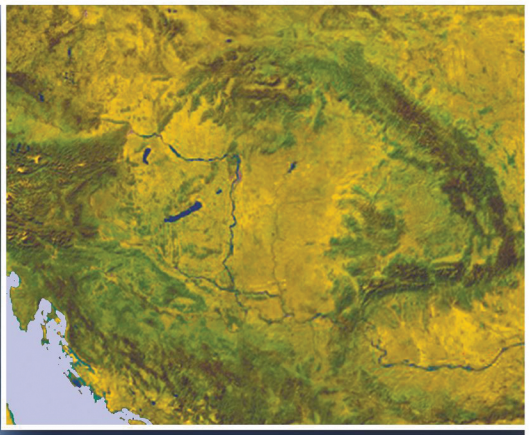
Hungarian Geographical Bulletin



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CONTENT

Book review section

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Characteristics and observed seasonal changes in Cold Air Outbreaks in Hungary using station data (1901–2020)

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Abstract

In this paper, we investigated Cold Air Outbreaks (CAOs) in Hungary using temperature data from ten weather stations located near populous Hungarian cities. Our main motivation for performing this research was the fact that in this rapidly changing climate, these events continue to represent a threat to infrastructure and human life, such as the outbreaks experienced in early 2021 (e.g., Texas, USA) and late 2022 (Winter Storm Elliott). In addition, no comprehensive study of CAOs in Hungary has been conducted using station data. The definition of CAO used in this paper is that the daily mean temperature had to be in the lower 10th percentile of the daily climatology for five consecutive days, and we allowed a maximum two-day gap between periods matching the criteria above, after which we merged events together. We found that the number of CAOs in Hungary decreased considerably in recent decades (due to increasing mean temperatures), and the climates of the investigated stations became increasingly homogenous. Developing our understanding of CAOs around the world is important because, due to climate change, their seasonal distribution may change in a way that negatively impacts our life and economy.

Keywords: cold air outbreaks, weather extremes, climate change, Hungary

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Introduction

Cold Air Outbreaks (CAOs) are massive weather events in which a cold air mass usually moves equatorward and persists in lower latitudes for periods of a few days up to weeks. These events have significant variability in duration, spatial extent, and frequency, which makes their research challenging. Most CAOs occur in the northern hemisphere, mainly because of the greater amount of land mass above mid-latitudes (Smith, E.T. and Sheridan, S.C. 2020). Additionally, cold outbreaks can also reach lower latitudes in the southern hemisphere, from June to August (Vera, C.S and Vigliarolo, P.K 2000), as we saw in 2021, where two CAOs hit South America (one in June and one in July), causing damage to crops and cocoa fields. The influence of CAOs has been researched the most in North America; here they may be even more severe than in Europe, as the mountain ranges of the continent cannot stop the movement of cold air deep into the southern parts of the USA. In Europe, winter precipitation could be associated with the number of winter CAOs, generally the decades with more CAOs also had higher snowfall totals in that season (Kis, A. and Pongrácz, R. 2021). CAOs also occur over oceans (maritime CAOs), causing heat loss to the oceans below (Papritz, L. and Spengler, T. 2017), and inducing polar-mesoscale cyclogenesis. Terpstra, A. *et al.* (2021) found that two-thirds of maritime CAOs in the North Atlantic Ocean generated these polar cyclones, which may cause strong winds and heavy snow over land (Brümmer, B. *et al.* 2009). Maritime cold air outbreaks (MCAOs) are slightly weaker and have less spatial extent in the southern hemisphere compared to the northern hemisphere. Still, the

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frequency of these MCAOs is similar in both hemispheres (Fletcher, J. *et al.* 2016). These southern hemisphere MCAOs are often induced by deep extratropical cyclones (Papritz, L. *et al.* 2015). There are many precursors to a CAO, such as massive blocking patterns (Kossakowska, M. and Zdunek, M. 2013), increased meridional jet stream (Rossby wave breaking) and sudden stratospheric warmings (Kolstad, E.W. *et al.* 2010; Zhang, M. *et al.* 2022). These intense events in the stratosphere can heavily influence the weather patterns in the northern hemisphere in winter, causing severe CAOs in North America and Europe (King, A.D. *et al.* 2019). Such an event occurred on 4 January 2021, which then caused a CAO in February when the cold air mass reached as south as Texas, leaving thousands without electricity and heating for days (Doss-Gollin, J. *et al.* 2021).

Intensive research is being performed on CAOs, despite their number decreasing in almost every part of the world in this changing climate (Smith, E.T. and Sheridan, S.C. 2020). There are many different approaches to the investigation of these extreme events, and there are even different CAO definitions because, ultimately, there is a lack of consensus among papers and researchers in other parts of the world. For example, Walsh, J.E. *et al.* (2001) used 1-3-5 day anomalies to detect CAOs and calculated backward trajectories to determine where the cold air mass originated. Tomassini, L. *et al.* (2012) used the lower 10th percentile in their climatology but worked with a more robust 15-day minimum duration. The spatial extent of CAOs may be investigated using reanalysis data (Walsh, J.E. *et al.* 2001; Smith, E.T. and Sheridan, S.C. 2020; Huang, J. *et al.* 2021) or station data (Smith, E.T. and Sheridan, S.C. 2018) or a combination of these two (Matthes, H. *et al.* 2015). Over land it is better to use near-surface variables (e.g., surface temperature or temperature at 2 metres) for the CAO criteria (Walsh, J.E. *et al.* 2001; Matthes, H. *et al.* 2015; Smith, E.T. and Sheridan, S.C. 2018), while over the oceans, it is advisable to use an upper atmospheric variable (e.g., 850 hPa temperature) (Kolstad, E.W. *et al.* 2009, 2010). In the warming climate, the frequency of these extreme cold events appears to be decreasing especially in the Arctic, where the rate of warming is the highest, therefore, we find the most negative trends at latitudes above 60°N (Matthes, H. *et al.* 2015). Although CAOs still occur even in unexpected places, sea ice loss in response to climate change may make these events less severe (Ayarzagüena, B. and Screen, J.A. 2016). However, there is a high level of uncertainty in the follow-up effects of sea ice loss: it may cause more persistent weather patterns (due to smaller temperature differences), leading to warmer but longer-lasting CAOs. It is also projected that most of Europe may get less snowfall, thus, less snow cover in the future (Kis, A. and Pongrácz, R. 2021), which lowers CAO intensity through the difference in radiative surfaces. Less intense CAOs may also mean lower heating demands in future heating seasons in the Carpathian Basin (Skarbit, N. *et al.* 2022). A new study (Smith, E.T. and Sheridan, S.C. 2021) using the CMIP6's socioeconomic pathways found that the number of CAO days may decrease in the future to near-zero across the globe (using the 1981–2010 climatology as reference), but they found significant variability in the North Atlantic region where CAO frequency may also increase as a result of climate change.

Focusing on Hungary, these CAOs generally occur during the advection of cold airmass from the northwest after cold fronts accompanied by strong winds or from the northeast – in this case, on the edge of a Scandinavian or Siberian high-pressure system. The biggest threats associated with these events are cold temperatures, which increase heating demands; wintry precipitation – especially freezing rain, which causes infrastructural damage and dangerous driving conditions; and frost damage to crops and blooming fruit trees in the spring. The strongest CAOs in the past ten years occurred in March 2018 and February 2021 (Horváth, Á. 2018; Kurcsics, M. *et al.* 2021).

Data and methods

We used daily mean temperatures obtained from the repository of the Hungarian Meteorologi-

cal Service (odp.met.hu). This is a high-quality dataset created from weather station observations in Hungary. Data from 10 stations were available (Sopron, Szombathely, Keszthely, Pécs, Budapest, Túrkeve, Szeged, Debrecen, Miskolc, Nyíregyháza) between 1901 and 2020 *(Figure 1).* The dataset has only a few missing days, which did not affect our results. Most of the stations are situated in lowland areas, but some of them are proximity to small mountainous areas.

We used the R programming language to calculate the results from the data. After importing into data frames, we used the "heatwaveR" package (Schlegel, R.W. and Smit, A.J. 2018), which was originally developed in Python for marine heatwaves, as in Hobday, A.J. *et al.* (2016), but can be used to detect CAOs over land. (The details of the setup of this package for this study can be found in the Appendix.) We used this package to produce a 30-year climatology from our daily data, which consists of the daily distribution of mean temperatures for every day of the calendar year (later referred only as climatology). We chose the period between 1991 and 2020 as our reference, mainly because this way we can detect more events, even in the climate change affected warmer last thirty years. The criteria of a CAO were the following:

– The daily mean temperature is in the lower 10th percentile of the climatology for five consecutive days.
– There is a maximum of a 2-day gap between periods matching the above criteria, in which case the two were considered as a single event.

Because we used station data, the spatial extent of these CAOs was not investigated (this is possible, but given the relatively small size of the country, we decided to focus only on duration and intensity). We used the following statistics in our research *(Table 1)*:

These statistics are the most reliable and representative for investigating different CAO events. We also used the start, peak and end date of each event, and for further categorization, we split the calendar year into four seasons (winter, spring, summer, and autumn) and later into months, using the start date of events in this process.

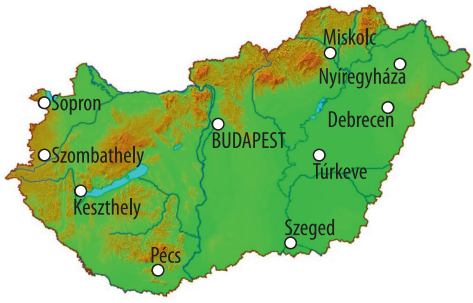


Fig. 1. Location of stations on the topographical map of Hungary

Results

In this section we first investigated the characteristics of CAOs in Hungary over the span of 120 years. After that we discuss how these events changed over time, looking at seasonal and regional aspects.

Characteristics of CAOs in Hungary

Using our CAO definition, we detected 3,237 events at 10 stations over the span of 120 years. From these CAOs, 983 started in the winter months, 803 in spring, 673 in summer and 778 in autumn. On a monthly

Table 1. List of statistics used in the analysis of CAOs

Statistic	Definition
Mean intensity	Average daily temperature anomaly during the event, °C
Peak intensity	Maximum daily temperature anomaly during the event, °C
Cumulative intensity	Sum of daily temperature anomalies during the event, °C
Absolute intensity	Daily mean temperature on the peak day of the event, °C
Duration	Duration of the event in days

scale, 445 events hit the country in January, which is nearly double the amount of the other month's average. On the other end, the stations recorded the least amount of CAOs in July (176). From the 120 years, only two (2015 and 2020) did not have any CAO, while in 1978, there were 68 events (all stations combined). The station near Sopron had the most events (394) during our research period of 1901–2020, while Szeged and Keszthely had the least (255 and 257 events, respectively). Sopron also had the strongest CAO event from 4 January 1942 to 22 February 1942, lasting 46 days and accumulating over 400 °C of cumulative CAO intensity. Going back to the seasonal scale *(Figure 2)*, we show the number of events at each station in four seasons (*Figure 2*, a), and the number of

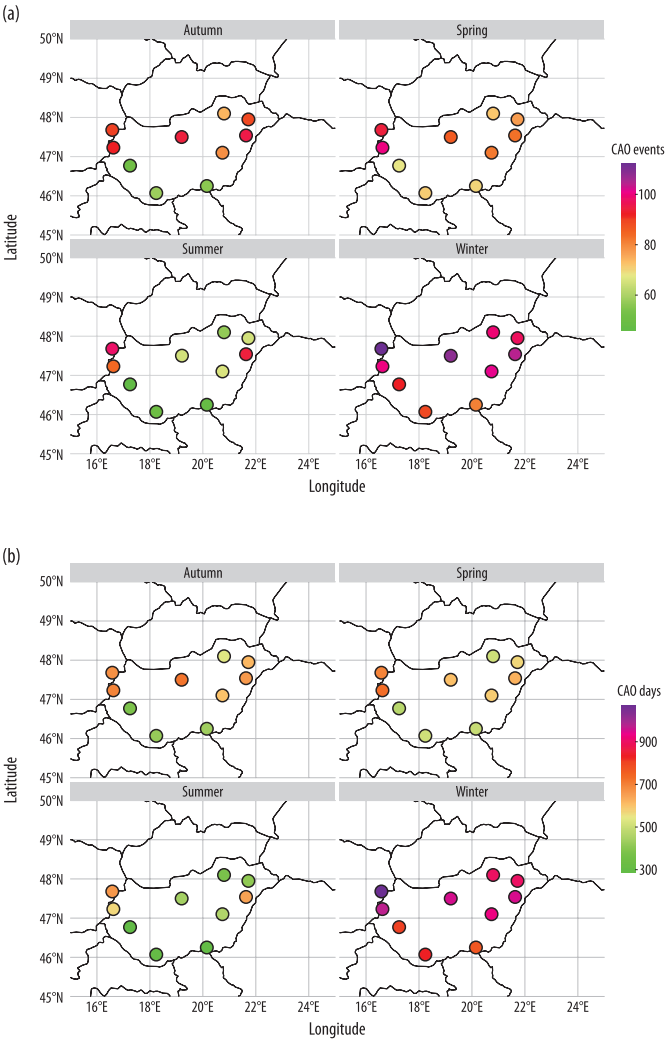


Fig. 2. The number of CAO events (a) and CAO days (b) between 1901 and 2020 at 10 Hungarian stations across four seasons. *Source*: Authors' own elaboration.

CAO days (duration of events summarised) in the same way (*Figure 2*, b). We can see that, on average, the winter season had the most events and CAO days, and the summer season had the least. The variation between the stations seems to be bigger in summer and autumn and smaller in winter and spring. We uncovered more regional differences on this scale, but these are discussed with the observed changes of CAOs occurred between 1901 and 2020.

After that, we looked at how the statistics in *Table 1* correlate during the whole period in each month. We visualised all CAO events on a scatterplot (*Figure 3*, a and b) to better understand the relation between the different statistics.

