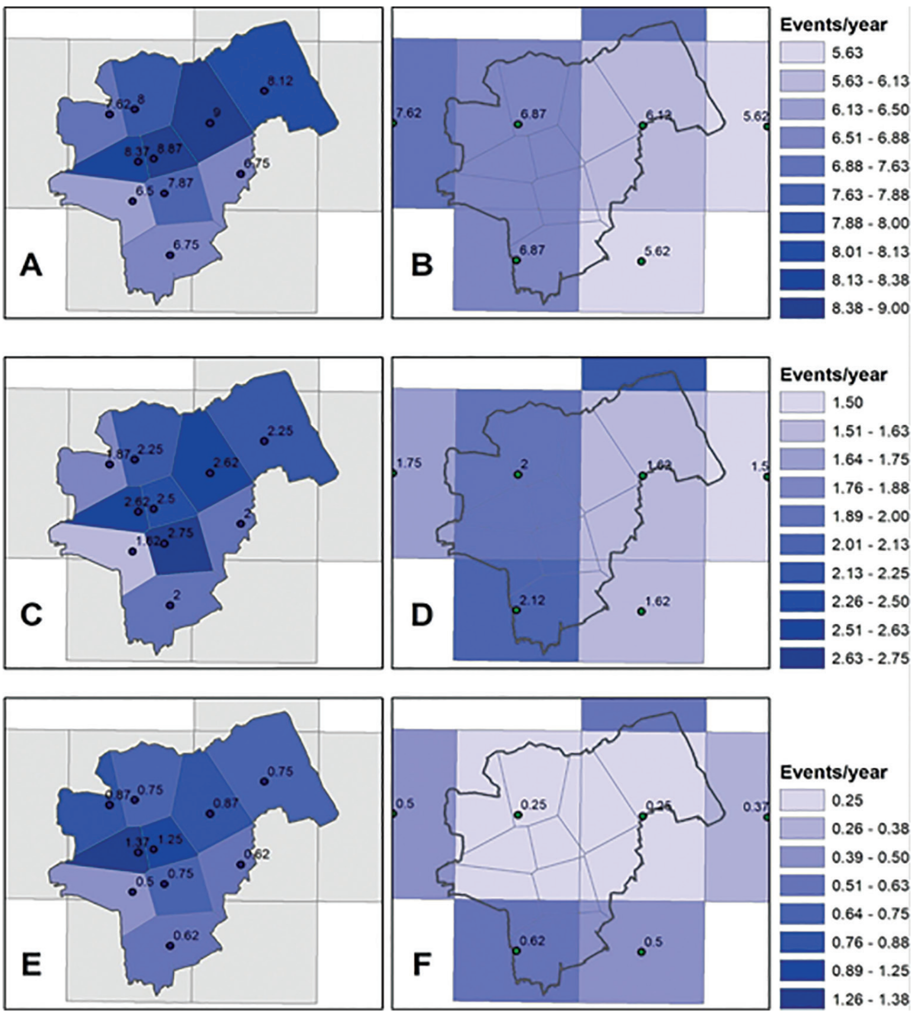


Fig. 9. Spatial distribution of the annual mean frequencies of the R ≥ 20 mm (A), R ≥ 30 mm (C), and R ≥ 40 mm (E) EPEs of the PHN stations and the corresponding values of the OMSZ grids (B, D and F) over the period of 2013 to 2020 in Pécs.

part of the city) and the southern outskirts. The PHN data revealed ever higher annual frequencies of the events with increasing elevation on the southern slopes of the Mecsek Hills; however, this pattern was more evident in the NE part of the city than in the NW.

The mean annual frequencies of the R ≥ 30 mm and R ≥ 40 mm EPEs showed a more similar pattern between the two datasets compared to the distribution of R ≥ 20 mm EPEs (see *Figure 9*, C and E). The OMSZ data revealed the highest frequencies in NE Pécs (grid 363, ~ 2.5 events per year) with a second maximum in the SW (2.12 events per year), based on R ≥ 30 mm events. Conversely, the PHN data showed a more marked dominance of higher frequencies in the central-eastern part of the city (~ 2.5 events/year). The highest frequencies were found in the south-central part of the city (Jegenyés) and in the north-eastern tip of Pécs, where OMSZ data indicated the lower frequency.

The spatial distribution of the R ≥ 40 mm EPEs of the PHN again showed a SW-NE gradient in contrast to the mosaic pattern of the OMSZ data (for the R ≥ 20 mm and R ≥ 30 mm events). The OMSZ data indicated no topographic influence with a maximum of about 0.6 events per year for the southern corner of the city, showing no effect of orography. Adversely, the PHN dataset showed a marked orographic gradient with a second SW-NE gradient in northern Pécs (see *Figure 9*, E and F).

Spatial pattern of seasonal frequencies of the EPEs

Our findings revealed profound seasonal differences for both the R ≥ 20 mm and R ≥ 40 mm events (*Figure 10*). Due to the climatic characteristics of the study area (Breuer, H. *et al.* 2017), the lowest frequencies of EPEs were found in winter (DJF), while the highest frequencies prevailed in summer (JJA) and fall (SON). As long as MAM, SON and DJF demonstrated higher frequencies in the northern neighbourhoods of Pécs. JJA presented a maximum in the centre of the city, separating lower frequency parts on the western and eastern locations while the OMSZ had a distinct maximum in the south (grid point 340). For the winter data, the PHN and the OMSZ datasets were rather similar. The largest differences were found during summer and autumn between the two datasets. While the PHN dataset showed a relatively centralized maximum in central Pécs for the summer, the maximum of the OMSZ was found in the south. A marked difference was found in the distribution of EPEs in SON where the OMSZ data was characterized with a distinct W-E separation in contrast to the NE dominance of EPEs in the PHN.

Discussion

Corroborating the findings of Kovács, A. and Kovács, P. 2007, and Kovács, E. *et al*. 2018 to a certain degree, the frequencies of EPEs were slightly higher on the southern slopes of the Mecsek Hills than in its southern foreground (Pécs Basin and Baranya Hills). The low orographic influence of the southern slopes of the Mecsek Hills, is in a partial accordance with the findings of Jakab, G. *et al.* (2019), and Lakatos, M. *et al.* (2020), who found higher frequencies of EPEs and maximum mean precipitation totals respectively for some of the hilly and mountainous areas of Hungary. Nonetheless, alongside with the higher annual rainfall totals, the orography-generated surplus frequency of EPEs in the Mecsek presumes the increasing likelihood of flash flood events, mass movements and intense soil erosion (Fábián, Sz. *et al.* 2006, 2009, 2016; Kovács, I.P. *et al*. 2015).

Consequently, monitoring networks do not only provide scientific data on rainfall pattern but may also function as a tool for flood mitigation and prevention (Czigány, Sz. *et al.* 2010b), management of ecosystem services (Syrbe, R.-U. and Grunewald, K. 2017) and may also be indispensable for the protection of farmlands, urban areas and habitats of endangered species (Nagy, G. *et al.* 2020). Additionally, weather monitoring networks seem to be suitable to reveal the

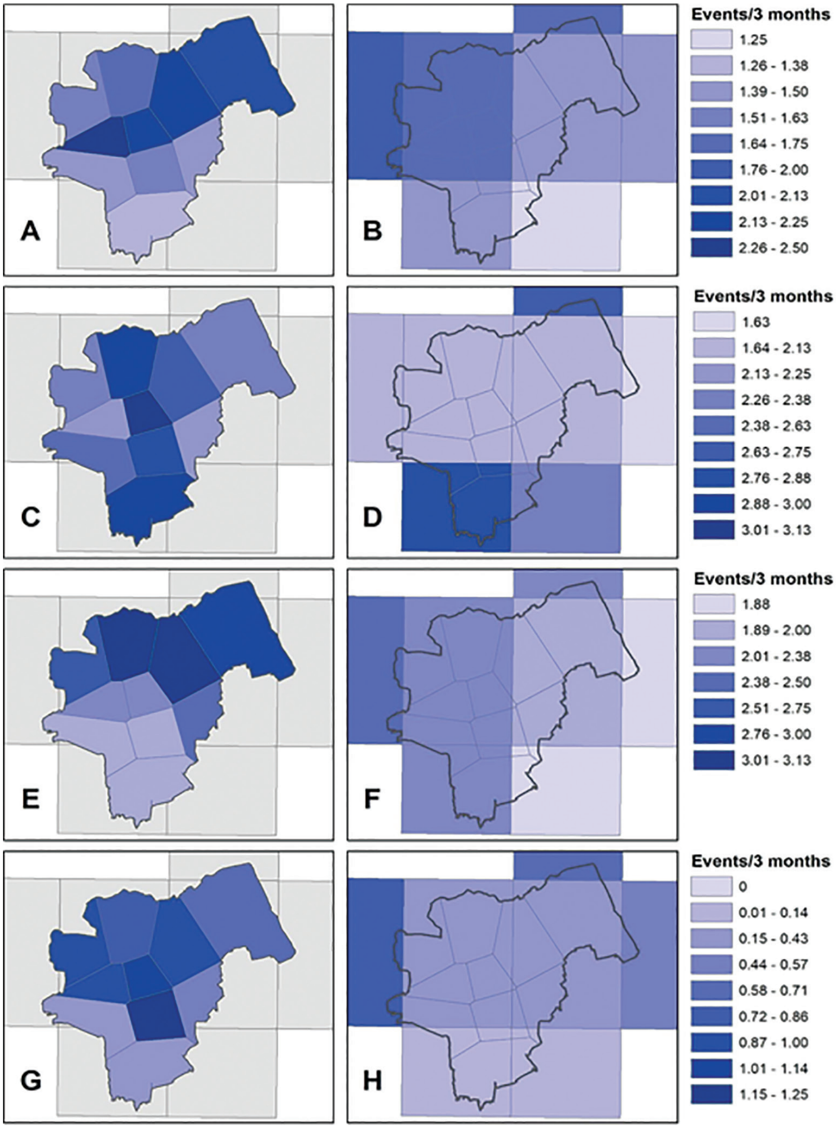


Fig. 10. Spatial distribution of the seasonal mean frequencies of the R ≥ 20 mm PHN EPEs (A, C, E and G) and the corresponding values of the OMSZ grids (B, D, F and H) over the period of 2013 to 2020 in Pécs, from spring (A and B) to winter (G and H), from top to bottom.

intensity, location and timing of EPEs, especially in developed areas, where hydrologic, erosional and geomorphic consequences of intense rainfall may threaten human lives and generate significant economic losses.

We found gridded OMSZ data suitable for the characterization of short-term mesoclimatic conditions of Pécs. However, compared to the PHN, some EPEs were absent in the OMSZ due to the different locations of the points of observation in the two datasets. Additionally, due to the blurring of the interpolation algorithm significant differences were generated between the two analysed datasets. Whereas the city of Pécs only covers a land area of 164 km^2, still, its rugged topography may contribute to the sporadic nature and large spatial heterogeneity of intense rainfalls especially in summer. Our results pointed out the adequacy of interpolated datasets for mesoscale detection of EPE distribution. Nonetheless, topographically representative monitoring networks provide more detailed microscale data for the hydrological management of urban areas. Additionally, data of dense rain gauge networks may complement interpolated datasets, facilitating the feasibility of complex environmental management strategies and precautionary measures, particularly during weather related catastrophes.

Conclusions

The following conclusions have been drawn from the present study:

i. The spatial pattern of the EPEs revealed differences between the OMSZ and the PHN datasets; on mesoclimatic scale OMSZ data is suitable for spatial analysis, however, particularly in summer, measured data are indispensable for flood forecasting. The PHN stations demonstrate a rather heterogeneous environment in respect of elevation, aspect and land use class among others. Nonetheless, the value of the grid point is not necessarily representative for the entire grid box, as precipitation values may be altered by various environmental factors (such as topography, land use type, vegetation, etc.). Given synoptic situations may be corrected in terms of the differences when the two datasets are compared, provided that the situations are correctly identified, and the comparative analysis is sufficiently long and contains a large number of EPEs. Therefore, the PHN can be used for the enhancement of the spatial pattern and resolution of the OMSZ dataset. Ground monitoring will also point out the spatial heterogeneity of climate in relatively small urban areas with rugged topography.

ii. In partial accordance with the OMSZ gridded dataset, the spatial pattern of the PHN-based EPEs in Pécs demonstrated a slight effect of topography and elevation;

iii. The temporal trend of the annual frequency of EPEs indicated a slight increase over the period of 1971 to 2020 for the OMSZ data;

iv. Compared to the PHN data, the annual frequency of the OMSZ dataset demonstrated an ambivalent picture, i.e., showed similar frequencies based on the R ≥ 20 mm and the R ≥ 30 mm EPEs but revealed higher frequencies for the R ≥ 40 mm EPEs over the period of 2013 to 2020.

v. Although the elevation-corrected gridded OMSZ dataset reflected the actual pattern of EPEs for Pécs with a relatively high accuracy, it cannot entirely replace data obtained by a dense rain gauge network.

vi. Our findings could potentially contribute to the correct parameterization of hydrological models, hence may be employed by urban planners. This study and its key conclusions may serve as a basis for the development and clarification of currently operating water resources management models. The experience gained will be used during practical water management activities to ensure a more even water supply for the end-users.

***Acknowledgement*:** The authors are grateful to Attila Sárosi and Tettye Forrásház Ltd. for their support and work on the maintenance and smooth operation of the rain gauge network. We thank the editors and the reviewers for careful thoughts and useful comments. The authors are indebted to Dénes Lóczy for revising and proofreading the English of the manuscript.'

REFERENCES

Ács, F., Breuer, H. and Skarbit, N. 2015. Climate of Hungary in the twentieth century according to Feddema. *Theoretical and Applied Climatology* 119. (1–2): 161–169. Available at https://doi.org/10.1007/s00704-014-1103-5

Balatonyi, L., Lengyel, B. and Berger, Á. 2022. Nature-based solutions as water management measures in Hungary. *Modern Geográfia* 17. (1): 73–85. Available at https://doi.org/10.15170/MG.2022.17.01.05

Bartholy, J. and Pongrácz, R. 2007. Regional analysis of extreme temperature and precipitation indices for the Carpathian Basin from 1946 to 2001. *Global and Planetary Change* 57. (1–2): 83–95. Available at https://doi.org/10.1016/j.gloplacha.2006.11.002

Berényi, A., Pongrácz, R. and Bartholy, J. 2021. Changes in extreme precipitation patterns in the southern lowland regions of Europe during the 1951–2019 period. *Modern Geográfia* 16. (4): 85–101. Available at https://doi.org/10.15170/MG.2021.16.04.05

Bötkös, T. 2006. Precipitation trends in Pécs. In *Sustainable Development in Central Europe. Pollution and Water Resources.* Ed.: Halasi-Kun, G.J., Columbia University Seminar Proceedings, Vol. 36. Pécs, PTE. 171–177.

Breuer, H., Ács, F. and Skarbit, N. 2017. Climate change in Hungary during the twentieth century according to Feddema. *Theoretical and Applied Climatology* 127. (3–4): 853–863. Available at https://doi.org/10.1007/s00704-015-1670-0

Cheval, S., Dumitrescu, A. and Birsan, M-V. 2017. Variability of the aridity in the South-Eastern Europe over 1961–2050. *Catena* 151. 74–86. Available at https://doi.org/10.1016/j.catena.2016.11.029

Czigány, Sz., Pirkhoffer, E. and Geresdi, I. 2010a. Impact of extreme rainfall and soil moisture on flash flood generation. *Időjárás – Quarterly Journal of the Hungarian Meteorological Service* 114. (1–2): 79–100.

Czigány, Sz., Pirkhoffer, E., Balassa, B., Bugya, T., Bötkös, T., Gyenizse, P., Nagyváradi, L., Lóczy, D. and Geresdi, I. 2010b. Villámárvíz, mint természeti veszélyforrás a Dél-Dunántúlon (Flash floods as a natural hazard in Southern Transdanubia). *Földrajzi Közlemények* 134. (3): 281–298.

Czigány, Sz., Pirkhoffer, E., Lóczy, D. and Balatonyi, L. 2013. Flash flood analysis for Southwest-Hungary. In *Geomorphological Impacts of Extreme Weather.* Ed.: Lóczy, D., Springer Geography series. Dordrecht, Springer, 67–82.

Dövényi, Z. (ed.) 2010. *Magyarország kistájainak katasztere* (Inventory of microregions in Hungary). Budapest, MTA Földrajztudományi Kutatóintézet. (in Hungarian)

Fábián, Sz.Á., Kovács, J., Lóczy, D., Schweitzer, F., Varga, G., Babák, K., Lampért, K. and Nagy, A. 2006. Geomorphologic hazards in the Carpathian foreland, Tolna County (Hungary). *Studia Gemorphologica Carpatho Balcanica* 40. 107–118.

Fábián, Sz.Á., Görcs, N.L., Kovács, I.P., Radvánszky, B. and Varga, G. 2009. Reconstruction of flash flood event in a small catchment: Nagykónyi, Hungary. *Zeitschrift für Geomorphologie* 53. Suppl. 2. 123–138. Available at http://dx.doi.org/10.1127/0372-8854/2009/0053S3-0123

Fábián, Sz.Á., Kalmár, P., Józsa, E. and Sobucki, M. 2016. Hydrogeomorphic exploration of a local headwater stream in low mountainous environment following detailed field survey protocol (Mecsek Mountains, Hungary). *Revista De Geomorfologie* 18. 77–90. Available at https://doi.org/10.21094/rg.2016.134

Geresdi, I., Xue, L. and Rasmussen, R. 2017. Evaluation of orographic cloud seeding using bin microphysics scheme: Two-dimensional approach. *Journal of Applied Meteorology and Climatology* 56. (5): 1443–1462. Available at https://doi.org/10.1175/JAMC-D-16-0045.1

Geresdi, I., Xue, L., Sarkadi, N. and Rasmussen, R. 2020. Evaluation of orographic cloud seeding using bin microphysics scheme. Three-dimensional simulation of real cases. *Journal of Applied Meteorology and Climatology* 59. (9): 1537–1555. Available at https://doi.org/10.1175/JAMC-D-19-0278.1

Grazzini, F., Craig, G., Keil, C., Antolini, G. and Pavan, V. 2019. Extreme precipitation events over Northern Italy. Part I: a systematic classification with machine learning techniques. *Quarterly Journal of the Royal Meteorological Society* 146. (726): 69–85. Available at https://doi.org/10.1002/qj.3635

Hanel, M., Vizina, A., Máca, P. and Pavlásek, J. 2012. A multi-model assessment of climate change impact on hydrological regime in the Czech Republic. *Journal of Hydrology and Hydromechanics* 60. (3): 152–161. Available at https://doi.org/10.2478/v10098-012-0013-4

Houze, R.A. 2012. Orographic effects on precipitating clouds. *Reviews of Geophysics* 50. (1): 1–47. Available at https://doi.org/10.1029/2011RG000365

Houze, R.A. 2014. Clouds and precipitation associated with hills and mountains. *Cloud Dynamics* 104. 369–402. Available at https://doi.org/10.1016/B978-0-12-374266-7.00012-3

Jakab, G., Biró, T., Kovács, Z., Papp, Á., Sarawut, N., Szalai, Z., Madarász, B. and Szabó, Sz. 2019. Spatial analysis of changes and anomalies of intense rainfalls in Hungary. *Hungarian Geographical Bulletin* 68. (3): 241–253. Available at https://doi.org/10.15201/hungeobull.68.3.3

Józsa, E., Lóczy, D., Soldati, M., Drăguţ, L.D. and Szabó, J. 2019. Distribution of landslides reconstructed from inventory data and estimation of landslide susceptibility in Hungary. *Hungarian Geographical Bulletin* 68. (3): 255–267. Available at https://doi.org/10.15201/hungeobull.68.3.4

Karlsson, I.B., Sonnenborg, T.O., Refsgaard, J.Ch., Trolle, D., Børgesen, C.D., Olesen, J.E., Jeppesen, E. and Jensen, K.H. 2016. Combined effects of climate models, hydrological model structures and land use scenarios on hydrological impacts of climate change. *Journal of Hydrology*

535. 301–317. Available at https://doi.org/10.1016/j.jhydrol.2016.01.069

Kis, A., Pongrácz, R., Bartholy, J. and Szabó, J.A. 2020. Projection of runoff characteristics as a response to regional climate change in a Central/Eastern European catchment. *Hydrological Sciences Journal* 65. (13): 2256–2273. Available at https://doi.org/10.1080/02626667.2020.1798008

Kirshbaum, D., Adler, B., Kalthoff, N., Barthlott, C. and Serafin, S. 2018. Moist orographic convection: Physical mechanisms and links to surface-exchange processes. *Atmosphere* 9. (3):80. Available at https://doi.org/10.3390/atmos9030080

Kocsis, T. and Anda, A. 2017. Analysis of precipitation time series at Keszthely, Hungary (1871–2014). *Időjárás – Quarterly Journal of the Hungarian Meteorological Service* 121. (1): 63–78.

Kovács, A. and Kovács P. 2007. Árvíz a Szinván: az orografikus csapadéktöbblet egy extrém esete (Flood on the Szinva Stream: an extreme case of orographic precipitation surplus). *Légkör* 52. (4): 5–8.

Kovács, A. and Jakab, A. 2021. Modelling the impacts of climate change on shallow groundwater conditions in Hungary. *Water* 13. (5): 668. Available at https://doi.org/10.3390/w13050668

Kovács, E., Puskás, J., Bán, Zs.B. and Kozma, K. 2018. Agro-climatological investigation in Kőszeghegyalja and Vas-hegy (Hungary). *Légkör* 63. (2): 68–74.

Kovács, I.P., Czigány, Sz., Józsa, E., Varga, T., Varga, G., Pirkhoffer, E. and Fábián, Sz.Á. 2015. Geohazards of the natural protected areas in Southern Transdanubia (Hungary). *Dynamiques Environnementales* 35. 97–110. Available at https://doi.org/10.4000/dynenviron.1182

Kovács, I.P., Czigány, Sz., Dobre, B., Fábián, Sz.Á., Sobucki, M., Varga, G. and Bugya, T. 2019a. A field survey–based method to characterise landslide development: a case study at the high bluff of the Danube, south-central Hungary. *Landslides* 16. 1567–1581. Available at https://doi.org/10.1007/s10346-019-01205-8

Kovács, I.P., Bugya, T., Czigány, Sz., Defilippi, M., Lóczy, D., Riccardi, P., Ronczyk, L. and Pasquali, P. 2019b. How to avoid false interpretations of Sentinel-1A TOPSAR interferometric data in landslide mapping? A case study: recent landslides in Transdanubia, Hungary. *Natural Hazards* 96. 693–712. Available at https://doi.org/10.1007/s11069-018-3564-9

Kunz, M. and Kottmeier, C. 2006. Orographic enhancement of precipitation over low mountain ranges. Part I: Model formulation and idealized simulations. *Journal of Applied Meteorology and Climatology* 45. (8): 1025–1040. Available at https://doi.org/10.1175/JAM2389.1

Lakatos, M. and Hoffmann, L. 2019. Növekvő csapadékintenzitás, magasabb mértékadó csapadékok a változó klímában (Increasing trend in short term precipitation and higher return levels due to climate change). In *Országos Települési Csapadékvízgazdálkodási Konferencia tanulmányai*. Ed.: Biró, T., Budapest, Dialóg Campus Kiadó, 8–16. Available at https://vtk.uni-nke.hu/document/vtk-uni-nke-hu/K%C3%A9zik%C3%B6nyv_csapad%C3%A9k.pdf (in Hungarian)

Lakatos, M., Izsák, B., Szentes, O., Hoffmann, L., Kircsi, A. and Bihari, Z. 2020. Return values of 60-minute extreme rainfall for Hungary. *Időjárás – Quarterly Journal of the Hungarian Meteorological Service* 124. (2): 143–156.

Lovász, Gy. 1977. *Baranya megye természeti földrajza* (Physical geography of Baranya county). Pécs, Baranya Megyei Levéltár.

Lovino, M., García, N.O. and Baethgen, W. 2014. Spatiotemporal analysis of extreme precipitation events in the Northeast region of Argentina (NEA). *Journal of Hydrology: Regional Studies* 2. 140–158. Available at https://doi.org/10.1016/j.ejrh.2014.09.001

Maheras, P., Tolika, K., Anagnostopoulou, C., Makra, L., Szpirosz, K. and Károssy, Cs. 2018. Relationship between mean and extreme precipitation and circulation types over Hungary. *International Journal of Climatology* 38. (12): 4518–4532. Available at https://doi.org/10.1002/joc.5684

Malby, A.R., Whyatt, J.D., Timmis, R.J., Wilby, R.L. and Orr, H.G. 2007. Long-term variations in orographic rainfall: analysis and implications for upland catchments. *Hydrological Sciences Journal* 52. (2): 276–291. Available at https://doi.org/10.1623/hysj.52.2.276

Minder, J.R., Durran, D.R., Roe, G.H. and Anders, A.M. 2008. The climatology of small-scale orographic precipitation over the Olympic Mountains: Patterns and processes. *Quarterly Journal of the Royal Meteorological Society* 134. (633): 817–839. Available at https://doi.org/10.1002/qj.258

Nagy, G., Lóczy, D., Czigány, Sz., Pirkhoffer, E., Fábián, Sz.Á., Ciglič, R. and Ferk, M. 2020. Soil moisture retention on slopes under different agricultural land uses in hilly regions of Southern Transdanubia. *Hungarian Geographical Bulletin* 68. (2): 263–280. Available at https://doi.org/10.15201/hungeobull.69.3.3

Napoli, A., Crespi, A., Ragone, F., Maugeri, M. and Pasquero, C. 2019. Variability of orographic enhancement of precipitation in the Alpine region. *Scientific Reports* 9. 13352. Available at https://doi.org/10.1038/s41598-019-49974-5

Pásztor, L., Waltner, I., Centeri, Cs., Belényesi, M. and Takács, K. 2016. Soil erosion of Hungary assessed by spatially explicit modelling. *Journal of Maps* 12. Supplement 1, 407–414. Available at https://doi.org/10.1080/17445647.2016.1233913

Pavelsky, T.M., Sobolowski, S., Kapnick, S.B. and Barnes J.B. 2012. Changes in orographic precipitation patterns caused by a shift from snow to rain. *Geophysical Research Letters* 39. L18706. Available at https://doi.org/10.1029/2012GL052741

Péczely, Gy. 1981. *Éghajlattan* (Climatology). Budapest, Tankönyvkiadó.

Pieczka, I., Pongrácz, R. and Bartholy, J. 2011. Comparison of simulated trends of regional climate change in the Carpathian Basin for the 21st century using three different emission scenarios. *Acta Silvatica and Lignaria Hungarica* 7. 9–22.

Pirkhoffer, E., Czigány, Sz. and Geresdi, I. 2009. Impact of rainfall pattern on the occurrence of flash floods in Hungary. *Zeitschrift für Geomorphologie* 53. Supplementary Issue 2. 139–157. Available at http://dx.doi.org/10.1127/0372-8854/2009/0053S3-0139

Pongrácz, R., Bartholy, J. and Kiss, A. 2014. Estimation of future precipitation conditions for Hungary with special focus on dry periods. *Időjárás – Quarterly Journal of the Hungarian Meteorological Service* 118. (4): 305–321.

Roe, G.H., Montgomery, D.R. and Hallet, B. 2003. Orographic precipitation and the relief of mountain ranges. *Journal of Geophysical Research: Solid Earth* 108. (B6): Available at https://doi.org/10.1029/2001JB001521

Roe, G.H. 2005. Orographic precipitation. *Annual Review of Earth and Planetary Sciences* 33. 645–671. Available at https://doi.org/10.1146/annurev.earth.33.092203.122541

Ronczyk, L., Czigány, Sz., Balatonyi, L. and Kriston, Á. 2012. Effects of excess urban runoff on wastewater flow in Pécs, Hungary. *Riscuri si Catastrofe* 11. 144–159.

Sarkadi, N., Geresdi, I. and Thompson, G. 2016. Numerical simulation of precipitation formation in the case of an orographically induced convective cloud: Comparison of the results of bin and bulk microphysical schemes. *Atmospheric Research* 180. 241–261. Available at https://doi.org/10.1016/j.atmosres.2016.04.010

Scaff, L., Rutllant, J.A., Rahn, D., Gascoin, S. and Rondanelli, R. 2017. Meteorological interpretation of orographic precipitation gradients along an Andes west slope basin at 30°S (Elqui Valley, Chile). *Journal of Hydrometeorology* 18. (3): 713–727. Available at https://doi.org/10.1175/JHM-D-16-0073.1

Schneck, T., Telbisz, T. and Zsuffa, I. 2021. Precipitation interpolation using digital terrain model and multivariate regression in hilly and low mountainous areas of Hungary. *Hungarian Geographical Bulletin* 70. (1): 35–48. Available at https://doi.org/10.15201/hungeobull.70.1.3

Syrbe, R.-U. and Grunewald, K. 2017. Ecosystem service supply and demand – the challenge to balance spatial mismatches. *International Journal of Biodiversity Science, Ecosystem Services & Management* 13. (2): 148–161. Available at https://doi.org/10.1080/21513732.2017.1407362

Szentimrey, T. and Bihari, Z. 2007. Mathematical background of the spatial interpolation methods and the software MISH (Meteorological Interpolation based on Surface Homogenized Data Basis). In *Proceedings from the Conference on Spatial Interpolation in Climatology and Meteorology*, Budapest, Hungary, 2004. COST Action 719, Budapest, COST Office, 17–27.

Veals, P.G., Steenburgh, W.J. and Campbell, L.S. 2018. Factors affecting the inland and orographic enhancement of lake-effect precipitation over the Tug Hill Plateau. *Monthly Weather Review* 146. (6): 1745–1762. Available at https://doi.org/10.1175/MWR-D-17-0385.1

Waltner, I., Saeidi, S., Grósz, J., Centeri, Cs. Laborczi, A. and Pásztor, L. 2020. Spatial assessment of the effects of land cover change on soil erosion in Hungary from 1990 to 2018. *International Journal of Geo-Information* 9. 667. Available at https://doi.org/10.3390/ijgi9110667

APPENDIX

Missing or incorrect data were found on the following days at the PHN stations:

Kertváros	4–12 March, 2020
Damjanich	15–26 October, 2015
	from 11 November, 2016 to January, 2017
Megyeri	7–8 March, 2015
Szentkút	from 1 January to 31 March, 2013
	from 28 December to 11 January, 2015
	28 March, 2018
	3–4 April, 2018
	from 16 April to 6 May, 2018
Tubes	26–27 September, 2015
	10–11 October, 2015
	22–25 September, 2017
Meszes	from 1 January to 31 March, 2013
	23–28 February, 2016
Rezgő út	22–30 November, 2015
	3 April, 2016
	13–28 August, 2016
	4–8 January, 2017
	20–22 February, 2017
	21–24 September, 2017

DOI: 10.15201/hungeobull.71.3.3 Hungarian Geographical Bulletin **71** 2022 (3) 249–269.

Age-group-based evaluation of residents' urban green space provision: Szeged, Hungary. A case study

Ronald András KOLCSÁR[1], Ákos K. CSETE[2], Anna KOVÁCS-GYŐRI[3] and Péter SZILASSI[1]

Abstract

Analysis of urban green space (UGS) provision is becoming increasingly important from an urban-planning perspective, as processes related to climate change tend to worsen the urban heat-island effect. In the present study, we aimed to map the UGS provision of Szeged, Hungary, using a GIS-based complex approach. Different age groups, especially the elderly, have different demands on the ecosystem services and infrastructure of UGSs. To provide an in-depth assessment of UGS provision for planners, we analysed the UGS availability and accessibility, using sub-block-level population data, which includes not only the total number of residents but also provides information about the age-group distribution for each building of the city. We delineated areas having different UGS provision levels (called provision zones) and assessed the age distribution of the residents living in each zone. We found that the residents within 2-min walking distance to public green spaces are older than expected by comparison to the age distribution of Szeged. In provision zones with abundant locally available UGSs (measured as UGS per capita within 50-m buffers), we found that the youngest (0–18 years) and oldest (≥ 61 years) inhabitants are overrepresented age groups, while the age group 19–40 has the lowest overall UGS provision within the city of Szeged. Our research, which has the potential to be adapted to other settlements, contributes to the identification of UGS-deficit areas in a city, thereby providing essential information for urban planners about where increases in UGS are most needed and helping to assess infrastructural enhancements that would be adequate for the locally most-dominant age groups.

Keywords: availability, accessibility, provision, urban park, green infrastructure

Received June 2022, accepted September 2022.

Introduction

The term urban green space (UGS) is defined by World Health Organization as an urban area covered by any kind of vegetation (WHO 2017; WHO Regional Office for Europe 2017). UGSs are among the main contributors to human well-being within a city (Neuvonen, M. *et al*. 2007; James, P. *et al*. 2009; Schipperijn, J. *et al*. 2010; Rossi, S.D. *et al*. 2015; Kothencz, G. *et al*. 2017; Kovács-Győri, A. *et al*. 2018; Csete, Á.K. *et al*. 2021). UGSs also contribute to the liveability of a settlement through a high variety of positive effects, which are collectively known as ecosystem services (MEA 2005; Makovníková, J. *et al*. 2019; CICES 2022). Via evapotranspiration and shading, vegetation impacts microclimates (MEA 2005; Takács, Á. *et al*. 2016; CICES 2022; TEEB 2022). The urban heat island effect, which is an increasingly significant problem in modern cities can also be mitigated by UGSs (Gál, T. *et al*. 2016; Henits, L. *et al*. 2016; Herbel, I. *et al*. 2016; Pongrácz, R. *et al*. 2016; Mucsi, L. *et al*. 2017). Other important regulating functions of UGSs include surface-runoff mitigation, the enhancement of air quality, as well as wind speed and noise reduction (MEA 2005; Csete, Á.K. and Gulyás, Á.

[1] Department of Geoinformatics, Physical and Environmental Geography, University of Szeged. Egyetem u. 2–6. H-6722 Szeged, Hungary. Correspondent author's e-mail: kolcsar@geo.u-szeged.hu
[2] Institute of Ecology and Botany, Centre for Ecological Research, Alkotmány u. 2-4. H-2163 Vácrátót, Hungary.
[3] IDA Lab, Paris-Lodron-Universität Salzburg, Jakob-Haringer-Str. 6. 5020 Salzburg, Austria.

2021; CICES 2022; TEEB 2022). Additionally, vegetation in private and community gardens may also contribute to food provision (MEA 2005; CICES 2022; TEEB 2022). In the form of cultural ecosystem services, UGSs help to create an aesthetic and calm environment ideal for both physical recreation and spiritual rejuvenation (MEA 2005; Razak, M.A.W.A. *et al*. 2016; Ayala-Azcárraga, C. *et al*. 2019; Szilassi, P. *et al*. 2020; Cheng, Y. *et al*. 2021; CICES 2022; TEEB 2022).

Considering all the advantages that UGSs provide, it is not unexpected that recently the issue of proper UGS provision has been receiving ever-growing attention within the field of urban planning (Zepp, H. *et al*. 2020). However, the definition and measurement of UGS provision and access are not uniform among researchers (Wolch, J.R. *et al*. 2014; Ekkel, E.D. and de Vries, S. 2017; Wüstemann, H. *et al*. 2017; Blaschke, T. and Kovács-Győri, A. 2020; Wu, L. and Kim, S.K. 2021). For example, Le Texier, M. *et al*. (2018) specified four levels of UGS provision and access: availability, fragmentation, public-private ownership, and accessibility. Other researchers identified five components of green space access, a concept similar to UGS provision: virtual access, viewing, utilizing and being in green space, active hands-on engagement, and ownership and/or management (Weldon, S. *et al*. 2007; Edwards, D. *et al*. 2009).

One of the most well-systematized definitions in connection with UGS provision comes from Biernacka, M. and Kronenberg, J. (2019). Their approach involves three levels of UGS provision: availability, accessibility, and attractiveness. Among these three, UGS availability is the most fundamental, as it indicates whether green space exists within a given proximity. The most common method for the evaluation of UGS availability is the calculation of the total area of UGSs within a buffer zone; it is most commonly measured in hectares or square metres per capita (Fuller, R.A. and Gaston, K.J. 2009; Kabisch, N. and Haase, D. 2014; Kabisch, N. *et al*. 2016; Biernacka, M. and Kronenberg, J. 2019; Biernacka, M. *et al*. 2020; Kolcsár, R.A. *et al*. 2021). Csomós, G. *et al*. (2021), however, used different, more-complex methodologies to quantify UGS availability. Owing to various physical or psychological barriers, the second level of UGS provision, UGS accessibility, is not guaranteed to all or to part of the population for any particular existing (and, thus, available) UGS (Wright, W.H.E. *et al*. 2012; Park, K. 2017; Biernacka, M. and Kronenberg, J. 2019; Biernacka, M. *et al*. 2020; Kolcsár, R.A. *et al*. 2021). Physical accessibility means the lack of physical barriers (e.g., busy streets, fences or buildings) along the road that can potentially hinder or preclude access to a given green space (Biernacka, M. and Kronenberg, J. 2019). Buildings and road networks also can highly modify pedestrian travel times by making the route between the starting point and destination far longer than the straight-line distance between the two points (Kolcsár, R.A. *et al*. 2021). Psychological accessibility is defined by more-abstract barriers, such as the real or perceived relative safety of areas that some might choose to avoid, thereby lengthening their travel time to the UGS (Park, K. 2017). UGS accessibility is usually mapped either within buffer zones (Oh, K. and Jeong, S. 2007; Wright, W.H.E. *et al*. 2012; Braquinho, C. *et al*. 2015; Bahrini, F. *et al*. 2017; Koprowska, K. *et al*. 2018; Csomós, G. *et al*. 2020) or with more-accurate methods (such as service areas) based on road networks (Shahid, R. *et al*. 2009; Le Texier, M. *et al*. 2018; Mora-Garcia, R.T. *et al*. 2018; Kolcsár, R.A. *et al*. 2021), and even more elaborate methods based on least cost path algorithms (e.g., using AccessMod and CostDistance) have been devised, such as applied by Chênes, C. *et al*. (2021). Among the three levels of UGS provision, attractiveness is arguably the most difficult to objectively measure. Any available and freely accessible green space needs to have certain qualities in order to attract residents to visit the area. UGS attractiveness is determined by various factors, which may involve cultural ecosystem services, aesthetic values, and infrastructure among others (Kronenberg,

J. 2015; Biernacka, M. and Kronenberg, J. 2019). The attractiveness of an UGS is shown to degrade by the increase of walking distance (Morar, T. *et al*. 2014), while some UGSs are simply unattractive to visitors (Wright, W.H.E. *et al*. 2012; Biernacka, M. and Kronenberg, J. 2019). In some studies, the terms UGS quantity and UGS quality are considered to correspond to the concepts of availability and attractiveness, respectively (You, H. 2016; Kraemer, R. and Kabisch, N. 2021). Evaluation of availability and accessibility of sectors other than UGSs (e.g., health care) is also possible with numerous occurrences in the scientific literature (Hare, T.S. and Barcus, H.R. 2007; Kwan, M.P. and Weber, J. 2008; McGrail, M.R. and Humphreys, J.S. 2009; Kraft, S. 2016; Uzzoli, A. *et al*. 2020). Van den Bosch, C.K. (2021) proposed the 3-30-300 rule, as a very similar concept of UGS provision. According to this rule, ideally, there should be at least three trees visible from one's window, while at the same time one's neighbourhood should have at least 30 percent UGS coverage (preferably trees), and one's home should be no farther, than 300 m from the nearest urban park.

Most authors agree that, depending on its size and function, a walking distance of 2–15 min to get to a public park is optimal for defining a catchment or area within which local residents can easily access public green spaces (Stanners, D. and Bourdeau, P. 1995; Barbosa, O. *et al*. 2007; Pafi, M. *et al*. 2016; Stessens, P. *et al*. 2017; Poleman, H. 2018; Kolcsár, R.A. *et al*. 2021). Although the growing number of spatial data sources and GIS analysis techniques make it easier to determine the number, and demographic characteristics (age, gender distribution, etc.) of the local inhabitants living within the different catchment areas of the public parks (Bok, J. and Kwon, Y. 2016; Wüstemann, H. *et al*. 2017; Poleman, H. 2018; Zepp, H. *et al*. 2020), to date little information is available on the age structures of different UGS provision zones.

The aim of the present study has been to investigate the age structure of areas with different UGS provisions in a Hungarian study area, specifically as a case study of Szeged. We sought to evaluate the UGS provision at the building-plot scale with a method that incorporates two of three UGS provision levels (availability and accessibility) identified by researchers (Biernacka, M. and Kronenberg, J. 2019; Kolcsár, R.A. *et al*. 2021). Given that the equality of UGS provision is an important component of environmental justice (Wen, C. *et al*. 2020), this method could potentially help urban planners to localize deficiency in the green infrastructure with the consideration of the age-related needs of local residents (Kemperman, A.D.A.M. and Timmermans, H.J.P. 2007; Artmann, M. *et al*. 2017; Levy-Storms, L. *et al*. 2018; Bozkurt, M. 2021; Yang, L. *et al*. 2021). Based on our overall aims, we set out to answer the following research questions in this research:

- How can we specify and delineate the low-, medium-, and high-level UGS provision zones?
- What is the age structure of local inhabitants living in low-, medium-, and high-level UGS provision zones?

Answering these questions is important from the perspective of urban planning, as it will help in the delineation of UGS-deficit areas within cities and, thus, where the improvement of UGS provision is necessary. Analysing UGS provision by age group is also essential for both environmental justice and urban park design.

Materials and methods

Study area

The study area of the present research, Szeged *(Figure 1),* is in the centre of the Southern Great Hungarian Plain (EU NUTS2 level statistical region of Hungary). By population, Szeged is the third largest city in Hungary and the second largest in the Great Hungarian Plains (KSH 2021).

The radio-concentric city has multiple urban parks of various sizes and structures, the largest of which (~ 20 ha), Erzsébet Liget

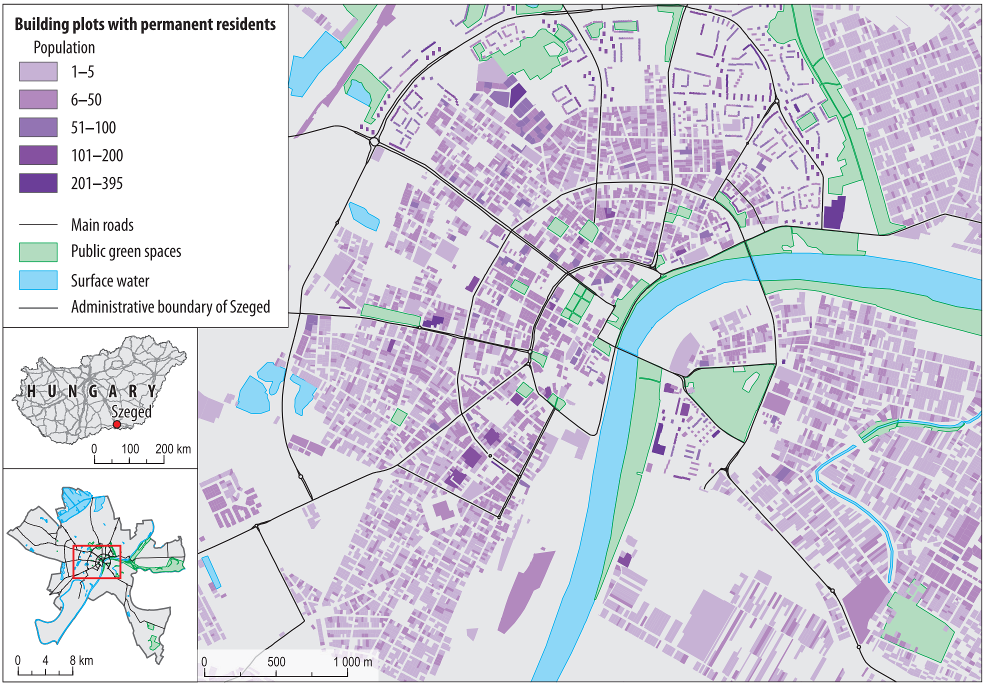


Fig. 1. Study area within Szeged, Hungary, showing building-plot-scale population distribution and public green spaces selected for accessibility estimation.

(Elisabeth Park) is located on the western side of Újszeged district. Besides its urban parks, Szeged has a notable amount of forest areas as well. These are decisively floodplain forests along the bank of its two rivers, Tisza and Maros. Informal green spaces (especially in the housing estate areas) and private gardens also constitute a significant part of the green infrastructure of Szeged.

Data used

A detailed address-level population database was used both for local UGS availability (as per-capita estimations) and for demographic analyses of the UGS provision zones (Belügyminisztérium 2019). To enable spatial evaluations and visualization, a polygon layer containing Szeged's building plots with permanent residents was also created (see *Figure 1*). Layer contained information solely about the population with permanent residency in Szeged, thus, other forms of residency (e.g., renters, students living in dormitories etc.) were not included in this study.

For local green space availability mapping, we used a high-resolution Normalized Difference Vegetation Index (NDVI) layer (0.5 x 0.5 m raster size) derived from an orthophoto (Lechner Tudásközpont, 2015). Public green space accessibility mapping required the usage of layers (e.g., road network and points of interest) from the open-source GIS database OpenStreetMap (Geofabrik, 2021). For both the local green space availability and public green space accessibility analyses, we incorporated the land-use and land-cover polygons of the 2018 version of the European Environmental Agencies Urban Atlas (Coopernicus, 2018).

Figures of the present paper were produced using data provided by Copernicus (Urban

Atlas), Geofabrik (OpenStreetMap), Lechner Tudásközpont (orthophoto of Szeged), the Hungarian Ministry of the Interior (address-level population data), and the 2018 building-code modification document of Szeged (building plots) (Lechner Tudásközpont 2015; Copernicus 2018; Fehér, É. 2018; Belügyminisztérium 2019; Geofabrik 2021).

Population data pre-processing

Building plots were chosen as the administrative unit for our study as they provide a realistic picture of the spatial extent of living space of the urban population (particularly for detached houses). The polygon layer containing building plots was digitized from maps in the 2018 building-code modification document for Szeged (Fehér, É. 2018). At our disposal was a building-polygon database that contained highly accurate, address-level population data (capita per building) based on the postal mailing addresses of all inhabitants of Szeged as of 1 January 2019 (Belügyminisztérium 2019). The building-polygon layer with population data was spatially joined to the polygon layer of the building plots. Generally, one building plot contains only one building, in the case of building-plot polygons containing two or more buildings, however, we used the sum of population values of all buildings within its area for the building-plot population. By joining the two layers, building plots with no permanent residents were deleted from the layer. Age-group categories in the source data were merged into larger categories to reduce fragmentation for the current analyses, thereby creating four new age groups: minors (0–18 years), young adults (19–40 years), middle-aged adults (41–60 years), and the elderly (≥ 61 years) *(Figure 2),* with differently attributed UGS usage habits and design requirements (Kemperman, A.D.A.M. and Timmermans, H.J.P. 2007; Artmann, M. *et al*. 2017; Levy-Storms, L. *et al*. 2018; Bozkurt, M. 2021; Yang, L. *et al*. 2021). The division of these four merged categories was restricted by the original, narrower age groups, which had very inconsistent ranges regarding the span of years

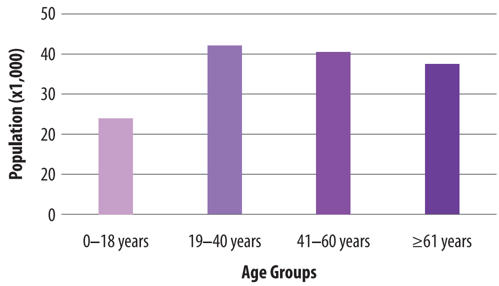


Fig. 2. The total number of residents within investigated age groups of Szeged, Hungary.

(e.g., 0–2 years, 3 years, 7–10 years, 41–45 years, 63–70 years, etc.). According to our population database, there were ~144,000 permanent residents within the study area (Szeged) on January 1, 2019.

Local green space availability analysis

We defined local green space availability (the local availability of any type of green space) as the total area of UGSs within 50-m-radius buffer zones of each building plot divided by the building plot's number of residents (square metres per capita). The size of the buffer zone was chosen according to J. Gehl's thresholds (2010), which were based on consideration of human-scale distance.

To delineate areas covered with vegetation within the city, we created a raster-based NDVI map from a high-resolution orthophoto (0.5 x 0.5-m raster size) provided by the University of Szeged Department of Climatology and Landscape Ecology. The image was acquired during May–July 2015 by Lechner Tudásközpont (2015). The footage was a four-band (RGB–NIR) UltraCam X orthophoto that had an appropriate resolution for highly accurate NDVI maps *(Figure 3).* 0 was chosen as the pixel value that represents minimal vegetation. Although the 0.2 value defined by the United States Geological Survey (USGS) is the most commonly accepted lower threshold of vegetation coverage (USGS 2018), Aquino, D. *et al*.

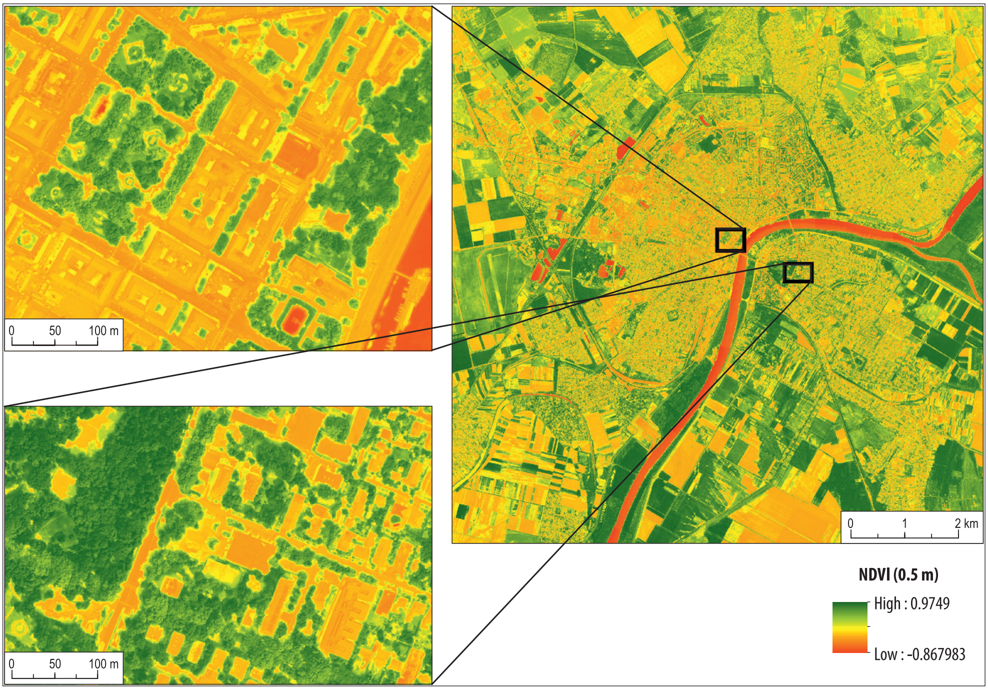


Fig. 3. Normalized Difference Vegetation Index (NDVI) layer generated from 2015 orthophoto of Szeged, Hungary.

(2018) argued that it is possible that areas with very low vegetation coverage to fall between NDVI values of 0 and 0.2. In the case of our orthophoto, the most realistic delineation of vegetation coverage was achieved by applying 0 as the minimum value. The suspected reason for a significant amount of UGSs was being found between values 0 and 0.2, was the heat stress that the vegetation suffered at the time of the data collection. Because of their seasonality and meager recreational value, plow fields were excluded from the NDVI map. To mask out these undesirable areas, we used the European Environmental Agencies Urban Atlas 2018 land-use and land-cover database's annual-crops polygons (code 21000) (Copernicus 2018).

After the selection procedure, 50-m buffer zones were generated around polygons enclosing building plots with permanent residents, and the sum of green pixels (NDVI ≥ 0) was calculated for each 50-m buffer zone *(Figure 4).* We calculated total vegetation coverages (as square meters) from the raster resolution and the sums of pixels within the buffer zones. Dividing the resulting values by the number of residents for each corresponding building plot, we determined how much local green space is available for an inhabitant of a given building plot within its 50-m buffer zone.

We then delineated zones with low, medium, and high local green space availability (local green space availability zones) based on the previously calculated square metres per capita values. We chose 50 m^2 per capita as the boundary value between low and medium categories based on the the recommendations of World Health Organization (2017) which is widely used in various publications (Morar, T. *et al.* 2014; Maryanti, M.R. *et al.* 2016). As the boundary value between medium and high categories, we used 500 m^2

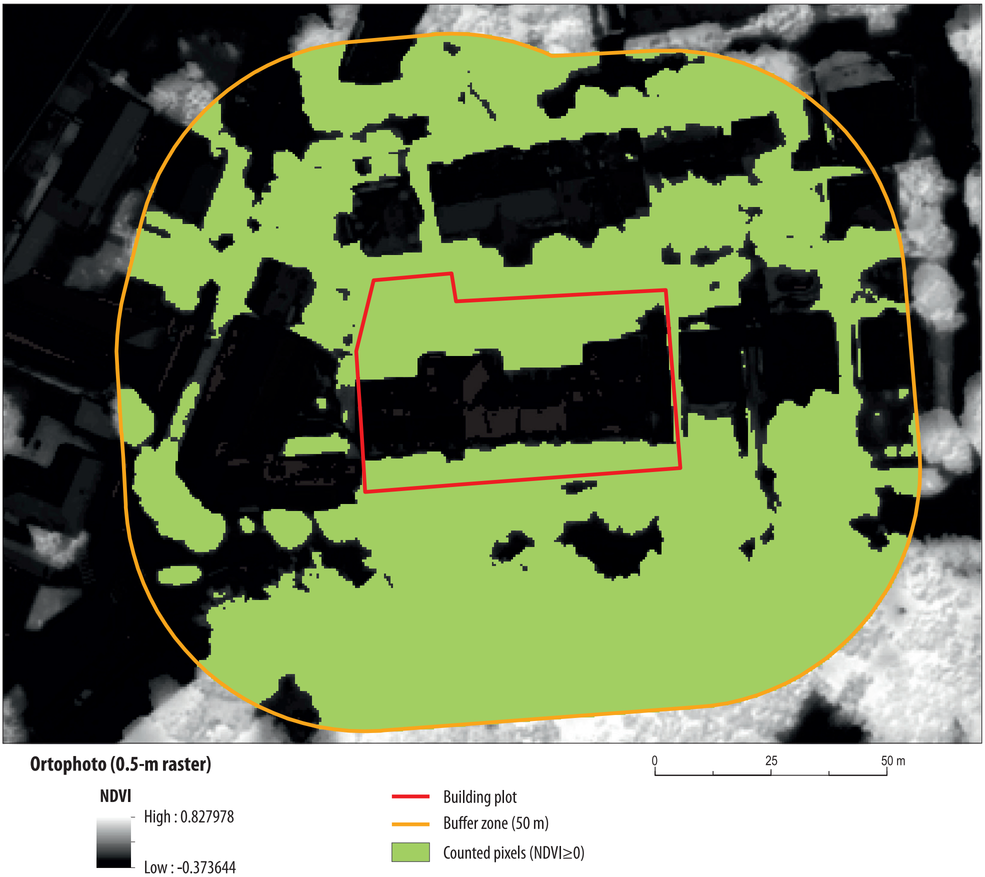


Fig. 4. Principle of calculation of local green space availability, demonstrated via example building plot. NDVI = Normalized Difference Vegetation Index.

per capita derived from the optimal minimum green space availability defined for use in Berlin (5,000 m^2 per capita within 500-m buffer zones) by converting it to the 50 m buffer zones of the present study (Kabisch, N. *et al*. 2016). A score between values 1–3 was also assigned to the local green space availability categories *(Table 1).*

Accessibility mapping of public green spaces

For the accessibility analysis, we created a subgroup of UGSs called public green spaces, which aims to include every urban park, public urban forest or any other functionally similar area. Additionally, we aimed to include in this category informal green spaces

Table 1. Category limits of local green space availability and public green space accessibility

Indicator	Low (score 1)	Medium (score 2)	High (score 3)
Local green space availability, m^2 per capita	< 50	50–500	> 500
Public green space accessibility, min.	> 10	2–10	< 2

as well, which are known contributors to the urban quality of life (Rupprecht, D.C. *et al*. 2015). Thus, on the basis of Kolcsár, R.A. *et al*. (2021) we defined public green spaces as areas which meet all of the following conditions:

1. The area must be defined by Urban Atlas (Copernicus 2018) land use and land cover database as either "Green urban areas" (14100), "Forests" (31000) or "Land without current use" (13400).

2. The area must be a public space.

3. The area has functions or services important enough to the public that it's reflected in OpenStreetMap's Point of Interest (POI) layer (Geofabrik 2021).

Because, by definition, public green spaces are open to everyone, accessibility analysis can be used to incorporate them in a city-scale UGS provision assessment. Private gardens on the other hand, by their nature are inaccessible to the public and, thus, were not included in the accessibility analysis.

The first step of our selection process was to select polygons defined in Urban Atlas as Green urban areas, Forests or Land without current use. The latter category was included because of its potential to contain informal green spaces. As the next step, we overlapped the point of interest (POI) layer, which consists of volunteered geographic information (Jiang, S. *et al*. 2015; Zhang, X. *et al*. 2017) with the selected UGSs to find the areas with at least one function or service significant enough to appear in the publicly accessible and editable database. In most cases, POI-s within these USG polygons represented objects connected to amenities (e.g., street furniture, drinking water, and toilets), recreation (e.g., playgrounds) or aesthetic values (e.g., statues, fountains, and landmarks) all of which can be connected to the multi-functionality of the USG. Because of this, the POI layer proved to be an invaluable tool to identify and delete UGS polygons with little to no functions. One UGS polygon was retained although it is not notably represented in the POI layer in the database. While none of the POI layer's points intersected its geometry, a point was found within its direct proximity which was identified as a POI of this particular public green space. The remaining polygons were individually evaluated as to whether or not they are publicly accessible, and all private areas were excluded from further analysis.

On the basis of the work of Stessens, P. *et al*. (2017) and Kolcsár, R.A. *et al*. (2021), we divided a selection of public green spaces into two separate groups by size: local public green spaces (0.3–10 ha) and district public green spaces (10–1,000 ha). We then assigned to each group a maximum walking distance to represent its catchment size: 200 m for local public green spaces and 800 m for district public green spaces.

Following Kolcsár, R.A. *et al*.'s methodology (2021), the OpenStreetMap road network was overlapped with the public green space polygons (Geofabrik 2021), and entry points were generated at the intersections of the road lines and the polygons. With the help of ArcGIS Pro's Network Analyst tool (ESRI 2018), service areas (catchments) were generated around these entry points to indicate the maximum pedestrian travel time required to reach any given point within the city. Assuming a 5-km/h pedestrian velocity, catchments were converted into travel times: ~2 min in the case of local public green spaces and ~10 min in the case of district public green spaces. Accordingly, catchments representing 2 min walking distance were generated around each of the entry points, while catchments representing 10 min walking distance were generated only around the entry points of district public green spaces. By merging these catchments together (2-minute catchments and 10-minute catchments separately), the public green space accessibility zones were created.

With the help of the Select Layer by Location tool of ArcGIS (using the centroids of each building-plot polygon with permanent residents), public green space accessibility zones were projected to the building plot layer. Each building plot was then categorized based on their public green space accessibility. Building plots with a centroid within < 2-min public green space accessibility zones were evaluated as exhibiting high public green space accessibility, and those within 2- to 10-min public green space accessibility zones were evaluated as exhibiting medium public green space accessibility. Any building plots outside the public green space accessibility zones (> 10-min) were defined as having low public green space accessibility. A score between the values of 1–3 was also assigned to the public green space accessibility categories (see *Table 1*).

Overall UGS provision assessment

Using the local green space availability and the public green space accessibility scores (1–3), we implemented a combined scoring system to evaluate the overall UGS provision of each building plot *(Table 2).* From these scores (2–6), we created the overall UGS provision categories. A three-level classification was created so the overall UGS provision results would be comparable with the local green space availability and public green space accessibility estimates. A five-level classification was also created to illustrate finer differences between provision zones.

Based on *Table 2*, overall UGS provision zones (and the corresponding scores) can be interpreted as follows:

Low UGS provision zones (score 2-3):

1. Areas with no or very little locally available UGS (below 50 m^2/capita) and no accessible public green space within 10 minutes of walking.

2. Areas with no or very little locally available UGS (below 50 m^2/capita), but the nearest public green space can be accessed between 10 and 2 minutes by walk.

3. Areas with an acceptable amount of locally available UGS (between 50 and 500 m^2/capita) but no accessible public green space within 10 minutes of walking.

Medium UGS provision zones (score 4):

1. Areas with no or very little locally available UGS (below 50 m^2/capita) but the nearest public green space can be accessed within 2 minutes by walk.

2. Areas with an acceptable amount of locally available UGS (between 50 and 500 m^2/capita) and an accessible public green space between 10 and 2 minutes by walk.

3. Areas with an abundance of locally available UGS (500 m^2/capita or higher), but no accessible public green space within 10 minutes of walking.

High UGS provision zones (score 5 and 6):

1. Areas with an acceptable amount of locally available UGS (between 50 and 500 m^2/capita) and the nearest public green space can be accessed within 2 minutes by walk.