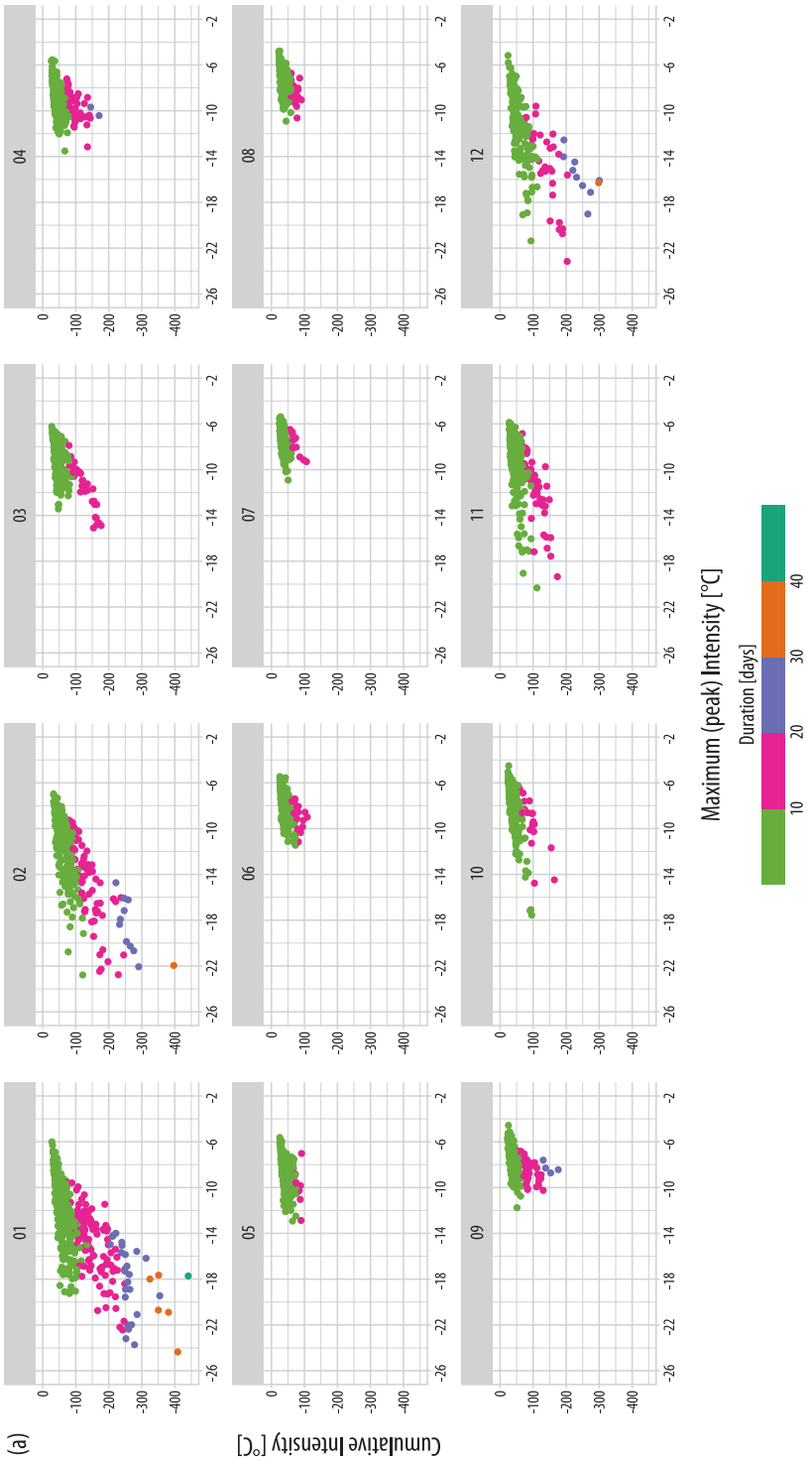
The duration of most CAOs was lower than 20 days with the majority of cases lasting between 5 and 10 days (green and pink colours on *Figure 3*, a). Longer-lasting CAOs only occurred in the three winter months and in April and September, but rarely in these last two months. As expected, longer events had the lowest cumulative intensities (in this case, meaning they were stronger), but the relation between peak intensities of CAOs and their respective duration is highly nonlinear. The cumulative intensity varied more between the months of the year, with the winter months having the strongest and the summer months having the weakest events in Hungary. The scatterplots also showed us the underlying relation between the peak and cumulative intensities of CAO events. This relation appears to be linear in some months (e.g., March, May, June, July, August, October, and November), while in the other months, it is more nonlinear (there are higher cumulative intensities to the same peak intensity). We can also observe that the winter months all have more variation between events, given that there were peaks with lower than -20 °C in these months. On *Figure 3*, b the colours represent the absolute intensity, which is defined as the daily mean temperature of the peak day during each event. In the summer months, daily mean temperatures dropped between 8 and 18 °C during CAO peaks, in spring and autumn it had a great variability between -10 and 15 °C, but in November, there were some events with even colder mean temperatures. The three winter months had the lowest daily temperatures at peaks, in many cases falling below -20 °C, which can cause infrastructural problems.

Observed changes of CAOs between 1901 and 2020

In the previous chapter, we introduced the characteristics of cold air outbreaks in Hungary and in this chapter, we analyse how the CAO statistics changed over time. We also investigate seasonal and regional differences, so our approach reflects that motivation *(Figure 4).*

Firstly, we looked at the seasonal changes to the five statistics mentioned earlier (mean, peak, cumulative, absolute intensity, and the duration of events). We used boxplots to visualise each year and added local regression smoothing (LOESS – locally estimated scatterplot smoothing) to our graphs. This is a nonparametric method for smoothing data, especially in the presence of outliers. It uses local weights to detect trends in shorter timeframes, which benefits us. Because the intensities are measured in negative values, we depict increasing (decreasing) intensity when the values get lower (higher).

In autumn, the duration of events ranged between 5 and 15 days; longer CAOs only occurred before 1920. There was a slightly increasing trend from 1970 to the mid-1990s, but overall, there is no significant change in duration (*Figure 4*, d). The mean and peak intensity in this season had a decreasing trend until 1950, then an increasing trend until 1990. In the last 30 years, both intensities decreased by nearly 1 °C, meaning that the CAOs became weaker (*Figure 4*, c and e). The cumulative intensity had the same trend as the mean and peak, but we could see some stronger events that occurred between 1980 and 2000 (*Figure 4*, b). Here, we can also see less difference between stations than in the case of the previous strong CAOs before 1940. The absolute intensity had its


(a)
Cumulative Intensity [°C]
01
02
03
04
05
06
07
08
09
10
11
12
0
-100
-200
-300
-400
-2
-6
-10
-14
-18
-22
-26
Maximum (peak) Intensity [°C]
Duration [days]
10
20
30
40

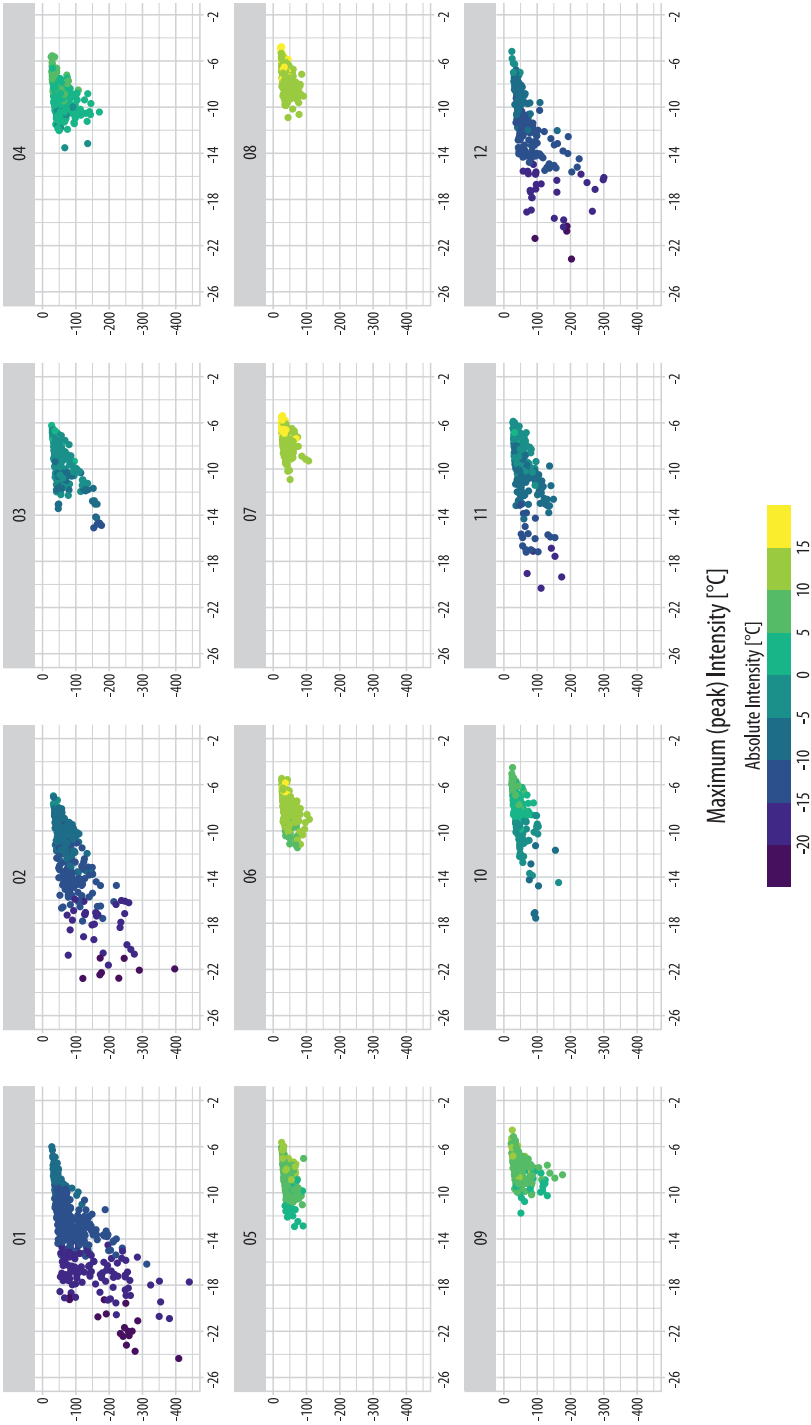
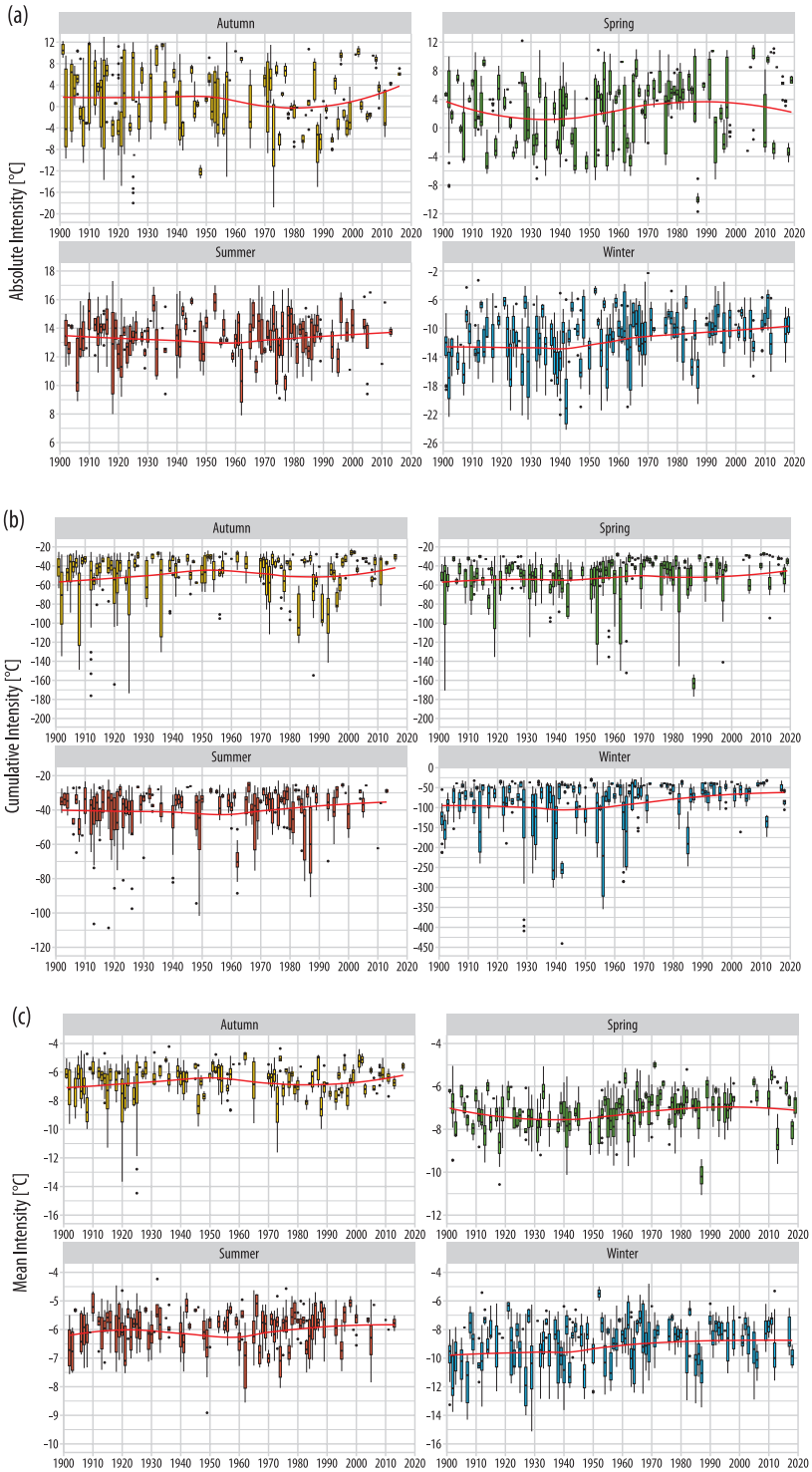


Fig. 3. Cumulative intensity of CAO events (y-axis) plotted against the maximum (peak) intensity of events (x-axis) during the whole 120-year period in each month of the calendar year. The colours show the duration of events in days (a), absolute intensity of events (b). All values except duration are in °C.
Source: Authors' own elaboration.


(a)
Autumn
Spring
Summer
Winter
Absolute Intensity [°C]
(b)
Autumn
Spring
Summer
Winter
Cumulative Intensity [°C]
(c)
Autumn
Spring
Summer
Winter
Mean Intensity [°C]
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

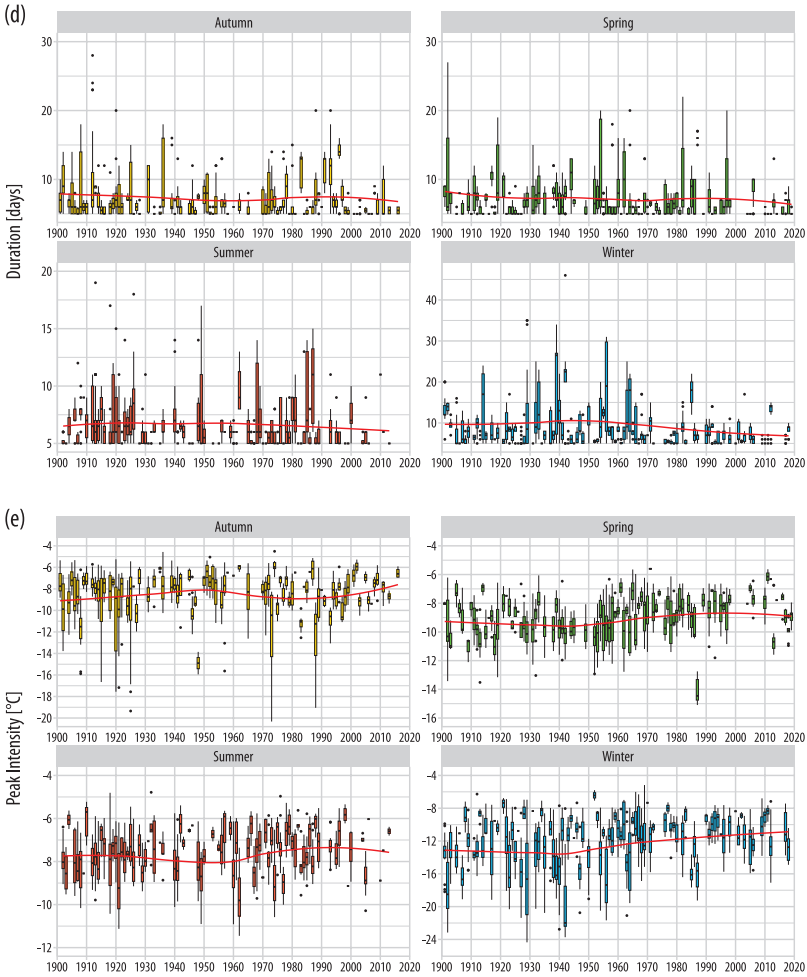


Fig. 4. Observed changes in the five CAO statistics used in our study between 1901 and 2020 across four seasons. Red line is local regression smoothing (LOESS) in every graph. We show the boxplots of Absolute intensity (a), Cumulative intensity (b), Mean intensity (c), Duration (d) and Peak intensity (e). *Source:* Authors' own elaboration.

most significant variation in the three autumn months compared to the other seasons. With the great internal variability and fewer and fewer events in the last 30 years, we have found no significant conclusions regarding this statistic (*Figure 4*, a).

Looking at the other transition season, spring, we can see similar characteristics to autumn in event duration, the last 20 years having shorter CAOs than the 100 years prior (see *Figure 4*, d). The mean and peak intensities reveal an interesting difference: in the last 20 years, there has been an increasing trend in both statistics in this season (see *Figure 4*, c and e), but due to a small number of cases, it is not significant. There was an increase in intensity until 1950, while a decreasing trend was found after that until the mid-1990s. On the other hand, the cumulative intensity of spring CAOs shows a decreasing trend in the

whole period, but there was a strong event in almost every decade, the strongest being in March of 1987 (see *Figure 4*, b). The absolute intensity ranged between -6 and 10 °C in this season, but with the same great variability as in autumn (see *Figure 4*, a).

The summer season had the weakest events of all seasons and mainly in two periods during the 120 years. The first period was between 1905 and 1925, and the second from the mid-1960s to 1990. Both periods had nearly identical characteristics, the first slightly colder than the latter. There were longer events at some stations in the 1980s (see *Figure 4*, d), but most events were shorter than 10 days in the summer months. Between these two periods, there were a small number of events, but in the last 30 years summer season CAOs started to disappear because of the effects of increased warming of summers in Hungary.