2. Areas with an abundance of locally available UGS (500 m^2/capita or higher), and an accessible public green space between 10 and 2 minutes by walk.

3. Areas with an abundance of locally available UGS (500 m^2/capita or higher), and the nearest public green space can be accessed within 2 minutes by walk.

Age-group distributions of UGS provision zones

We performed age-group-based demographic analyses of the data within the building-plot polygons. As a result of the overall UGS provision evaluations, the age-group distribution could be estimated for the three UGS provision zones (low, medium, and high) as

Table 2. Numeric evaluation of overall urban green space provision

Indicator	Public green space accessibility scores		
Local green space availability scores	Low (score 1)	Medium (score 2)	High (score 3)
Low (score 1)	very low (score 2)	low (score 3)	medium (score 4)
Medium (score 2)	low (score 3)	medium (score 4)	high (score 5)
High (score 3)	medium (score 4)	high (score 5)	very high (score 6)

well as separately for the local green space availability and the public green space accessibility zones. In addition to the actual population numbers (p_a), we also calculated an estimated population number (p_e) (Eq. 1), showing what would be the number of residents within each age group if the age distribution of the given provision zone's population were the same as that of the entire city.

Comparing these two values (p_a vs. p_e) gives an insight into which age groups are underrepresented or overrepresented within the high, medium, or low zones regarding local green space availability, public green space accessibility, or overall UGS provision:

$$p_e = 0.01\ p_t \cdot r, \tag{1}$$

where p_e is the estimated population of a given age group within given overall UGS provision zone, local green space availability zone, or public green space accessibility zone (low, medium, or high); p_t is the total population (sum of four age groups) within a given overall UGS provision zone, local green space availability zone, or public green space accessibility zone (low, medium, or high); and r is the proportion of a given age group within the total city population.

We then calculated the percentage difference (Eq. 2) between p_a and p_e by

$$d = (p_a - p_e)/p_a \cdot 100, \tag{2}$$

where d is the percentage difference between the actual and expected number of residents within a given age group of the given overall UGS provision zone, local green space availability zone, or public green space accessibility zone (low, medium, or high); p_e is the estimated population of a given age group within the given overall UGS provision zone, local green space availability zone, or public green space accessibility zone (low, medium, or high); and p_a is the actual population of a given age group within the given overall UGS provision zone, local green space availability zone, or public green space accessibility zone (low, medium, or high).

Results

Overall urban green space provision mapping

On the basis of the local green space availability map *(Figure 5)*, we concluded that the overall state of local green space availability in Szeged is good. About 88 percent of the building plots have high local green space availability, while the average score is ~2.8. As expected, the largest concentration of building plots (classified as high, or scored as 3) are in the suburban areas, where detached houses are dominant. Building plots classified as medium (scored as 2) or low (scored as 1) are primarily in the city centre, where the dense building coverage and high proportion of paved areas result in low NDVI values, and in housing areas where an otherwise acceptable amount of vegetation coverage has to satisfy the needs of a large residential population.

Based on the results, the state of public green space accessibility appears to be lower throughout Szeged. Only ~16 percent of the building plots were identified as being part of the high public green space accessibility zones. In this case, the average score of the city was 1.6. Public green space accessibility maps *(Figures 6* and *7)* indicate that the best public green space accessibility is within the more densely populated downtown of Szeged, where large public green spaces are more prominent, complementing the results of the local green space availability map. Low public green space accessibility building plots are primarily identified in the suburban areas, where public green spaces are less frequent compared to the city centre.

Regarding the spatial characteristics of the overall UGS provision zones *(Figure 8)*, it can be stated that in general, the overall UGS provision of Szeged is good. Approximately 38 percent of the building plots received high scores (5 or 6) as a result of the aggregation of their local green space availability and public green space accessibility scores. Additionally, another ~58 percent of the building plots were categorized as having medium overall

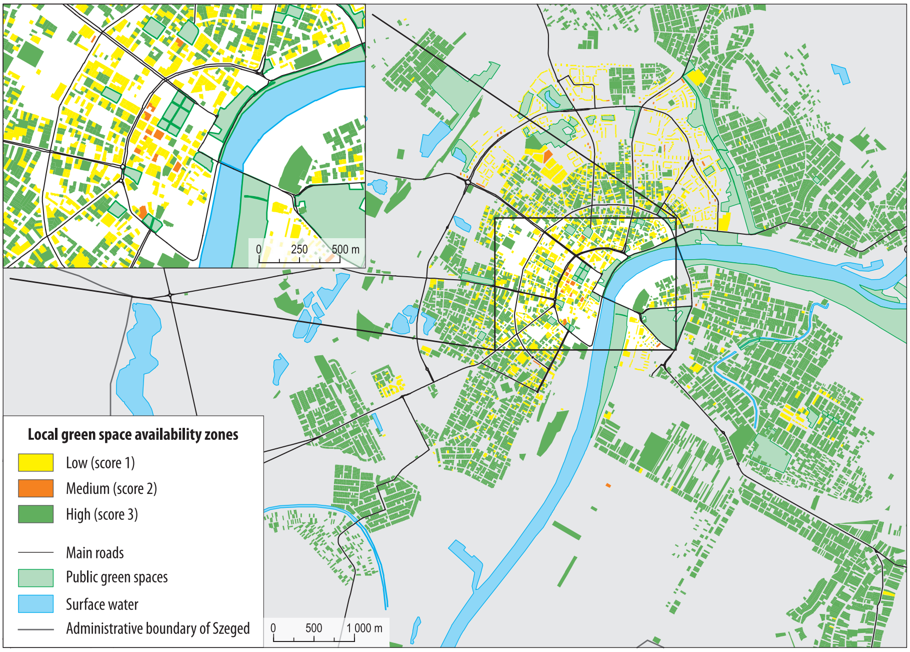


Fig. 5. Building-plot-scale local green space availability (square meters per capita), Szeged, Hungary.

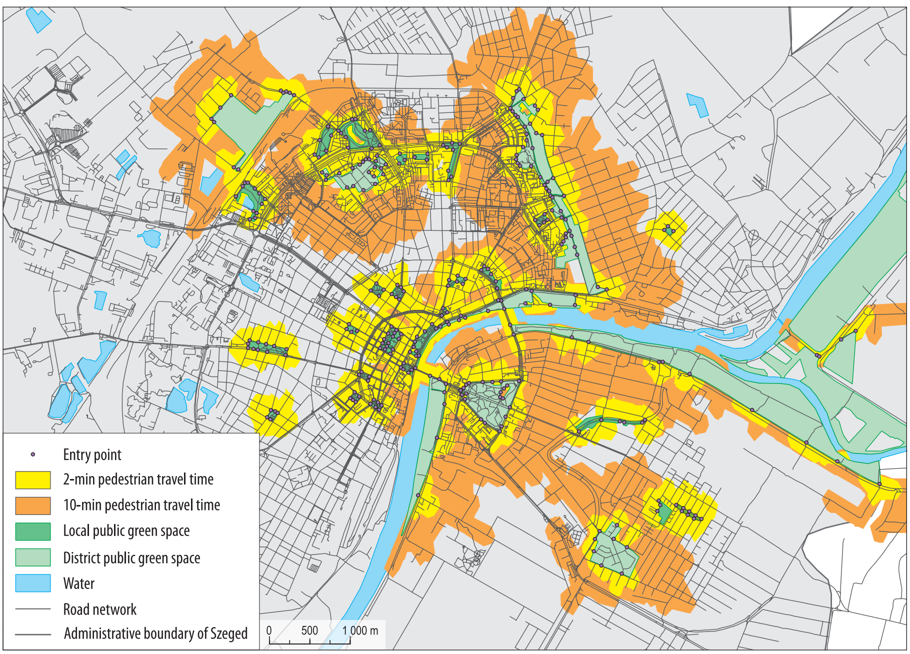


Fig. 6. Accessibility map, showing selected public green spaces with their designated size-based catchments in Szeged, Hungary.

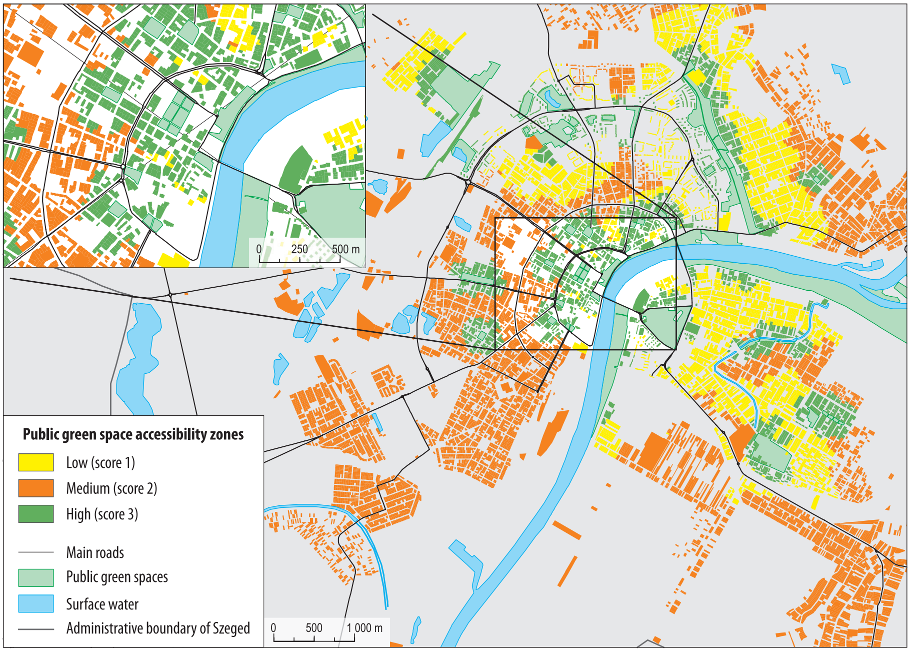


Fig. 7. Building-plot-scale public green space accessibility, Szeged, Hungary.

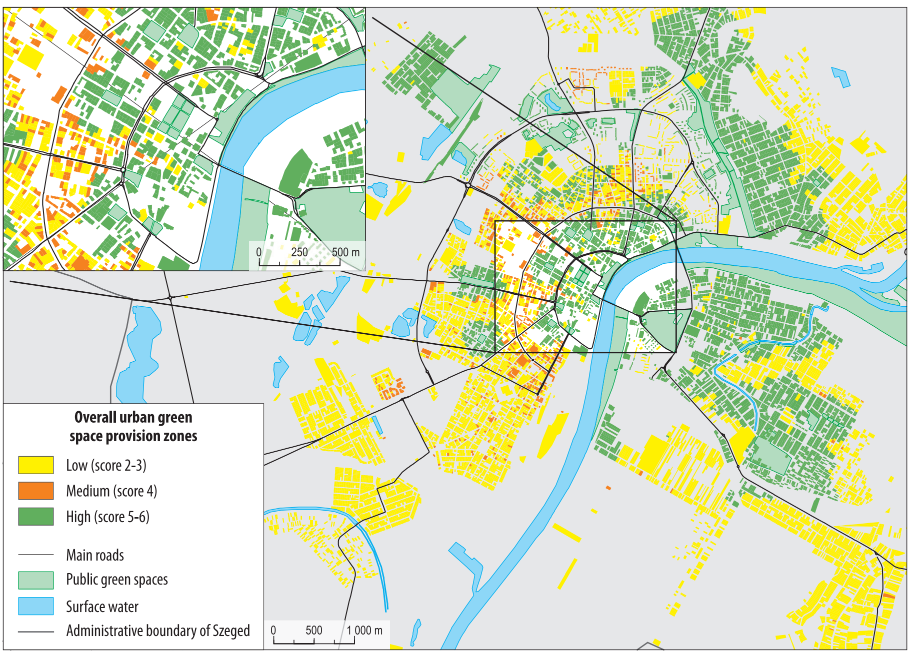


Fig. 8. Building-plot-scale overall urban green space provision map of Szeged, Hungary.

UGS provision (with a score of 4). The average overall UGS provision score in Szeged was 4.5. *Figure 8* also shows areas within the city that lack both local green space availability and public green space accessibility.

Building plots with a very low or low public green space accessibility score *(Figure 9)* need the most attention regarding green space development. Building plots in the very high overall UGS provision zones are generally found in the direct proximity of the public green spaces where part of the locally available green space is the closest accessible public space itself.

Population distribution assessment

Results of the age-group analyses of different overall UGS provision zones (three-level classification) show that the vast majority of residents live in either medium or high overall UGS provision zones. However, a notable number of people (~ 19,000) of the total population (~144,000) live in areas categorized as low overall UGS provision zones *(Figure 10).*

The population diagram *(Figure 11)* indicates that only a very small proportion of the population (~ 800 people) live in the green-deficit areas, for which the lowest possible overall UGS provision score (2) was applied. In contrast, the population of very high overall UGS provision zones (score 6) is nominally < 9,000.

Both underrepresentation and overrepresentation are apparent when looking at the age groups *(Figure 12).* Compared to the age distribution of Szeged, the 0–18 age group is overrepresented in the areas with high local green space availability, implying that relatively speaking this age group has the best local green space availability in the city,

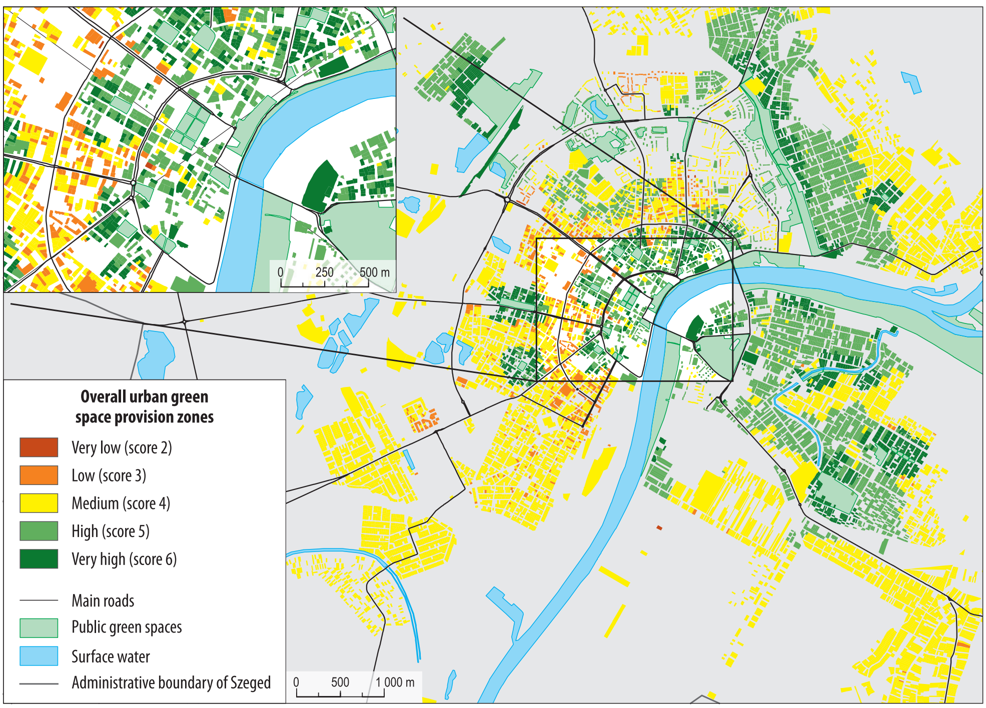


Fig. 9. Building-plot-scale map of Szeged, Hungary, showing five urban green space provision zones.

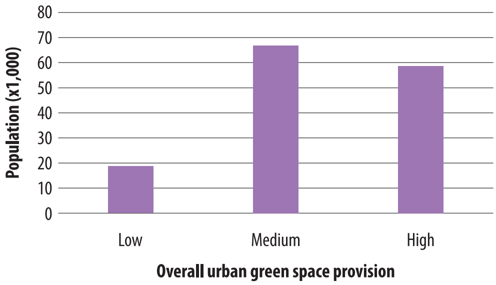


Fig. 10. Total population distribution of three overall urban green space provision categories for Szeged, Hungary.

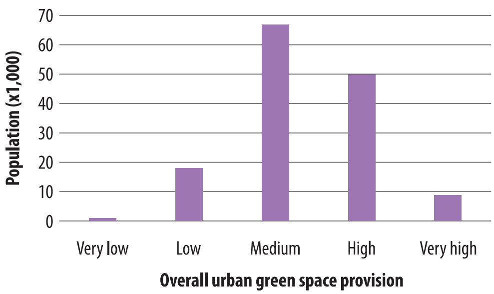


Fig. 11. Population distributions of five overall urban green space provision zones in Szeged, Hungary.

while in an absolute sense, members of age group 41–60 are present within these zones in the largest number. In contrast, the 19–40 age group is highly underrepresented in the high local green space availability zones compared to the proportion of the other age groups. Similarly to the age group of 0–18, age groups of 41–60, and ≥ 61 are also overrepresented in areas with high local green space availability.

In many cases, we found that the population distribution from the public green space accessibility analyses show patterns opposite to the results of the local green space availability mapping *(Figure 13).*

The age group of 0–18 is strongly overrepresented in areas of low public green space accessibility. In contrast, age groups of 19–40 and ≥ 61 are overrepresented in areas of high public green space accessibility. It is also noteworthy that more than a third of the total population lives within low public green space accessibility zones. Overall UGS provision analysis shows that while only a small proportion of the residents can be found in

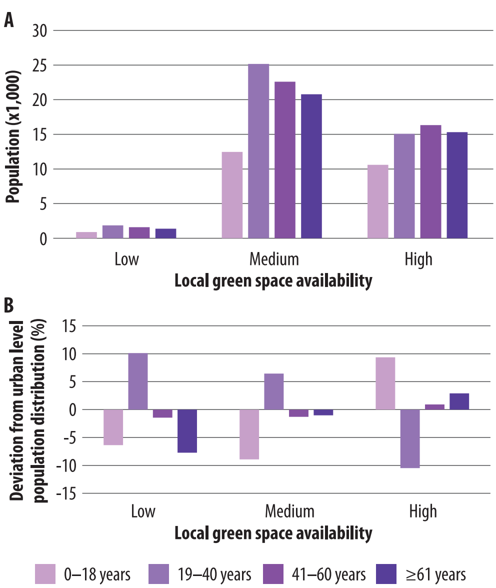


Fig. 12. Age-group distributions, Szeged, Hungary. A = Local green space availability zones; B = Percentage differences between actual and expected population.

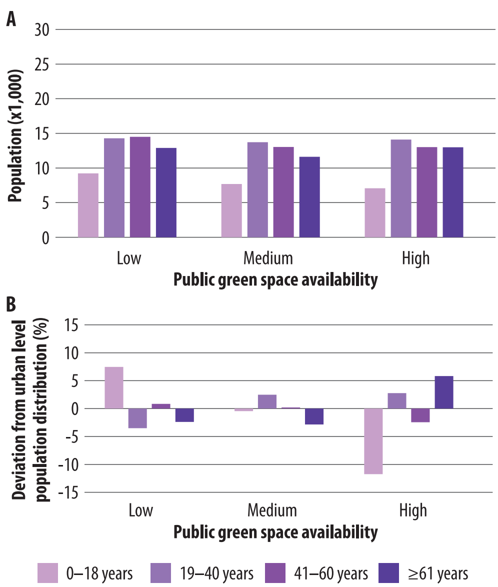


Fig. 13. Age-group distributions, Szeged, Hungary. A = Public green space accessibility; B = Percentage differences between actual and expected population.

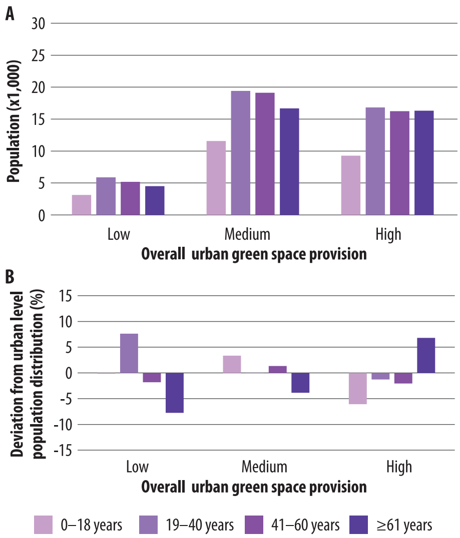


Fig. 14. Age-group distributions, Szeged, Hungary: (A) Overall urban green space provision zones; (B) Percentage difference between actual and expected population.

areas with low classification, their relative distribution within the zones favours the ≥ 61 age group *(Figure 14)*. Within the low overall UGS provision zone, the 19–40 age group is the most overrepresented. In contrast, in the high overall UGS provision zone, every age group but the elderly (≥ 61) appears to be underrepresented compared to the actual age distribution of the entire population of Szeged (see *Figure 14*).

Discussion

As regards our findings, it can be stated, that based on our results the average level of overall UGS provision in the city is slightly above medium. Our methodology identified areas within Szeged with a low score regarding both aspects (accessibility and availability) of UGS provision. Given that Kemperman, A.D.A.M. and Timmermans, H.J.P. (2007) argued that families with children are more likely to visit urban parks, the underrepresentation of age group 0–18 in public green space accessibility can be considered suboptimal. The elderly being favoured regarding UGS provision is not unique to Szeged, Wen, C. *et al*. (2020) drew similar conclusions in the case of Hannover, Germany. Good UGS provision is unquestionably beneficial for the elderly (especially for those ≥ 65), because UGSs provide them numerous physical and psychological benefits (Loukaitou-Sideris, A. *et al*. 2016), however, the UGS usage habits of this age group have their own peculiarities which need to be addressed in urban planning. According to Kemperman, A.D.A.M. and Timmermans, H.J.P. (2007) for instance, UGS usage habits of seniors tend to be extreme, as they either visit urban parks or other public green spaces very frequently or almost never. Their willingness to visit UGSs is largely defined by the ecosystem services provided by these UGSs (e.g., where trees provide enough shading and sufficiently cool microclimate) as well as the infrastructure of both the UGSs and its neighbourhood (e.g., street furniture, well-maintained safe roads, etc.) (Kabisch, N. and Haase, D. 2014; Kántor, N. 2016; Loukaitou-Sideris, A. *et al*. 2016; Arnberger, A. *et al*. 2017; Artmann, M. *et al*. 2017; Wen, C. *et al*. 2020). Because public green space accessibility favours seniors in Szeged, urban development should primarily focus on infrastructure development of these existing public green spaces as well as their neighbourhood to enhance the effective UGS usage by this age group (Levy-Storms, L. *et al*. 2018).

The value of the overall UGS provision metric used in present the study could realistically be increased in two possible ways. The first way is to increase the vegetation coverage (represented by NDVI values) within the 50-m proximity of the building plots where local green space availability is low. This can be done primarily via grassing or by bush or tree plantation, as well as by the creation of green roofs and green walls. The second possibility is to establish new public green spaces at the centre or otherwise in close proximity to building-plot clusters that have low UGS provision values. This method enhances both public green space accessibility and local green space availability. This type of green space provision development might be most efficient in areas with large, but functionless green space patches, where urban parks or public gardens can be created via landscaping and expanding the area's functions. Although the establishment of urban parks or other similar public green spaces is often limited by resources and available space, a growing body of literature demonstrates that pocket parks can be an effective solution to this problem, such as the work of Kerishnan, P.B. and Maruthaveeran, S. (2021), Naghibi, M. *et al*. (2021) or Rosso, F. *et al*. (2022).

Our methodology also enables identifying age groups that are underrepresented in high UGS provision areas (e.g., age group of 0–18 years in the case of Szeged) to prioritize UGS development in low UGS provision areas where the concentration of the age group is higher.

Conclusions

In this study, we calculated the building-plot-scale UGS provision for Szeged, Hungary with a methodology incorporating two of the prior-established UGS provision levels: availability and accessibility (Biernacka, M. and Kronenberg, J. 2019). In Szeged, local green space availability is higher in the peripheral, single-family housing areas, while public green space accessibility is higher in the densely populated city centre. These two metrics complement each other, providing good overall UGS provision conditions throughout the residential areas of the entire city. The majority of the residents live in areas with medium or high UGS provision. All the age groups except the elderly (≥ 61) are underrepresented in areas with high overall UGS provision. This is especially true of the 0–18 age group.

Our methodology proved to be an adequate tool to delineate zones within Szeged with insufficient UGS provision, as well as identify disadvantageous age groups within these areas. We hope that the present methodology and our results will be applicable in other cities for high-resolution preliminary UGS provision assessments as well.

There are, however, certain limitations that need to be addressed in the future. Our methodology used numerous parameters based on (or derived from) internationally accepted thresholds (e.g., category-limit values and applied buffer-zone radius for local green space availability, catchment sizes for public green space accessibility, etc.). In the future, more robust inferences could be made of the UGS provision by sensitivity analyses to different parameters.

Future studies should also aim to investigate the UGS provision of different age groups separately, applying parameters that better reflect the examined focus group. For example, the public green space accessibility assessment of the elderly, who are generally less mobile than the younger age groups, should be carried out with a lower average walking velocity (compared to the 5 km per hour walking speed used in the present study). In future studies, vehicle-based accessibility mapping besides the walking-based method should also be considered.

A clear limitation of the broad applicability of our framework is that data at a similar resolution might not be available for other study areas. Knowing such limitations, certain input data can be replaced by more broadly available but less-detailed data, such as population attributes from the 2012 and 2018 European Environmental Agencies Urban Atlas land use and land cover databases (Copernicus 2018; Kolcsár, R.A. *et al*. 2021). A different, raster-based method for the identification of public green spaces, e.g., methodologies proposed by Huang, B. *et al*. (2018), and Bui, D.H. and Mucsi, L. (2021), should also be tested in the future.

***Acknowledgements*:** Project no. TKP2021-NVA-09 has been implemented with the support provided by the Ministry of Innovation and Technology of Hungary from the National Research, Development and

Innovation Fund, financed under the TKP2021-NVA funding scheme. The study was also supported by NTP-NFTÖ-20 of the Ministry of Human Capacities, Hungary and the Hungarian Ministry of Interior. We wish to show our appreciation for the Hungarian Ministry of Interior for providing us with the detailed population data of Szeged, without which the present study would not have been possible; for Enago for the grammatical and stylistic improvements on our manuscript; and for the Department of Climatology and Landscape Ecology for their contribution to our work via Szeged's orthophoto footage. We are also thankful for the kind work of the anonym reviewer, who supplied us with useful comments on an earlier version of this paper; as well as our colleague, who took her time to do the proofreading on the revised version of our manuscript. Finally, wish to extend our special thanks to Máté Tóth, for his kind professional advices regarding some of the spatial data that were used in the research.

REFERENCES

Aquino, D. do N., Neto, O.C. da R., Moreira, M.A., Teixeira, A. dos S. and de Andrade, E.M. 2018. Use of remote sensing to identify areas at risk of degradation in the semi-arid region. *Revista Ciencia Agronomica* 49. (3): 420–429. Available at https://doi.org/10.5935/1806-6690.20180047

Arnberger, A., Allex, B., Eder, R., Ebenberger, M., Wanka, A., Kolland, F., Wallner, P. and Hutter, H.P. 2017. Elderly resident's uses of and preferences for urban green spaces during heat periods. *Urban Forestry and Urban Greening* 21. 102–115. Available at https://doi.org/10.1016/j.ufug.2016.11.012

Artmann, M., Chen, X., Iojă, C., Hof, A., Onose, D., Poniży, L., Lamovšek, A.Z. and Breuste, J. 2017. The role of urban green spaces in care facilities for elderly people across European cities. *Urban Forestry and Urban Greening* 27. 203–213. Available at https://doi.org/10.1016/j.ufug.2017.08.007

Ayala-Azcárraga, C., Diaz, D. and Zambrano, L. 2019. Characteristics of urban parks and their relation to user well-being. *Landscape and Urban Planning* 189. 27–35. Available at https://doi.org/10.1016/j.landurbplan.2019.04.005

Bahrini, F., Bell, S. and Mokhtarzadeh, S. 2017. The relationship between the distribution and use patterns of parks and their spatial accessibility at the city level: A case study from Tehran, Iran. *Urban Forestry and Urban Greening* 27. 332–342. Available at https://doi.org/10.1016/j.ufug.2017.05.018

Barbosa, O., Tratalos, J.A., Armsworth, P.R., Davies, R.G., Fuller, R.A., Johnson, P. and Gaston, K.J. 2007. Who benefits from access to green space? A case study from Sheffield, UK. *Landscape and Urban Planning* 83. 187–195. Available at https://doi.org/10.1016/j.landurbplan.2007.04.004

Belügyminisztérium 2019. Hungarian Ministry of the Interior. Database of the Hungarian Ministry of the Interior 2018. Budapest, Hungarian Ministry of Interior.

Biernacka, M. and Kronenberg, J. 2019. Urban green space availability, accessibility and attractiveness, and the delivery of ecosystem services. *Cities and the Environment* 12. (1):5. Available at https://digitalcommons.lmu.edu/cate/vol12/iss1/5

Biernacka, M., Kronenberg, J. and Łaszkiewicz, E. 2020. An integrated system of monitoring the availability, accessibility and attractiveness of urban parks and green squares. *Applied Geography* 116. 102152. Available at https://doi.org/10.1016/j.apgeog.2020.102152

Blaschke, T. and Kovács-Győri, A. 2020. *Earth observation to substantiate the sustainable development goal 11: Practical considerations and experiences from Austria*. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XLIII-B4-2020, XXIV ISPRS Congress. Available at https://doi.org/10.5194/isprs-archives-XLIII-B4-2020-769-2020

Bok, J. and Kwon, Y. 2016. Comparable measures of accessibility to public transport using the general transit feed specification. *Sustainability (Switzerland)* 8. (3): 1–224. Available at https://doi.org/10.3390/su8030224

Bozkurt, M. 2021. Metropolitan children's physical fitness: The relationship between overweight and obesity prevalence, socioeconomic status, urban green space access, and physical activity. *Urban Forestry and Urban Greening* 64. 127272. Available at https://doi.org/10.1016/j.ufug.2021.127272

Braquinho, C., Cvejić, R., Eler, K., Gonzales, P., Haase, D., Hansen, R., Kabisch, N., Lorance Rall, E., Niemela, J., Pauleit, S., Pintar, M., Lafortezza, R., Santos, A., Strohbach, M., Vierikko, K. and Železnikar, Š. 2015. *A Typology of Urban Green Spaces, Ecosystem Provisioning Services and Demands.* Green Surge, Report D3.1. EU FP7. Available at https://assets.centralparknyc.org/pdfs/institute/p2p-upelp/1.004_Greensurge_A+Typology+of+Urban+Green+Spaces.pdf

Bui, D.H. and Mucsi, L. 2021. From land cover map to land use map: A combined pixel-based and object-based approach using multi-temporal Landsat data, a random forest classifier, and decision rules. *Remote Sensing* 13. (9): 1700. Available at https://doi.org/10.3390/rs13091700

Chênes, C., Giuliani, G. and Ray, N. 2021. Modelling physical accessibility to public green spaces in Switzerland to support the SDG11. *Geomatics* 1. (4): 383–398. Available at https://doi.org/10.3390/geomatics1040022

Cheng, Y., Zhang, J., Wei, W. and Zhao, B. 2021. Effects of urban parks on residents' expressed happiness before and during the COVID-19 pandemic. *Landscape and Urban Planning* 212. 104118. Available at https://doi.org/10.1016/j.landurbplan.2021.104118

CICES 2022. *Common International Classification of Ecosystem Services. CICES Version 5.1.* Copenhagen, European Environment Agency.