Lastly, we analysed the changes in winter season, which had the most and strongest events. There were many cases where longer than 20-day CAOs occurred between 1930 and 1970 (see *Figure 4*, d). After that, there was only one occurrence of this duration, the length of events decreased to an average of 5 to 10 days. We also discovered a decreasing trend in mean intensity (see *Figure 4*, c) in the whole period (1 °C per 120 years) and a slightly greater decrease in peak intensity (see *Figure 4*, e) (1.5 °C per 80 years from 1940). There were more strong events looking at the cumulative intensity until 1970 with greater variability, but after that, we observed the same decreasing trend, only two years had strong events (see *Figure 4*, b). The absolute intensity had greater variation until 1990, ranging between -22 and -2 °C, with the last 30 years having smaller variation (see *Figure 4*, a).

We also compared the four seasons during our research period on a simple line chart *(Figure 5)* to illustrate the shift in seasonal CAO occurrence. For our comparison, we chose the 10-year moving average of CAO days on an annual basis and the station average (for simplicity). We can see that the number of CAO days decreased in the winter season and increased in the other three seasons in the first 20-30 years, the autumn and summer seasons had 10 and 9 CAO days yearly, while winter and spring seasons had around 6 days. The moving average of winter season CAO days increased rapidly after 1925 until 1950, reaching 10 to 15 days annually. After a short decline, it had the most days of the seasons until the early-1970s. The spring season had a peak in the early-1960s, with 10 CAO days yearly, while autumn and summer seasons had just a few days annually. Around 1975, all seasons had the same moving average number of CAO days, and the summer season had the greatest number of them for a short period. The autumn season had two smaller peaks, one in 1980 and another in 1997, while the winter season had a third peak between 1985 and 1995. In the last 20 years, all seasons have had a decreasing trend, with the moving average falling below 5 CAO days.

To assess regional and seasonal differences together throughout the years, we constructed *Figure 6*, a and b, where we visualised the number of CAO days summarised in each decade at each station. We used decades here for simplification, knowing that it can mask inter-decadal characteristics, but we could already analyse those on previous figures. On *Figure 6*, b we split the winter season further into months and added November from the autumn season to our regional analysis, because these were the months with the greatest number of events and had the greatest internal variability.

We can see that in autumn, the most CAO days occurred in the 1910s, 1920s, 1970s and 1990s. Budapest had more than 120 CAO days in the 1910s, but no regional trends appear in the data (see *Figure 6*, a). The other two decades had a more homogenous distribution of CAO days, most stations having 60-90 days in these 10-year periods. In the 2010s, Budapest had no CAO events during the autumn season. In spring, the most CAO days occurred in the 1950s and 1960s, in this timeframe, Sopron, Szombathely and Túrkeve stations had over 90 CAO days. We found two opposite regional patterns, one in the 1970s and one in the 1990s. In the first decade, the western stations (Sopron, Szombathely,

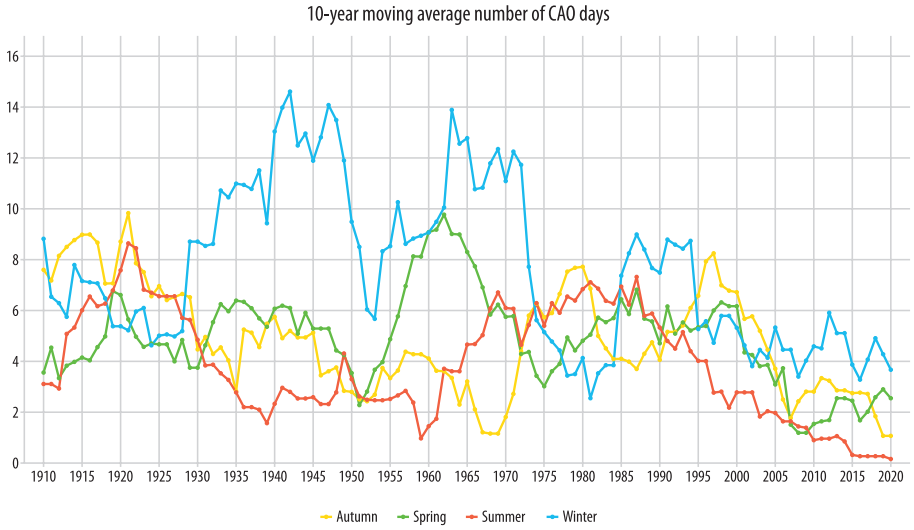


Fig. 5. 10-year moving average (right-aligned) number of CAO days (station average shown) during our research period (1901–2020). *Source:* Authors' own elaboration.

Pécs, Keszthely) had more than 45 CAO days, while the rest of the stations in the east had less. In the second decade, the stations in the eastern part of Hungary had between 60 and 90 CAO days, while the western stations had slightly fewer CAO days than that figure. In the summer season, Sopron had 146 CAO days in the 1910s, which is an outlier among all stations. Debrecen also had more summer CAO days than any other station: 95 in the 1920s, 101 in the 1980s and 107 in the 1970s. In the last 30 years, the number of CAOs decreased rapidly this season. Only 3 out of 10 stations registered CAO days in the last decade. The winter season had the greatest number of days, mainly in the first seven decades of the whole period. In 10 cases, the decadal number of CAO days was over 120 days, in the 1940s, Sopron even had 193 CAO days, which is another outlier. We did not detect any clear regional patterns in winter, but in most decades the stations in the northern part of Hungary had more CAO days, than the southern stations. This is because the cold airmass usually arrives with north-westerly or north-easterly winds to the Carpathian Basin in this season.

We also investigated the distribution of cold air outbreak days with the same method in November, December, January, and February months to see if we can find any regional patterns below the seasonal scale (see *Figure 6*, b). November CAOs mainly occurred in three decades: 1900s, 1920s, and 1980s. Regional differences were present in some decades, but we did not find a clear trend. Looking at December, there were many CAO days in the 1930s and 1990s and a regional pattern in the 1960s, where the western stations had more event days. In some decades, the two north-eastern stations (Miskolc, Nyíregyháza) had more CAO days, implying a synoptic forcing from this direction. The greatest number of CAO days occurred in January, most frequently in a 30-year window from 1940 to 1970. In this period, most stations had over 60 CAO days per decade, Sopron station registered over 100 CAO days in the 1940s. Regional differences do appear in this month in a few

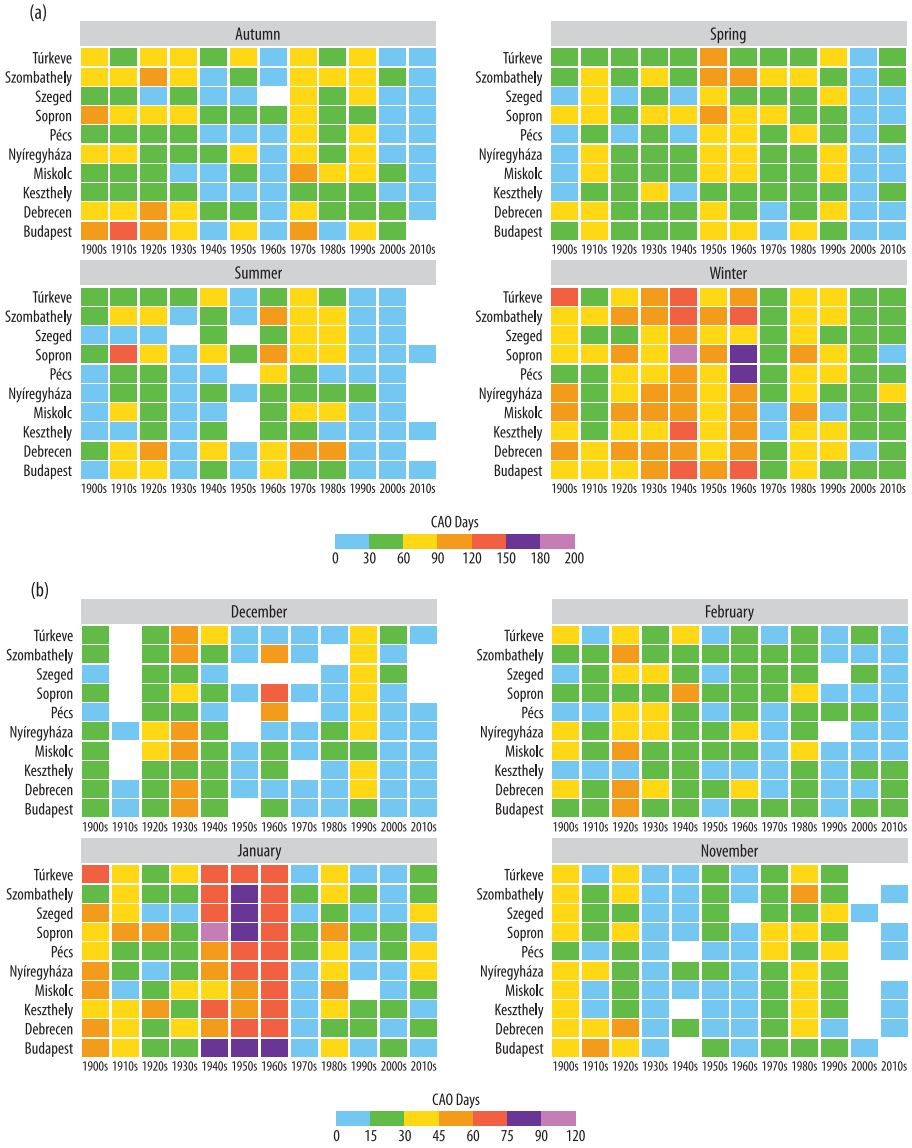


Fig. 6. Number of CAO days visualised at 10 Hungarian stations in the last 12 decades (1901–2020) across four seasons (a), and in November, December, January and February (b). *Source:* Authors' own elaboration.

decades, with the same east-west pattern we discovered previously. In February, we can see a great variability in event occurrence, the 1920s had the most CAO days in Hungary. No clear trend of a regional pattern was found in this month.

Finally, we created an overview for all stations like *Figure 7*, where we visualised all CAO events in a way that allowed us to see the seasonal and annual changes, the duration of events, and each event's peak intensity. We then selected Budapest station for a visual example.

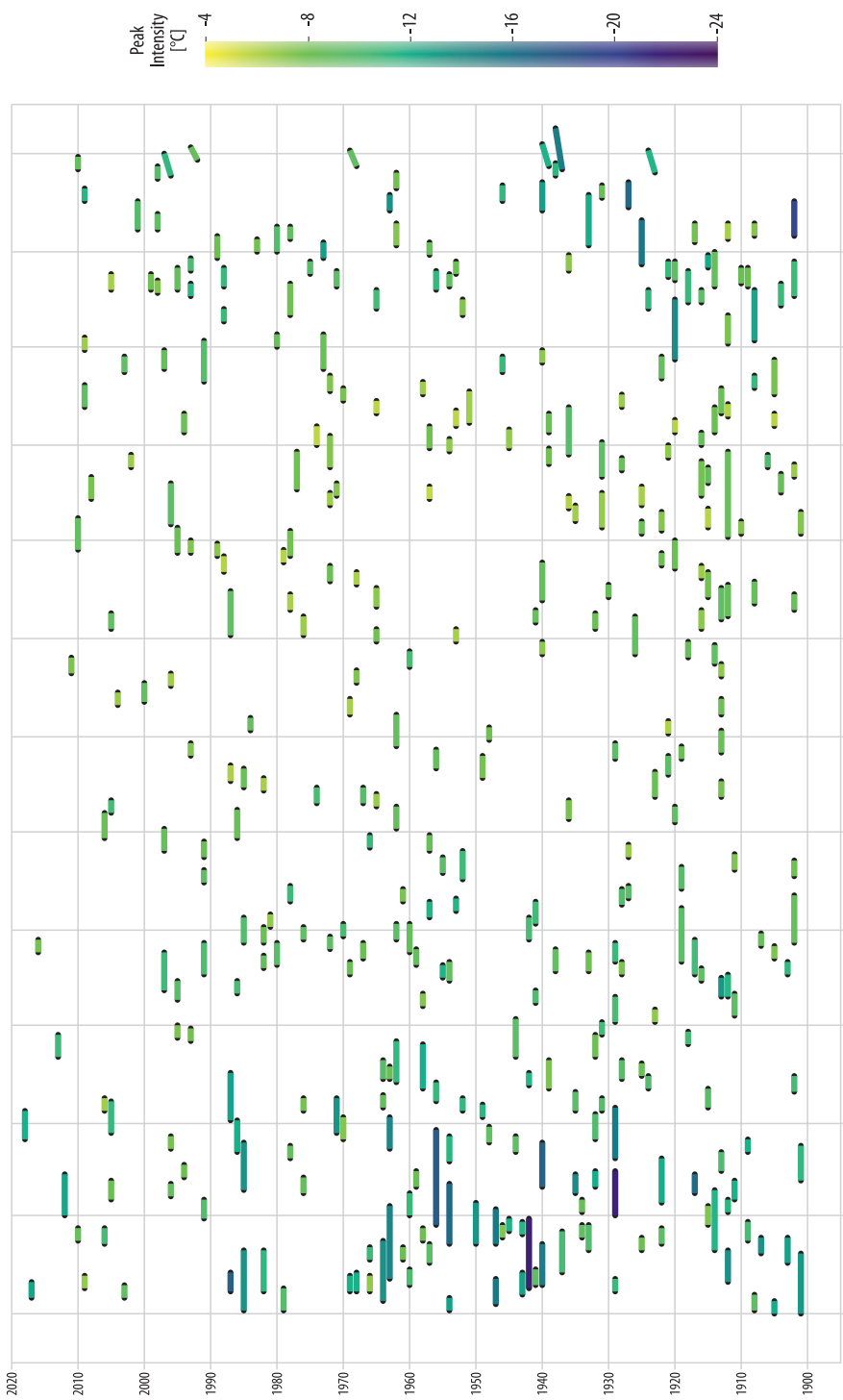


Fig. 7. An overview of all CAO events which occurred at Budapest from 1901 to 2020. We can see the distribution of events in the calendar year. Sloped lines at the end of the year represent events which lasted throughout the new year. *Source:* Authors' own elaboration.

Discussion

We compiled a climatology of cold air outbreaks in Hungary using station data during the last 120 years. In our method, we used 2-day non-CAO gap criteria, which allowed us to merge events together or increase event length in some cases where milder temperatures occurred for one- or two-days during CAOs. This way, we detected longer events, especially in summer and transition seasons, which could be the strength of our method. We analysed the characteristics and observed changes with carefully constructed graphs, which best represent the most important results obtained from this kind of data. Our intention with this study was only to thoroughly investigate cold air outbreaks, which affected Hungary, we did not want to compile or compare other cold weather phenomena within the boundaries of this research.

Our work differs from that of Spinoni, J. *et al.* (2015) in some ways, whose research was the closest to this investigation of CAOs in Hungary. They used "CARPATCLIM", a high-quality gridded dataset for the period 1961–2010 and a broad area surrounded by the Carpathian Mountain Range, in contrast to our station approach. They used a similar CAO (there: cold wave) definition of 5 consecutive days below the 10th percentile of the climatology (baseline period: 1971–2000), but for the night and daytime minimum/maximum temperatures. Also, the two-day gap between these days was not used as we did in our method. They also investigated these events on a seasonal basis and found an increasing trend in their statistics in autumn, which is opposite to what we found in spring. They also found that the rate of change is greatest in the winter season, similar to our results. Despite the differences between the methods, the decreasing trend of CAOs is still present in both investigations.

We could also use less robust cold indicators, like cold snaps or cold spells (CSPs), because these shorter events can also cause problems in the agricultural sector and road transport, like that experienced in March of 2013. The characteristics of these events at early spring are also important to understand better our changing climate and the shift of the seasons in Central Europe. The frequency of CSPs is also decreasing with the warming climate, but CSPs have been more frequent in recent decades than CAOs, so we are planning a comparison study between these indicators of cold weather.

Even though the number of CAOs (and the focus on them) has decreased in recent decades, investigating the changes in their seasonal distribution could be a research focus for the coming years. Understanding CAOs not just in the winter months may be critical to better predict the occurrence of these phenomena in the future. We also proved that cold air outbreaks represent a robust set of statistics relating to cold weather phenomena, and their reduction is a great indicator of a warming climate, so applying the methodology to different parts of the Earth where the rate of warming differs may be interested in research on recent decades.

Conclusions

This paper investigated Cold Air Outbreaks in Hungary using observational data from 10 Hungarian weather stations. We discovered some interesting facts using a robust CAO definition as well as the already-known effects of climate change in our region:

- Until the 1990s CAOs occurred with great seasonal variability, but in the last 30 years, their number declined rapidly (pointing to that we can use CAOs as an indicator of climate change because these long-lasting cold periods provide us with a robust set of statistics).
- Summer and autumn seasons have had the least number of events recently; only the winter months and early spring have had significant CAOs in the last decades.
- Almost all investigated statistics declined because of the warming in this region in the last 30 years. The only increasing trend was found in spring, where the mean and peak intensity had a slight increase in this timespan.

– We only found regional differences in the country in just a few decades, with no clear trend. These differences generally occurred between the western and the eastern part of Hungary, which could potentially reveal the origin of cold airmass.

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Effects of recreational and residential functional land use on urban soils

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Abstract

Soils in residential areas of cities are heavily degraded, and the environmentally protective and formative functions are instead realized by the soils in recreational areas (city parks, etc.). The study aimed to analyse the influence of functional land use and the level of anthropogenic impact on the properties of anthropogenic horizons (Au and Aτ) in the city of Volgograd, Russia. In this study, we analysed 50 soil samples from the city's recreational and residential functional areas under field and laboratory conditions. The study evaluated the morphological aspects (thickness, colour, structure, and presence of artefacts), physical properties (bulk density, texture), and chemical properties (pH_{water}, salt content, $CaCO_3$, C_{org}, SOC_{stoc}) of the soils. The anthropogenic Au horizons in residential areas exhibited a clumpy structure, numerous artefacts, and significant compaction. Conversely, the soils in recreational zones contained fewer anthropogenic artefacts, with the Aτ horizons characterized by a lumpy structure. The anthropogenic horizons' median and mean property values in the functional zones showed significant differences. The acid-alkaline properties of the studied horizons were weakly alkaline in recreational areas and alkaline in residential areas. A common feature of all anthropogenic horizons was the variability in chemical, physical, and morphological properties depending on the functional zone and level of anthropogenic load. The indicators of a specific level of anthropogenic impact on urban landscapes included horizon thickness, C_{org} content, colour, and structure.

Keywords: soils of recreational areas, residential areas, Technic, Urbic, Technosols, physical and chemical properties of soils

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Introduction

Soil cover in cities is characterized by diversity and heterogeneity, featuring a combination of natural, natural-anthropogenic, and anthropogenic soils. Despite significant changes in morphological, physical, and chemical properties compared to natural horizons, anthropogenic horizons play ecological roles by providing conditions for vegetation growth and enhancing the quality of urban life for the population (Blume, H.P. 1989; Novák, T.J. *et al.* 2020).

A horizons exhibit varying morphological, chemical, and physical properties depending on the functional zone and the level of anthropogenic influence (Pouyat, R.V. *et al.* 2007; Zhevelev, H. and Kutiel, B.P. 2012; De Lucia, B. *et al.* 2013). For instance, soils in transportation, industrial, and residential areas tend to have high density (Zhao, D. *et al.* 2013; Chupina, V.I. 2020). Soil in recreational areas often contains elevated levels of C_{org} (Zhao, D. *et al.* 2013; Charzyński, P. *et al.* 2018). In residential zones, surface sealing and lowering of the water table lead to reduced soil moisture content (Blume, H.P. 1989; Burghardt, W. 2006; Sándor, G. *et al.* 2013). Urban soils become more alkaline due to dust deposits rich in calcium and magnesium carbonates, as well as the use of deicing agents. Additionally, pH levels tend to in-

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crease due to decreased organic matter resulting from reduced vegetation biomass (Brevik, E.C. and Fenton, T.E. 2012; Zhevelev, H.M. *et al.* 2013). Some studies have observed a pH decrease attributed to precipitation acidification (Sukopp, H. *et al.* 1979). The use of heavy machinery in residential areas can cause soil compaction, reduced pore size, and the formation of a clumpy structure (Jim, C. and Ng, Y. 2018). This, in turn, slows down the infiltration of atmospheric moisture, energy transfer, plant growth, aeration, and organic carbon accumulation (Scalenghe, R. and Marsan, F.A. 2009; Jim, C. and Ng, Y. 2018). Consequently, soil structure degradation and a decrease in organic carbon content occur (De Lucia, B. *et al.* 2013).

In general, anthropogenic A horizons exhibit a wide range of properties across most cities worldwide. This variability has been observed in cities such as Zielona Góra in Poland (Greinert, A. 2015), Paris in France (Cambou, A. *et al.* 2018), Rostov-on-Don and Murmansk in Russia (Dvornikov, Y.A. *et al.* 2021), and Ghent in Belgium (Delbecque, N. *et al.* 2022). However, cities like Detroit and New York City in the USA (Howard, J. and Orlicki, K. [2015], and Huot, H. *et al.* [2016]), the Rostov agglomeration in Russia (Bezuglova, O.S. *et al.* 2018), Toruń in Poland (Charzyński, P. *et al.* 2018), Moscow in Russia (Prokof'eva, T. *et al.* 2020), Akure and Okitipupa towns in Nigeria (Adelana, A.O. *et al.* 2023) show similarities in certain properties of anthropogenic horizons across different functional zones, such as pH, thickness, and grain-size composition.

The objective of the study was to analyse the morphological, chemical, and physical properties of anthropogenic soil horizons Au and Aт in Volgograd city based on the functional land use type and the level of anthropogenic impact.

Hypothesis: The properties of anthropogenic soil horizons will exhibit distinct variations depending on the functional zoning of an urban area, with significant differences between residential and recreational zones. We predict that soil horizons in recreational zones will demonstrate distinctive characteristics compared to those in residential areas, reflecting the specific land use practices and human activities associated with each zoning type.

Materials and methods

Study area

Volgograd, a major industrial city in the Russian Federation, boasts significant industrial and residential capabilities. The town is situated in an area characterized by Cambisols (Protocalcic), Cambisols (Protocalcic, Sodic), and Haplic Kastanozems of varying grain-size compositions. The soils within the city limits have undergone extensive transformation, with residential and industrial areas featuring Urbic Technosols and Ekranic Technosols, while recreational areas include Technosols (Mollic), Hortic Anthrosols, Cambisols (Protocalcic, Technic), and Haplic Kastanozems (Technic) (Gordienko, O. *et al.* 2022), classified according to the World Reference Base for Soil Resources (WRB) (IUSS Working Group, 2022). The primary factor influencing soil formation is anthropogenic.

In the city development plan for Volgograd, residential areas are designated for the construction of residential, public, and industrial structures, along with roads and streets, while recreational zones encompass city parks, squares, and boulevards *(Figure 1)*.

The study focused on the soils of recreational areas and adjacent residential zones, specifically Druzhba Park (48°35′3.53″N, 44°26′31.27″E), Sasha Filippov Park (48°41′42.84″N, 44°29′58.67″E), and the city arboretum (48°38′37.22″N, 44°26′11.06″E). These selected research sites vary in terms of anthropogenic impact and recreational usage yet share similar geomorphological conditions.

In 1943, Volgograd (at that time Stalingrad) was entirely devastated. Reconstruction efforts commenced promptly after the cessation of hostilities in February 1943. The majority of explosion craters, defensive positions, and ruined structures were cleared

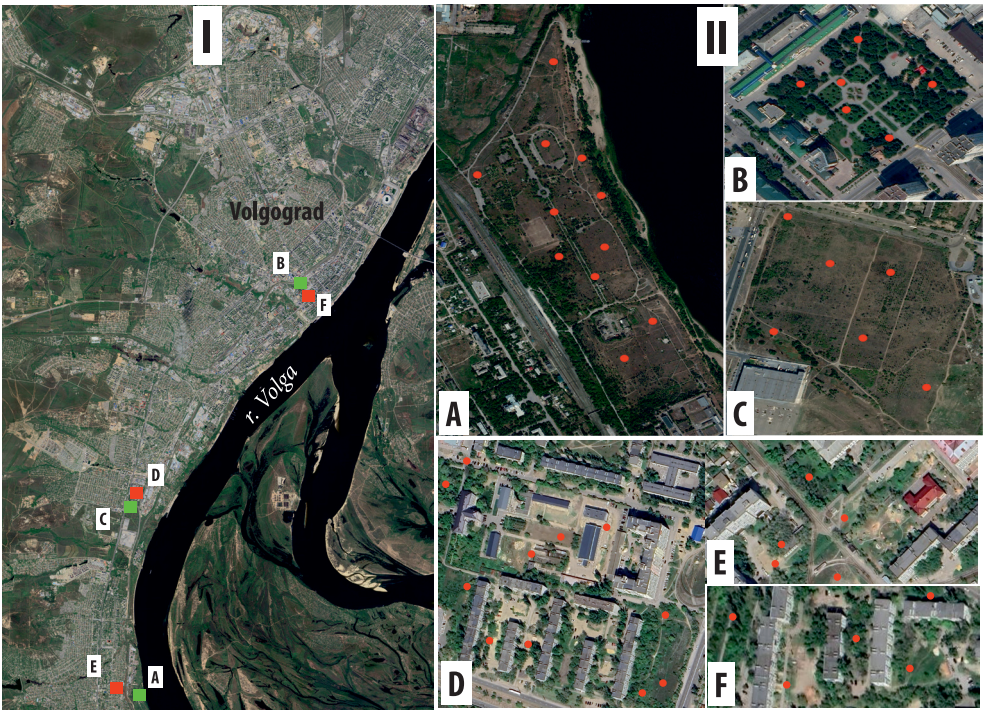

Fig. 1. Map-scheme of research objects. I = Study areas within the boundaries of the urbanized part of the city; II = Study sites in the recreational (A, B, C), and residential (D, E, F) area. *Source*: Authors' own elaboration.

through mechanical means and deposited into nearby gullies. Consequently, soil formation within the city is initiated simultaneously in all zones under uniform conditions.

The study focused on the anthropogenic horizons designated Au and Aτ, as per FAO classification, analogous to Russian urban horizons UR and RAT (FAO, 2006; Прокоф'ева, Т.V. *et al.* 2017). Despite residential and recreational soils potentially belonging to different Reference Soil Groups, they commonly feature the presence of anthropogenic horizons Au and Aτ.

The anthropogenic horizons were categorized into groups to test the hypothesis regarding variations in properties based on anthropogenic load and functional zones *(Figure 2)*:

Total sampling of A horizons (50 samples), corresponding to the number of soil genetic horizons, including:

1. Aτ (33 samples) from recreational areas,
2. Au (17 samples) from residential areas.

The distinction between Au and Aτ horizons is based on their genesis and artefact volume (%). Au horizons (qualifier Urbic) are predominantly found in residential, industrial, and transport zones, characterized by the introduction of various substrates on the surface, containing ≥ 20 percent artefacts (mainly building and household waste) and often sandy or rocky. Aτ horizons, while similar in origin to Au, contain soil material deliberately transported by humans from outside the immediate environment, with 5–10 percent artefacts, unaffected by natural recycling or movement processes.

Soil properties and indicators such as horizon thickness, structure, colour (based on Munsell scale), bulk density (BD), physical clay content (< 0.01 mm), pH (water), salt content, $CaCO_3$, C_{org} content, and SOC_{stoc} (soil organic carbon stock) were compared and analysed.

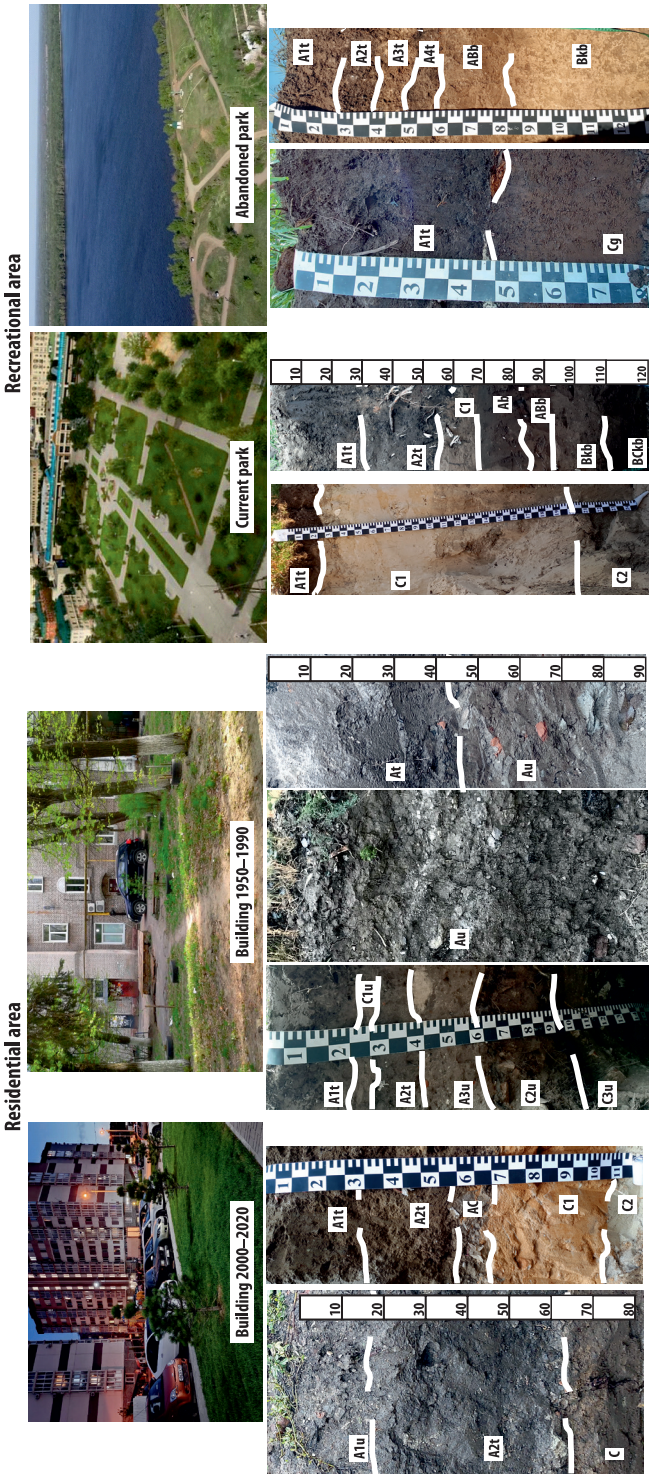

Fig. 2. Examples of soil profiles with anthropogenic Au and Aт horizons in recreational and residential functional zones. *Source:* Authors' own elaboration.

Methods

Soil morphological properties

Between 2022 and 2024, a total of 44 soil sections were laid out and described. Transects were established at depths ranging from 1.5 to 2.0 metres. Each transect underwent morphological description and soil sampling by genetic horizons. The selection of transect locations was influenced by the on-farm zoning of the area, considering factors such as paths, palisades, and inner spaces of residential areas. During fieldwork, soil samples were collected, and their colours were recorded based on the Munsell chart. The soil colour data obtained in the field were used to calculate the soil humus horizon index values, as per the equation:

$$ADI = \frac{HT}{(V \cdot C)} + 1, \quad (1)$$

where *ADI* is the A horizon development index, *HT* is the horizon thickness in cm; *V* stands for value, and *C* stands for colour chroma according to the Munsell chart (Mazurek, R. *et al.* 2016). Soil classification was conducted in accordance with the international soil classification WRB 2022 (IUSS Working Group, 2022). Artefacts were described based on their abundance, size, shape, and fragment nature. The

size, abundance, and origin of artefacts were classified per FAO recommendations (FAO, 2006). Sampling was carried out from the horizon's centre (where the expression is most pronounced). If multiple samples were collected from the same horizon, they were taken at balanced intervals.