Copernicus 2018. *Urban Atlas 2018.* Copernicus Land Monitoring Service, EU.

Csete, Á.K. and Gulyás, Á. 2021. Green infrastructure-based hydrological modelling, a comparison between different urban districts, through the case of Szeged, Hungary. *Hungarian Geographical Bulletin* 70. (4): 353–368. Available at https://doi.org/10.15201/hungeobull.70.4.5

Csete, Á.K., Kolcsár, R.A. and Gulyás, Á. 2021. Rainwater harvesting potential and vegetation irrigation assessment derived from building data-based hydrological modelling through the case study of Szeged. *Carpathian Journal of Earth and Environmental Sciences* 16. (2): 469–482. Available at https://doi.org/10.26471/cjees/2021/016/192

Csomós, G., Farkas, J.Z. and Kovács, Z. 2020. Access to urban green spaces and environmental inequality in post-socialist cities. *Hungarian Geographical Bulletin* 69. (2): 191–207. Available at https://doi.org/10.15201/hungeobull.69.2.7

Csomós, G., Farkas, Z.J., Kolcsár, R.A., Szilassi, P. and Kovács, Z. 2021. Measuring socio-economic disparities in green space availability in post-socialist cities. *Habitat International* 117. 102434. Available at https://doi.org/10.1016/j.habitatint.2021.102434

Edwards, D., Elliott, A., Hislop, M., Martin, S., Morris, J., O'Brien, L., Peace, A., Sarajevs, V., Serrand, M. and Valatin, G. 2009. *A Valuation of the Economic and Social Contribution of Forestry for People in Scotland.* Edinburgh, Forestry Commission Scotland. Available at https://cdn.forestresearch.gov.uk/2009/01/fcrp101.pdf

Ekkel, E.D. and de Vries, S. 2017. Nearby green space and human health: Evaluating accessibility metrics. *Landscape and Urban Planning* 157. 214–220. Available at https://doi.org/10.1016/j.landurbplan.2016.06.008

ESRI 2018. Environmental Systems Research Institute. ArcGIS Network Analyst. Redlands, California, ESRI.

Fehér, É. 2018. *Szeged megyei jogú város építési szabályzatának módosítása a lakás rendeltetési egységekhez tartozó telekhányadok meghatározására vonatkozóan* (Modification of regulation of constructions for county seat Szeged retating to building plot rate of flat units). Szeged, Szeged Megyei Jogú Város Önkormányzata. Available at https://docplayer.hu/105688815-Szeged-megyei-jogu-varos-epitesi-szabalyzatanak.html

Fuller, R.A. and Gaston, K.J. 2009. The scaling of green space coverage in European cities. *Biology Letters* 5. (3): 352–355. Available at https://doi.org/10.1098/rsbl.2009.0010

Gál, T., Skarbit, N. and Unger, J. 2016. Urban heat island patterns and their dynamics based on an urban climate measurement network. *Hungarian Geographical Bulletin* 65. (2): 105–116. Available at https://doi.org/10.15201/hungeobull.65.2.2

Gehl, J. 2010. *Cities for People*. Washington, D. C., Island Press.

Geofabrik 2018. Geofabrik OpenStreetMap Data Extracts. Access date: 2018.12.05.

Geofabrik 2021. Geofabrik OpenStreetMap Data Extracts Access date: 2021.02.05.

Hare, T.S. and Barcus, H.R. 2007. Geographical accessibility and Kentucky's heart-related hospital services. *Applied Geography* 27. (3–4): 181–205. Available at https://doi.org/10.1016/j.apgeog.2007.07.004

Henits, L., Jürgens, C. and Mucsi, L. 2016. Seasonal multitemporal land-cover classification and change detection analysis of Bochum, Germany, using multitemporal Landsat TM data. *International Journal of Remote Sensing* 37. (15): 3439–3454. Available at https://doi.org/10.1080/01431161.2015.1125558

Herbel, I., Croitoru, A.E., Rus, I., Harpa, G.V. and Ciupertea, A.F. 2016. Detection of atmospheric urban heat island through direct measurements in Cluj-Napoca city, Romania. *Hungarian Geographical Bulletin* 65. (2): 117–128. Available at https://doi.org/10.15201/hungeobull.65.2.3

Huang, B., Zhao, B. and Song, Y. 2018. Urban land-use mapping using a deep convolutional neural network with high spatial resolution multispectral remote sensing imagery. *Remote Sensing of Environment* 214. 73–86. Available at https://doi.org/10.1016/J.RSE.2018.04.050

James, P., Tzoulas, K., Adams, M.D., Barber, A., Box, J., Breuste, J., Elmqvist, T., Frith, M., Gordon, C., Greening, K.L., Handley, J., Haworth, S., Kazmierczak, A. E., Johnston, M., Korpela, K., Moretti, M., Niemelä, J., Pauleit, S., Roe, M.H., Sadler, J.P. and Ward Thompson, C. 2009. Towards an integrated understanding of green space in the European built environment. *Urban Forestry and Urban Greening* 8. (2): 65–75. Available at https://doi.org/10.1016/j.ufug.2009.02.001

Jiang, S., Alves, A., Rodrigues, F., Ferreira, J. and Pereira, F.C. 2015. Mining point-of-interest data from social networks for urban land use classification and disaggregation. *Computers, Environment and Urban Systems* 53. 36–46. Available at https://doi.org/10.1016/j.compenvurbsys.2014.12.001

Kabisch, N. and Haase, D. 2014. Green justice or just green? Provision of urban green spaces in Berlin, Germany. *Landscape and Urban Planning* 122. 129–139. Available at https://doi.org/10.1016/j.landurbanplan.2013.11.016

Kabisch, N., Strohbach, M., Haase, D. and Kronenberg, J. 2016. Urban green space availability in European cities. *Ecological Indicators* 70. 586–596. Available at https://doi.org/10.1016/j.ecolind.2016.02.029

Kántor, N. 2016. Differences between the evaluation of thermal environment in shaded and sunny position. *Hungarian Geographical Bulletin* 65. (2): 139–153. Available at https://doi.org/10.15201/hungeobull.65.2.5

Kemperman, A.D.A.M. and Timmermans, H.J.P. 2007. Heterogeneity in urban park use of aging visitors: A latent class analysis. *Leisure Sciences* 28. (1): 57–71. Available at https://doi.org/10.1080/01490400500332710

Kerishnan, P.B. and Maruthaveeran, S. 2021. Factors contributing to the usage of pocket parks – A review of the evidence. *Urban Forestry and Urban Greening* 58. 126985. Available at https://doi.org/10.1016/j.ufug.2021.126985

Kolcsár, R.A., Csikós, N. and Szilassi, P. 2021. Testing the limitations of buffer zones and Urban atlas population data in urban green space provision analyses through the case study of Szeged, Hungary. *Urban Forestry and Urban Greening* 57. 126942. Available at https://doi.org/10.1016/j.ufug.2020.126942

Koprowska, K., Łaszkiewicz, E., Kronenberg, J. and Marcińczak, S. 2018. Subjective perception of noise exposure in relation to urban green space availability. *Urban Forestry and Urban Greening* 31. 93–102. Available at https://doi.org/10.1016/j.ufug.2018.01.018

Kothencz, G., Kolcsár, R., Cabrera-Barona, P. and Szilassi, P. 2017. Urban green space perception and its contribution to well-being. *International Journal of Environmental Research and Public Health* 14. (7): 766. Available at https://doi.org/10.3390/ijerph14070766

Kovács-Győri, A., Ristea, A., Kolcsar, R., Resch, B., Crivellari, A. and Blaschke, T. 2018. Beyond spatial proximity-classifying parks and their visitors in london based on spatiotemporal and sentiment analysis of twitter data. *ISPRS International Journal of Geo-Information* 7. (9): 378. Available at https://doi.org/10.3390/ijgi7090378

Kraemer, R. and Kabisch, N. 2021. Parks in context: advancing citywide spatial quality assessments of urban green spaces using fine-scaled indicators. *Ecology and Society* 26. (2): 45. Available at https://doi.org/10.5751/es-12485-260245

Kraft, S. 2016. Measuring and modelling the spatial accessibility of public transport stops in GIS. *Hungarian Geographical Bulletin* 65. (1): 57–69. Available at https://doi.org/10.15201/hungeobull.65.1.5

Kronenberg, J. 2015. Why not to green a city? Institutional barriers to preserving urban ecosystem services. *Ecosystem Services* 12. 218–227. Available at https://doi.org/10.1016/j.ecoser.2014.07.002

KSH 2021. Hungarian Statistical Office. *Demography, 2020.* Budapest, Hungarian Central Statistical Office.

Kwan, M.P. and Weber, J. 2008. Scale and accessibility: Implications for the analysis of land use-travel interaction. *Applied Geography* 28. (2): 110–123. Available at https://doi.org/10.1016/j.apgeog.2007.07.002

Le Texier, M., Schiel, K. and Caruso, G. 2018. The provision of urban green space and its accessibility: Spatial data effects in Brussels. *PLoS ONE* 13. (10): e0204684. Available at https://doi.org/10.1371/journal.pone.0204684

Lechner Tudásközpont 2015. Data from the Lechner Knowledge Center (former Institute of Geodesy, Cartography and Remote Sensing), Budapest.

Levy-Storms, L., Chen, L. and Loukaitou-Sideris, A. 2018. Older adults' needs and preferences for open space and physical activity in and near parks: A systematic review. *Journal of Aging and Physical Activity* 26. (4): 682–696. Available at https://doi.org/10.1123/japa.2016-0354

Loukaitou-Sideris, A., Levy-Storms, L., Chen, L. and Brozen, M. 2016. Parks for an aging population: Needs and preferences of low-income seniors in Los Angeles. *Journal of the American Planning Association* 82. (3): 236–251. Available at https://doi.org/10.1080/01944363.2016.1163238

Makovníková, J., Pálka, B., Široň, M., Kizeková, M. and Kanianska, R. 2019. The potential of regulating ecosystem service – filtering potential for inorganic pollutants – supplied by soils of Slovakia. *Hungarian Geographical Bulletin* 68. (2): 177–185. Available at https://doi.org/10.15201/hungeobull.68.2.5

Maryanti, M.R., Khadijah, H., Uzair, A.M., Megat, M.A.R. and Ghazali, M. 2016. The urban green space provision using the standards approach: issues and challenges of its implementation in Malaysia. *Sustainable Development and Planning* 8. 369–379. Available at https://doi.org/10.2495/sdp160311

McGrail, M.R. and Humphreys, J.S. 2009. Measuring spatial accessibility to primary care in rural areas: Improving the effectiveness of the two-step floating catchment area method. *Applied Geography* 29. (4): 533–541. Available at https://doi.org/10.1016/j.apgeog.2008.12.003

MEA 2005. Millennium Ecosystem Assessment. World Resources Institute, UNEP. Available at https://www.millenniumassessment.org/en/Index-2.html

Mora-Garcia, R.T., Marti-Ciriquian, P., Perez-Sanchez, R. and Cespedes-Lopez, M.F. 2018. *A comparative analysis of manhattan, euclidean and network distances. Why are network distances more useful to urban professionals?* International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management. SGEM Scientific eLibrary. Available at https://www.sgem.org/index.php/elibrary?view=publication&task=show&id=602

Morar, T., Radoslav, R., Spiridon, L. and Păcurar, L. 2014. Assessing pedestrian accessibility to green space using GIS. *Transylvanian Review of Administrative Sciences* 10. (42): 116–139.

Mucsi, L., Liska, C.M., Henits, L., Tobak, Z., Csendes, B. and Nagy, L. 2017. The evaluation and application of an urban land cover map with image data fusion and laboratory measurements. *Hungarian Geographical Bulletin* 66. (2): 145–156. Available at https://doi.org/10.15201/hungeobull.66.2.4

Naghibi, M., Faizi, M. and Ekhlassi, A. 2021. Design possibilities of leftover spaces as a pocket park in relation to planting enclosure. *Urban Forestry and Urban Greening* 64. 127273. Available at https://doi.org/10.1016/j.ufug.2021.127273

Neuvonen, M., Sievänen, T., Tönnes, S. and Koskela, T. 2007. Access to green areas and the frequency of visits – A case study in Helsinki. *Urban Forestry and Urban Greening* 6. (4): 235–247. Available at https://doi.org/10.1016/j.ufug.2007.05.003

Oh, K. and Jeong, S. 2007. Assessing the spatial distribution of urban parks using GIS. *Landscape and Urban Planning* 82. (1–2): 25–32. Available at https://doi.org/10.1016/j.landurbplan.2007.01.014

Pafi, M., Siragusa, A., Ferri, S. and Halkia, S. 2016. *Measuring the accessibility of urban green areas: A comparison of the Green ESM with other datasets in four European cities*. JRC Publications repository. Luxembourg, Publications Office of the European Union. Available at https://publications.jrc.ec.europa.eu/repository/handle/JRC102525

Park, K. 2017. Psychological park accessibility: a systematic literature review of perceptual components affecting park use. *Landscape Research* 42. (5): 508–520. Available at https://doi.org/10.1080/01426397.2016.1267127

Poleman, H. 2018. *A walk to the park? Assessing access to green areas in Europe's cities. Update using completed Copernicus urban atlas data.* WP 01/2018. European Commission. Available at https://ec.europa.eu/regional_policy/sources/docgener/work/2018_01_green_urban_area.pdf

Pongrácz, R., Bartholy, J., Dezső, Z. and Dian, C. 2016. Analysis of the air temperature and relative humidity measurements in Budapest-Ferencváros. *Hungarian Geographical Bulletin* 65. (2): 93–103. Available at https://doi.org/10.15201/hungeobull.65.2.1

Razak, M.A.W.A., Othman, N. and Nazir, N.N.M. 2016. Connecting people with nature: Urban park and human well-being. *Procedia – Social and Behavioral Sciences* 222. 476–484. Available at https://doi.org/10.1016/J.SBSPRO.2016.05.138

Rossi, S.D., Byrne, J.A. and Pickering, C.M. 2015. The role of distance in peri-urban national park use: Who visits them and how far do they travel? *Applied Geography* 63. 77–88. Available at https://doi.org/10.1016/J.APGEOG.2015.06.008

Rosso, F., Cappa, F., Spitzmiller, R. and Ferrero, M. 2022. Pocket parks towards more sustainable cities. Architectural, environmental, managerial and legal considerations towards an integrated framework: A case study in the Mediterranean region. *Environmental Challenges* 7. 100402. Available at https://doi.org/10.1016/j.ufug.2021.126985

Rupprecht, D.C., Byrne, J.A., Ueda, H., and Lo, A.Y. 2015. 'It's real, not fake like a park': Residents' perception and use of informal urban green-space in Brisbane, Australia and Sapporo, Japan. *Landscape and Urban Planning* 143. 205–218. Available at https://doi.org/10.1016/j.landurbplan.2015.07.003

Schipperijn, J., Stigsdotter, U.K., Randrup, T.B. and Troelsen, J. 2010. Influences on the use of urban green space – A case study in Odense, Denmark. *Urban Forestry and Urban Greening* 9. (1): 25–32. Available at https://doi.org/10.1016/j.ufug.2009.09.002

Shahid, R., Bertazzon, S., Knudtson, M.L. and Ghali, W.A. 2009. Comparison of distance measures in spatial analytical modeling for health service planning. *BMC Health Services Research* 9. 200. Available at https://doi.org/10.1186/1472-6963-9-200

Stanners, D. and Bourdeau, P. (eds.) 1995. *Europe's Environment: the Dobris Assessment*. *Specially prepared for the presentation of the European Environment Agency*. London, Earthscan Publications. Available at https://www.eea.europa.eu/publications/92-827-5122-8/page001.html

Stessens, P., Khan, A.Z., Huysmans, M. and Canters, F. 2017. Analysing urban green space accessibility and quality: A GIS-based model as spatial decision support for urban ecosystem services in Brussels. *Ecosystem Services* 28. 328–340.

Szilassi, P., Breuste, J., Kolcsár, A.R. and Aigner, G. 2020. Mobile application-based field survey as possible tool for investigating visitors' perception and preferences of the vegetation. In *Making Green Cities*. Eds.: Breuste, J., Artmann, M., Ioja, C. and Quareshi, S., Cham, Springer, 459–473.

Takács, Á., Kovács, A., Kiss, M., Gulyás, Á. and Kántor, N. 2016. Study on the transmissivity characteristics of urban trees in Szeged, Hungary. *Hungarian Geographical Bulletin* 65. (2): 155–167. Available at https://doi.org/10.15201/hungeobull.65.2.6

TEEB 2022. *The Economics of Ecosystems and Biodiversity Project*. United Nations Environment Programme. Geneva, Switzerland, UNEP FI.

USGS 2018. United States Geological Survey. NDVI, the Foundation for Remote Sensing Phenology U.S. Geological Survey.

Uzzoli, A., Egri, Z., Szilágyi, D. and Pál, V. 2020. Does better availability mean better accessibility? Spatial inequalities in the care of acute myocardial infarction in Hungary. *Hungarian Geographical Bulletin* 69. (4): 401–418. Available at https://doi.org/10.15201/hungeobull.69.4.5

Van den Bosch, C.K. 2021. *Promoting health and wellbeing through urban forests – Introducing the 3-30-300 rule.* IUCN Urban Alliance publication. Available at https://iucnurbanalliance.org/promoting-health-and-wellbeing-through-urban-forests-introducing-the-3-30-300-rule/

Weldon, S., Bailey, C. and O'Brien, L. 2007. *New pathways for health and well-being in Scotland: Research to understand and overcome barriers to accessing woodlands.* Edinburgh, Forestry Commission Scotland. Available at https://cdn.forestresearch.gov.uk/2007/11/new_pathways_to_health_summary.pdf

Wen, C., Albert, C. and von Haaren, C. 2020. Equality in access to urban green spaces: A case study in Hannover, Germany, with a focus on the elderly population. *Urban Forestry and Urban Greening* 55. 126820. Available at https://doi.org/10.1016/j.ufug.2020.126820

Wolch, J.R., Byrne, J. and Newell, J.P. 2014. Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban Planning* 125. 234–244. Available at https://doi.org/10.1016/j.landurbplan.2014.01.017

WHO 2017. *Urban planning, environment and health: from evidence to policy action.* WHO report. New York, UN World Health Organization.

WHO Regional Office for Europe 2017. *Urban green spaces: a brief for action.* WHO report. New York, UN World Health Organization..

Wright, W.H.E., Zarger, R.K. and Mihelcic, J.R. 2012. Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America. *Landscape and Urban Planning* 107. (3): 272–282. Available at https://doi.org/10.1016/j.landurbplan.2012.06.003

Wu, L. and Kim, S.K. 2021. Exploring the equality of accessing urban green spaces: A comparative study of 341 Chinese cities. *Ecological Indicators* 121. 107080. Available at https://doi.org/10.1016/j.ecolind.2020.107080

Wüstemann, H., Kalisch, D. and Kolbe, J. 2017. Access to urban green space and environmental inequalities in Germany. *Landscape and Urban Planning* 164. 124–131. Available at https://doi.org/10.1016/j.landurbplan.2017.04.002

Yang, L., Liu, J., Liang, Y., Lu, Y. and Yang, H. 2021. Spatially varying effects of street greenery on walking time of older adults. *ISPRS International Journal of Geo-Information* 10. (9): 596. Available at https://doi.org/10.3390/ijgi10090596

You, H. 2016. Characterizing the inequalities in urban public green space provision in Shenzhen, China. *Habitat International* 56. 176–180. Available at https://doi.org/10.1016/j.habitatint.2016.05.006

Zepp, H., Gross, L. and Inostroza, L. 2020. And the winner is? Comparing urban green space provision and accessibility in eight European metropolitan areas using a spatially explicit approach. *Urban Forestry and Urban Greening* 49. 126603. Available at https://doi.org/10.1016/j.ufug.2020.126603

Zhang, X., Du, S. and Wang, Q. 2017. Hierarchical semantic cognition for urban functional zones with VHR satellite images and POI data. *ISPRS Journal of Photogrammetry and Remote Sensing* 132. 170–184. Available at https://doi.org/10.1016/j.isprsjprs.2017.09.007

DOI: 10.15201/hungeobull.71.3.4 Hungarian Geographical Bulletin **71** 2022 (3) 271–286.

Rethinking of identity under war: Pryazovia renaissance and regional centre ambitions in Mariupol before 2022

Oleksiy GNATIUK[1], Konstyantyn MEZENTSEV[1] and Grygorii PIDGRUSHNYI[2]

Abstract

The article addresses identity transformation in geopolitical fault-line city under a semi-frozen military conflict. Until 2014, the Donbas, a region in the eastern Ukraine, had a strong identity cultivated by the local industrial and financial groups. The Russian-backed military conflict induced rethinking of Donbas identity, giving a chance for revival of silenced regional identities. Our case study is Mariupol, the second most populous city in Donetsk oblast and the informal capital of Pryazovia that stepped out from the shadow of Donetsk. The research is based on the survey data (n = 1,251) collected in 2020 through personal interviews, analysed using descriptive statistics and binary logistic regression. The hypothesis that emerging Pryazovia identity should qualitatively differ from presumably stigmatized Donbas identity was confirmed only partially. The identity rethinking seems to be neither rapid no straightforward. Donbas identity appears quite persistent, while Pryazovia identity functions mainly as a complementary one. Instead of escape from the stigmatized Donbas identity, we observe rather its redefinition, including on local-centric ("Mariupolocentrism") and Ukraine-centric bases.

Keywords: identity, geopolitical fault-line city, military conflict, Pryazovia, Mariupol

Received May 2022, accepted July 2022.

Introduction

Military events in Ukraine, taking place since 2014 as a result of geopolitical clash between the Putin's Russia and Ukraine supported by the West, have a strong social and political dimension for the Ukrainian society. Until 2014, the Donbas had a strong regional identity, successfully transformed into political dividends by local industrial and financial groups (Korzhov, G. 2006; Kotyhorenko, V. *et al.* 2014; Kuzio, T. 2015; Pakhomenko, S. 2015). Donetsk, the administrative centre of the eponymous oblast, was a powerful industrial, educational and cultural centre and closed the list of the 5 largest Ukrainian metropolises. However, the Russian-backed occupation of the predominantly industrial and highly urbanized parts of Donetsk and Luhansk oblasts, constituting the core of the Donbas, provided for the residents of government-controlled part a chance to revive and rethink other forgotten regional identities (Semyvolos, I. 2016). Furthermore, large cities in the Ukrainian government-controlled part of the region received new opportunities for their development. In particular, Mariupol, the second most populous city in Donetsk oblast and the informal capital of Pryazovia, stepped out from the shadow of Donetsk and started searching for its own distinctiveness and identity, which included a civic movement for the administrative separation of Pryazovia from Donetsk oblast (Ruschenko, I. *et al.* 2015).

Nowadays, the peaceful smooth development of Mariupol and of its identity may be

[1] Taras Shevchenko National University of Kyiv, Department of Economic and Social Geography, 64/13 vol. Volodymyrska 01601, Kyiv, Ukraine. Correspondent author's e-mail: alexgnat22@ukr.net

[2] Institute of Geography, UNAS. 44 vul. Volodymyrska, 01054 Kyiv, Ukraine.

discussed only in the past tense, as Russian troops have largely destroyed the city, and the city together with the surrounding region lost the majority of their residents due to emigration, flight, and deportations. Even so, there are important lessons from the development of urban identity in Mariupol in the relatively peaceful period of 2014–2021 to be learned. First, the story told by Mariupol illustrates how geopolitical tensions and military actions have induced the contestation of old imagined communities and identities. Second, it shows how self-identification processes and search for new identities may unfold in geopolitical fault-line city, of which Mariupol is a sparkling example (Gentile, M. 2017, 2020). In view of this, the study aims to investigate the identity transformation in geopolitical fault-line city under the influence of a semi-frozen military conflict, focusing on the rethinking of the existing (probably) stigmatized identity: is it disappearing, giving way to new identities, or rather redefines itself on a new basis? The research is primarily process- and theory-oriented – the particular case of Mariupol serves here as a model for the processes that may occur in the other cities in similar conditions. At the same time, despite the fact that empirical data used in the research are not relevant anymore due to the ongoing Russian-Ukrainian war, the results have some practical relevance as giving insights how opposing geopolitical actors may employ or reconfigure the urban identity of Mariupol in medium and long-term perspective.

Donbas identity: consolidated and contested

As it often happens with informal regions, there is no consensus on what the Donbas is. The word "Donbas" is actually a portmanteau formed from "Donets Basin", an abbreviation of "Donets Coal Basin". The name of the coal basin, in turn, is a reference to the Donets Ridge and the river Donets. Being equated to the Donets Coal Basin, Donbas should include Donetsk oblast except for its northern and southern parts, the southern part of Luhansk oblast, the eastern part of Dnipropetrovsk oblast, as well as the western part of Rostov oblast in Russia. From this point of view, certain parts of Donetsk and Luhansk oblasts are not covered by the Donbas but rather should be included into other historical regions, such as Slobozhanschyna and Pryazovia *(Figure 1).*

However, the most common definition of Donbas today refers to the whole Donetsk and Luhansk oblasts of Ukraine – a transformation once again giving evidence that regions are historically contingent dynamic processes (Pred, A. 1984) and social constructs (Cresswell, T. 2013) involving an enormous influence of the cultural, historical and geographical context which plays a cardinal role in the formation of regions (Graham, B. 2000; Kasala, K. and Šifta, M. 2017). In particular, perceptual borders of regions are changing under the influence of the modern administrative division (cf. Šerý, M. and Šimáček, P. 2012; Vaishar, A. and Zapletalová, J. 2016; Melnychuk, A. and Gnatiuk, O. 2018; Nowak, K. 2018; Gnatiuk, O. and Melnychuk, A. 2019, 2021; Marek, P. 2020). For instance, a whole modern administrative unit may be perceptually equated to a particular historical informal region under favourable circumstances (cf. Gnatiuk, O. and Melnychuk, A. 2019). Moreover, prior to the military conflict in Eastern Ukraine, Donbas identity seemed attractive to neighbouring regions due to the huge financial and symbolic capital of Donetsk, which made it a powerful attractor for the residents of Donetsk oblast and beyond (Semyvolos, I. 2016). The image of Donbas consisting of Donetsk and Luhansk oblasts in their integrity may be enhanced also by the school handbooks presenting the Donetsk economic/geographic region exactly in this way (Pistun, M. *et al.* 2004; Zastavnyi, F. 2010).

Industrialization and urbanization that started in the second half of the 19th century and continued during the most of the 20th century led to the influx of workers from Russia resulting in a highly industrialized region, a kind of a melting pot for Russians and Ukrainians with Russian-speaking cities surrounded by a Ukrainian-speaking countryside (Shulman, S. 1998; Korzhov,

Fig. 1. Donbas, Pryazovia, and Slobozhanschyna on the map of Ukraine. DPR = Donetsk People's Republic; LPR = Luhansk People's Republic.

G. 2006; Kuzio, T. 2017; Haran, O. *et al.* 2019). Soviet politics paid special attention to the Donbas as an industrial base of the country and significantly contributed in this way to the formation of a specific regional identity (Kuromiya, H. 1998; Osipian, A. 2015; Yakubova, L. 2015a, b; Kuzio, T. 2017; Stebelsky, I. 2018). From the very beginning of the Ukraine's independence, the Donbas was a deeply Russified area (Stebelsky, I. 2018) with a strong prevalence of Donbas regional identity over the national and local identity, as well as strong pro-Soviet sentiments (Flynn, M. 1996; Shulman, S. 1998; Sereda, V. 2007). After the deep economic crisis connected with the demise of the USSR, the industrial parts of Donetsk and Luhansk oblasts transformed into the economic and electoral fiefdoms of new local elites consisting of a mixture of representatives of the Soviet nomenclature, "Red Directors," and organized crime (Zimmer, K. and Haran, O. 2008; Kuzio, T. 2015, 2017). Gradually the Donbas became a region with an almost absolute political monopoly of the Party of Regions which was based on economic control and client–patron relations (Wilson, A. 2005; Korzhov, G. 2006; Zimmer, K. and Haran, O. 2008; Kuzio, T. 2015, 2017), where the ordinary people, often faced with poor living standards, were told by the local elite that the Donbas mission is "to feed" Kyiv and "agrarian" Western and Central Ukraine (Wilson, A. 2016; Haran, O. *et al.* 2019). In fact, the economies of the Donetsk and Luhansk oblasts remained among the most depressed in Ukraine, and the post-Soviet Donbas was certainly no engine of national prosperity (Gentile, M. and Marcińczak, S. 2012; Mykhnenko, V. 2020). The key features of Donbas regional identity, stimulated by local regional elites as an argument in the election campaigns, can be summarized as Ukrainian-Russian dual ethnicity, dominance of the Russian language, industrial culture, sincere veneration of the Soviet past, and sympathy towards Russian history and state (Pakhomenko, S. 2015). Industrial culture is understood here as a dynamic phenomenon in which past and present industrial production is embedded in the human physical environment, social structures, cognitive abilities, and institutions that may influence the future development choices of a community (Bole, D. 2021).

The Russian-backed occupation of the predominantly industrial parts of Donetsk and Luhansk oblasts, including oblast administrative centres, had double consequences. On the one hand, strongly developed regional identity of Donbas, coming into collision with the Ukrainian nation-state project, served as the internal precondition enabling the success of separatist pro-Russian propaganda messages, which facilitated the formation of the puppet statelets DPR and LPR (Pakhomenko, S. 2015). For instance, in 2015, people in the Donetsk and Luhansk oblasts were using pro-Russian sources of information much more actively than in the adjacent regions (Dobysh, M. 2019). Noteworthy, cities of the two Donbas oblasts are relatively underrepresented in the Ukrainian Wikipedia and overrepresented in the Russian, compared to the other Ukrainian regions (Gnatiuk, O. and Glybovets, V. 2021). The Donbas regional identity was shown to be a significant factor affecting the public attitudes to the parts of the conflict (Kudelia, S. and van Zyl, J. 2019), although the role of the Kremlin's military intervention was paramount for the commencement of hostilities (Hedenskog, J. 2014; Wilson, A. 2016; Mykhnenko, V. 2020). Moreover, further development of the Donbas identity narrative is observed within the self-proclaimed separatist "republics" (Abibok, Yu. 2018). On the other hand, there is a chance for rethinking the own identity by the residents of Ukraine-controlled parts of Donetsk and Luhansk oblasts. Despite the outlined mainstream features, the identity of Donbas hardly may be considered as homogenous (Zolkina, M. 2017), in particular regarding the attitudes to the Russian and Ukrainian cultures, as well as to the Soviet legacies: "The pro-Russian nature of Donbas still remains one of the patented self-identification myths" (Korzhov, G. 2006).