Soil chemical properties

Samples were collected from each Au horizon of the soil profiles. In the laboratory studies, the following soil indicators were determined:

- Soil pH was measured potentio-metrically in the supernatant suspension of a 1:2.5 soil-to-liquid mixture (water) using the pH-meter-millivoltmeter pH-410 (Van Reeuwijk, L.P. 2002).
- Total salt content was instrumentally determined using the conductometer HI98302 DiST 2 in soil-water extracts at a ratio of 1:5 (Van Reeuwijk, L.P. 2002).
- Soil organic carbon content was assessed following the Nikitin method with a colourimetric endpoint suggested by Orlov-Grindel (Mineev, V.G. 2001).
- Soil organic carbon stock (SOC_{stoc}) for mineral soils was calculated using an equation:

$$SOC_{stoc} = C_{org} \cdot BD \cdot d \cdot CF_{st}, \quad (2)$$

where C_{org} is the soil organic carbon in percent; BD is the bulk density in g cm^{-3}; d is the depth of the horizon in cm; CF_{st} is the correction factor for stoniness $(CF_{st} = 1 - \frac{\%\,stones}{100})$, including subtraction of gravel and stones (FAO, 2017).

Carbonate content was determined through the metric method, involving the decomposition with a titrated hydrochloric acid solution followed by titration of excess acid with alkali (Arinushkina, E.V. 1962).

Soil physical properties

The soil's particle size distribution (% clay, % silt, % sand) was determined using the Kachinsky pipette method (Kachinsky, N.A. 1958). Bulk density was measured separately using the Cylindrical Core Method for undisturbed samples (98.5 cm^{-3}) (Kachinsky, N.A. 1958).

Statistical processing of data

The results were statistically analysed using the statistical software system R 4.4.0 (Dmitriev, E. 1995). Descriptive statistics were calculated, such as minimum, maximum, mean, and standard deviation. Statistical methods like the Jarque–Bera test, Mann–Whitney U-criterion, and T-criterion were employed. Pearson and Spearman correlation coefficients were used to establish correlation relationships.

The Jarque–Bera (*J–B*) test assessed the normality of data distribution by determining skewness and kurtosis. The test was calculated using a specific formula:

$$J - B = \frac{N}{6} \cdot (Sk^2 + \frac{(K-3)^2}{4}), \quad (3)$$

where N is the sample volume, Sk is the skewness, K is the kurtosis. If the value of $J–B > 5.991$, it means that the hypothesis of normal distribution of the sample is rejected, i.e., the distribution is non-normal.

After establishing the normality and non-normality of data distribution, tests were performed to check the equality of mean values in two samples (Au and Aτ). The T-criterion was used for the normal distribution of data according to the formula

$$T = \frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}}, \quad (4)$$

where M_1 is the arithmetic mean of the first comparable population (group), M_2 is the arithmetic mean of the second comparable population (group), m_1 is the mean error of the first arithmetic mean, m_2 is the mean error of the second arithmetic mean.

In cases where data were not normally distributed, the Mann–Whitney U-criterion

was applied to assess differences between two independent samples. The U-criterion calculation considered sample volumes and rank sums, with lower values indicating more reliable differences in parameter values between samples:

$$U = n_x \cdot n_y + \frac{n(n+1)}{2} - T, \quad (5)$$

where n_x and n_y are sample volumes; n is the sample volume with the larger rank sum; T is the larger sum of ranks from samples X and Y.

Results

The histogram of the generalized data distribution for the thickness of all anthropogenic horizons indicated a lognormal distribution, with values predominantly falling within the range of 10–50 cm (minimum – 3; maximum – 110; median = 24 ± 3 cm). The thickness distribution in recreational and residential areas was described as normal, while the overall sample showed a lognormal distribution *(Figure 3).* In residential areas, the average thickness was 46 ± 7 cm, whereas in recreational areas, it was 18 ± 2 cm.

The structure of the anthropogenic horizons varied from clumpy to lumpy, with differing ratios by zone. Of the total horizons observed, 66 percent exhibited a lumpy structure, while 34 percent displayed a clumpy structure. The distribution of structure types also differed by functional zones: the clumpy structure predominated in residential areas, while the lumpy structure was more prevalent in recreational areas.

The colour of anthropogenic horizons exhibits a range of variations. In residential areas, the colour spans from 2.5YR to 7.5YR, with values between 4 and 6 and chroma ranging from 2 to 4. Conversely, in recreational zones, the colour tends to be darker, typically classified as 10YR with values of 3 to 6 and chroma between 2 and 4.

The A horizon's pH_{water} values exhibited a normal distribution (see *Figure 3*). Across all anthropogenic horizons, pH ranged from 6.6 to 8.5 (mean = 7.9 ± 0.1 cm). Specifically, the pH mean in residential areas was 8.0 ± 0.1 cm, while in recreational areas, it measured 7.7 ± 0.1 cm.

The distribution of salt content values in all anthropogenic horizons followed a lognormal distribution (see *Figure 3*). Overall, the horizons were characterized as non-saline, with a median of 0.12 ± 0.01 percent. Minimal differences were observed between the zones, with a median of 0.12 ± 0.02 percent in the recreational zone and a mean of 0.14 ± 0.02 percent in the residential zone.

The distribution of $CaCO_3$ data in the general sample and recreational area was non-normal, while in the residential area, it was normal (see *Figure 3*). The minimum $CaCO_3$ values differed by 0.4 percent between residential and recreational areas and the maximum by 0.3 percent. The median $CaCO_3$ value for the total sample was 1.3 ± 0.2 percent, while in the recreational zone it was 1.2 ± 0.3 percent. In the residential area, the mean $CaCO_3$ content was 1.7 ± 0.3 percent.

After analysing the histograms of the C_{org} content distribution, it was observed that the data distribution in the general sample and recreational area is non-normal (see *Figure 3*). The C_{org} content in the horizons ranged from 0.3 to 4.9 percent with a median of 1.2 ± 0.03 percent. There were notable variations in this index across zones. Specifically, the mean C_{org} content in the residential zone was 1 ± 0.1 percent, while in the recreational zone, the median was 1.4 ± 0.2 percent. The highest recorded rates were 4.9 percent in the recreational zone and 1.9 percent in the residential zone.

The distribution of SOC_{stoc} data for the total sample displayed leftward asymmetry, as shown in *Figure 3*. In the residential area, the distribution was normal. The generalized SOC_{stoc} values ranged widely from 4 to 168 g kg^{-1}, with a median of 39 ± 6 g kg^{-1}. The mean in the Au horizons was 45 ± 12 g kg^{-1}, while in the Aτ horizons, the median was 34 ± 7 g kg^{-1}.

The distribution of clay content data in all three samples of the A horizon is characterized as normal (see *Figure 3*). The maximum clay content was observed in the residential zone at

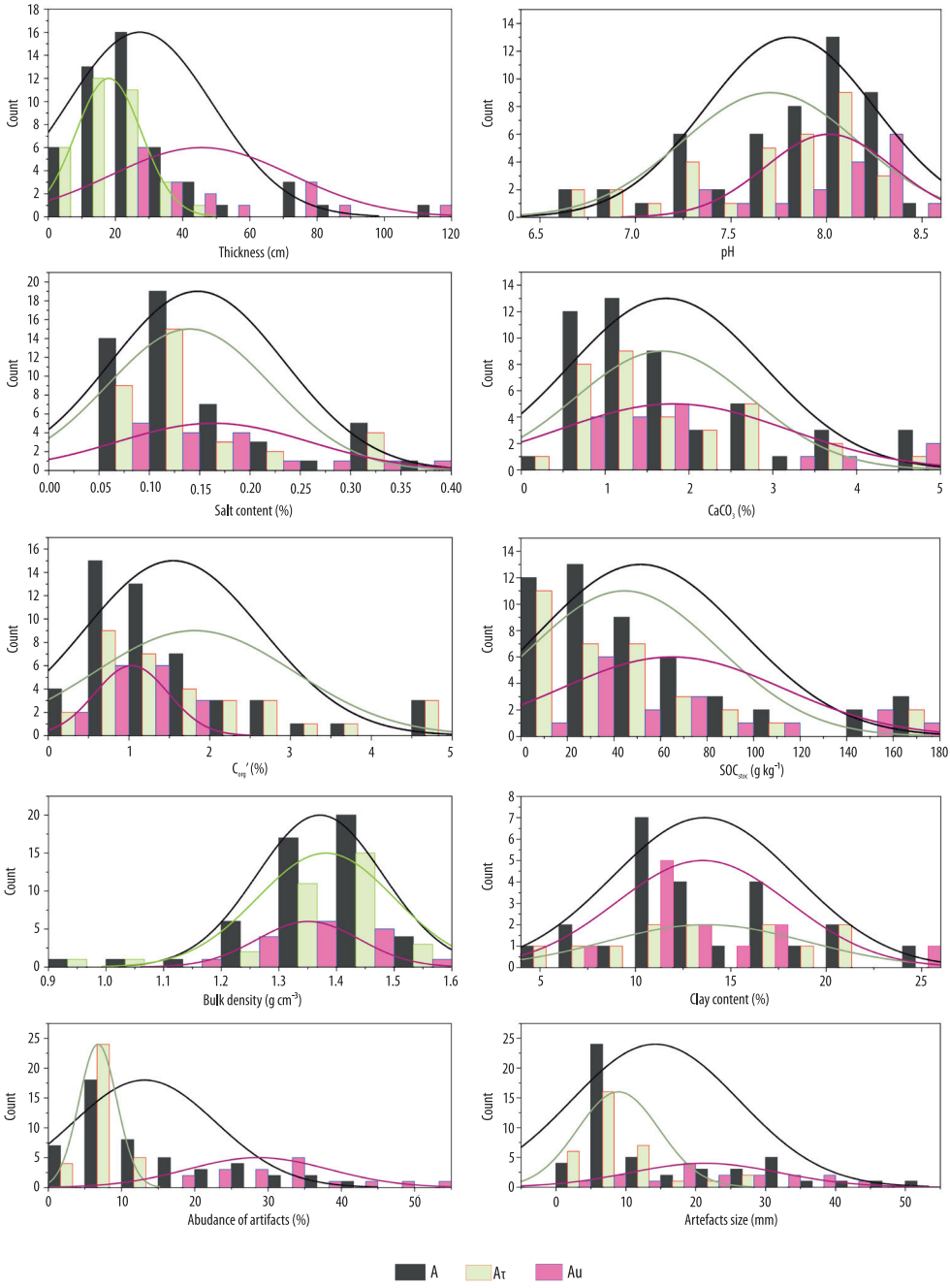

Fig. 3. Distribution of data in anthropogenic horizons of different functional zones. *Source*: Authors' own elaboration.

42 percent, while the minimum was 7 percent in the recreational zone. Notably, high clay content values in the residential areas were sporadic, whereas in recreational areas, the data mainly clustered around 17–25 percent, with some variation from 7 to 38 percent. The predominant clay content range in residential areas was 10–20 percent. Most Au horizons were classified as sandy loam, while Aτ horizons were categorized as loam, sandy loam, and loamy sand *(Figure 4).* The distribution of particular fractions varied across functional zones, with Aτ horizons showing dominance in coarse silt and clay along with the sandy fraction. In contrast, residential areas exhibited a prevalence of small and medium sand fractions. The density histogram for all studied horizons displayed a normal distribution (see *Figure 3*), with a mean value of 1.4 ± 0.02 g cm^{-3}.

Discussion and conclusions

Correlation of anthropogenic horizons properties

The greatest differences between the horizons (p-value from 0 to 0.02, at p = 0.05) were found in pH, C_{org}, SOC_{stoc}, and thickness horizons *(Table 1).* Consequently, these parameters are indicators of the level of anthropogenic load on the territory.

Spearman and Pearson correlation coefficients were used to identify the relationship between soil properties. The non-normal data distribution causes the use of the Spearman coefficient. The result of the J–B test revealed that the distribution of data in the recreational areas obeys a non-normal distribution, except for indicators such as pH, thickness, density, and clay content (see *Table 1*).

In most cases, correlations were absent or weak due to the great heterogeneity of soil properties of all anthropogenic horizons ($r < 0.5$). Stronger relationships were found between soil density and calcium carbonate content and C_{org}; between calcium carbonate content and C_{org}. As the calcium carbonate content increased, the content of C_{org} and SOC_{stoc} increased. Often, the reverse correlation was observed. For example, when soil density increased, C_{org} and SOC_{stoc} decreased (*Figure 5*, A).

The analysis of the relationship between anthropogenic horizons' chemical and physical properties in different functional zones

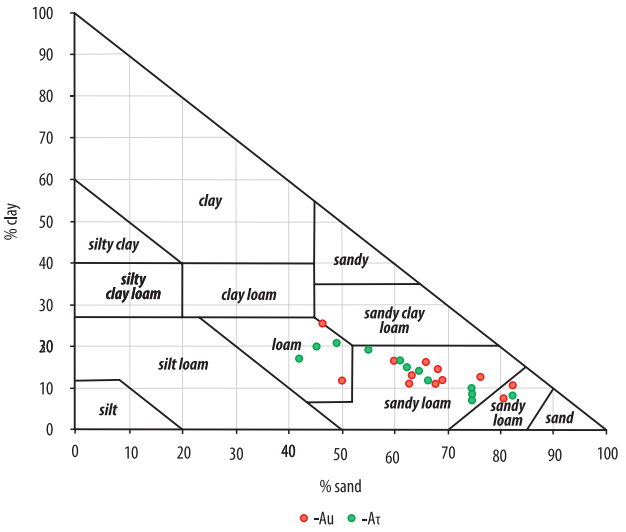

Fig. 4. Texture classes anthropogenic horizons of different functional zones. *Source*: Authors' own elaboration.

Table 1. Variations between Au and Aτ horizons according to Mann–Whitney U-test, T-test, and Jarque–Bera test

Variable	Mann–Whitney U-test	T-test	Jarque–Bera test	
	p-value ≤ 0.05		Aτ	Au
pH_{water}	–	0.02	4.0	2.0
Salt content, %	0.40	–	11.0	5.0
Bulk density, g cm^{-3}	–	0.40	5.5	0.4
$CaCO_3$, %	0.90	–	7.0	5.9
Thickness, cm	–	0.01^{10-3}	2.0	3.0
C_{org}, %	0.02	–	10.0	1.0
SOC_{stoc}, g kg^{-1}	0.08	–	30.0	2.0
Clay, %	–	0.90	1.0	2.0
Abundance of artefacts, %	0.01^{10-3}	–	13.4	6.8
Artefacts size, cm	0.01^{10-3}	–	21.0	10.8

Source: Authors' own elaboration.

revealed that the C_{org} in Au increased with decreasing salt content (r = 0.5) and increasing thickness. The content of calcium carbonates increased with decreasing soil density and increasing horizon thickness. A strong correlation coefficient (r = 0.9) was found between SOC_{stoc} and thickness. Therefore, the higher the Au thickness, the more SOC_{stoc} it contains (*Figure 5*, B).

Similarly, the Aτ horizon properties in recreational zones exhibit similar relationships (*Figure 5*, C). With increasing $CaCO_3$ content, there was an increase in pH (r = 0.5), while C_{org} decreased with increasing density (r = -0.6) and with increasing $CaCO_3$ content (r = 0.6). A correlation was also found between C_{org} content and SOC_{stoc} (r = 0.7).

In conclusion, the statistical analysis indicates that the properties of A horizons show significant variability in chemical, physical (particularly density), and morphological characteristics depending on the functional zone and, consequently, the level of anthropogenic load *(Figure 6).*

Thus, the main types of impact on the residential area were littering and surface sealing. For recreational areas, the anthropogenic impact is reduced due to the special regime of the territory use. Anthropogenic impacts in green areas can include irrigation, the introduction of fertile reclamation mixtures, as well as cleaning the area from domestic and construction waste (Burghardt, W. 2006; Novák, T.J. *et al.* 2020).

Changes in the morphological properties of horizons depending on the anthropogenic load level

Among the morphological indicators, the highest differences were noted in the thickness and structure. The differences were due to the functioning regimes of the territory. In recreational areas with lower anthropogenic impact, the growth of Aτ thickness is sedimentologic, resulting from the slow dust accumulation on the surface (Prokof'eva, T.V. *et al.* 2017). Conversely, in residential areas with higher anthropogenic impact, the growth of horizons is primarily due to the constant addition of new anthropogenic material.