Rethinking the regional identity of the Donbas has developed in two directions: the top-down and the bottom-up. The first direction is represented by the new narrative on Donbas launched by Ukrainian government officials about the artificiality of Donbas as a region. In other words, the new narrative opposes the use of the term Donbas for something more than the coal mining area. In particular, Oleksiy Danilov, the Secretary of the National Security and Defence Council of Ukraine, expressed this argument in the following way: "There is no Donbas; it is very dangerous when we start saying such things. This is the definition imposed by the Russian Federation". According to Danilov, "the concept of Donbas has been purposefully used by the intelligence services of the Russia as an instrument of information warfare since 2000, and especially actively during the Russian aggression against Ukraine since 2014. The goal is to oppose and artificially separate a certain region of Ukraine as a territory that seems to have special rights and status, which gives further grounds to justify the creation and existence of the pseudo-states" (Dorosh, S. 2021).

The second direction is a redefinition of the existing Donbas identity or the search for a new one by ordinary people. Among the factors pushing the residents of the government-controlled Donetsk and Luhansk regions to rethink their regional identity, there may be the need to mentally escape from the Donbas, which has become a symbol of war and decline since 2014. Also, the Donbas is no longer a single industrial complex, as most of the highly industrialized areas of the two oblasts were left outside the government-controlled territory. In 2014–2021, Donetsk lost both administrative and symbolic status for the government-controlled areas, and, thus, people should have reoriented to the other centres. “What is Donbas now? Donbas is where the war is. Many call it the “Old Industrial Area”. The so-called “Russian-Ukrainian alliance” has existed there… … It disintegrated in 2014, when these people started to determine who they are” (Semyvolos, I. 2016).

Mariupol in 2014–2021: capital of re-emerged Pryazovia or Donetsk's successor?

The southern part of Donetsk oblast seems to be one of the areas that have distanced from the Donbas. In the broadest geographic sense, Pryazovia (literally Cis-Azov region) is referred to the northern coast of the Sea of Azov. From this point of view, Pryazovia includes the southern parts of Donetsk and Zaporizhia oblasts and the eastern part of Kherson oblast in Ukraine, as well as a portion of Rostov oblast of Russia adjacent to the northern shore of the Taganrog Bay. Pryazovia differs from the surrounding areas from the standpoint of economy and history. Except for the city of Mariupol, it is a less urbanized, agrarian, fishing, and seaside resort region in contrast to the highly urbanized industrial and mining areas of Donbas and Prydniprovia bordering it from the north. Pryazovia has a significantly more heterogeneous ethnic structure compared to surrounding areas. Ukrainian Cossacks came to the northern shore of the Sea of Azov in the middle of 18th century and founded such military administrative units as Kalmiuska Palanka of the Zaporozhian Sich (1739–1775) and Azov Cossack Host (1832–1862). The Azov Greeks were relocated to Pryazovia from the Crimea by decree of tsar Catherine II in 1778–1779. Also, Pryazovia was settled by German colonists, Russian Old Believers, Dukhobors and Molokans. In the days of the Ukrainian People's Republic (1917–1921), the Azov Land with the centre in Mariupol was envisaged as one of the first-order administrative units of the state (Kotyhorenko, V. *et. al.* 2014; Ruschenko, I. *et al.* 2015).

Indirect evidence of the developing Pryazovia identity comes from toponyms. Although the names of enterprises and organizations, derived from “Donbas”, tend to spread across the whole Donetsk and Luhansk oblasts, they are relatively scarce in the extreme southern part of Donetsk oblast (Gnatiuk, O. and Melnychuk, A. 2019), while the latter appears extremely reach with names derived from “Pryazovia” (MAPIAR 2019). Direct evidence comes from sociologists. Survey carried out in 2015 (Ruschenko, I. *et al.* 2015) used two markers of Pryazovia identity: (1) identification of a residence place as Pryazovia and (2) self-identification as Pryazovia resident. As for the first marker, 27.1 percent of respondents identified their place of residence as “Pryazovia”. Regarding the second marker, 63.6 percent of the respondents considered themselves Pryazovians (30.9% – definitely yes; 32.7% – rather yes).

Mariupol, a mid-sized port city (population ca. 450,000) in the southern part of Donetsk oblast, is the largest city and the informal capital of Pryazovia (Davydenko, O. 2019). According to the survey of 2015, the highest priority to Pryazovia as a perceived residence place (41.2%) was observed exactly in Mariupol, and the three top-ranked famous personalities representing Pryazovia turned out to be Mariupolitans (Ruschenko, I. *et al.* 2015). Mariupol was temporarily controlled by the DPR during the late spring months of 2014, but soon liberated by the Ukrainian troops on June 13, 2014 and de-facto converted into the administrative centre of Donetsk oblast. However, since October 11, 2014 the oblast government moved to the much smaller city of Kramatorsk (population ca. 150,000) in the northern part of Donetsk oblast, although military agencies remained in Mariupol due to its proximity to the front line. In 2022, during the wide-scale Russian military invasion into Ukraine, Mariupol was besieged by Russian troops and systematically destroyed by them.

The first historical settlements at the site of contemporary Mariupol were established by Zaporozhian Cossacks and Crimean Greeks

(Kotyhorenko, V. *et. al.* 2014). Until the end of the 19th century, Mariupol was a port city that prospered due to trade and fishing. The new period of the city development began in 1898 with opening of a steelworks. Until 2022, the city's economy was dominated by two large steelworks, both controlled by the Metinvest Corporation. Mariupol is often considered as a typical company town, in which owners and managers of dominant factories, nicknamed job-givers, have a decisive voice in the city's decision-making (Matsuzato, K. 2018), while grateful employees and members of their families are thanking them with their votes in the elections (Dehterenko, A. 2008). The industrialization resulted in massive inflow of workers and their families and, consequently, in rapid growth of the city's population, as well as gradual loss of original urban identity. Nowadays, the city is predominantly Russian-speaking: in 2001, 89.7 percent of urban population spoke Russian, 9.9 percent spoke Ukrainian, and only 0.2 percent spoke Mariupol Greek and Urum; at the same time, Ukrainians constituted 48.7 percent of the urban population, Russians 44.4 percent and Greek 4.3 percent (Population Census 2001).

Furthermore, Mariupol has all grounds to be considered as a geopolitical fault-line city – a site of heightened political confrontation, where irreconcilable narratives tensely coexist, and where fundamental aspects of historical memory collide (Gentile, M. 2017). It is located in proximity of the Russian border with all expected consequences like intense cross-border ties, exposure to the Russia's informational spaces, relatively weak connections to the national centre of power in Kyiv, and blurred national identity. In 2020, Mariupolitans appeared to be surprisingly frank in revealing opinions that contradict the nationwide narrative of Ukrainian unity, and the city population was divided between a large openly pro-Russian minority of at least 40 percent and a small explicitly pro-Ukrainian and pro-European minority, represented by between 10 and 20 percent of the population (Gentile, M. 2020).

Nevertheless, the initial difference in local history and economy in Mariupol from the rest of Donetsk oblast still manifests itself. For instance, Matsuzato, K. (2018) noticed the local politician's expression on the local mentality that "the Donbas people are coal miners, so they act as they are ordered to. We are metallurgists, so we do not act unless we are persuaded and convinced". After the occupation of a portion of Donetsk oblast by the Russian-supported separatists in 2014, proposals to separate Pryazovia from Donetsk oblast were voiced by a plenty of politicians and statesmen. For instance, Serhii Taruta, ex-governor of Donetsk oblast, claimed that "intellectuals in Mariupol distinguish Pryazovia from the coal-mining Donbas". The idea of uniting the historical areas of Pryazovia into a single administrative unit (oblast) was definitely supported by 17.8 percent and rather supported by 43.6 percent of the respondents (Ruschenko, I. *et al.* 2015). Thus, it is probable that since 2014 some part of Mariupolitans is cultivating the Pryazovia identity as an alternative or supplement to Donbas identity.

On the other hand, the occupation of Donetsk since 2014 resulted in the competition between the cities claiming the role of a new oblast capital, primarily Mariupol and Kramatorsk. In 2019, a petition was registered on the website of the President of Ukraine with a proposal to change the name of Donetsk oblast to Mariupol oblast. The petitioner argued that the administration and residents of Donetsk have shown "disloyalty to the Ukrainian state and sided with the Russian occupiers", so it is advisable to move the regional centre to Mariupol and rename the whole oblast. This petition did not receive the required number of votes for consideration by the President, but it can be considered as a message of relevant public inquiry from, at least, a part of Mariupolitans (Radio Svoboda, 2019). Here we see coexisting and competing ideas "Mariupol is a capital of Pryazovia" vs. "Mariupol is a capital of [Donetsk] oblast": the first is clearly linked to the Pryazovia identity, the latter identifies

Mariupol rather as a Donbas city – a successor of Donetsk, but both ideas have in common the desire to make Mariupol a regional centre, no matter the name of the region.

Data and methods

The research is based on the survey data (n = 1,251, aged 18+) collected in Mariupol in 2020 through personal interviews commissioned from the Kyiv-based Center for Social Indicators, which shares its resources with the Kyiv International Institute of Sociology. The sample relies on a household-based sampling frame, and only one person was selected within each household using a somewhat modified version of the so-called Kish table (Kish, L. 1949). The response rate is 30 percent, taking into account all forms of non-response. The main themes covered by the survey relate to current political and geopolitical situation in Ukraine in general and in Mariupol in particular.

In the first stage of the study, we assess how widespread Pryazovia identity is in Mariupol, and how it relates to Donbas identity and to the desire to see Mariupol as the regional (oblast) centre. For this, we analyse responses to the following survey questions:

– Q1: (agreement with statement) "Pryazovia differs from the rest of Donetsk oblast in the specifics of the local society and culture" (four-option symmetric Likert scale: completely agree, rather agree, rather disagree and completely disagree);
– Q2: Mariupol is primarily a city of…? (options: Donechchyna, Donbas, Pryazovia, South-Eastern Ukraine);
– Q3: (agreement with statement) "It is necessary to create the Pryazovia oblast, and Mariupol should be its centre" (four-option symmetric Likert scale: completely agree, rather agree, rather disagree and completely disagree);
– Q4: (agreement with statement) "Mariupol should be the regional centre of Donetsk oblast (instead of Kramatorsk)" (four-option symmetric Likert scale: completely agree, rather agree, rather disagree and completely disagree).

Positive (completely agree, rather agree) answers to the first question, as well as the answer "Pryazovia" to the second question, are considered as indicators (markers) of identification with Pryazovia. The third and the fourth questions are designed to estimate the support for the status of Mariupol as a regional centre (the phenomenon of "Mariupolocentrism") in two versions, corresponding to the ideas of the "capital of Pryazovia" and "Donetsk's successor", respectively.

The second stage of the study was designed to determine the specific predictors of Pryazovia identity and "Mariupolocentrism" (if any), employing binary logistic regression. Our dependent variables are based on the four aforementioned indicative questions and are designed as indicators of Pryazovia identity and "Mariupolocentrism":

– Dependent Variable (DV)1: Agreement that Mariupol is primarily a city of Pryazovia (yes = 1, otherwise = 0);
– DV2: Agreement that Pryazovia differs from the rest of Donetsk oblast in the specifics of the local society and culture (agree = 1, otherwise = 0);
– DV3: Support for creating new Pryazovia oblast with a centre in Mariupol (agree = 1, otherwise = 0);
– DV4: Support for moving the centre of Donetsk oblast to Mariupol (agree = 1, otherwise = 0).

In defining independent variables, summarized in *Table 1*, we started out from the idea that Pryazovia identity and "Mariupolocentrism" should qualitatively differ from Donbas identity (see Pakhomenko, S. 2015; Semyvolos, I. 2016). The hypothesis is that Donbas becomes stigmatized for a pro-Ukrainian and pro-European part of the population since it begins to associate with geopolitical rival (Russia), as well as war, destruction, and decline. The reactive search for a new host identity is a way to escape from the traumatic past via distancing from the stigmatized identity. Consequently, self-identification with Pryazovia and, to a lesser extent, "Mariupolocentrism", are expected to have positive correlation with Ukrainian ethnic-national identity, non-industrial culture, and negative (or at least neutral) attitudes towards the Soviet past and the Russian geopolitical narrative. Also, we expect from positive correlation with the support for Ukrainian central government policy and legislation, which reflects Ukrainian civic-national identity *(Table 1).*

Table 1. Independent variables for binary logistic regression and their rationale

Independent variable (covariate)	Rationale
Sex: male (ref. female)	Standard demographic control
Age: 40–59 years; 60+ (ref. 18–39 years)	Standard demographic control
Education: higher (in)complete: (ref. other)	It is expected that people with higher education are more aware of Pryazovia history and geography
Feeling European: yes (ref. no)	Indicator of European identity
Feeling Soviet: yes (ref. no)	Indicator of Soviet identity
Language used at home: Ukrainian and/or other, except for Russian (ref. other)	Indicator of Ukrainian ethnic identity. This is stronger indicator than simply 'Feeling Ukrainian' since many ethnic Ukrainians speak Russian
Heavy industry should be the basis for the development of Ukraine: agree (ref. disagree)	Indicator of industrial culture
Crimea is and will always be a part of Ukraine: agree (ref. disagree)	Indicator of central government policy support: attitude to the territorial integrity of Ukraine
Russian must be the second state language in Ukraine: agree (ref. disagree)	Indicator of central government policy support: attitude to the national language policy
Was it necessary to demolish the monuments to Lenin?: yes (ref. no)	Indicator of central government policy support: attitude to the national decommunization policy
Was 11 May 2014 DPR referendum legitimate: agree (ref. disagree)	Attitude to the Russian-supported Donbas separatism
Ukraine should be in Russia's sphere of influence: agree (ref. disagree)	Support for the Russian geopolitical narrative
Ukraine is actually ruled by external forces such as the George Soros or Bill Gates organizations: agree (ref. disagree)	Belief in one of the most widespread Russian propaganda myths

Expectably, older age correlates with feeling Soviet, but not completely, and all models have passed the multi-collinearity test (VIF values) with good margin.

Results and discussion

More than a half of respondents (59.9%) think that Pryazovia differs from other parts of Donetsk oblast in the specifics of the local society and culture, including 17.3 percent of respondents that definitely agreed with this statement *(Table 2).* On the other side, only 10.2 percent of respondents definitely disagree with the cultural and societal difference of Pryazovia from the Donbas. In this way, the opinion about the cultural and societal distinction of Pryazovia from the rest of Donetsk oblast is prevalent among Mariupolitans. At the same time, only 16.6 percent of respondents consider Mariupol primarily a city of Pryazovia, while the vast majority (54.4%) considers it primarily the city of Donbas. Thus, although 64.5 percent of respondents declared at least one marker of Pryazovia identity, only 11.9 percent declared both of them *(Figure 2,* a*).* This means that the vast majority of those who recognize the cultural distinction of Pryazovia consider Mariupol primarily a city of the Donbas. Such results suggest that although for most Mariupolitans Pryazovia

Table 2. *Responses to the indicative questions for Pryazovia identity, in percent*

Yes		No		Hard to say
Definitely yes	Rather yes	Rather no	Definitely no	
Q1: Pryazovia differs from the rest of Donetsk oblast in the specifics of the local society and culture				
59.9		33.3		6.2
17.3	42.6	23.1	10.2	
Q2: Mariupol is primarily a city of				
Donechchyna	Donbas	Pryazovia	South-Eastern Ukraine	
11.8	54.4	16.6	14.7	

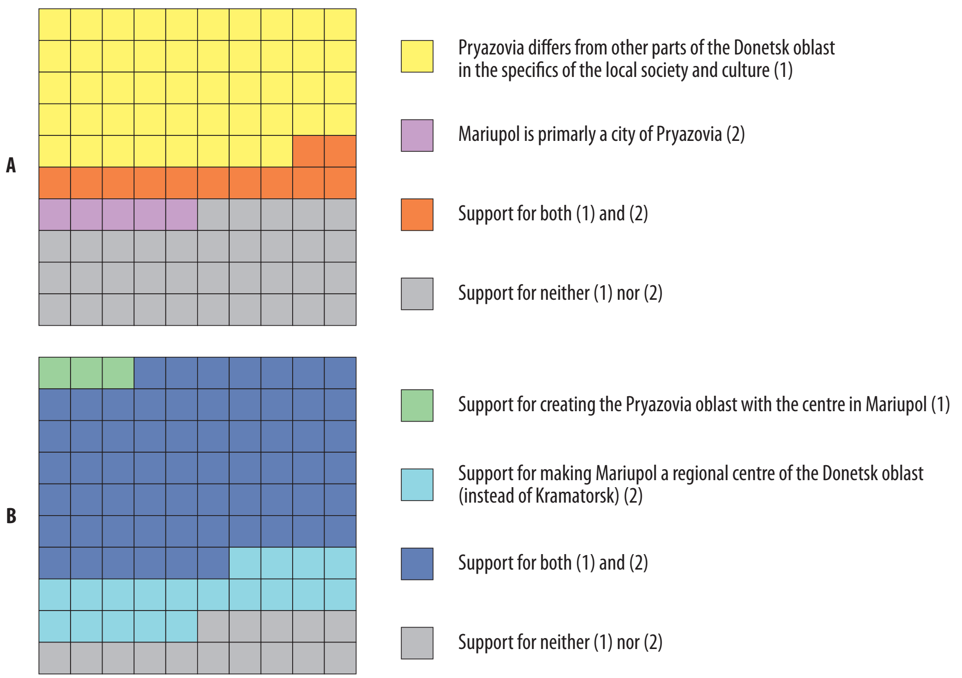


Fig. 2. Distribution of Pryazovia identity and "Mariupolocentrism" markers in the Mariupol population

is clearly not the same as Donbas, it is rather a distinct part (a kind) of the Donbas then something outside from the Donbas. In other words, our findings support the model according to which Pryazovia is a culturally specific sub-region of Donbas rather than a separate region compared to the Donbas. While the first model is supported by almost two thirds of respondents, the second is supported by only one in ten respondents. Consequently, Pryazovia identity appears to be rather a sub-identity built over the Donbas identity than truly independent identity equal to Donbas identity. Of course, it is necessary to keep in mind that only the identity of Mariupolitans is discussed here; in the other territories, for instance, outside Donetsk oblast, other models of Pryazovia identity are possible.

The vast majority of respondents want to see Mariupol as an administrative regional (oblast) centre *(Table 3).* Those who support the idea of Mariupol as the centre of Donetsk oblast (81.9%) prevail over those who support the idea of Mariupol as the centre of the newly formed Pryazovia oblast (66.0%). However, these two groups of respondents widely intersect – the fact meaning that most respondents support both options *(Figure 2*, b*)*. Notably, even among the respondents who definitely deny the cultural distinction of Pryazovia, 46.5 percent and 26.8 percent respectively stay in favour of making Mariupol the centre of Donetsk / Pryazovia oblast. Simultaneously, those who recognize the cultural distinction of Pryazovia are more supportive of moving the centre of Donetsk oblast to Mariupol than of the formation of separate Pryazovia oblast. This not only supports the conclusion about the umbrella status of Donbas identity for Pryazovia identity, but also means that for significant part of the respondents the main thing is the status of the regional centre for Mariupol – no matter which region: most Pryazovians are "Mariupolocentrists", but not all "Mariupolocentrists" are Pryazovians (see *Figure 2).*

According to binary logistic regression model *(Table 4)*, people who consider Mariupol to be primarily a city of Pryazovia demonstrate strong Ukrainian civic identity on a number of issues. In particular, they disapprove Russian as a second state language and consider DPR referendum illegitimate. Also, they reject Russian propaganda myth about the external control on Ukrainian government, and they are certainly not bearers of industrial culture. We found statistically significant correlation neither with feeling European or Soviet nor, especially, with Ukrainian ethnic identity. Model quality check indicates that it is well calibrated and explains a significant part of the dependent variable dispersion. Thus, this relatively thing group of Mariupolitans at least partially fit out initial assumption about the Pryazovia identity predictors. These people seem to be the strongest Pryazovians with a clear pro-Ukrainian civic position, immunity to the Russian propaganda, and strong negation of industrial culture. However, their pro-Ukrainian and anti-Russian position is embedded into the local context of the ongoing geopolitical clash and reflects their civic identity rather than ethnic one. In particular, these people may speak Russian language at home and feel Soviet, but they obviously seeking to distance from Donbas identity and to support the Ukrainian government position.

The characteristics of people recognizing Pryazovia as a region different from the rest of Donetsk oblast fits the initial hypothesis on Pryazovia identity significantly worse. Although they support for territorial integrity of Ukraine and refuse to accept Russian as a second state language, they tend to believe that Ukraine should be in Russia's sphere of influence and that DPR referendum was legitimate. Correlation with European and Soviet self-identifications, as well as with Ukrainian ethnic identity, was not found for this dependent variable too. Besides, the selected model performs badly in this case considering the statistical tests. Thus, we consider these people to be a rather vague group

Table 3. Responses to the indicative questions for "Mariupolocentrism", in percent

Yes		No		Hard to say
Definitely yes	Rather yes	Rather no	Definitely no	
Q3: It is necessary to create Pryazovia oblast, and Mariupol should be its centre				
66.0		16.3		17.4
23.3	42.7	11.4	4.9	
Q4: Mariupol should be regional centre of Donetsk oblast (instead of Kramatorsk)				
81.9		8.8		9.1
35.6	46.3	7.2	1.6	

Table 4. Binary logistic regression results: predictors of Pryazovia identity

Independent variables (covariates)	Odds coefficient = Exp(B)	
	DV1: Mariupol is primarily a city of Pryazovia	DV2: Pryazovia differs from the rest of Donetsk oblast
Male (ref. female)	1.222	1.049
Age 40–59 years (ref. 18–39 years)	1.634*	1.028
Age 60+ years (ref. 18–39 years)	1.442	0.975
Education: higher (in)complete: (ref. other)	0.838	1.247
Feeling European: yes (ref. no)	1.411	0.836
Feeling Soviet: yes (ref. no)	0.757	0.772
Language used at home: Ukrainian and/or other, except for Russian (ref. other)	1.376	2.518
Heavy industry should be the basis for the development of Ukraine: agree (ref. disagree)	0.403***	1.029
Crimea is and will always be a part of Ukraine: agree (ref. disagree)	1.078	1.569***
Russian must be the second state language in Ukraine: agree (ref. disagree)	0.572*	0.646*
Was it necessary to demolish the monuments to Lenin?: yes (ref. no)	0.997	1.301
Was 11 May 2014 DPR referendum legitimate: agree (ref. disagree)	0.455***	1.845***
Ukraine should be in Russia's sphere of influence: agree (ref. disagree)	0.707	1.553*
Ukraine is actually ruled by external forces such as the George Soros or Bill Gates organizations: agree (ref. disagree)	0.468***	1.063
Constant	1.164	1.211
Hosmer-Lemeshow Test (Sig.)	0.565	0.028
Nagelkerke R Square	0.205	0.076

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

in terms of their geopolitical preferences and civic positions. Probably, their awareness of Pryazovia refers to their *objective knowledge* on the local geography and history rather than *conscious identity* resulting from rethinking of the current situation in the region.

Table 5 characterizes all "Mariupolocentrists" as people with higher education and supporters of the territorial integrity of Ukraine. This is where the similarity between the two groups of "Mariupolocentrists" ends. Apart from the support for the belonging of Crimea to Ukraine, supporters of Mariupol as a centre of Pryazovia oblast turned out to be opponents of the Ukrainian government position. In particular, they support the official status of the Russian language, agree with the legitimacy of DPR referendum, and believe in Russian propaganda myth that Ukraine is ruled by external forces. Consequently, this Pryazovia-focused kind of "Mariupolocentrism" represents something opposite to that initially expected from Pryazovia identity. The attitude to the status of Crimea indicates that the Ukrainian state is present in their world views, but their vision of Ukraine fits the Russian narrative. We may guess that they imagine hypothetical Pryazovia oblast as a region with a broad autonomy from the central government in Kyiv.

At the same time, supporters of Mariupol as a centre of Donetsk oblast are rather amorphous group almost indistinguishable from the rest of Mariupolitans, since this kind of

Table 5. Binary logistic regression results: predictors of "Mariupolocentrism"

Independent variables (covariates)	Odds coefficient = Exp(B)	
	DV3: Support for Mariupol as a centre of Pryazovia oblast	DV4: Support for Mariupol as a centre of Donetsk oblast
Male (ref. female)	0.902	0.989
Age 40–59 years (ref. 18–39 years)	1.030	0.868
Age 60+ years (ref. 18–39 years)	1.410	0.903
Education: higher (in)complete: (ref. other)	1.508*	1.923***
Feeling European: yes (ref. no)	1.021	1.214
Feeling Soviet: yes (ref. no)	0.721	0.824
Language used at home: Ukrainian and/or other, except for Russian (ref. other)	1.300	1.378
Heavy industry should be the basis for the development of Ukraine: agree (ref. disagree)	0.751	0.672
Crimea is and will always be a part of Ukraine: agree (ref. disagree)	3.766***	1.492*
Russian must be the second state language in Ukraine: agree (ref. disagree)	4.097***	0.821
Was it necessary to demolish the monuments to Lenin?: yes (ref. no)	1.049	0.807
Was 11 May 2014 DPR referendum legitimate: agree (ref. disagree)	1.380*	1.251
Ukraine should be in Russia's sphere of influence: agree (ref. disagree)	0.796	1.048
Ukraine is actually ruled by external forces such as the George Soros or Bill Gates organizations: agree (ref. disagree)	1.350*	0.647*
Constant	0.293	7.809***
Hosmer-Lemeshow Test (Sig.)	0.148	0.647
Nagelkerke R Square	0.161	0.016

Notes: *p < 0.05; * p < 0.01; ***p < 0.001.

"Mariupolocentrism" has no statistically significant predictors in terms of both ethnic and civic identities and geopolitical preferences. Their refusal to believe in the Russian propaganda myth may follow from their higher level of education and, consequently, greater capacity to critical thinking. We guess that their motivation to make Mariupol a regional centre is driven by rather economic than geopolitical reasons and reflects the desire to improve the position of Mariupol in the competition for resources, as well as economic and political influence (cf. Paasi, A. 2009).

Discussing the findings, it is necessary to keep in mind that the answers of the respondents could be potentially distorted by the interviewer effect. The political situation in Ukraine and the ongoing Russian-Ukrainian conflict of the last 8 years could create some biases in the answers of the respondents. The general explanation for this is known as social desirability bias – respondents answer some sensitive questions in such a way as to comply with what they think society find more desirable, even if they hold only vague or no preferences on the issue or have a different opinion (Berinsky, A.J. 1999). The respondents could avoid responses that might offend the interviewer of the opposing geopolitical preferences and of being frank (or at least franker) with similar views (cf. Lipps, O. and Lutz, G. 2010; Németh, R. and Luksander, A. 2018). In particular, given that the interviewers represented the Kyiv-based sociological services, some respondents could have been inclined to conceal their sympathies for Russia and the separatist movements. However, the survey was performed by the reputed sociological institutes, and measures have been taken to eliminate the interviewers conveying significantly biased results during the test surveys prior to the main study.

Conclusions

The case of Mariupol shows how military events, accompanied by the spatial disintegration of the old regions with the emergence of new borders and front lines, lead to urban identity rethinking. The identity that prevailed before the conflict (e.g., Donbas identity) becomes stigmatized for a certain part of population as being associated with (geo)political rivals, war crimes, destruction, and decline. In order to escape from the stigmatized past, people start to search for a new identity, which may be invented de novo or represent already existing identity that had been silenced due to the historical circumstances but receives a new momentum for development (e.g., Pryazovia identity). At the same time, the case of Mariupol, a geopolitical fault-line city with already existing internal tensions and irreconcilable narratives (Gentile, M. 2020), clearly shows that this identity rethinking is neither rapid no straightforward. After almost a decade of the conflict, only tiny minority of Mariupolitans have developed strong new identity challenging the very grounds of the stigmatized old identity. Instead, Donbas identity appears quite persistent, while the new Pryazovia identity functions mainly as a complementary one. Such identity dualism may represent just a first step in escaping the stigmatised identity. However, the other possibility is that the majority of Mariupolitans are not consciously rejecting their old stigmatized identity but rather are starting to build it upon an alternative Ukraine-centric narrative. In this way, stigmatized identity is redefined on a new ground by a part of population, which contributes to growing heterogeneity of Donbas identity (cf. Korzhov, G. 2006; Zolkina, M. 2017).

The rethinking of identity is influenced also by the conflict-driven redrawing of political and administrative map. If the perceptual core of the existing region is cut off by the contact line or newly emerging administrative border, it loses its visible integrity, so the population of its peripheral parts is tempted to break with the old identity and seek a new one. Previous studies have demonstrated the dynamism of the region's perceptual boundaries due to the administrative changes in historical retrospective (cf. Gnatiuk, O. and Melnychuk, A. 2019 for Ukraine; Marek, P. 2020 for Czechia). The case of Mariupol, where Donbas identity is redefined and simultaneously gradually complemented/substituted by Pryazovia identity, allows us to contemplate this process in real time. As a result, the disappearance of old regional identity and the emergence of new identities are observed (cf. Paasi, A. 2009: "The institutionalization of a region is accompanied with the de-institutionalization of some other regional units which takes place either through integration or dispersion"). In this way, the military conflict revealed the internal heterogeneity of the Donbas, revitalizing informal borders artificially hidden by the Soviet administrative division (cf. Semyvolos, I. 2016; Zolkina, M. 2017).

The search for a new identity includes reassessment of the city's role in the region. "Mariupolocentrism" may be considered as a shift from the regional (Donbas) identity to local level (urban) identity. The public request for higher administrative status for Mariupol can be seen also as a desire to institutionalize (and, accordingly, legalize) a new regional identity as a projection of local urban identity. Transforming into the regional capital would be an attempt to officially map the territorial shape of the urban region (either redefined Donbas or newly minted Pryazovia). For some people, rethinking of identity may be driven by rather economic than geopolitical reasons, since the official status of a regional centre would allow Mariupol to compete more successfully for resources: “Established regions are then ‘ready’ to be used in struggles over power and resources (which manifests itself most typically in regional policy)” (Paasi, A. 2009). Consequently, bearers of different markers of new identity may be quite diverse (up to contrasting) in terms of civic attitudes and geopolitical preferences. Nevertheless, in case of Mariupol, civic-national identity, including law abidance, shared beliefs and adherence to state-promoted values and institutions (Shulman, S. 2002; Leong, Ch. *et al.* 2020), is more relevant in understanding the military conflict driven identity transformation compared with ethnic-national identity (cf. Gentile, M. 2015; Giuliano, E. 2018; Aliyev, H. 2019; Kulyk, V. 2019) – a conclusion that may be extrapolated on the other geopolitical fault-line cities in Ukraine.

From the practical case-oriented point of view, the results of the survey might be important for further analysis of the situation in the region in a medium- and long-term perspective after the end of the war. Given that the city is currently destroyed, the status of Mariupol as the capital of Donetsk oblast is not relevant at least until its rebuilding, although the symbolical significance of a city substantially increased on the both sides of the conflict. The local territorial identity of Pryazovia might be used by the Russian occupational administration to legitimate establishment of a hypothetical “Pryazovia” statelet or a “federal region” as a part of Russia, exploiting the Pryazovia-focused kind of “Mariupolocentrism” with certain pro-Russian cultural sentiments. However, according to our analysis, the strongest bearers of Pryazovia identity clearly support pro-Ukrainian civic position and resist the Russian propaganda, therefore such attempts, if any, will most likely not be successful. On the other hand, if the city is recaptured by Ukrainian army, the idea of Pryazovia might be promoted by the Ukrainian state in order to build *de novo* the urban identity of a resurrected city and ultimately link it with the Ukrainian nation-state geopolitical narrative. This potentially refers not only to Mariupol, but to the other cities on the coast of Sea of Azov under the Russian occupation as well (Melitopol, Berdiansk, etc).

Acknowledgement: Funding from the Norwegian Research Council (NORRUSS grant 287267, “Ukrainian Geopolitical Fault-line Cities: Urban Identity, Geopolitics and Urban Policy”). We thank the anonymous reviewers for their valuable comments. This paper, started to be written already in 2021, before the full-scale Russian invasion into Ukraine, is dedicated to memory of the inhabitants and defenders of Mariupol, brutally destroyed by Russian troops in the spring 2022.

REFERENCES

Abibok, Yu. 2018. *Identity policy in the self-proclaimed republics in east Ukraine.* Guest Commentary 270. Warsaw, Centre for Eastern Studies (OSW). Available at https://www.osw.waw.pl/en/publikacje/osw-commentary/2018-06-06/identity-policy-self-proclaimed-republics-east-ukraine-0

Aliyev, H. 2019. The logic of ethnic responsibility and pro-government mobilization in East Ukraine conflict. *Comparative Political Studies* 52. (8): 1200–1231. Doi: 10.1177/0010414019830730.

Berinsky, A.J. 1999. The two faces of public opinion. *American Journal of Political Science* 43. 1209–1230. Doi: 10.2307/2991824.

Bole, D. 2021. “What is industrial culture anyway?” Theoretical framing of the concept in economic geography. *Geography Compass* 15. (7): e12595. Doi: 10.1111/gec3.12595.

Cresswell, T. 2013. *Geographic Thought. A Critical Introduction*. Chichester, Wiley-Blackwell.

Davydenko, O. 2019. *Stari budynky Mariupolia. Ekskursija stolytseju ukrajinskoho Pryazovja.* Radio Svoboda. Available at https://www.radiosvoboda.org/a/30287084.html

Dehterenko, A. 2008. *Etnonatsionalnyj aspect zhyttiedijalnosti terytorialnykh hromad Ukrajinskoho Pivnichnoho Pryazovja*. Mariupol, Novyj Svit.

Dobysh, M. 2019. Euromaidan and conflict in Eastern Ukraine in social networking sites: Territorial differences of pro-Russian subscriptions in Ukraine. *Hungarian Geographical Bulletin* 68. (1): 51–64. Doi: 10.15201/hungeobull.68.1.4.

Dorosh, S. 2021. *RNBO, Danilov i Donbas. Chy spravdi hovoryty “narod Donbasu” nebezpechno*. BBC News

Ukraine. Available at https://www.bbc.com/ukrainian/features-56606837

Flynn, M. 1996. Political mobilization in eastern Ukraine: The referendum of 1994 in the Donetsk oblast. *The European Legacy: Toward New Paradigms* 1. (1): 342–349.

Gentile, M. and Marcińczak, S. 2012. No more work for Stakhanov: Migrants and stayers in the depopulating Donbas, Ukraine. *Urban Geography* 33. (3): 401–419. Doi: 10.2747/0272-3638.33.3.401.

Gentile, M. 2015. West-oriented in the East-oriented Donbas: A political stratigraphy of geopolitical identity in Luhansk, Ukraine. *Post-Soviet Affairs* 31. (3): 201–223. Doi: 10.1080/1060586X.2014.995410.

Gentile, M. 2017. Geopolitical fault-line cities. In *Migration and the Ukraine Crisis: A Two-country Perspective*. Eds.: Pikulicka-Wilczewska, A. and Uehling, G., Bristol, E-International Relations, 6–24. Available at http://www.e-ir.info/wp-content/uploads/2017/06/Migration-and-The-Ukraine-Crisis-E-IR.pdf

Gentile, M. 2020. *The 'Elephant' in Mariupol: What geopolitical moods prevail in the city.* Kyiv, Vox Ukraine. Available at: https://voxukraine.org/en/the-elephant-in-mariupol/

Giuliano, E. 2018. Who supported separatism in Donbas? Ethnicity and popular opinion at the start of the Ukraine crisis. *Post-Soviet Affairs* 34. (2–3): 158–178. Doi: 10.1080/1060586X.2018.1447769.

Gnatiuk, O. and Glybovets, V. 2021. Uneven geographies in the various language editions of Wikipedia: the case of Ukrainian cities. *Hungarian Geographical Bulletin* 70. (3): 249–266. Doi: 10.15201/hungeobull.70.3.4.

Gnatiuk, O. and Melnychuk, A. 2019. Identities with historical regions – are they adapting to modern administrative division? The case of Ukraine. *European Spatial Research and Policy* 26. (1): 175–194. Doi: 10.18778/1231-1952.26.1.09.

Gnatiuk, O. and Melnychuk, A. 2021. Historical heraldic symbols as a marker of reproducing and transforming regional identity: the case of Ukraine. *Geographia Polonica* 94. (4): 589–607. Doi: 10.7163/GPol.0222.

Graham, B. 2000. The past in place: Historical geographies of identity. In *Modern Historical Geographies*. Eds.: Graham, B. and Nash C., Harlow, Pearson Education Ltd., 70–99.

Haran, O., Maksym, Ya. and Zolkina, M. 2019. Identity, war, and peace: public attitudes in the Ukraine-controlled Donbas. *Eurasian Geography and Economics* 60. (6): 684–708, Doi: 10.1080/15387216.2019.1667845.

Hedenskog, J. 2014. Ukraine – challenges for the future. In *Rude Awakening – Ramifications of Russian Aggression towards Ukraine*. Eds.: Granholm, N., Malminen, J. and Persson, G., Stockholm, Totalförsvarets forskningsinstitut, 51–56.

Kasala, K. and Šifta, M. 2017. The region as a concept: traditional and constructivist view. *AUC Geographica* 52. (2): 111–121. Doi: 10.14712/23361980.2017.17.

Kish, L. 1949. A procedure for objective respondent selection within the household. *Journal of the American Statistical Association* 44. (247): 380–387.

Korzhov, G. 2006. Regionalnaja identichnost Donbassa: genesis i tendentsii razvitija v uslovijakh obschestvennoj transformatsii. *Sotsiologija: Teorija, Metody, Marketing* 4. 38–51.

Kotyhorenko, V., Kalakura, O., Kovach, L., Kotsur, V., Kochan, N., Makarenko, N., Nikolajets, Yu., Panchuk, M. and Rafalskyi, O. 2014. *Donbas v Etnopolitychnomu Vymiri*. Kyiv, I.F. Kuras Institute of Political and Ethnic Studies, National Academy of Sciences of Ukraine.

Kudelia, S. and van Zyl, J. 2019. In my name: The impact of regional identity on civilian attitudes in the armed conflict in Donbas. *Nationalities Papers* 47. Special Issue 5: Special Issue on the Donbas Conflict. 801–821. Doi: 10.1017/nps.2019.68.

Kulyk, V. 2019. Identity in transformation: Russian-speakers in post-Soviet Ukraine. *Europe-Asia Studies* 71. (1): 156–178. Doi: 10.1080/09668136.2017.1379054.

Kuromiya, H. 1998. *Freedom and Terror in the Donbas – A Ukrainian-Russian Borderland, 1870s–1990s.* New York, Cambridge University Press.

Kuzio, T. 2015. The rise and fall of the Party of Regions political machine. *Problems of Post-Communism* 62. 174–186. Doi:10.1080/10758216.2015.1020127.

Kuzio, T. 2017. *Putin's War against Ukraine. Revolution, Nationalism, and Crime*. Toronto, Chair of Ukrainian Studies.

Leong, Ch., Komisarof, A., Dandy, J., Jasinskaja-Lahti, I., Safdar, S., Hanke, K. and Teng, E. 2020. What does it take to become "one of us?" Redefining ethnic-civic citizenship using markers of everyday nationhood. *International Journal of Intercultural Relations* 78. 10–19. Doi: 10.1016/j.ijintrel.2020.04.006.

Lipps, O. and Lutz, G. 2010. How answers on political attitudes are shaped by interviewers: Evidence from a panel survey. *Swiss Journal of Sociology* 36. 345–358.

MAPIAR 2019. *Nazvy istoryko-etnohrafichnykh rehioniv Ukrajiny u nazvakh pidpryjemstv ta orhanizatsij*. Available at https://mapiar.co.ua/2019/09/29/istorychni-rehiony-u-nazvakh-kompanii/

Marek, P. 2020. Transformation of the identity of a region: Theory and the empirical case of the perceptual regions of Bohemia and Moravia, Czech Republic. *Moravian Geographical Reports* 28. (3): 154–169. Doi: 10.2478/mgr-2020-0012.

Matsuzato, K. 2018. The Donbas War and politics in cities on the front: Mariupol and Kramatorsk. *Nationalities Papers* 46. (6): 1008–1027. Doi: 10.1080/00905992.2018.1480598.

Melnychuk, A. and Gnatiuk, O. 2018. Regional identity and the renewal of spatial administrative structures: The case of Podolia, Ukraine. *Moravian Geographical Reports* 26. (1): 42–54. Doi: 10.2478/mgr-2018-0004.

Mykhnenko, V. 2020. Causes and consequences of the war in Eastern Ukraine: An economic geography perspective. *Europe-Asia Studies* 72. (3): 528–560. Doi: 10.1080/09668136.2019.1684447.

Németh, R. and Luksander, A. 2018. Strong impact of interviewers on respondents' political choice: evidence from Hungary. *Field Methods* 30. (2): 155–170. Doi: 10.1177/1525822X18769502.

Nowak, K. 2018. The impact of the voivodeship boundaries on regional identity and perception of the Małopolska and Śląsk regions. *Studia Regionalne i Lokalne* 1. (71): 62–81. Doi: 10.7366/1509499517104.

Osipian, A. 2015. Historical myths, enemy images, and regional identity in the Donbass Insurgency (Spring 2014). *Journal of Soviet and Post-Soviet Politics and Society* 1. 109–140.

Paasi, A. 2009. The resurgence of the 'Region' and 'Regional Identity': theoretical perspectives and empirical observations on regional dynamics in Europe. *Review of International Studies* 35. 121–146. Doi: 10.1017/S0260210509008456.

Pakhomenko, S. 2015. Identity factor in terms of the Ukrainian crisis (the example of the Donbas region). *Bezpieczeństwo – Teoria i Praktyka* 3. 95–102.

Pistun, M., Mezentsev, K. and Tiorlo, V. 2004. *Rehionalna Polityka v Ukrajini: Suspilno-heohrafichnyj Aspekt*. Kyiv, Kyiv University Press.

Pred, A. 1984. Place as historically contingent process: Structuration and the time-geography of becoming places. *Annals of the Association of American Geographers* 74. (2): 279–297. Doi: 10.1111/j.1467-8306.1984.tb01453.x.

Radio Svoboda 2019. Donetsk or Mariupol: Who and why proposes to change the name of the region? Available at https://www.radiosvoboda.org/a/29792261.html

Ruschenko, I. (ed.) *et al.* 2015. *Sotsialno-politychni ujavlennia zhyteliv Pryazovja: identychnosti, pytannia vijny i myru, konfliktnyj potentsial*. Sociologic Survey Report. Kharkiv, National University of Kharkiv.

Semyvolos, I. 2016. *Iz prykhodom ukrajinskoji armiji na Donbasi pochalysia zminy. Pro novi identychnosti ta sposoby myslennia na Skhodi.* TEXTY.ORG.UA. Available at https://texty.org.ua/articles/68582/Iz_pryhodom_ukrajinskoji_armiji_na_Donbasi_pochalysa-68582/

Sereda, V. 2007. Regional historical identities and memory. Ukraina Moderna. Lviv–Donetsk. *Social Identities in Contemporary Ukraine* 12. (2): 160–209.

Šerý, M. and Šimáček, P. 2012. Perception of the historical border between Moravia and Silesia by residents of the Jeseník area as a partial aspect of their regional identity (Czech Republic). *Moravian Geographical Reports* 20. (2): 36–46.

Shulman, S. 1998. Competing versus complementary identities: Ukrainian-Russian relations and the loyalties of Russians in Ukraine. *Nationalities Papers* 26. (4): 615–632. Doi: 10.1080/00905999808408591.

Shulman, S. 2002. Challenging the civic/ethnic and west/east dichotomies in the study of nationalism. *Comparative Political Studies* 35. (5): 554–585. Doi: 10.1177/0010414002035005003.

Stebelsky, I. 2018. A tale of two regions: Geopolitics, identities, narratives, and conflict in Kharkiv and the Donbas. *Eurasian Geography and Economics* 59. 28–50. Doi:10.1080/15387216.2018.1428904.

Vaishar, A. and Zapletalová, J. 2016. Regional identities of Czech historical lands. *Hungarian Geographical Bulletin* 65. (1): 15–25. Doi: 10.15201/hungeobull.65.1.2.

Wilson, A. 2005. *Ukraine's Orange Revolution*. New Haven, CT, Yale University Press.

Wilson, A. 2016. The Donbas in 2014: Explaining civil conflict perhaps, but not Civil War. *Europe-Asia Studies* 68. (4): 631–652. Doi: 10.1080/09668136.2016.1176994.

Yakubova, L. 2015a. Etnonatsionalna spetsyfika Donbasu. *Rehionalna Istorija Ukrajiny* 9. 229–244.

Yakubova, L. 2015b. Protses ukrajinskoho natsijetvorennia vs imperski praktyky marhinalizatsiji na Donbasi (XVIII - pochatok XXI st.). *Ukrajinskyj Istorychnyj Zhurnal* 4. 173–188.

Zastavnyi, F. 2010. *Ekonomichni rajony Ukrajiny. Realiji ta perspektyvy*. Lviv, Svit.

Zimmer K. and Haran, O. 2008. Unfriendly takeover: Successor parties in Ukraine. *Communist and Post-Communist Studies* 41. 541–561. Doi:10.1016/j.postcomstud.2008.09.002.

Zolkina, M. 2017. The Donbas: new trends in public opinion. In *Constructing a Political Nation: Transformation of the Attitudes of Ukrainians during the War in the Donbas*. Eds.: Haran, O. and Yakovlev, M., Kyiv, Stylos, 159–182.

Methods for measuring the spatial mobility of tourists using a network theory approach

Gabriella NOD[1] and Antal AUBERT[1]

Abstract

The present study uses the methodological tools of network theory to investigate the spatial movements of tourists in the sample area, which is the South Transdanubian tourism region of Hungary. The basic idea of the study is that tourist movements across settlements in a larger tourist destination make a coherent network. As long as the approach is correct, this network can be measured by properties that are characteristic of networks, such as centrality or degree. A review of the methodology of similar studies previously published on the subject has been used to supplement the method of analysis used below. As a result, the study not only characterised the sample area municipalities in terms of network characteristics, but also classified them into clusters for strategic planning purposes on the basis of the mobility propensity of the tourists staying there.

Keywords: destination management, tourism mobility, cluster analysis, network theory

Received March 2022, accepted August 2022.

Introduction

The tourism industry has a long-standing desire to predict the movement of tourists within and across destinations, their consumption and the popularity of tourist destinations. Researches focusing on this have used a variety of approaches. There are many studies on consumption theory, where the aim is to assess tourists' choices based on their consumption decisions (Bernecker, P. 1962; Kotler, P. 1967; Mas-Colell, A. *et al.* 1995; Csapó, J. and M. Császár, Zs. 2021; Telbisz, T. *et al.* 2022) and their spatial movements (D'Agata, R. *et al.* 2013; Pécsek, B. 2015; Asero, V. *et al.* 2016). Also, the role of consumer preferences in travel decisions has been studied for decades (e.g., Woodside and Lysonski's "General destination choice model") (Woodside, A. and Lysonski, S. 1989). The former use economic and sociological perspectives, but the researches also include geographical approaches, for example, the optimal road accessibility of a given tourist destination (Tóth, G. and Dávid, L. 2009). In recent years, network approach research has become popular (Scott, N. *et al.* 2008a; 2009; Madarász, E. and Papp, Zs. 2013; Casanueva, C. *et al.* 2014), and thanks to digital advances we can now work with big data and determine the location and movement of an individual based on GPS coordinates or cell phone cellular data (Spinney, J.E. 2003; Ahas, R. and Mark, U. 2005; Díez-Díaz, F. *et al.* 2007; Wind, S. 2015; Zheng, W. *et al.* 2017).

We have therefore seen several attempts to measure the number of visitors. At the moment, Hungary is in the process of introducing the registration and mandatory data reporting in the system of the National Tourism Data Supply Centre (NTAK), as a supplement to the "Government Decree 239/2009 (X. 20.) on the detailed conditions for the provision of accommodation services and the procedure for issuing accommodation operating licences". The obligation to provide data mainly concerned accommo-

[1] Department of Tourism, Institute of Geography and Earth Sciences, University of Pécs. Ifjúság u. 6. H-7624, Pécs, Hungary. E-mails: gabica13@gamma.ttk.pte.hu, aubert@gamma.ttk.pte.hu

dation establishments and is now gradually being introduced for catering establishments and operators of tourist attractions as well.

In the long term, the obligation to provide data now in the implementation phase will provide a database for tracking the consumer choices of guests, and will also form the basis of the process discussed below, which could also be a tool for promoting the development of a destination marketing strategy or a development plan at regional level. The literature on tourism destination management and tourist mobility; in Hungary (Piskóti, I. 2007; Sziva, I. 2014; Nod, G. *et al.* 2019; Aubert, A. *et al.* 2021) is well established, but the system is just in a phase of transformation, in Butler's life cycle model (Butler, R.W. 1980), it is in the process of repositioning itself in the National Tourism Development Strategy 2030 – Tourism 2.0 (2021), which designates 11 tourist regions (Government Decree 429/2020 [IX. 14.]) within the borders of the country (Hungarian Tourism Agency 2021). The method presented in the study supports the development of regional strategies and the optimisation of the management system.

The following study applies the network approach, one of the many theories outlined above, to investigate the mobility of tourists arriving in the South Transdanubian tourism region of Hungary during their stay in the region, with the aim of determining the visitation of certain destinations, the length of stay in the region and the degree of mobility of tourists during their stay and in which direction.

The theory is not alien to the literature. Asero, V. *et al.* (2016) conducted a similar study in Sicily (with a similar sample to the one used in the present study), with the aim of identifying tourism networks by analysing tourism mobility across destinations. The results show that tourists' choices define the role of a destination within a network as "central" or "peripheral". Similar clusters, but delineated on the basis of several variables, are formed by the findings discussed later in this paper. A fundamental difference between the results of the two studies is that while Asero, V. *et al.* (2016) use a functional approach, the present study uses a more geographic approach and also characterises the municipalities under study by other network characteristics based on tourism mobility.

Since network research not only allows the discovery of network patterns, but also the prediction of their future functioning by knowing the properties and behaviour of the network (Scott, N. *et al.* 2008b, 2009), it is an excellent tool for strategic planning.

The literature on network theory can be traced back to the Swiss mathematician Leonard Euler (1741), who interpreted graph theory in the urban spatial structure by using the logical pattern of the bridges of the former Prussian town Königsberg (today Kaliningrad, Russia) and road network. The tourist movements examined in this study also connect several settlements, i.e., they are measurable physical movements. However, they do not follow optimal public, rail or water routes, but 'artificial' routes formed by tourists' motivations.

The discovery of Euler, L. (1741) laid the foundations for the development of graph theory, for which the terminology and formal tools were created by the Hungarian mathematician Dénes Kőnig (1936). The randomness and complexity of the networks that surround us in reality were described by the Erdős-Rényi model (Erdős, P. and Rényi, A. 1960), followed by the Watts-Strogatz model, which detected the formation of groups within the network (Watts, D.J. and Strogatz, S.H. 1998). The most recent major success in the study of networks was achieved by the research team led by Albert-László Barabási (2002), who described scale-independence using the example of the World Wide Web (Albert, R. and Barabási, A.-L. 2002).

According to the hypothesis formulated during the research design, *the role of each destination in the supply market of the region can be measured by the tourist movements of tourists across destinations (H1)*. To measure this, the study uses the centrality and degree calculations of network theory developed by Albert, R. and Barabási, A.-L. (2002), Letenyei, L. (2006), and Barabási, A.-L. (2016) to determine the centrality of the settlements.

The research designed to support this hypothesis is based on the following three research questions:

Q1: Can tourism movements in the region be understood as a coherent network?

Q2: Can the characteristics of the network (centrality, number of degrees) be used to characterise the position of a destination within the region?

Q3: Does the mobility of the visitor staying in a given settlement characterise the market role of the settlement?

Two studies are presented in the paper to support the hypothesis and answer the questions. The first presents the extent of the network of connections of each destination (with other settlements in the region) using central and degree measures. The second part of the research characterises and classifies each settlement into separate clusters based on the mobility willingness of the guests staying there.

Readers interested in the study but less familiar with the subject are recommended to consider the list of basic terms used later:

Centrality – the most obvious measure of centrality is the number of connections (degrees) of each point relative to the total number of connections. This is called degree centrality or proximity. It expresses the distance of an individual in the network from other individuals (Freeman, L.C. 1979).

Degree centrality (CD) – the activity of an actor in a network is measured by the number of other actors directly connected to it, i.e., the degree of the actor (Bolland, J.M. 1988).

Hub (di) – a concept from graph theory, the apex of a network, a point that is connected to other actors in the network (Kőnig, D. 1936).

Edge (Li) – a segment connecting the vertices forming a graph, each edge running between two vertices (Kőnig, D. 1936).

Methodology

The methodology developed on the basis of the research questions was tested on an existing data set. The survey was carried out by the Department of Tourism of the Faculty of Sciences, University of Pécs, during the last active tourism peak seasons (in 2018 and 2019 from May to September) before the pandemic, and aimed to map the travel and consumption habits of tourists arriving at the South Transdanubian tourist region. The survey was carried out in collaboration with the authors of this study (Gabriella Nod project coordinator, and Antal Aubert project manager). The primary data collection was done on paper through a field quantitative survey (in the form of a questionnaire, using assistants to help filling out). The representativeness was based on the spatial distribution, taking into account the data on tourist arrivals previously published by the Hungarian Central Statistical Office (KSH) in 2018. Data processing was performed on a sample of N = 430 items.

Sampling was done by a field survey with a Pécs focus. The Baranya County seat accounts for 16 percent of the sample, Szekszárd, Kaposvár and the Harkány–Villány–Siklós triangle have a significant share, similar to the KSH (2018) data.

7.9 percent of respondents were foreigners, 10 percent came to the region from Budapest, and 27.9 percent were travelling within South Transdanubia during the survey. The male/female ratio among the respondents was 5.5 to 4.5. The top 3 travel motivations were relaxation/regeneration (65.35% of cases), city visits (44.19%) and hiking in nature (25.58%). Data on the *accommodation used* by respondents, *destinations visited*, *travel motivation* and general *demographic factors* influencing the decision were processed.

In the sample area, i.e., the South Transdanubian tourism region, 529,384 guests stayed in *commercial accommodations* (providing business accommodation and meeting the legal requirements: minimum 5 rooms or 10 beds (Government Decree 239/2009 [X. 20.]) in 2019 (KSH, 2020). Prior to the introduction of the data supply system in 2020, only the guest flows of commercial accommodation were included in the statistics, so we had only estimates of the actual guest night numbers, which is why "invisible or hidden tourism" is an important research topic (Gonda, T.

et al. 2018; Michalkó, G. and Ilyés, N. 2020). The big data database to be built from 2020 onwards will now allow tracking guest movements and drawing conclusions for the narrow section of the profession that has access to this data. In the absence of access to data, similar sampling could help track tourists' spatial movements and improve the available measurement tools and methodology.

Mobility map analysis

The first part of the research aims to model the tourist movements of tourists within a sample area (region) as a coherent network, and then to determine the position of each destination within the region in terms of the direction and frequency of movements. The network science literature most commonly uses *centrality* and *prestige* analysis for position analysis, the former being applied to undirected and the latter to directed networks (Albert, R. and Barabási, A.-L. 2002; Letenyei, L. 2006; Tiszberger, M. 2015; Gao, C. *et al.* 2022). In the present study, the touristic movements of tourists within the region represent the interconnections of the network, the settlements where tourists used accommodation services became the *hubs (di)* of the network, the links between them, i.e., the tourist movements, are the *edges (Li)*. The settlement providing accommodation is therefore the hub and the settlements visited from there form the other elements of the network, i.e., there were tourist movements from hub *di* to a settlement with *k* elements. At this stage of the analysis, the network should therefore be treated as a directed network.

The cartographic representation of tourist movements was done in QGis 3.10 software and the data analysis (determination of the touristic position of the destination, analysis of the frequency of contacts) was done in Microsoft Excel.

Focal point testing in the network

One possible way to characterize the positions of settlements based on the data is to use *degree centrality* (*CD*), where analysis assumes that the degree (i.e., the number of other actors directly connected to it) is a good measure of the activity of an actor, following Letenyei, L. (2006).

$$CD(n_i) = d(n_i) = \sum_j x_{ij}, \quad (1)$$

where $d(n_i)$ is the degree of operator i, i.e., the sum of the values in row i of the matrix (Letenyei, L. 2006).

The degree number of the settlements $d(n_i)$, indicates the number of destinations that send visitors to the municipality. Since the indicator depends on the size of the network, for comparability this number must be divided by the maximum value of the network, which is g–1 (if it is connected to all other actors), where g is the number of members in the network, i.e., the number of settlements in the network (in the case of the study: 120).

$$C'D(n_i) = d(n_i) / (g–1), \quad (2)$$

where $d(n_i)$ is the degree of the operator i and g is the number of members in the network (Tiszberger, M. 2015).

Let k denote the number of members of the subnetwork formed by d_i, i.e., all the settlements that are connected to d_i (either as sending or receiving parties). $Fd(n_i)$ denotes the frequency of connections made. L_i denotes the number of connections realized, i.e., all connections made to d_i, whether outward or inward from d_i. N_i denotes the number of tourists staying in and visitors to a given settlement within the sample (N = 430). $Fd(n_i)$, or *frequency of degree*, denotes the total number of movements to *di* from the sending settlements $d(n_i)$.

Total tourism movements between sending settlements and designated settlements as a proportion of potential movements

This requires the ratio of total number of tourism movements ($Fd(n_i)$) from the sending settlements ($d(n_i)$) to the total number of possible movements to the designated settlement (d_i). In other words, the percentage of visitors staying in the sending settlement who visited the designated settlement:

Number of guests staying in the sending settlements / Total number of tourist movements to the selected settlement = ∑ (number of guests) $d(n_i)$ / $Fd(n_i)$.

Positioning of settlements according to the propensity of tourists to mobilise

The next part of the study focuses on the market positioning of each destination, using data on accommodation and destinations visited from the survey responses. The remainder of the study also uses the previously described degree number $d(n_i)$, i.e., the number of other settlements that send guests directly to the surveyed settlement.

Suppose that by *n* number of guests stay at settlement *di* who visit settlement $t_1, t_2 ... t_n$. We can determine the percentage of the *n* number of guests staying in settlement *di* who visit settlements $t_1, t_2 ... t_n$ and vice versa. This allows us to measure both an inward and an outward networking. These indicators serve to define the positioning of destinations, which can also optimise the structure of co-operations and destination management.

Once the database has been sorted, the study determines the number of guests staying in each settlement ($N(g_i)$ *number of guests*) and the number of settlements visited by guests during their stay in the region (k_{out}), which also indicates the extent of mobility of the settlement. The average number of settlements visited by a guest gives the mobility propensity of a settlement (M_w, *willingness to be mobile*). The "popularity" of a settlement is further measured by the degree number of the settlement $d(n_i)$ and the degree frequency $Fd(n_i)$. The former represents the number of sending settlements and the latter the number of guests from the sending settlement. Since each settlement has a mobility propensity score and a popularity score, *a k-means calculation* can be used to determine the position of the settlements, i.e., which cluster is closest to the central value of the cluster based on the position of the two scores (Tan, P.-N. *et al.* 2006):

ROOT(("Popularity"-INDEX(BLOCK(Cluster mean X,Y))^2 + (M_w-INDEX(BLOCK (Cluster mean X,Y))^2, (3)

where the coordinates of the mean of each cluster are given as criteria.

Analysis of findings

The performance of some tourist destinations is determined by the size of the sending area, so the results are presented first by plotting the movements of visitors to the region between their place of residence and their destination of choice in the region in vector form *(Figure 1).* (For readability of the map, only movements of domestic tourists are displayed.)

In the case of the present study area, the spatially representative survey describes a strong intra-regional movement, with 13.0 percent of the respondents living in Baranya county, 8.7 percent in Somogy county and 6.3 percent in Tolna county (counties of South Transdanubia). A significant proportion of foreign visitors to South Transdanubia come from the capital city Budapest (10.3%) and Pest county (2.6%), Fejér county (8.7%), and the proportion of foreign tourists not shown in the map (8.2%) is also significant. (Given the history of the region and the visiting habits of the expatriate German and Swabian population still living here, it is not surprising that a significant proportion of foreign visitors are Austrian and German.)

Characteristics of the network

The analysis of a mobility map helps to determine the position of a tourist destination within the region, i.e., whether it is a destination in its own right or whether it offers a complementary service to the region's tourism

Fig. 1. Tourist arrivals in the South Transdanubian tourist region, 2018. *Source*: Survey and editing by the authors.

offer. In total, tourists surveyed used accommodation services in 60 municipalities and visited 98 settlements with touristic intentions.