The colour of anthropogenic horizons is directly related to their origin. The products of Au horizons in residential areas are mineral horizons B (Cambic) and Bk (Calcic), as well as soil-forming rocks of loess-like loams and clays (BCk and Ck). As a result, the colour of these horizons is characterized by a light and pale appearance. Conversely, in recreational zones, the colour of the horizons is

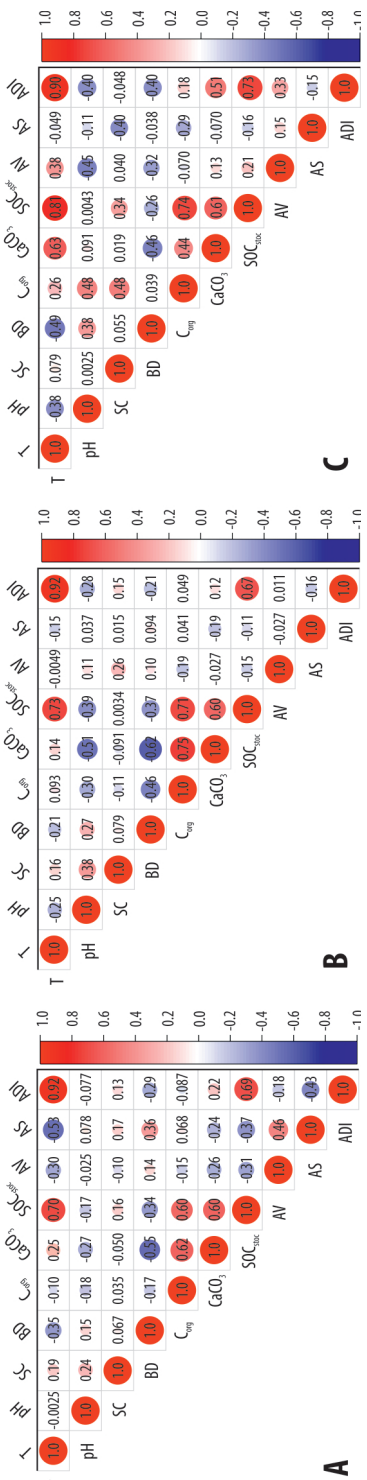

Fig. 5. Correlation coefficients: A = for A (Spearman); B = for Au (Pearson); C = for Aτ horizons (Pearson). T = Thickness, cm; SC = Salt content, %; BD = Bulk density, g cm^{-3}; AV = Abundance of artefacts, %; AS = Artefacts size, cm. *Source:* Authors' own elaboration.

darker and more saturated. In the green areas of Volgograd, Aτ horizons consist of the remains of the original Mollic and Cambic horizons (Kastanozems and Cambisols). The ADI index was calculated to determine the relationship of A horizon colour with other properties. The ADI is based on the horizons' thickness and the value and saturation (chroma) of the wet soil colour. Au horizons are characterized by ADI values ranging from 4 to 15 (median = 6 ± 1.0). In Aτ horizons of recreational zones, the median ADI is 4 ± 0.3 (min – 1, max – 8). Thus, the lighter the horizons are on the Munsell scale, the higher the ADI values. This is supported by the correlations between ADI and SOC_{stoc} (r = -0.67 and r = -0.73), both for the total sample and for horizons in residential and recreational areas. Therefore, the colour of urban soil horizons can be used to assess potential organic matter reserves indirectly.

The structure of the horizons is directly related to human activity. In recreational areas where agronomic techniques such as irrigation and tillage are used, the structure of these Aτ horizons is characterized by lumpy aggregates with rounded sides. On the other hand, in residential areas, the Au horizons are consistently impacted by technogenic factors, resulting in compaction and enlargement of aggregates, leading to the formation of a clumpy structure, exacerbated by moisture deficiency (Gordienko, O. *et al.* 2022).

Artefacts in the Au horizons were predominantly identified in the form of construction, household debris fragments, and metal structures. Their composition significantly varied based on the functional zone. In residential zones, their content ranged from 15 to 50 percent (median = 30 ± 2%), leading to the use of the Urbic qualifier, and in some cases, the additional qualifier Hyperartefactic (layer containing ≥ 50% of artefacts) was applied. Conversely, artefacts in recreational zones were present in smaller quantities – 5 to 10 percent (median = 7 ± 0.5%), making it challenging to classify the soils in this zone as Technosols. Therefore, the additional qualifier Technic (layer containing ≥ 10% of artefacts) was employed. The nature

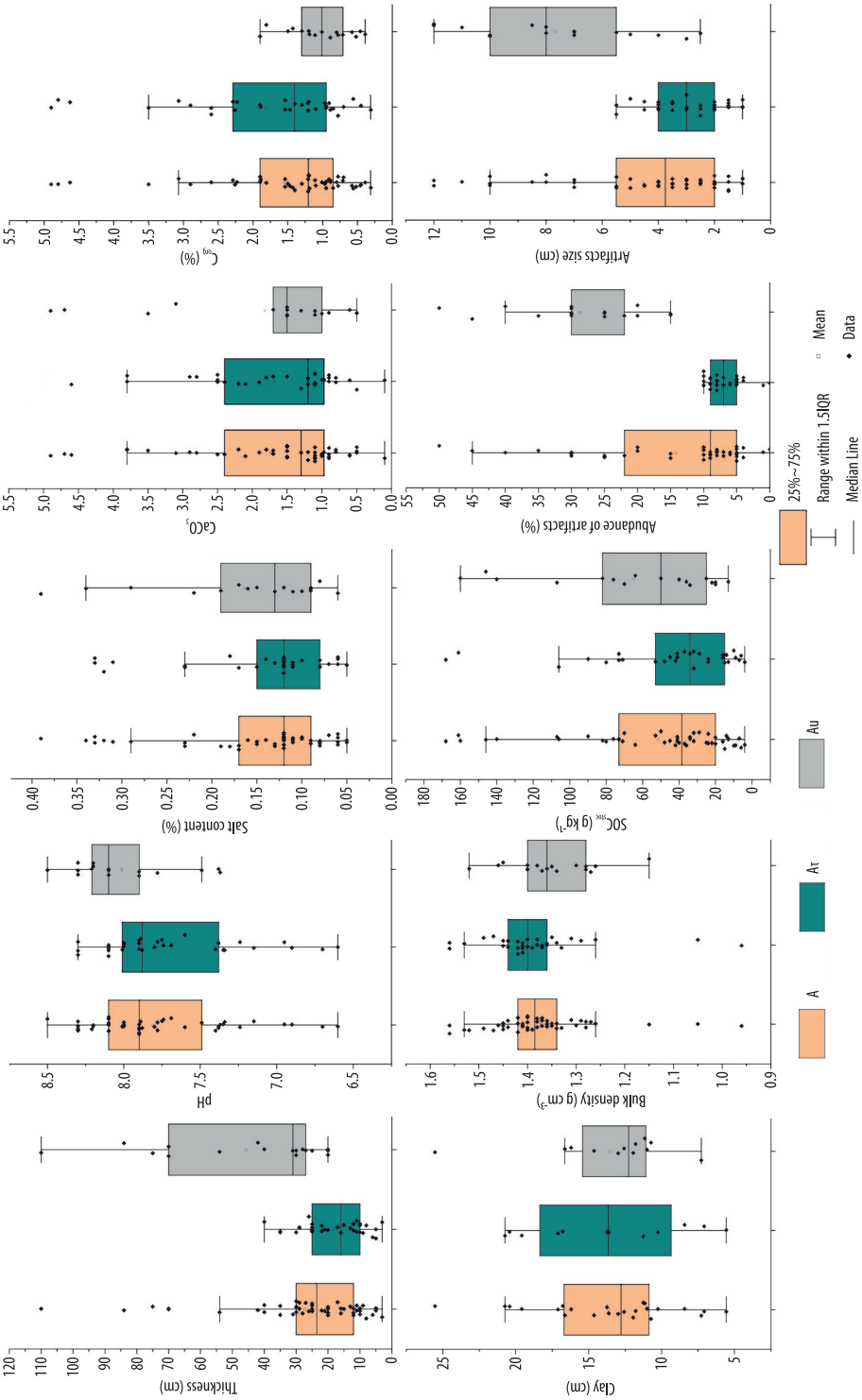

Fig. 6. Variation of properties in anthropogenic horizons. *Source*: Authors' own elaboration.

of artefacts largely depended on the functional zone. In residential areas, artefacts consisted of plastic, glass, and fragments of household and construction debris (such as bricks, concrete, and ceramics). Another significant aspect of artefacts was their size. In the Au horizons, artefact sizes ranged from 2.5 to 12.0 cm (median = 8 ± 1 cm). Artefacts up to 5 cm comprised plastic, glass, and household material fragments, while those exceeding 5 cm were predominantly building materials (such as brick, concrete, and ceramics). In the Aτ horizons, artefact sizes ranged from 1.0 to 6.0 cm (median = 3 ± 1 cm).

Changes in the chemical and physical properties of horizons depend on the anthropogenic load level

The weakly alkaline reaction observed in the Aτ horizons was attributed to the absence of carbonate-containing materials inflow and the leaching process facilitated by irrigation. In residential areas where carbonate inclusions were prevalent, and irrigation was lacking, an increase in $CaCO_3$ content and alkalization was noted. The elevated pH levels in urban soils were likely caused by the release of alkaline substances from calcareous materials (Jim, C. 1998). A similar scenario was observed in urban soils in Hong Kong (China) (Jim, C. 1987; Lam, K-C. *et al.* 2006), in Kumasi (Ghana) (Stow, D.A. *et al.* 2016), in Moscow and Rostov (Russia) (Kasimov, N.S. *et al.* [2016], and Bezuglova, O.S. *et al.* [2018]).

The total salt content in the various Au and Aτ horizons corresponded to the values found in natural horizons of soils in the dry-steppe zone (Kastanozems and Cambisols).

During the morphological description Au horizons in the residential area, it was observed that not only individual structural elements of the soils reacted with a 10 percent HCl solution, but there was also continuous swelling of the soil fine earth. Consequently, active dissolution and redistribution of carbonate inclusions occurred in urban soils (Prokof'eva, T.V. *et al.* 2017). The carbonates in the Au horizons were sourced from the dissolving inclusions of construction debris and dust-aerosol deposition (Kasimov, N.S. *et al.* 2016). This hypothesis is supported by scientific research (Howard, J. and Orlicki, K. 2015; Khalidy, R. *et al.* 2022). In the anthropogenic horizons of Volgograd, no significant correlations between $CaCO_3$ and the volumes and sizes of artefacts were identified. Therefore, it can be inferred that the source of carbonates is the material of the Au horizons. It was previously established that Au horizons in residential zones consisted of B, Bk, BCk, and Ck horizons; hence, the high carbonate values and effervescence from hydrochloric acid were attributed to their mechanical mixing.

The high C_{org} values in the Aτ horizons can be attributed to the systematic introduction of fertile mineral substrates, the optimal water-air regime of soils, and the presence of dense herbaceous, tree, and shrub vegetation, whose decomposition contributes to additional soil carbon accumulation (Vasenev, V.I. and Kuzyakov, Y. 2017; O'Riordan, R. *et al.* 2021). In the residential area, carbon sources may include bituminous-asphalt mixtures, soot, petroleum products, and organic suspended particles (Okolelova, A.A. *et al.* 2021). A direct correlation was observed between the $CaCO_3$ content and the increase in C_{org} content ($r = 0.6$). Two hypotheses can explain this correlation. The first hypothesis suggests that carbonates do not directly influence the increase in C_{org} since both dust deposition and one-time human inflow can form Au horizons. Therefore, the anthropogenic allochthonous material already contains certain levels of carbonates and C_{org} upon arrival at the surface. According to the second hypothesis, carbonates present in different A horizons within a single profile slow down both the accumulation of C_{org} (from top to bottom of the profile) and its loss to lower horizons due to their bonding properties. The high Ca activity facilitates the fixation of humus by the mineral component of the soil, leading to its retention in the profile through a coagulating effect on soil colloids, including organic matter, thereby inhibiting its migration through the soil profile in solution form.

Infrastructure construction in urban areas results in significant loss of SOC_{stoc} through the removal and displacement of both natural and anthropogenic topsoil and compaction (Elvidge, C.D. *et al.* 2007; Raciti, S.M. *et al.* 2012). In Yixing (China), a correlation between horizon compaction and an increase in SOC_{stoc} was observed (Zhao, D. *et al.* 2013; Wei, Z. *et al.* 2014). However, in our study, the opposite relationship is observed. Greening initiatives notably positively impact SOC_{stoc}, enhancing net primary productivity through urban trees and lawns (Zirkle, G. *et al.* 2011; Nowak, D.J. and Crane, D.E. 2013). Despite similar average densities, the primary factor contributing to the high SOC_{stoc} levels is the average C_{org} values (*Figure 7*, upper) and the thickness of the horizon. The anthropogenic Au horizons are characterized by greater thickness, resulting in higher average SOC_{stoc} levels (*Figure 7*, bottom). It was determined that a high $CaCO_3$ content serves as a source of calcium, promoting mechanisms of flocculation and aggregation of soil particles. This enhances the cementing effect on soil aggregates, improves soil structure, and prolongs the preservation of SOC_{stoc}. This relationship may explain the correlation between SOC_{stoc} and $CaCO_3$ ($r = 0.6$).

Human activities have resulted in the over-compaction of soil horizons. The high-density values observed in both residential areas (maximum – 1.5 g cm^{-3}) and recreational areas (maximum – 1.6 g cm^{-3}) are primarily attributed to the significant anthropogenic load. The over-compaction of Aτ

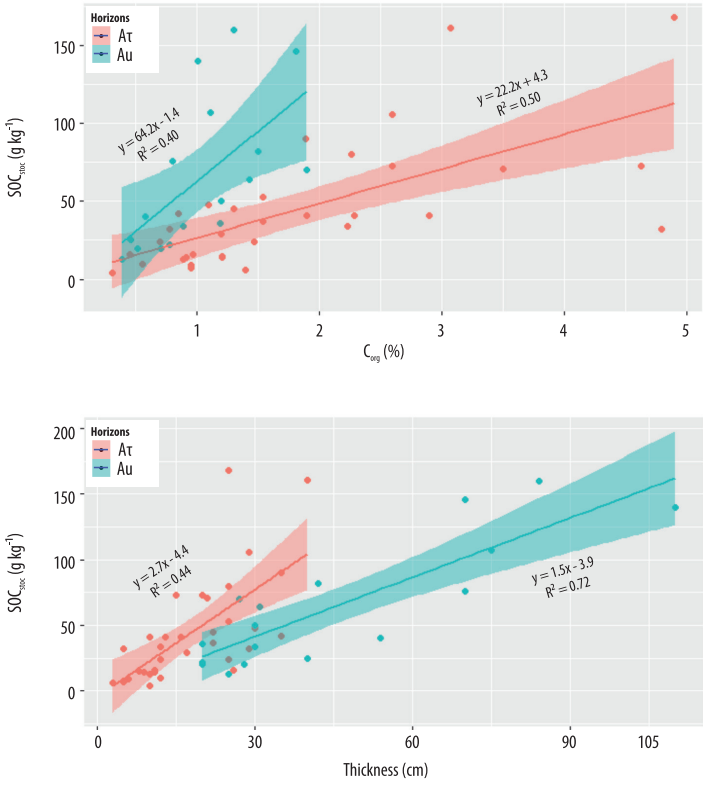

Fig. 7. Relationship between C_{org} and SOC_{stoc} (upper), and between thickness and SOC_{stoc} (bottom).
Source: Authors' own elaboration.

horizons can be attributed to increased recreational pressure in recreational areas. These findings align with soil density values observed in other cities worldwide, where recreational areas also exhibit increased density (Lorenz, K. and Kandeler, E. 2005). On Au horizons, compaction is induced by transportation activities, construction, and the use of technogenic hard materials for area sealing.

The texture of the Au horizons is characterized as sandy loam. In recreational areas, the introduction of sand through landscaping and reclamation activities alters the texture of Aτ horizons from the loam class to the sandy loam class.

In conclusion, the individual properties such as thickness, C_{org}, and SOC_{stoc} of anthropogenic horizons exhibit significant variability in urban landscapes, challenging the definition of a typical "urban soil." Statistical analysis of data on various properties has enabled the identification of both general trends and distinctive characteristics. The variability of chemical, physical (especially density), and morphological properties based on functional zones and anthropogenic load levels is common. Despite the diverse range of measured properties, correlations between the properties of anthropogenic horizons and land use types have been established. The most significant variations in thickness, stocks, and organic matter content were observed. In residential zones, the thickness varies from 20 to 110 cm, while in recreational zones, it ranges from 3 to 40 cm. The highest C_{org} values were recorded in the recreational zone at 4.9 percent, whereas the lowest was in the residential zone at 0.1 percent. The average SOC_{stoc} in the Au horizons was 45 ± 11.5 g kg^{-1}, with a median of 34 ± 7.0 g kg^{-1} in recreational areas.