As the total number of elements of the network (accommodation + visited destination) is 120 settlements, corrected by the number of settlements that are both accommodations and destinations, it is not possible to present the full sample, i.e., all the contacts of all the settlements, due to space limitations, but the study highlights some of them that demonstrate the applied research methodology. The population size of the municipalities was defined as a criterion, with the lower limit being the level of small urban municipality (> 10,000 inhabitants). In Baranya, Tolna and Somogy counties, there are 14 municipalities above this population, 10 of which are statistically assessable on the basis of the survey. This group is completed by Villány and Harkány *(Table 1)*, which do not meet the population criterion but are important in the region because of their small-town status and tourist offer.

Although Siófok corresponds to a medium-sized city in terms of population and was named by the respondents as a preferred destination in the open-ended questions, as a settlement on the shore of Lake Balaton it was part of the priority tourism development area (Government Decree 429/2016 [XII. 15.]), which means that its development opportunities and access to funding sources differ significantly from other typical settlements in South Transdanubia, which is why it was not included in the study.

Degree centrality in the network

After the data collected during the sampling were digitized and sorted into a database, the data of the 12 settlements to be analysed were selected: the number of respondents using accommodation services in the settlement (the number of guests staying in the settlement), and the number of sending settlements (the degree of settlement), i.e., from which settlements the guests staying there came to the settlement under study *(Table 2)*. It is important to note that the data in the table

Table 1. Municipalities in South Transdanubia included in the study

Town	Local population, persons	County	Type of settlement
Pécs	144,188	Baranya	Big city
Kaposvár	61,920	Somogy	Medium-sized cities
Szekszárd	32,156	Tolna	
Komló	22,832	Baranya	
Paks	18,788	Tolna	Towns
Dombóvár	17,995	Tolna	
Mohács	17,143	Baranya	
Bonyhád	12,982	Tolna	
Tolna	10,987	Tolna	
Szigetvár	10,545	Baranya	
Harkány	4,632	Baranya	
Villány	2,282	Baranya	

Source: Own editing based on 2019 KSH data.

only include data from the sample; the statistics shows that these municipalities have proportionally higher guest flows. However, since the sample was spatially representative, the approach is relevant for the methodology.

To interpret the data in *Table 2*, let us take Pécs as an example. In the case of Pécs, 27 other settlements were visited by guests staying here (111 persons) and 35 other accommodation establishments (settlements) sent tourists to the county seat. The corrected degree-centrality of the settlement in the total network is 0.29, that is 29 percent of all the settlements in the network are linked to Pécs. Our Pécs-centred network is connected to 45 peaks (each settlement with which Pécs is connected is represented as a peak in the network, whether it is a sending or receiving municipality or both). The adjusted *degree-centred value* is therefore a good measure of the centrality of a settlement in the network, and, where appropriate, its position in the tourism market. The high networking of Pécs as a regional centre is not surprising, while the higher values of Szekszárd, Mohács, Harkány and Villány are associated with a strong local tourism offer. Next, the share of total tourism movements from the sending settlements to Pécs is presented in relation to the potential movements. That is, the percentage of visitors staying in the sending settlement who actually visit Pécs. In the case of Pécs, the rate is 44.1 percent, i.e., almost half of all possible movements to Pécs are made in the Pécs-centred network. A significant value is also seen in the case of Harkány and Villány, where one in four of the guests staying in the sending settlements is sure to visit the settlement that is the centre of the network (Harkány or Villány, as the case may be). The value indicates a kind of likeliness of the proportion of the guest flows in the vicinity of a given settlement within the actual guest flows of that settlement. This value can therefore be used for forecasting and as a tool for strategic planning. The value *Li* represents the total tourist flows to Pécs, i.e., the number of tourists staying here and the number of visitors coming for one day in the sample.

Positioning of settlements according to the mobility propensity of tourists staying in them

Of the 430 guests surveyed in the sample, 395 had used accommodation services during their stay in the region. The average number of nights spent by a guest in the region was 4.1 (standard deviation being 3.09). In total, respondents used accommodations in 62 settlements and visited 101 settlements for tourism purposes. Guests staying in one settlement moved to an average of 5.34 additional

Table 2. Metrics of the networks in the surveyed municipalities

Town	Number of guests staying in the settlement	Number of destination visited, pcs	Degree centrality, $d(n_i)$	Degree of the settlement, $C'D(n_i)$	Number of network items, pcs	Frequency of degree, $Fd(n_i)$	$Fd(n_i)$ compared to all possible movements, %	Passing edges Li, pcs
Pécs	111	27	35	0.29	45	116	41.1	227
Kaposvár	11	10	7	0.06	13	18	9.7	29
Szekszárd	35	20	23	0.19	35	33	16.7	68
Komló	10	13	3	0.03	13	8	4.8	18
Paks	5	5	5	0.04	7	9	16.7	14
Mohács	11	9	18	0.15	22	33	12.2	44
Dombóvár	20	11	7	0.06	14	10	6.3	30
Bonyhád	6	4	8	0.07	10	12	7.0	18
Tolna	2	3	1	0.01	4	2	5.7	4
Szigetvár	3	5	11	0.09	15	38	14.4	41
Harkány	36	18	13	0.11	25	56	30.4	92
Villány	16	8	19	0.16	22	68	24.6	84

Source: Own survey.

settlements during their stay. A settlement was visited by staying guests from another 3.14 settlements, on the average.

Based on the number of guests staying in a settlement $N(g_i)$ and the number of settlements they visited during their stay in the region (k_{out}), we obtain the average number of settlements visited by a guest, which shows the mobility propensity of guests staying in a settlement ($M_{w'}$) *(Figure 2).* Together, the number of tourists staying in a municipality and the number of guests visiting it in the course of the query give the "popularity" indicator of the settlement, which is categorised by colours in *Figure 3.*

The mobility propensity score ranges from 0.3 to 8.0 for the present study, where three broad groups are typically distinguished. The value below 1.0 is typical of those settlements where one or two guests' opinions were collected and the number of other settlements visited by them is low; the group's use of accommodation is characterised by more cost-effective solutions (33.3% stayed with a relative/friend, 23.8% in a boarding house, 14.3% in a holiday home). Bikal is an exception in the group, with higher accommodation expenditure (87.5% of Bikal guests stayed in a hotel), but Bikal and its medieval-style experience facility offer a complete stay of several days, which explains the low mobility.

The next groups are typically medium-sized towns and large cities, with high numbers of guests and lower mobility willingness, explained by the complex and multifunctional tourism offer of the destinations. Smaller municipalities also scored high in terms of mobility, where, as in the first category, the number of guests staying and the expenditure on accommodation are typically low (46.7% staying with friends/relatives, 26.7% in campsites and 20–20% in rural accommodation or boarding houses) but where mobility is high. In the light of the data, this group is characterised by a longer length of stay (6.6 nights on average).

The *mobility propensity* values, complemented by the *number of guests* $N(g_i)$, the *number of degrees* $d(n_i)$ and the *frequency of*

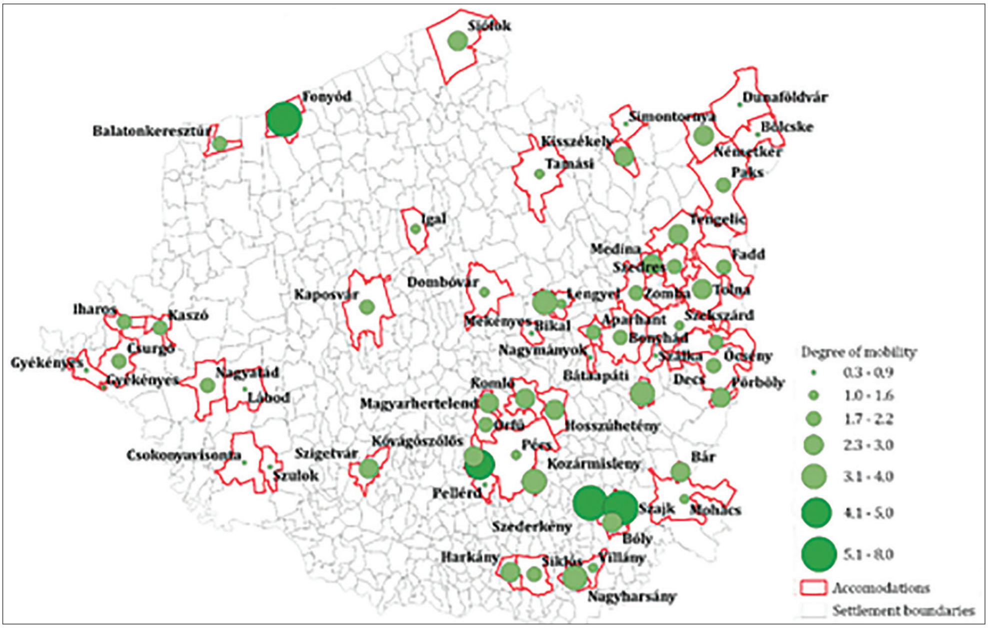


Fig. 2. The surveyed settlements of the South Transdanubian tourism region according to the mobility propensity of the visitors staying there. *Source*: Survey and editing by the authors.

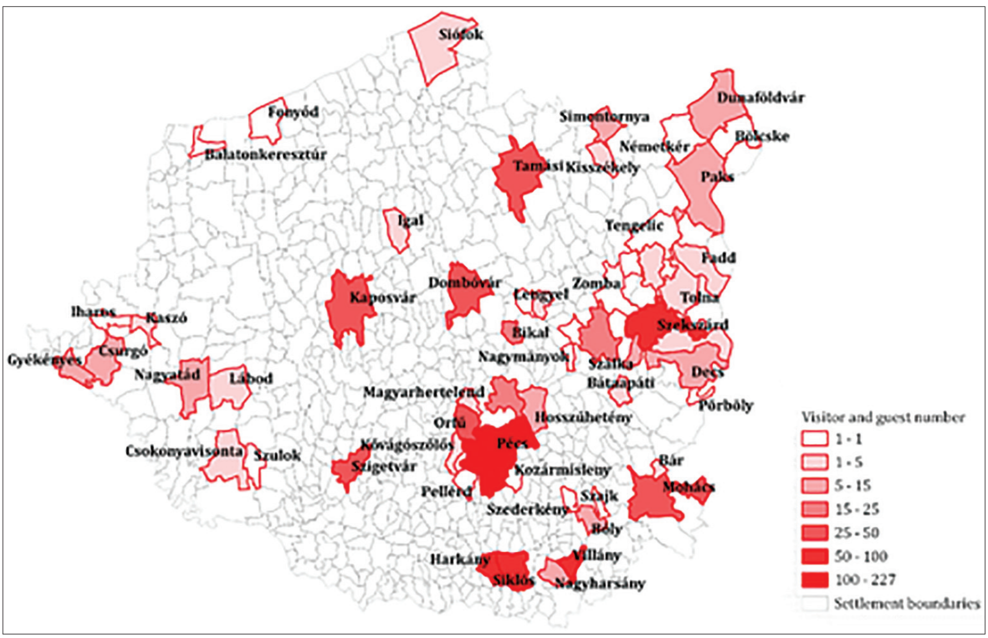


Fig. 3. The popularity of the surveyed settlements in the South Transdanubian tourism region in terms of the number of guests and visitors. *Source*: Survey and editing by the authors.

degrees $Fd(n_i)$, which help to measure the "popularity" of the settlements, divide settlements into six categories: less preferred municipality with high propensity to move out; less preferred municipality with low propensity to move out; medium preferred municipality with higher propensity to move out; medium preferred municipality with lower propensity to move out; preferred municipality with high propensity to move out; and preferred municipality with low propensity to move out. The k-means calculation used in the cluster analysis, based on the position of each municipality according to two values (popularity value and mobility propensity), placed the municipalities in the group closest to the central value of each cluster *(Table 3).*

The municipalities receiving each cluster value and their spatial distribution within the sample area are illustrated in *Figure 4.*

Figure 4 distinguishes six clusters. As in Asero, V. *et al.* (2016), the categories can be generalised and applied to the development of regional or (depending on the available data) national strategies. The number of visitors staying in and visiting a municipality is an indicator of its popularity, while the mobility propensity measures the tourist retention capacity of the municipality, the lower the mobility, the stronger the tourist retention capacity of the municipality. At the same time, the multiplier effect of tourism may be stronger in the vicinity of settlements with high mobility, i.e., settlements in the vicinity are more likely to experience an increase in visitor numbers. Based on the mobility propensity scores of visitors to a settlement, another grouping can also be applied, similar to the categories known from the literature on settlement geography (Pirisi, G. and Trócsányi, A. 2019):

- *Independent settlement* from which the resident guest does not move or moves only slightly. These are low mobility settlements with a group-specific or broad touristic offer.
- *A "sleeping" settlement*, with *a* favourable accommodation offer for the visitor, but little or no other tourism offer; characterised by a high mobility propensity.
- *A cooperative settlement* with its own touristic offer, but its strength lies at the regional level, where it creates, together with other municipalities in the region, an attractive touristic offer.

Conclusions

The study applies two approaches based on the methodological tools of network theory. To support the hypothesis formulated in the introduction (*the role of individual destinations in the supply market of the region can be measured by the tourist flows across destinations*), it primarily models the tourist flows within the region as a coherent network. This is demonstrated in chapter 3.2 by presenting the characteristics of the network (degree number and centrality), i.e., by answering question *Q1* (Can tourism movements in the region be interpreted as a coherent network?) and *Q2* (Can the characteristics of the network (centrality, degree) be used to depict the position of each destination within the region?). The degree number and the centrality of the settlements provide a

Table 3. Clusters defined by k-means

Cluster number	Popularity, persons	Mobility, M_w settlement/person	Cluster characteristics
1st	1.00	7.33	Less preferred with high propensity to move out
2nd	1.45	2.24	Less preferred with low propensity to move out
3rd	5.22	3.05	Medium preferred with higher propensity to move out
4th	5.91	1.46	Medium preferred with lower propensity to move out
5th	28.50	1.77	Preferred with high propensity to move out
6th	109.80	1.82	Preferred with low propensity to move out

Source: Own survey.

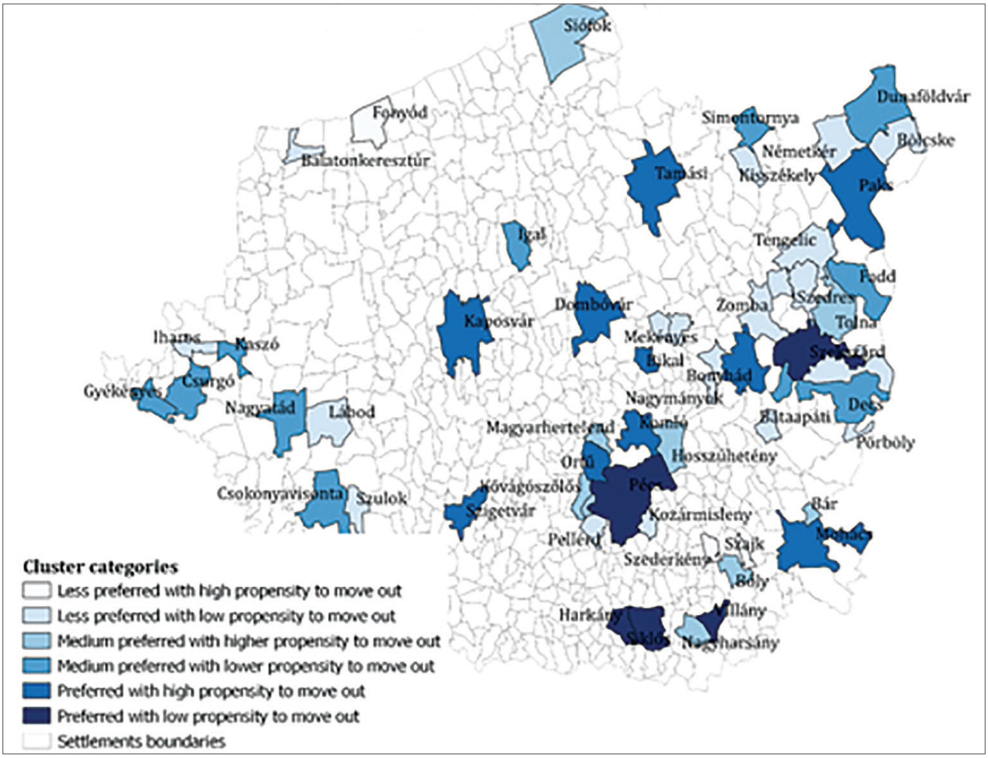


Fig. 4. Clusters based on the mobility propensity and popularity of the studied settlements in South Transdanubia. *Source*: Own survey, own editing.

good measure of their position in the region's tourism offer, and their links, which can be statistically demonstrated by analysing the data, can also serve as a guide for cooperation.

Finally, research question *Q3* would characterise a given settlement on the basis of the mobility propensity of the guests staying in a destination. To demonstrate this, the study calculates a mobility propensity score for each settlement where respondents used accommodation services at the time of the survey. It then calculates the popularity of the settlement based on the number of guests staying there, the degree number of the settlement and the frequency of the degree number. Finally, clusters are formed based on the indicators of popularity of the settlement and the mobility propensity scores. The resulting clusters are geographically independent and can be applied in practice anywhere. They are of strategic importance as they can be used as logical categories in development plans.

The weakness of the study is that it does not use a complete regional database, only a small sample. This flaw can be overcome by accessing the above-mentioned national statistical database under construction. This type of data collection is also an internationally known practice, and so it is not confined within the country's borders. It is innovative in the sense that few studies have so far dealt with network analysis of tourism movements at international level. It identified network characteristics based on the tourism movements studied and presented a possible clustering of tourist destinations based on the popularity of the locality and the mobility propensity of the visitors staying there.

Acknowledgements: The PhD student, as project coordinator is grateful to the Márton Áron Special College of the Eötvös Loránd University. The research was supported by the ÚNKP-21-3 New National Excellence program of the Ministry for Innovation and Technology from the source of the National Reseach, Development and Innovation Fund.

REFERENCES

Ahas, R. and Mark, U. 2005. Location based services – New challenges for planning and public administration? *Futures* 37. (6): 547–561.

Albert, R. and Barabási, A.-L. 2002. Statistical mechanics of complex networks. *Reviews of Modern Physics* 74. 47–97.

Aubert, A., Berghauer, S., Beták, N., Mókusné Pálfi, A. and Nod, G. 2021. Turisztikai szervezetek online marketing tevékenységének vizsgálata: a szlovák-magyar-ukrán (kárpátaljai) példa (Survey of online marketing activities of tourism organisations: a Slovakian-Hungarian-Ukrainian [Transcarpathian] example). In *Interregionális kutatási eredmények a turizmusban: örökségvédelem, intézményrendszer, helyi termékek (Hun-Au-Slo-Ukr)*. Eds.: Mókusné Pálfi, A. and Nod, G., Pécs, University of Pécs, Department of Tourism, 70–90.

Asero, V., Gozzo, S. and Tomaselli, V. 2016. Building tourism networks through tourist mobility. *Journal of Travel Research* 55. (6): 751–763. Available at https://doi.org/10.1177/0047287515569777

Barabási, A.-L. 2016. *Network Science*. Cambridge, UK, Cambridge University Press.

Bernecker, P. 1962. *Grundlagenlehre des Fremdenverkehrs*. Wien, Österreich, Österreichchischer Gewerbeverlag.

Bolland, J.M. 1988. Sorting out centrality: An analysis of the performance of four centrality models in real and simulated networks. *Social Networks* 10. (3): 233–253.

Butler, R.W. 1980. The concept of the tourist area life-cycle of evolution: implications for management of resources. *Canadian Geographer* 24. (1): 5–12.

Casanueva, C., Gallego, Á. and García-Sánchez, M-R. 2014. Social network analysis in tourism. *Current Issues in Tourism* 19. (2): 1190–1209. Available at https://doi.org/10.1080/13683500.2014.990422

Csapó, J. and M. Császár, Zs. 2021. A Magyarországon tanuló külföldi egyetemi hallgatók turisztikai fogyasztási szokásainak elsődleges elemzése (A primary analysis of tourism consumption habits of international university students studying in Hungary). *Turizmus Bulletin* 21. (2): 15–23. Available at https://doi.org/10.14267/TURBULL.2021v21n2.2

D'Agata, R., Gozzo, S. and Tomaselli, V. 2013. Network analysis approach to map tourism mobility. *Quality and Quantity* 47. (6): 3167–3184. Available at https://doi.org/10.1007/s11135-012-9710-7

Díez-Díaz, F., González-Rodríguez, M. and Vidau, A. 2007. An accessible and collaborative tourist guide based on augmented reality and mobile devices. In *Universal Access in Human-Computer Interaction. Ambient Interaction*. UAHCI 2007. Lecture Notes in Computer Science, Vol. 4555. Ed.: Stephanidis, C., Berlin–Heidelberg, Springer. Available at https://doi.org/10.1007/978-3-540-73281-5_38

Erdős, P. and Rényi, A. 1960. On the evolution of random graphs. *Magyar Tudományos Akadémia Matematikai Kutató Intézet Közleményei* 5. 17–61.

Euler, L. 1741. *Solutio problematis ad geometriam situs pertinentis*. Euler Archive – All Works, 53. Available at https://scholarlycommons.pacific.edu/euler-works/53

Freeman, L.C. 1979. Centrality in social networks conceptual clarification. *Social Networks* 1. (3): 215–239.

Gao, C., Zhong, Y., Mensah, I.A., Tao, S. and He, Y. 2022. Spatio-temporal impact of global migration on carbon transfers based on complex network and stepwise regression analysis. *Sustainability* 14. (844): 1–19. Available at https://doi.org/10.3390/su14020844

Gonda, T., Raffay, Z. and Csóka, L. 2018. Orfű rejtett konvencionális turizmusa (The hidden conventional tourism of Orfű). *Turisztikai és Vidékfejlesztési Tanulmányok* 3. (1): 4–19. Available at https://journals.lib.pte.hu/index.php/tvt/article/download/4368/4100/8264

Government Decree 239/2009 (X. 20.) on the "detailed conditions for pursuing accommodation service activities and the procedure for issuing accommodation licenses".

Government Decree 429/2016. (XII. 15.) on the „prioritized tourist development areas".

Government Decree 429/2020 (IX. 14.) on the "definition of tourist regions".

Hungarian Tourism Agency 2021. Tourist Regions. Available at https://mtu.gov.hu/cikkek/11-turisztikai-terseg-terkep-es-telepuleslista-1918 (accessed on 21/11/2021) (in Hungarian)

Kotler. P. 1967. *Marketing Management, Analysis, Planning and Control*. Upper Saddle River, NJ, USA, Prentice-Hall.

Kőnig, D. 1936. *Theorie der endlichen und unendlichen graphen. Kombinatorische Topologie der Streckenkomplexe*. Leipzig, Akademische Verlagsgesellschaft M. B. H.

KSH 2018, 2020, 2021. Hungarian Central Statistical Office. Regional breakdown of tourism data of commercial accommodation establishments. Available at https://www.ksh.hu/stadat_eves_4_5 (accessed on 10/12/21).

Letenyei, L. 2006. Településkutatás (Settlement research). *Tér és Társadalom* 20. (2): 143–156. Available at https://doi.org/10.17649/TET.20.2.1911

Madarász, E. and Papp, Zs. 2013. Delimiting the "Balaton Riviera". Tourist destination by using network analysis. *Hungarian Geographical Bulletin* 62. (3): 289–312. Available at https://ojs.mtak.hu/index.php/hungeobull/article/view/2963

Mas-Colell, A., Whinston, M.D. and Green, J.R. 1995. *Microeconomic Theory*. Oxford, UK, Oxford University Press.

Michalkó, G. and Ilyés, N. 2020. A nemkonvencionális turisztikai mobilitás magyarországi sajátosságai, különös tekintettel a turizmusból származó bevételek növelésének lehetőségére (The specificities of unconventional tourism mobility in Hungary, with a special focus on the potential for increasing tourism revenues). *Turizmus Bulletin* 20. Special number. 6–18. Doi: 10.14267/turbull. 2020v20n4.1

National Tourism Development Strategy 2030. Budapest, Magyar Turisztikai Ügynökség. Available at https://mtu.gov.hu/documents/prod/NTS2030_Turizmus2.0-Strategia.pdf (in Hungarian)

Nod, G., Pálfi, A. and Aubert, A. 2019. Az egyéni utazásszervezés térnyerése a digitális társadalomban (Raising of the individual organizations of passenger travels in the digital society). In *Turizmus, fogyasztás, generációk. II. Nemzetközi Turizmus Konferencia: Tanulmánykötet*. Eds.; Csapó, J. *et al.*, Pécs, University of Pécs, 161–171.

Pécsek, B. 2015. The role of slow design elements in managing tourist flow on the example of Bruges, Belgium. *Hungarian Geographical Bulletin* 64. (2): 143–154. Available at https://doi.org/10.15201/hungeobull.64.2.5

Pirisi, G. and Trócsányi, A. (eds.) 2019. *Fejezetek a társadalomföldrajz világából* (Chapters from the world of social geography). PTE TTK Földrajzi és Földtudományi Intézet. Pécs, Publikon Kiadó.

Piskóti, I. 2007. *Desztináció-menedzsment lépésről-lépésre* (Destination management step-by-step). Eger-Miskolc, NORDA.

Scott, N., Baggio, R. and Cooper, C. 2008a. *Network Analysis and Tourism. From Theory to Practice.* Aspect of Tourism series. Bristol, UK, Channel View Publications.

Scott, N., Cooper, C. and Baggio, R. 2008b. Destination networks: Four Australian cases. *Annals of Tourism Research* 35. (1): 169–188.

Scott, N., Cooper, C. and Baggio, R. 2009. *Use of Network Analysis in Tourism Research*. First Edition. Aspect of Tourism series. Bristol, UK, Channel View Publications.

Spinney, J.E. 2003. Mobile positioning and LBS applications. *Geography* 88. (4): 256–265.

Sziva, I. 2014. The role of cooperative strategies in destinations' competitiveness in a turbulent environment. *Journal of Tourism and Hospitality Management* 2. (3): 97–105.

Tan, P-N., Steinbach, M. and Kumar, V. 2006. *Introduction to Data Mining*. 1st Edition. New Jersey, Pearson Education, Inc. Available at https://gyires.inf.unideb.hu/KMITT/a04/ch08s02.html

Telbisz, T., Šulc, I., Mari, L. and Radeljak Kaufmann, P. 2022. Attitudes and preferences of visitors of Krka National Park, Croatia. *Hungarian Geographical Bulletin* 71. (2): 117–132. Available at https://doi.org/10.15201/hungeobull.71.2.2

Tiszberger, M. 2015. *A hálózatkutatás módszertani vizsgálati lehetőségei – szakirodalmi összefoglalás* (Methodological options for network research – a literature review). Pécs, University of Pécs. Available at https://ktk.pte.hu/sites/ktk.pte.hu/files/images/szervezet/intezetek/mti/tiszberger_a_halozatkutatas_modszertani_vizsgalati_lehetosegei_2015.pdf

Tóth, G. and Dávid, L. 2009. Az elérhetőség és az idegenforgalom kapcsolata (The connection between accessibility and tourism). *Tér és Társadalom* 23. (3): 45–62. Doi: 10.17649/TET.23.3.1256.

Watts, D.J. and Strogatz, S.H. 1998. Collective dynamics of 'small-world' networks. *Nature* 393. (6684): 440–442. Doi:10.1038/30918. PMID 9623998.

Wind, S. 2015. Simulating and modelling urban flows: Experimenting with tracking technologies in urban design. *Arkitektur & Design.* A&D Skriftserie Vol. 91. Available at https://vbn.aau.dk/ws/files/214876372/SUF_booklet_SMALL.pdf

Woodside, A. and Lysonski, S. 1989. A general model of traveller destination choice. *Journal of Travel Research* 17. (4): 8–14.

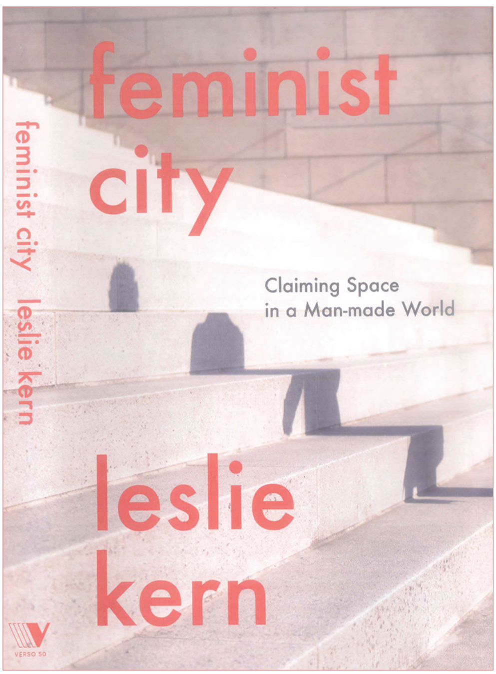
Zheng, W., Huang, X. and Li, Y. 2017. Understanding the tourist mobility using GPS: Where is the next place? *Tourism Management* 59. (4): 267–280. Available at https://doi.org/10.1016/j.tourman.2016.08.009

BOOK REVIEW SECTION

Kern, L.: Feminist City: Claiming Space in a Man-made World. London and New York, Verso, 2020. 204 p.

Leslie Kern is an associate professor of geography and women's and gender studies at Mount Allison University, Canada, and she writes about gender, gentrification, and feminism and teaches urban, social, and feminist geography. In her recent book *Feminist City*, published in 2020, she explores the man-made city drawing on her own experiences as a woman living in different urban contexts (including Toronto, London, and New York). She reflects on her experience as a girl, a woman, a friend, and a mother, utilising the growing and diverse knowledge accumulated by feminist and critical urban researchers and geographers.

The present book review takes the opportunity to go beyond summarising this extraordinary book, and it aims to highlight the rejection (or at least lack of engagement with) feminism and feminist theories in the context of Hungary in the field of geography and outside. Anti-feminist and anti-gender sentiments are embedded in popular and political discourses internationally, in Central and Eastern Europe, and in Hungary in particular (Grzebalska, W. and Pető, A. 2018). This is especially relevant in countries like Hungary, where feminist movements were never as strong as the rhetoric that claimed their threat to traditional national values. Feminism critiques the patriarchal structure of society (thus, the fact that men dominate decision-making and traditionally masculine characteristics enable one to hold power), and it highlights what's wrong with patriarchy and how it leads to gendered and other forms of inequalities. Gender has become an important concept for feminists to be able to discuss inequalities that are the result of socialisation and social (power) relations. Within feminism, there are many trends and approaches that are often in conflict with each other. However, feminism is by no means limited to the critique of gender inequality, but it is concerned with racism, classism, ableism, and other forms of inequalities as well.



Feminist urban research or feminist geography still barely made it to Hungary. Judit Timár (1993, 2019) has written about feminist geography and women in geography in 1993 first and since then, she has incorporated a feminist perspective into her research. Nevertheless, feminism and feminist theory are still greatly missing from geography in Hungary (Sági, M. 2018; Timár, J. 2018). Therefore, this review also hopes to highlight the variety of research areas which could benefit from feminist approaches.