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Assessment of the landscape identity through participation in the framework of a landscape character research

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Abstract

The physical and emotional character of the landscape is an increasingly important ecosystem service factor in Hungary, too, and the strong identity of residents with the landscape is part of their well-being. Between 2016 and 2022, we prepared the landscape character map of the entire country. One of the essential elements of the project was that in four study areas – Sopron–Lake Fertő region (containing Sopron Mountains and Basin together with Lake Fertő), Gerecse Mountains, Tápió-vidék region and Tiszazug region – as landscape units, we tried to reveal the feelings of the residents related to the landscape using different methods. One of the most effective tools was surveys organised in workshops (personal or online) when we inquired about how the residents see landscape patterns, land use, and the changes in the surroundings of their settlements. One of the most important lessons learned from the study areas was that the local citizens usually have an indisposition for large-scale alterations of the accustomed environment, which leads to less familiar feelings and weakens the near natural character of the landscape. The results were compared with international experience.

Keywords: landscape identity, landscape character, community research, participatory planning, European Landscape Convention

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Introduction

The unique particularity of the landscapes, as perceived by people, contributes to the attachment of man to the place or the area they live in and correlates with the given man-nature relationship. What we perceive is not just an independent spot-like feature but the entire area with its multiple natural and cultural elements and characteristics. People are bound to their landscape through perception. The cultural and human geographical land-

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scape approach, emphasising the aesthetical, perceptual qualities, has been strengthening since the turn of the millennium (Cosgrove, D.E. 1984, 2003; Wylie, J.W. 2007). The landscape is full of meaningful symbolic content, which has been crucial since the early history of humans (Schama, S. 1995; Ingold, T. 2002). Perception of the landscape is, therefore, a widespread and valued research topic (Kim, J. and Kaplan, R. 2004; Antrop, M. 2005; Olwig, K.R. 2006; Gobster, P.H. *et al.* 2019; Opdam, P. 2020; De Vries, S. *et al.* 2021).

Landscape character is defined as a "distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another" and "it is what makes each part of the landscape distinct and gives each its particular sense of place" (Swanwick, C. 2002; Wascher, D.M. 2005). Beyond the term landscape character, landscape identity also became a commonly used expression. The two concepts are relatively close. However, they are not synonyms. "Landscape identity is the unique psycho-social perception of a place defined in a spatial, cultural space" (Stobbelaar, D.J. and Pedroli, B. 2011; Minca, C. 2013; Konkoly-Gyuró, É. 2018). The word "identity" is derived from the Latin *identitas*, meaning "sameness". In other words, the landscape identity is "the perceived uniqueness of the place" (Ramos, I.L. *et al.* 2016).

Both character and identity can be captured at several scales and an individual/personal or collective perception (Lowenthal, D. 2007; Lewicka, M. 2008; Knez, I. and Eliasson, I. 2017; Belanche, D. *et al.* 2021). Scales extend from local to national, or we might speak of continental identity or character (Dixon, J. and Durrheim, K. 2000; Dossche, R. *et al.* 2016; Butler, A. *et al.* 2017; Jankó, F. *et al.* 2018; Butler, A. and Sarlöv-Herlin, I. 2019). According to the most accepted environmental psychology ideas, the human perception of the landscape is largely influenced by evolutionary heritage (Lowenthal, D. 2007), which can be traced back to the satisfaction of basic physical needs and a sense of security (Maslow, A.H. 1943; Kaplan, S. and Kaplan, R. 1982; De la Fuente de Val, G. *et al.* 2006). Due to the former component, people are attracted to landscapes that are fertile and easy to control in terms of topography and plant coverage, as well as clear and legible. The security for *Homo sapiens* was originally provided by the landscape structure of the wooded savannah, where there is a sufficient view of the area, but there is also the possibility of hiding in the patches of trees and bushes (Appleton, J. 1975; Hunziker, M. *et al.* 2007). This so-called prospect and refuge theory also explains why the open, semi-open or closed appearance of the field of view has a particular weight in the assessment of landscape or as a waterfront, water surface that expands the spatial experience (Coeterier, J.F. 1996; Butler, A. *et al.* 2017; Häfner, K. *et al.* 2018).

Several researchers are convinced that for humans, environments with an intermediate level of complexity should be preferred, which would have provided survival benefits to our "ancestors" (Orians, G.H. 1986; De la Fuente de Val, G. *et al.* 2006). In comparison, an overly homogeneous or an extremely mosaic-like landscape both offered worse chances of survival. Some believe that even in the background of the attractiveness and popularity of the landscape, an attitude seeking safety can be discovered, but according to others, it is much more strongly shaped by learned behaviour and cultural background than aesthetic judgment (Tveit, M. *et al.* 2006; Häfner, K. *et al.* 2018).

According to the European Landscape Convention 2000 (ELC 2000) (Council of Europe, 2000), the identification and valuation of the landscapes requires the participation of the local stakeholders and inhabitants. The future strategies concerning the human environment and landscapes have to be based on collective decision and participation. Consequently, the research of landscape character and identity with participatory methods contributes to landscape management, protection and planning, as well as to several sectoral strategies, e.g., tourism, agriculture, and urbanism (Konkoly-Gyuró, É. 2013; Csorba,

P. and Csatári, B. 2017). Moreover, participation in landscape identification and valuation can strengthen the reliability and acceptance of local initiatives and interventions (Imecs, Z. *et al.* 2022; Lengerer, F. *et al.* 2022).

The focus on public participation in the ELC is in line with the general principles of democracy, as the transparency of the decision-making is a prior requirement. (Jones, M. 2007; Bándi, Gy. 2011; Semian, M. and Nováček, A. 2017; Kahila-Tani, M. *et al.* 2019; Santé, I. *et al.* 2020; Zachrisson, A. *et al.* 2021). Genuine cooperation with the stakeholders is needed in regional development, environmental conservation and landscape planning (Konkoly-Gyuró, É. 2013; Fodor, L. and Pump, J. 2016; Berki, Zs. 2018). The legal framework of participation in Hungary was constructed right after the political changes in 1989–1990 concerning environmental impact assessments, as well as local and regional development strategies and planning (Hungary's Government Decree No. 86/1993, 20/2001, 314/2005 and 314/2012.). The practice of actual participation in decision-making, however, often remains at a basic level, or the bottom-up initiatives still need to be improved. According to the National Landscape Strategy (NLS) of Hungary (2017–2026), "Only a quarter of the NGO members are active members, that is one of the lowest proportion in the EU."

The higher the level of participation stands, the stronger the landscape identity is. As the NLS states, a survey concerning the inhabitants' relationship towards their landscape needs to be included in Hungary. Our study is an attempt – at least partly – to respond to this need in the case studies of a nationwide landscape character assessment. The five-year Hungarian research project was launched in 2016 by the Ministry of Agriculture (KEHOP-4.3.0-VEKOP-15-2016-00001), and aimed at a national characterisation along with case studies at the micro-regional and local level. Online questionnaires and a series of workshops served the inclusion of local perceptions (Konkoly-Gyuró, É. and Csőszi, M. 2021). In the case studies, we used similar methods (Sain, M. and Rab, J. 2018), however, unique, innovative approaches have also been tried (Boromisza, Zs. *et al.* 2022).

The aim of the scientific project was to prepare Hungary's first landscape character map and its explanation, with the help of which even non-professional decision-makers can determine the landscape character of a given planning area. The scientific goal, therefore, served a practical purpose at the same time in the form of useful information for the landscape planning process.

Materials and methods

The classification of landscape character depends more on the subjective perception of the person than, for example, the classification of landscape types. It is difficult to reconcile scientific research with the emotional aspect, with the fact that the "acceptance" of the landscape depends on the emotional state and personality of the observer and the grade of the emotional and identity relationship of the observer with the given landscape. This can only be enhanced if a sufficiently large number of subjective opinions are considered, i.e., subjective opinions are statistically balanced.

The four micro-regional and local case studies represent the landscape diversity of Hungary and cover the majority of landscape types identified in the previous countrywide GIS assessment (Konkoly-Gyuró, É. *et al.* 2021) *(Figure 1)*. The study area designation did not follow the physical geographical landscapes (Csorba, P. *et al.* 2018). During the research, our goal was to create a perceptual landscape character map interpreted more broadly than the physical geographical landscapes, in which the attitude and sense of identity of the local people also appear. In addition, land use, nature protection, demographics, and infrastructure data used for the survey are available from the municipality.

The Tiszazug region is situated between the rivers Tisza and Körös in the central part of the Great Hungarian Plain. The Tiszazug well represents the different landscape types of the

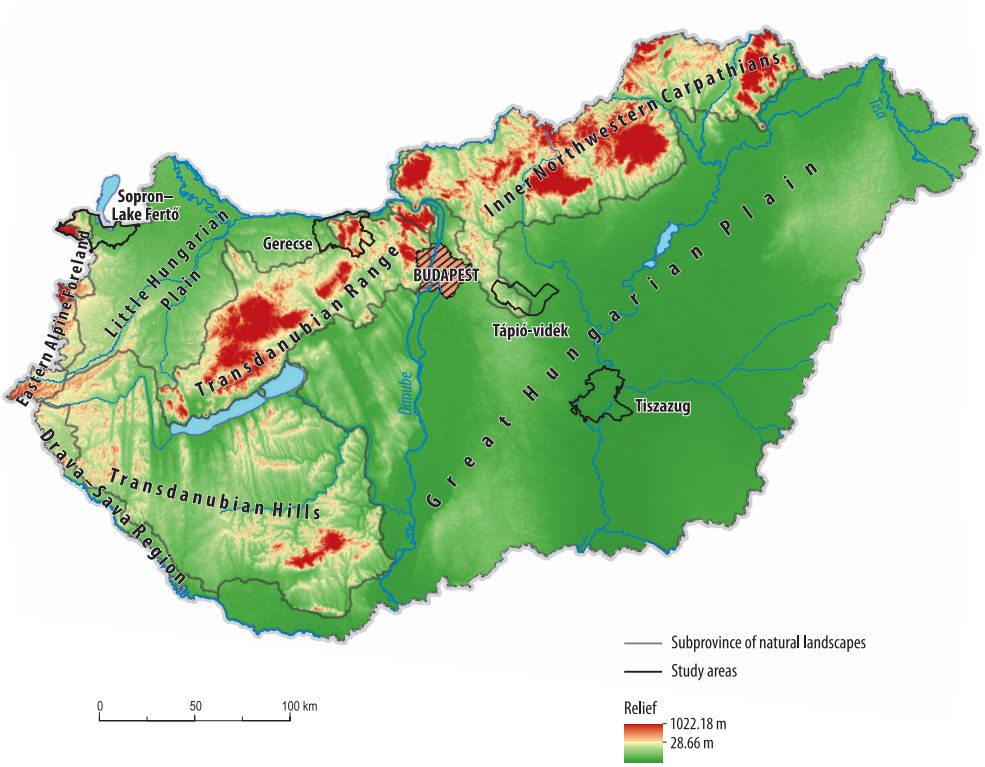

Fig. 1. Location of the four study areas in Hungary. *Source:* Authors' own elaboration based on European Digital Elevation Model (EU-DEM), version 1.1 from EEA, 2016.

Great Hungarian Plain: low alluvial plains, higher loess plateaus, and sandy hills. There are arable lands on the plateaus with chernozem soils, orchards and vineyards on the sandy soils, and minor meadows and arable lands on the low alluvial plains *(Figure 2)*. The society of the study area is in a severe demographic crisis: the population of the region decreased by 25 percent since the 1970s. Due to the decreasing and ageing population, economic activity is also declining in the region. Most industrial facilities are abandoned.

The area of Sopron–Lake Fertő region at the north-western border of Hungary consists of various landscape types between 150–650 m a.s.l. (see *Figure 2*). On the foothills of the Alps, we find forested low mountains and hills covered by vineyards and recreational areas. Between them lies an urbanised basin with the town of Sopron. The higher and lower lowlands, wetlands and shallow alkaline lake extend toward the Little Hungarian Plain. There are densely populated urban and intensively used, rural, agricultural areas with growing populations and natural and semi-natural national park (NP) zones, partly overlapping with cultural landscapes inscribed on the world heritage (WH) list. Both NP and WH areas are transboundary, extending toward Austria and more and more demand for touristic and recreational use can be detected.

The Gerecse Mountains study area has forested hills ranging between 300–600 m a.s.l. on the east, but plains with significant wetlands and arable lands also occur in the west-

ern part (see *Figure 2*). Culturally important small town, Tata and villages are located in the south-central part, while the northern edge of the study area along the Danube river and the Slovakian border is represented by mining and industrial use and partly by wine production and recreation functions. This study area involves several different landscape character types and can be subdivided into many sections. The most authentic parts are the enclosed basins of the Gerecse Mountains containing small villages of rural land use mixture with forested and steep hills and ridges.

The Tápió-vidék region study area in the Central Hungary region, in Pest county, covers nine settlements. According to the CORINE Land Cover (2018) database, arable land covers more than half (57%) of the study area. Deciduous forests and transitional forest-shrub areas account for almost 20 percent. The western part represents a hilly landscape with higher forest coverage, whereas in the eastern part, lowland landscapes are dominant, with planted woodlets, spacious agricultural lands and wetlands (see *Figure 2*). There are few nature reserves, mainly wetlands along little brooks. The settlement density is significantly higher than the national average.

Data expressing landscape mosaics, land use diversity, and ecological fragmentation

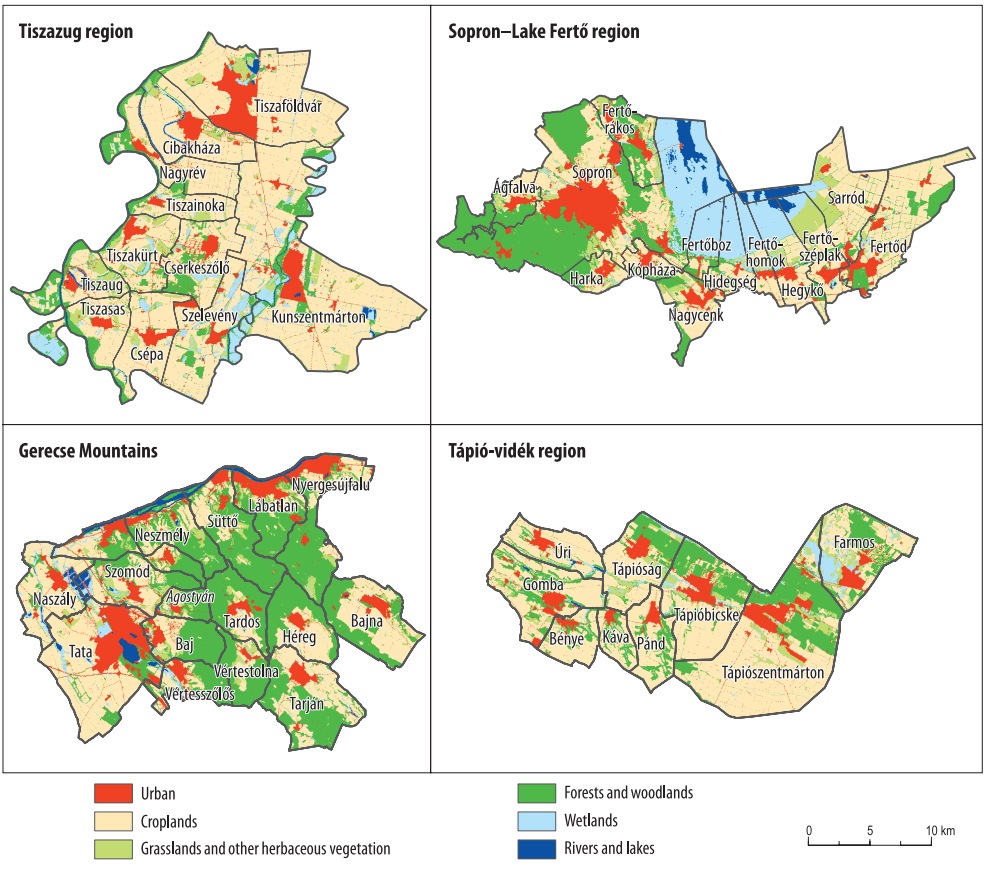

Fig. 2. Main ecosystems of the four study areas. *Source:* Authors' own elaboration based on Ecosystem Map of Hungary (project KEHOP-430-VEKOP-15-2016-00001, Ministry of Agriculture, 2019).

of the study areas (mean patch size, Shannon diversity, fragmentation) play a significant role in the character of the landscape and point out the significant differences between the individual plots *(Table 1)*. In the case of the Tiszazug, landscape mosaics are in strong correlation with large arable plots and protected grasslands around Lake Fertő. Land use diversity is highest in the Tápió-vidék region, while in the case of Gerecse Mountains the landscape is the most uniform due to extensive forests (61%). The hemeroby level shows the strongest anthropogenic influence (α – euhemerobic) in the Tápió region and the Tiszazug, where the proportion of protected areas is negligible.