Kern is not only concerned with gendered inequalities, but by drawing on intersectional feminist ontology, she is able to highlight inequalities that are produced in cities, predominantly, designed by a very narrow segment of society: white, able-bodied, affluent men. While this book engages with feminist epistemology, it is not a traditional academic book presenting research articles in a traditional manner, but it is structured around the personal experiences of the author as a woman in the city and utilises popular culture. Therefore, the *Feminist City* is accessible to a wide audience and able to engage not only academic readers interested in gender and urban studies but anyone open to reflecting on the everyday urban experience of women and other marginalised groups from a critical perspective.

The *Introduction: City of Men* starts with establishing the relevance of women's experience as a distinctive experience of the city. Kern starts with a personal reflection on moving to Toronto from the suburbs to start university just like her brother did, highlighting the inherent differences in city life for the two: "our experiences of city life have been vastly different. I doubt Josh has ever had to walk home with his keys sticking out from his fist or been shoved for taking up too much space with a baby stroller. Since we share the same skin colour, religion, ability, class background, and a good chunk of our DNA, I have to conclude that gender is the difference that matters." (p. 2). Following the introduction, Kern structured the book into five chapters each focusing on a perspective of women experiencing the city: *City of Moms, City of Friends, City of One, City of Protest, City of Fear*.

City of Moms discusses the struggles women face from pregnancy through child rearing while living in the city. Discussing changes in the way one perceives their own body as well as the way that body navigates the wider environment. "If you've ever been pregnant, the 'geography closest in' gets real strange, fast. Suddenly, you're someone else's environment." (p. 22). Pregnancy contributes to the lack of anonymity and invisibility women experience in the city; it makes women's bodies public property that can be touched and discussed even by complete strangers. The chapter summarises the existing literature on feminist urban research concerned with the long-discussed public/private, suburbia/city centre divide that has defined women's and men's places and activities in the context of US and UK middle classes (e.g., Jane Jacobs, Linda McDowell, Susan Saegart), the gentrification led by middle-class families moving back to the city choosing and/or forced into two-earner family model. It discusses the everyday experiences of breastfeeding, walking, and commuting around the city with pushchairs and small children on narrow, wobbly sidewalks and so on. The chapter, however, is not stuck with the experiences of white, middle-class women, but emphasises the importance of intersectional approaches, reinforcing that a feminist approach to the city must always be concerned with any forms of oppression, including race, class and ability, considering the distinctive circumstance of mothers. Kern argues that in order to achieve a feminist city, it "must be care-centred not because women should remain largely responsible for care work, but because the city has the potential to spread care work more evenly" (p. 54).

City of Friends starts with the image of the four friends of the *Sex and City* TV series. The then-revolutionary set is centred around female friendship. The TV show presents the idea that The City (New York) is actually not just a location, but the fifth friend. As Kern refers to Wunker, E. (2016), focusing on female friendship has revolutionary potential as it depicts an alternative to the nuclear family, to gendered roles and "defies patriarchal logic". It takes the focus away from traditional female reproductive roles and reimagines love outside of heteronormative (or even homonormative) relations as a primary organiser of everyday life and motivations.

Kern highlights the increasing depiction of female friendship in popular culture that goes beyond the floppy friendship overpowered by love interests and jealousy, enclosed in the bedrooms of white-middle-class girls. Recent portrayals are more likely to be placed in a public urban environment. These stories are also more likely to allow girls (with diverse socio-economic, and racial backgrounds) to take up and claim their space in the city. As Kern writes "[p]erhaps imagining the city centred on friendship seems impossible simply because of this: if women dedicated even a little bit more of their love, labour, and emotional support to their friend networks, the system – as men know it – would come crashing down. It's a radical prospect to consider, and one that profoundly decentres both the family and the state" (p. 86).

City of One is concerned with the personal lived experience of the city as women by themselves negotiate their everyday lives. Elizabeth Wilson (1995) refers back to Victorian London where moral panic surrounding women's increased visibility on the street can be best highlighted referring to sex workers as "public women". Thus, the idea was that women alone on the streets would be mistaken for being poor or being a sex worker.

Kern warns the reader about the easy trap of romanticisation of past public spaces without new technologies where allegedly people were more sociable with each other. She argues that – like popular discourses around anti-social children and the destruction caused to "bonds of civility and sociability that hold human societies together" (p. 87) – urban researchers also subscribe to this sentiment. While blaming smartphones and headphones for the lack of participation in public life and hostile cities, such equipment is in fact enabling more comfortable access to the urban space for many. As Kern writes: "I love having my headphones and music with me in the city too, but for me and many other women, they provide more than a form of entertainment. They may be small, but they create a social barrier against the all-too regular and almost always unwanted intrusions of men. It's impossible to know how many unwelcome conversations and incidents of street harassment I've avoided or been unaware of because of my headphones" (p. 88).

Being alone under such circumstances is a privilege. Women often feel made to feel like "guests" in their own city, people of colour as trespassers or criminals, and disabled people often experience well-meaning, but unwanted physical contact from strangers persisting to helping without consent (e.g., by taking the hand of a visually impaired person).

City of Protest draws on the idea of "the right to the city". For Kern, like many, participation in protests brings a "sense of belonging in the city", while confirming a "righteous indignation at the widespread injustices" that affect one personally, but also the "lives of millions of others". She argues that activism is at the core of achieving the feminist city, as marginalised groups are unlikely just to be presented with – "freedom, rights, recognition, resources – without a struggle" (p. 118).

Examples throughout history and across geographies have highlighted that in most cases women's life in cities (and otherwise) got better through activist movements: "For me – [Kern writes] – activist spaces are my greatest teachers. I wouldn't be able to articulate what a feminist city aspires to without those experiences. I've learned a lot about how to protest over the years, but more importantly, I've learned that a feminist city is one you have to be willing to fight for" (p. 141).

The fifth chapter, *City of Fear*, is the most relevant to my own research (Sági, M. 2022) and perhaps this has been one of the most discussed topics in academia when it comes to women and the city. The idea of "female fear" is so embedded in socialisation that it has been often mistaken for being an innate trait of girls and women. Understanding and mapping fear of crime has been a focus for many social scientists for many decades, where surveys have piled data on where, when, and from whom women fear. "Study after study produced similar patterns: women identified cities, night-time, and strangers as primary sources of threat" (p. 145). Nevertheless, the concern over women's fear (and safety) in the city has brought a paradox that was already clear by the 1990s: Data has suggested that while women are significantly more likely to be abused and harassed by people they know (including home and workplace) than in public space, men are more likely to experience crimes in public spaces (assault and mugging). At the same time, studies have consistently reported that women are more afraid of strangers in public spaces. This has been conceptualised as the "paradox of women's fear", often characterising women's feelings as "irrational" and "unexplained" (p. 145). Kern, drawing on existing literature, collects the multiple arguments that dissolve this alleged paradox and irrationality and highlights that the paradox exists only when gendered power structures are ignored. One of these arguments is that "the crime women most fear is rape. The crime men most fear is robbery. Robbery is a bad thing to have happen to you. Rape is worse" (p. 146). Socialisation from early childhood throughout women's life course has a major effect on fear in public. Warnings from significant others, teachers and peers are further reinforced by media representation (both fiction and news reporting), implying that stranger danger is always around.

Meanwhile, domestic violence and abuse by acquaintances are tabooised and receive much less public attention, in media coverage, educational environment and from significant others. As Kern writes, the feminist explanation for this phenomenon is that women's fear is being directed outward strengthens the patriarchal power structure and women's dependence on the nuclear family and the reinforcement of the image of home as the space of security.

In the chapter it is emphasised that fear limits women's everyday experiences of the city, accumulating a variety of hidden costs. This includes time and energy-consuming measures, such as getting off the subway earlier, taking longer routes, avoiding shortcuts through parks, pretending to be on the phone, and squeezing keys in our fists. The combination of these self-imposed measures adds up to exhausting everyday routines. Fear also affects financial decisions, including paying more for cabs to get home safely or paying more for housing in order to live in a more secure area or building.

Where (else) does space come into this? – Kern asks the question to further reinforce the important role of geography. – Drawing on Gill Valentine, she writes that geography in fact provides potential control over fear. It is impossible to control *whom* we encounter on the streets; it is also unlikely that we can control *when* we go from one place to another. However, we have some control over what routes we take, consequently, we (dis)place our fears onto specific locations within the city, such as alleys and underpasses. Therefore, women's fear in public space is far from irrational,"we're accurately reflecting the messages society has drilled into us" (p. 149).

It is an important message of this chapter that fear cannot be just "designed out" of the city; the physical environment and social power relations are tightly connected. The chapter is closed with the statement that there is no perfect recipe for the feminist city that is safe and comforting. Nevertheless, Kern argues that it won't require private or governmental safety measures and it definitely won't be achieved by sacrificing marginalised groups (e.g., homeless people) for the needs of more privileged women.

Kern concludes with the chapter titled *City of Possibility* and closes the book with the following thoughts: "The feminist city is an aspirational project, one without a "master" plan that in fact resists the lure of mastery. The feminist city is an ongoing experiment in living differently, living better, and living more justly in an urban world" (p. 167).

I highly recommend Leslie Kern's book, the *Feminist City*, to everyone interested in feminist urbanism and geography, and even more so to those who are not interested in it, to those who believe it is not relevant to our realities, to those who think negatively about feminism – in academia and otherwise. This book should not be dismissed in the context of Hungary on the grounds that it is not relevant to the Central and Eastern European context. Keeping in mind the diversity of women's experiences, I hope that this book review was able to highlight some of the topics that make it clear that the *Feminist City* has great explanatory potential for urban life in the context of Hungary and, more broadly, in Central and Eastern Europe.

Mirjam Sági[1]

[1] Institute for Regional Studies, Centre for Economic and Regional Studies, Eötvös Loránd Research Network, Békéscsaba, Hungary. E-mail: sagi.mirjam@krtk.hu

REFERENCES

Grzebalska, W. and Pető, A. 2018. The gendered modus operandi of the illiberal transformation in Hungary and Poland. *Women's Studies International Forum* 68. (3): 164–172.

Longhurst, R. 1994. The geography closest in – the body… the politics of pregnability. *Australian Geographical Studies* 32. (2): 214–223.

Sági, M. 2018. Test és tér: Patriarchális viszonyok újratermelése városi köztereken (Body and space: Reproduction of patriarchal relations in urban public spaces). In *Kortárs térelméletek kelet-közép-európai kontextusban.* Ed.: Faragó, L., Budapest, Dialóg Campus, 205–218.

Sági, M. 2022. The geographical scales of fear: spatiality of emotions, emotional spatialities. *Hungarian Geographical Bulletin* 71. (1): 55–65.

Timár, J. 1993. A nők tanulmányozása a földrajzban, avagy: van-e létjogosultsága a feminista geográfiának Magyarországon? (Studying women in geography, or: does feminist geography have grounds in Hungary?). *Tér és Társadalom* 7. (1–2): 1–18.

Timár, J. 2018. A feminista és a marxista földrajz kapcsolata: összekötő és elválasztó diskurzusok a térről (Connection of feminist and marxist geography: connecting and dividing discourses about the space). In *Kortárs térelméletek kelet-közép-európai kontextusban.* Ed.: Faragó, L., Budapest, Dialóg Campus, 187–203.

Timár, J. 2019. Hungarian feminist geography in a curved space? *Gender, Place and Culture* 26. (7–9): 1094–1102.

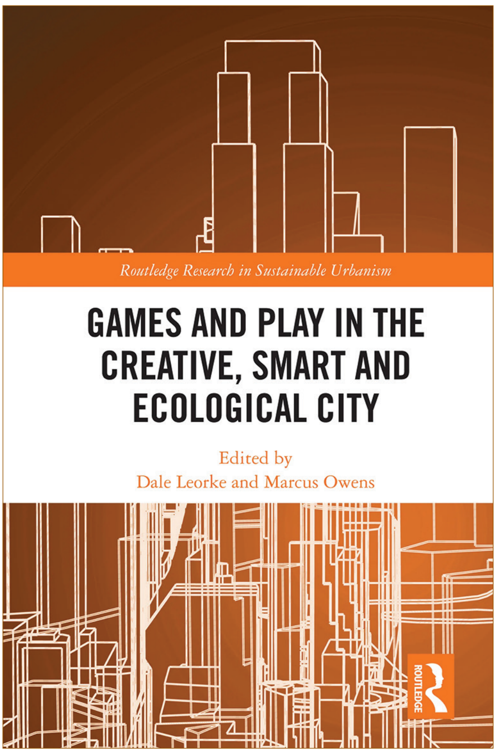
Wilson, E. 1995. The rhetoric of urban space. *New Left Review* 209. 146–160.

Wunker, E. 2016. *Notes from a Feminist Killjoy: Essays on Everyday Life.* Toronto, BookThug.

Leorke, D. and Owens, M. (eds.): Games and Play in the Creative, Smart and Ecological City. Abingdon and New York, Routledge, 2021. 280 p.

Nowadays, due to the growing importance of creativity and experiences in consumption and everyday life, the role of games and play is increasing in all kinds of activities. These trends transform urban life as well: with the emerging concepts of creative, smart, sustainable cities, new methodologies and approaches appear as well. At the same time, digitalisation became nearly essential to the everyday life – at least in the developed world. In the past two decades more and more examples emerged in relation to games and game design, while the phenomenon of the gamification has received an increasing attention. These examples often seek answers to the question: how can games contribute to the governance of a city? The book of Dale Leorke and Marcus Owens offers some answers to this question and raises further research options.

The objective of the volume is to create an empirical basis that can bring together the different concepts related to the city (i.e., smart city, creative city, ecological city) and provides opportunities for further discussions. The book focuses on three comprehensive sets of urban discourses that cover the topics of the creative and cultural economies of cities, the smart and playable cities, and the ecological city itself. However, it does not discuss gamification per se, which is the use of game elements in such everyday situations that does not count as a game (Arnold, B.J. 2014).



The book is edited by Leorke and Owens, and it is a collection studies, which are integrated into three bigger parts (*The creative and cultural economies of cities, Smart and playable cities,* and *Ecological cities: sustainability and resilience*) and eleven chapters. The three parts correspond to the three main focuses of the book. (Although the first numbered chapter is Chapter 2 because the Introduction chapter counts as the first one.) The chapters include comparative case studies, theoretical and historical arguments, and critical examinations.

The *Introduction* thoroughly stages the precarious subject of smart, creative, and ecological solutions and concepts within the city, and the growing matter of games and play, the possibilities of a playable city. It presents the three main focuses of the volume and brings up the key questions. The chapter also mentions that the three highlighted discourses are not covering the whole matter; there are other crucial issues that are out of scope, such as gender issues, the class situation, etc.

Part I has the creative city in its spotlight. Hence, the studies in this section are exploring the interrelation between games and the creative city. It represents how games contribute to the creative city. However, in many cases, the critique of the creative city concept can be read, for example about how it contributed to the growing marginalisation and inequality, and some referred to it as a 'shallow' concept (*Mute* 2009; Howe, R. *et. al.* 2014). In the chapters of this part, the use of different games is presented along with how they affected city planning and the attitudes towards the city, for example through increasing tourism or changing the way the citizens see their city or neighbourhood.

The first chapter of Part I (*Games, play and playfulness in the creative city: a brief overview*) is a summary of how the concepts enlisted in the title are in an eminently deep connection with the ideas of the creative and smart city. The focus of the study is the creative city, thus, the author, Dale Leorke, often refers to Richard Florida as well as his counterparts, who criticised his theories. He emphasises that the gaming industry is one of the key elements that attract the creative class, thus, videogames have a growing importance. He also defines the concepts of games, play and playfulness, and underpins their necessity "both as drivers of economic growth in the city generally and as perceived 'counters' to the top-down, instrumental and techno-centric smart city vision" (p. 30). as Leorke says. The brief essence of the study is that games make up the industry that needs creative workers, whereas play is genuinely the collective name of leisure events like festivals and street occasions, as well as informal street games, parkouring etc. Lastly, playfulness – as Leorke refers to Bernard Suits (1978) – is something that can appear anywhere in any form, such as decorating, street art, or DIY urbanism projects. Leorke outlines three ways that these terms figure into the creative city agenda, because – as he argues – the roles of games and play can be found in cities that neither label themselves as 'creative' nor use policies related to the creative city. The three ways are that games and play (i) exist as a creative industry, (ii) promote playful and playable cities; and (iii) playfully instil citizens with a creative ethos. The first refers to the growing industry of videogames that needs creative workers such as designers, programmers, artists, and scriptwriters. The second refers to the 'counter' to the top-down, techno-centric vision of the smart city" (p. 32.) as Leorke says. And the third one refers to the need for stronger citizen involvement. At the end of the article, Leorke mentions questions for further research, such as how case studies can reveal the ways games and play are incorporated into creative city agendas.

The next chapter (*Promoting Yokosuka through videogame tourism: the Sehnmue Sacred Spot Guide Map)* is a case study by Carlos Ramírez-Moreno and Dale Leorke. The authors focus on the effects of 'contents tourism' (Seaton, P. *et al.* 2017) on urban economy through the example of Yokosuka, Japan. The chapter presents the growing relevance of media-related tourism within tourism in general, i.e., when visitors travel to a locality because it was part of a movie or a video game. The authors give examples for the video game-related tourism and highlight how important it is for the Japanese tourism sector. Later they describe the computer game called *Shenmue* and the city of Yokosuka and display how the initiative of the *Shenmue Sacred Spot Guide Map* succeeded in the reinvigorating of Yokosuka's economy. With the mix of fieldwork and interviews, the authors skilfully examine the effects and the use of the pamphlet (i.e., the Guide Map), although they underline that it is roughly impossible to measure the direct impact on the economy. Nonetheless, it was a successful initiative that helped even the local boutiques situated near the popular scenes of the game to increase their customer traffic.

Chapter 4 (*Geogames for change: co-creating the future of cities with games*) is written by Alenka Poplin, Bruno de Andrade and Ítalo Sousa de Sena. Compared to the previous chapter, it provides a more geographical and more urban approach. It is another case study with two games in its focus: an analogue one, named *Geodesign Card Game*, and a digital one, named *GeoMinasCraft.* The games are included in the analysis of the phenomenon called 'geo-games for change' that suggest that serious games can contribute to a more immerse citizen involvement into urban design and co-creation (Squire, K.D. and Jenkins, H. 2003; Michael, D. and Chen, S. 2005; Squire, K.D. and Giovanetto, L. 2005; Squire, K.D. 2006; Ratan, R. and Ritterfeld, U. 2009; Ritterfeld, U. *et al.* 2009). The authors highlight the need for a more inclusive participation that – by their opinion – can be reached through a more playful way. The experiments with the two above-mentioned games were made with children and youth between the ages of 4 and 11, and between 7 and 16. Decision-making, communication, creativity, and cooperation were in the focus. Hence, the participants had to work together and solve problems related to the landscape, e.g., restoring an old mining site or finding the best solution for an area to be improved. The experiments were recognised as successful since the children achieved the goals of the games in both cases. They could learn about their environment, while they learnt how to cooperate. The authors claim that their research is the first step towards a more inclusive and participatory planning that is also a 'fun' activity. They also argue that children underperform when it comes to city-related decision making but their ideas and problem-solving skills are valuable.

Part II concerns the concept of the smart city, and the way games and play can be instilled in it. Similarly, to the previous part, a critical way of seeing appears here. It is also presented how games could make the smart city more playable, thus, acceptable in the context of decision-making and developments that might temporarily make the inhabitants' life more difficult.

The first chapter of this part (*Urban play in practice: seven lenses exploring the sociocultural value of playable cities)* was written by Troy Innocent. In a sense, the author articulates a critique of the smart city and offers the concept of the playable city as a bottom-up, community-led alternative, in contrast to corporation-led top-down smart cities. He argues that since the urban is a complex phenomenon, the urban play is a complex one, too. He introduces seven lenses – as he refers to them – through which the different actors of a city can be understood. Although there are differences, there are overlaps as well, and with the deeper awareness of both, it would be easier to integrate the urban play into the concept of the playable city. I find it important to mention that the author tries to represent an objective point of view underlining both the benefits and detriments of the urban play and suggesting the need for further research.

Chapter 6 (*The postdigital playground: children's public play spaces in the smart city*) is a study of Bjørn Nansen and Thomas Apperley. The chapter explores the ways of how the children's play and the digital world can be connected, especially because of the growing popularity of the smart city concept. The authors use the term 'post-digitalisation' which means that the line between the non-digital and the digital is blurred (Berry, D. 2014). The chapter suggests that the digitalisation of children's public spaces (i.e., playgrounds, public parks) as such is inevitable. It presents two case studies that are related to the idea of using mobile devices on playgrounds and public parks. The two games (*Disney Fairies Trail* and *Hybrid Play*) are mobile applications for children. In the first one, the user can catch fairies in nature through augmented reality technique, and in the meantime, they can learn about the environment, especially plants. The other game uses a special motion sensor on playground tools, and the user has to apply these tools (e.g., the swing) in order to be able to play the game on the smartphone. It is remarkable that the two games received different feedbacks, which suggests that not all ideas were useful. While the first game received positive feedback from the users, who emphasised its educative features, the other game mostly got negative feedback, which implies that the idea is not particularly useful. The authors highlight the aim for further studies on the topic, particularly because they argue that children and public spaces for children are often neglected in smart city concepts.

Chapter 7 (*Playful mobility and playable infrastructures in smart cities*) by Kyle Moore focuses on the location-based games, such as *Ingress* and *Pokémon Go*, which use geolocation. He examines the effects of such games on mobility suggesting that concept of 'situated play' is not exactly transparent. While he discovered the possibilities of a location-based game through a participatory fieldwork, he noted that mobility is not necessarily easy or available for anyone. Thus, there is a chance that these games create new forms of inequalities. However, these games still can be useful tools for exploring landscapes. Another crucial element of this chapter is the issue of the data underlying these games and how they are used, the problem of micro-transactions between the developer and the user, as well as exclusionary mechanisms concerning those who cannot afford these games and equipment. Nevertheless, location-based games are key elements for allowing the smart city to be playful as well.

The next chapter (*In praise of stupid: Games, play and ideology in the smart city)* is written by Jonathan Jae-an Crisman, Ken S. McAllister and Judd Ethan Ruggill, who scrutinise the relation of the smart city and smart game. They take an in-depth look at the attributes of the smart game and the history behind it, also the parallels between smart games and smart cities and how they should operate. They mention the dichotomy of the aspiration for designing smart cities yet operating by the ideology of the neoliberalism. However, the gamified ways for citizen involvement, for example the *Big Easy Budget Game,* which was used to collect feedback on the municipal budgeting process in New Orleans, provide the possibility of smoother processes of participation while providing data for the government and the opportunity of accepting or disregarding the citizens' opinions. The authors also mention the concepts of 'stupid games' and 'stupid cities' and set them against the concepts of being smart. In this narrative, a city is 'stupid' if it lacks a consistent agenda and smart mechanisms of management, and relies on a preliminary information-sharing infrastructure. 'Stupid games' are less complex in terms of storytelling, visuals, and responses on user behaviour. In other words, they need more efforts from the user than 'smart' games. They argue that smart cities are being made by the people who live there and not necessarily by the technology. They also argue that if the digital solutions do not provide a better and liveable environment for all the inhabitants (and not only for the rich), then these digital solutions seem 'not smart so much as short-sighted or, worse, techno-fetishistic and exploitative' (p. 160). Their conclusion for the chapter is that 'smart' is not always the better and sometimes the 'stupid' provides the proper practices for better governance.

In the last chapter of Part II (*Expanded phenomenologies: Leveraging game engines and virtual worlds in design research for the real*), Matthew Seibert writes about rethinking landscape and the experience of landscape, linking it to the experience of the virtual world and the landscape that is being lived. He thoroughly explores the different – and not exactly geographical – definitions of the landscape, as well as how we, as humans, sense our environment not only through direct experiences but former knowledge as well. To prove this, he uses the example of Merleau-Ponty of seeing a cube only from one angle (Merleau-Ponty, M. 2012). He connects these interpretations with one's experience within the virtual world and the ways already existing knowledge can complement a primarily audio-visual sensation. In the second part of the chapter, he argues that due to the above-mentioned reasons – that are deeply detailed and explained in the article – videogame engines could provide a tool for a better city planning. To prove that he presents a survey by which he states that within a virtual world users would try to experience the environment as much as they can, even those things that they would not or could not in the real world. He ends the chapter by claiming that: 'Virtual environments do not create laws to be referenced when thinking about cities and their making. But they do create reliable and systematic knowledge for new urban futures.' (p. 182).

Part III has the idea of sustainable city in its spotlight. As an interesting element, this part not only discusses contemporary issues but examines the events of the past as well. In this part, games appear as tools to help better respond to global issues, such as the climate change, or the ecological crises of the past.

In Chapter 10 *(Modelling a critical resilience: Board games and the agonism of engagement)* Janette Kim writes about the urgency for a better public process. In her chapter, she finds it essential to focus more on climate change, especially sea-level rise, and how the resilience of societies can be improved. She argues that it is often a problem that stakeholders, the community, decisionmakers, and other actors cannot come to an agreement, yet the global climate issues are threatening everyday life. For a better process, she invented two board games that serve as tools for mediating communication and decision-making. The experiment with these games, however, have encountered difficulties. Nonetheless, the author draws attention to the contemporary problem of climate change that is neglected when it comes to city planning. On the other hand, although the problem of sea-level rise is a critical problem indeed, there are other pressing issues related to climate change, which are not mentioned by the author.

In the next chapter, Gabriele Ferri, Mattia Thibault and Judith Veenkamp write about the *Co-creation and participation for designing sustainable playable cities*. Similarly, to some of the previous chapters, this one provides a critique of the smart city concept. The authors created a comparative analysis of two artefacts of the EU Horizon 2020 project Mobility Urban Values (MUV). One is a gamified application, the MUV, the other is an air pollution visualizer device, the Asphyxia. The aim of this examination is to find alternative strategies for a more sustainable citizen engagement. They came to the conclusion that playable and sustainable ideas could complement each other for a better overall approach, while countering the smart city's excessive top-down appeal.

The last chapter is written by Marcus Owens, one of the editors of the volume. In *Designing the Whole Earth as a magic circle,* he aims to present the increasing role of games and gamification in the accelerating urbanisation of the 20th century. The focus is on planetary urbanisation, ecology, sustainability, and the relationship of these with game design. But the title of the chapter, in fact, refers to the work of Buckminster Fuller, called the World Game, and the propositions of Stewart Brand responding to the emerging crises (i.e., ecological and economic) of the post-WWII Fordist system in the 1960s. Reading this chapter, one can realise that games and gamified approaches were used already throughout history. This indicates that using game design for planning and solving not only local but even planetary issues is not a new trend emerging. Instead, it is something that only started to attract more attention in the past decade. This could be perhaps because of the growing culture of gaming, the ongoing development of games, and the increasing digitalisation of everyday life.

The volume does not have a conclusion at the end, although each part is summarised in the Introduction. Nevertheless, this book is a fine collection of different studies related to gamification. It brings up new research questions, and although it could not encompass everything – as it was mentioned at the beginning of the review –, it provides different approaches to gamified city planning and participation, and the studies can serve as starting point for future research. It also contributes to illuminating mainstream concepts of the smart, sustainable and creative city from a new point of view – the perspective of games, play and playfulness, the phenomena that can help citizens better understand and accept decision-making, have more interest towards their environment, and take a better opportunity for their ideas to be heard. The volume is a useful reading to those who want to get acquainted with the concepts of the smart, creative, and ecological city while discovering innovative solutions for city planning. Also, it is most helpful for further studies on gamification in urban planning.

Katinka Tóbiás[1]

REFERENCES

Arnold, B.J. 2014. *Gamification in education*. – Conference Paper. Annual Conference of the American Society of Business and Behavioral Sciences (ASBBS), 1–8.

Berry, D. 2014. The post-digital ornament. *Stunlaw Blog Post,* June 6. Available at http://stunlaw.blogspot.com.au/2014/06/the-post-digital-ornament.html

Howe, R., Nichols, D. and Davison, G. 2014. *Trendyville: The Battle for Australia's Inner Cities.* Melbourne, Monash University Publishing.

Merleau-Ponty, M. 2012. *Phenomenology of Perception*. New York, Routledge.

Michael, D. and Chen, S. 2005. *Serious Games: Games that Educate, Train and Inform.* Boston, Course Technology PTR.

Mute 2009. The creative city in ruins [editorial]. Mute 2. (12). Available at www.metamute.org/editorial/magazine/mute-vol-2-no.-12-%E2%88%92-creative-city-ruins

Ratan, R. and Ritterfeld, U. 2009. Classifying serious games. In *Serious Games: Mechanisms and Effects.* Eds.: Ritterfeld, U., Cody, M. and Vorderer, P., New York and London, Routledge, 10–24.

Ritterfeld, U., Cody, M. and Vorderer, P. (eds.) 2009. *Serious Games: Mechanisms and Effects.* New York and London, Routledge.

Seaton, P., Yamamura, T., Sugawa-Shimada, A. and Jang, K. 2017. *Contents Tourism in Japan: Pilgrimages to 'Sacred Sites' of Popular Culture.* Amherst, Cambria Press.

Squire, K.D. and Giovanetto, L. 2005. *The Higher Education of Gaming.* Vancouver, Digital Gaming Research Conference.

Suits, B. 1978. *The Grasshopper: Games, Life and Utopia.* Toronto, University of Toronto Press.

[1] University of Szeged, Department of Economic and Social Geography, Szeged, Hungary.
E-mail: tobias.katinka@geo.u-szeged.hu

Publisher:
Research Centre for Astronomy and Earth Sciences
1121 Budapest, Konkoly Thege Miklós út 15–17., Hungary

Editorial office:
Geographical Institute, Research Centre for Astronomy and Earth Sciences
1112 Budapest, Budaörsi út 45., Hungary
Phone, fax: +36 1 309 2628
E-mail: geobull@mtafki.hu, kovacs.zoltan@csfk.org
Distribution: Gabriella Petz, petz.gabriella@csfk.org
Full text is available at https://ojs3.mtak.hu/index.php/hungeobull

Typography: Eszter Garai-Édler
Technical staff: Fanni Koczó, Anikó Kovács, Gáspár Mezei

Cover design: Anna Redl
Printed by: Premier Nyomda Kft.

HU ISSN 2064–5031
HU E-ISSN 2064–5147

Distributed by the Geographical Institute, Research Centre for Astronomy and Earth Sciences

Subscription directly at the Geographical Institute, Research Centre for Astronomy and Earth Sciences (H-1112 Budapest, Budaörsi út 45), by postal order or transfer to the account IBAN: HU24 10032000-01730841-00000000. Individual copies can be purchased in the library of the Institute at the above address.