The methods used, with the help of which we got to know the opinions of local residents, the methods used were significantly influenced by social and demographic conditions in the study area. For example, there are very active NGOs in Sopron (Sopron–Lake Fertő region), and there was no problem organising the discussions. However, the majority of non-governmental organisations employ intellectual workers. The character of the landscape is significantly influenced by vine production, but grape growers are hardly represented in civic forums. In contrast, the Tiszazug study area is a traditional agricultural region, but with a very passive, ageing society. It was possible mainly to reach pensioners there. All study areas have nature conservation areas, but professionals were not always active partners in the research.

During the preparative phase, we identified the local stakeholders from the different organisations and social groups. Invitees arrived from diverse branches, e.g., nature conservation, cultural heritage protection, water management, architecture, research and higher education, and various social groups. Beyond governmental and management organisations, NGOs and non-official inhabitants participated in the workshops.

The first introductory workshop gave an overview of the purpose of the entire landscape character project and the actual workshop. In the first meeting, the researcher aimed to collect basic information on the personal landscape perception of the attendees. It included the mental maps of the landscape, main characteristics, unique places, values and conflicts. The second workshop confronted the experts' views and the locals' perceptions after fulfilling the expert field surveys and the precision of the landscape character types and areas in the study areas. The third workshop focused on the landscape changes and their evaluation, as well as formulating the quality objectives for the future. The last workshop presented the results and asked for feedback from the locals about the conclusions drawn by the experts. It also had the purpose of defining the future tasks.

Various tools have been applied during the workshops:
– mental maps and short questionnaires;
– small-group round table discussions and consultations;

Table 1. Characteristics of the study areas influencing landscape character

Indicators	Tiszazug region	Sopron Mountains and Basin	Lake Fertő	Gerecse Mountains	Tápió-vidék region
Proportion of arable land, %	60.00	15.00	32.00	10.00	57.00
Proportion of forest, %	6.00	46.00	20.00	61.00	16.00
Proportion of built-up area, %	4.00	10.00	2.00	2.00	11.00
Mean patch size, km^2	2.10	1.00	2.60	1.20	1.40
Shannon diversity	1.50	1.48	1.44	1.35	1.81
Landscape ecological fragmentation	2.40	4.00	1.05	1.60	4.00
Proportion of protected area, %	5.00	42.00	35.00	41.00	5.00
Intensity of human intervention (hemeroby level)	α – euheme-robic	Mesoheme-robic	Oligoheme-robic	Mesoheme-robic	α – euheme-robic

– photo series facilitating the expression of opinion, e.g., written voting on the characteristics and preferences of photo series;
– open questions and answers: voting, e.g., about main conflicts based on a predefined list of problems;
– interactive landscaping board game;
– free association drawing;
– public participatory GIS (ppGIS) mapping of distinct characteristic elements of the landscape.

Results and discussion

Willingness of participation

Significant differences were shown in the number of workshop participants and their activity in the study areas *(Table 2)*. The low willingness and general pessimism of the Tiszazug area (5–10 participants) is an extremity. However, the number of online respondents was far higher here: 70 people filled in the online questionnaire. Another problem was that usually different people participated in the four workshops, i.e., those who joined later needed to be more familiar with what was discussed earlier.

In the Sopron–Lake Fertő region (in addition to online respondents), we had 89 participants at the workshops, 46 on-site and 43 online attendees. The majority of them arrived mainly from the town of Sopron. Only a few participants from the villages took part. For the profession, we had a more balanced picture. Representatives of nature conservation, forestry, water management, architecture, heritage protection, and interested citizens were present, but no official decision-maker attended the workshops.

In the Gerecse study area, workshops and interactive events were visited by 64 people. The most popular event was outdoors at the start point of a memorial hiking trip of locals in Pusztamarót (part of Nyergesújfalu town). The participants focused on landscapes and could easily express their impressions as part of their hiking schedule with an attitude open to landscape-related questions. The events organised indoors had only 8–10 participants on average, reaching only the most active members of landscape management. These active persons usually came from the fields of nature conservation, wildlife management, decision-making, forestry, tourism, monument protection, architecture and landscape architecture.

In the Tápió-vidék area, the personal workshops were visited by 161 people altogether. The first workshop was organised in 4 local primary schools, with the participation of 102 pupils. Organising a workshop as a school lesson means a higher attendance evidently, whereas those workshops proved attractive to local people, where they were already in their comfort zone (e.g., the workshop took place at an outdoor public swimming pool).

It must be noted that most of the workshop organisation phase coincided with the Covid-19 pandemic, partly during lockdown periods. Therefore, many events have been held in a hybrid form (on-site and online) or only online. However, due to the manifold online activities, participation was undoubtedly lower than usual.

Perception of the landscape character in the study areas

The most beautiful landscape segment for the inhabitants of the Tiszazug is the scenery with the water body in the frame of floodplain forests visible at the ferry on the Tisza river *(Photo 1)*.

In their view, the most characteristic landscape of the Tiszazug shows up from the top of the flood control dams with the mosaic-like land use structure of the protected floodplain, the dark line of the floodplain forests along the river and the steeples of the tiny villages built on the islands exempt from inundations *(Table 3)*. However, most have mentioned an oxbow lake belted with trees and reeds as a "favourite place". They consider tranquility, the nearness of nature and the tiny villages that fit into the landscape as

Table 2. Locations, dates and participants of the workshops

Location and time of the workshops, month/year	Method of data collection	Number of participants	Age of participants, years	Typical occupation of participants
Tiszazug region				
Tiszaföldvár town, Geographical Museum, 02/2020	Opening meeting personal attendance	18	16–50	Municipal employees, nature conservation specialists, students
Tiszakürt village, Arboretum, 07/2020	Personal attendance	12	30–60	Scientific experts, nature conservationists
Tiszaföldvár–Debrecen, 10/2020	Online	14	40–60	Agricultural workers
Tiszaföldvár–Debrecen, 10/2020	Online	10	30–50	Teachers, municipal employees
Tiszaföldvár–Debrecen, 04/2021	Closing meeting online	15	30–50	Employees in museums, libraries, nature conservation specialists
Tiszaföldvár–Debrecen, 06/2021	Online questionnaire	70	16–35	Students, intellectuals
Tiszaföldvár town and Cserkeszőlő village, 09/2021	Personal questionnaire	18	50–70	Pensioners
Sopron–Lake Fertő region				
Fertőd town, 05/2019	Preparative meeting personal attendance	22	30–60	Experts, landscape planners, decision makers
Fertőd town, 10/2019	Online questionnaire	70	20–70	Civil activists, experts
Fertőd town, 10/2020	Online questionnaire	68	14–18	Students specialising in tourism
Sopron town, 09/2020	Personal attendance and online	14	20–60	Civil experts
Sopron town, 10/2020	Personal attendance and online	22	40–70	Civil experts
Sopron town, 11/2020	Closing discussion online	31	30–60	Experts, planners, decision makers
Gerecse Mountains				
Nyergesújfalu town, 06/2019	Opening discussion, personal attendance	26	35–70	Experts, planners, teachers

Table 2. Continued

Location and time of the workshops, month/year	Method of data collection	Number of participants	Age of participants, years	Typical occupation of participants
Pusztamarót, memorial place, 09/2019	Personal attendance	41	15–75	Hiking tourists
Gerecse various villages, 05 and 06/2020	Online questionnaire	171	15–80	Decision makers, teachers, students, local people
Tata town, 09/2020	Personal attendance	18	35–70	Agricultural workers, engineers, landscape planner
Nyergesújfalu town, House of Culture, 09/2020	Closing discussion personal attendance and online	10	30–45	Landscape planners, nature conservation specialists, students
Bajna village, Community House, 09/2020	Personal attendance and online	13	30–65	Landscape planner, hunter, employees in museums, libraries
Tarján village, restaurant, 09/2020	Personal attendance and online	16	35–65	Decision makers, landscape planner, forester
Tápió-vidék region				
Tápióság village, 09/2019	Opening meeting personal attendance	25	6–14	Students, civil experts, specialists
Tápiószentmárton village, 09/2019	Personal attendance	27	6–14	Students
Gomba village, 09/2019	Personal attendance	24	6–14	Students
Farmos village, 09/2019	Personal attendance	26	6–14	Students
Tápióbicske village, 09/2019	Personal attendance	18	40–70	Civil
Farmos village, 07/2020	Personal attendance	10	14–40	Planners, civil experts of NGOs
Tápiószentmárton village, 04/2021	Closing meeting personal attendance	20	20–50	Civil experts, tourists
Budapest–Tápiószentmárton, 03/2021	Closing discussion online	6	30–50	Planners, specialists

Photo 1. Ferry boat on the Tisza river (upper left); Varied hilly landscape along Lake Fertő (upper right); Wetland in Farmos village (bottom left); Local tourist groups expressing their opinion about landscape elements with public participatory GIS (bottom right). *Source:* Photos taken by the authors.

particular values of the Tiszazug. They deem the abandonment of the former floodplain and sandy orchards, along with the raunchiness of the emptying villages, unfavourable tendencies. They do not consider the extensive planted poplar forests and arable lands attractive landscape elements. They judge the decreasing landscape diversity as an adverse land use change caused mainly by the abandonment of grazing and small-scale farming in the floodplains.

*Table 3. Elements and factors determining the character of the Tiszazug region landscape based on answers to the questionnaires**

Elements and factors	Very important, %	Important, %	Less important, %
Tisza river	92	5	3
Silence	80	15	5
Oxbow lakes	71	19	10
Traditional buildings	60	30	10
Vineyards, orchards	55	40	5
Great arable parcels	50	42	8
Dam	50	35	15
Thermal water and spa	50	35	15
Floodplain vegetation	45	40	15
Forest	40	45	15
Tiny villages	40	50	10
Great pastures	35	50	15
Livestock farm	15	40	45
Highway	5	15	80

*N = 88.

Citizens of the Tiszazug have appreciated floodplain meadows and wet hollows in former river beds as prominent landscape aesthetic values. They emphasised that tree plantations and close-to-natural forests with high species diversity belong to different types from the aspect of landscape character. The first one has been clearly judged destructive to the landscape. From artificial plantations, tree rows (typically Lombardy poplar and

Pseudoacacia) planted along dirt roads, vineyards and orchards have been considered beneficial landscape elements. Citizens were disappointed that plum, apple, and sour cherry orchards had almost completely disappeared from the region that had been famous for its orchards. They have acknowledged that the environment of the untended building groups with a recreation (mainly angling) function built on water banks during the 1980s has an individual character.

The most significant development perspective for the Tiszazug might be the rural water bank tourism. However, citizens can see the threats of mass tourism. They have stated that the substantial values of the Tiszazug water banks are tranquillity and nearness to nature. Therefore, the loss of these values would have a strong negative effect on their emotional association with the landscape. An excellent example of this is the local centre of thermal tourism, Cserkeszőlő, which has become an "extraneous patch" in the region and is not an actual Tiszazug location anymore, according to them.

Our interviewees are not responsible for the emptying, ageing, spoiling of infrastructure and alarming public safety in some places in the Tiszazug. However, local entrepreneurs feel that there is a minimal willingness to cooperate and to think innovatively in Tiszaföldvár and its vicinity. According to the workshop participants, there have not been – or at least not known – any coherent regional and settlement development concepts. Local governments make a bid for any financial support available without any concept. Specifically, young people have missed online content on spatial and settlement development on the homepages of settlements in Tiszazug. There is a relatively weak NGO activity in the region, which is also reflected in the fact that most of the interviewed persons could not mention any NGOs in the nature conservation or environmental protection field.

The most preferred sceneries of the Lake Fertő landscape are those which open from a high point, e.g., from a well-known lookout tower toward the lake basin or the hill range encircling the basin. This opinion highlights the significance of the extensive overview and the readability of the landscape. The most characteristic land cover types have been the grasslands and wetlands, giving the unique habitat structure of the Fertő-Hanság National Park. Built elements like streets and settlement views, showing traditional buildings, were mainly preferred. Nature, along with the traces of human hands and the baroque garden of the famous Esterházy castle, was frequently mentioned, signalling the complex approach considering humans and cultural objects as integral parts of the landscape. This view underlines the validity of the world heritage cultural landscape. The round table discussion and the online questionnaire brought the concerns of the citizens, e.g., the functional and management questions and the threats toward the traditional character.

Workshops organised in the town of Sopron highlighted the diversity of the landscapes within this small area (a fertile basin with a historic town between the forested mountains and the gentle hills with various land cover and the proximity of the lake basin and the Alps). They expressed their preference for the forested mountains, which are considered particularly valuable for the town from an ecological/climatic and recreational point of view. Vineyards, gardens and orchards (see *Photo 1*) of the surrounding hills have also been appreciated. The expanding modern residential areas, the new motorway construction, and the agglomeration of neighbouring villages endanger the latter. Respondents were proud of the history of their city and the tangible and intangible cultural heritage. They criticised the rapid expansion of the city, the change of the formerly quiet settlement due to the growing number of incomers and the new constructions without sufficient participation of the local citizens.

In the Tápió-vidék region, information was gained on favourite and characteristic sites. The buildings that currently dominate them, such as their home and school, have appeared

in large numbers on their drawings, but the natural values of the given settlement have generally been illustrated more often. This suggests that outdoor green spaces play an essential role in the lives of young people in the Tápió-vidék region. The second workshop was organised for the representatives of local NGOs (10 participants). Information was collected on the values, problems, landscape changes and locations, primarily using the community mapping method. The third workshop took place in a bird-ringing nature conservation camp with 20 local participants. The focal topics were landscape values, problems, changes and visions/expectations for the future. The results showed that the delimitation of landscape units, their interpretation, and the formulation of territorial differences appear in the minds of the population from a completely different perspective, thus, providing less input during the creation of study area/local types from national landscape character types. Locals also perceive the difference between the previously identified landscape character units, but the differences are primarily seen in the services and technical infrastructure of some settlements (built-up areas), changes in natural features along landscape boundaries, and landscape contrasts are less recognised based on the results of the present research. The popularity and awareness of natural values are very positive results and differ significantly from the findings of previous research in other study area, partly with a similar age group. The involvement of locals is beneficial in formulating the objectives of future visions for the landscape.

During the workshops, the locals highlighted some built landscape elements (e.g., castles, mansions, wine cellars), in addition to fishing lakes, wetlands (see *Photo 1*) and nature trails as characteristic features of most settlements in the Tápió-vidék region. The results of the expert studies support these observations, lakes also appear as a landscape character-defining element in many cases. However, some built features, although they may locally define the landscape and townscape, do not fundamentally influence landscape character.

In the Gerecse study area, the most characteristic landscape sceneries with marked identity for the locals are related to the Gerecse Mountains. Still, the historical town centre of Tata, with the lake and castle and the forested Danube riverbank, are sites that also create identity. Many consider them as their favourite place. Most of them recognised and considered as a problem the change of local climate, the disappearing tree alleys along the roads. Abandonment of land, demolishment of old buildings and increase in new built-up areas were mentioned among the changes and problems as well. The positive changes were the construction of bicycle paths, picnic and rest areas along the rivers, creeks and hiking routes.

Most participants liked to express their opinions about the landscape in front of an extensive analogue (not digital) map of the study area. Still, only professionals and local experts felt comfortable to localise their preferences on the map. The average locals and laypeople usually need a bit of orientation and guidance to geo-locate the changes in landscape characteristics, problems, favourite places, etc., on a map (see *Photo 1*).

Perception of the landscape character in the study areas

During the final workshop, we informed the citizens of the Tiszazug study area that the project's recommendations – according to our expectations – would be part of the new EU agricultural subvention system. It would be one of the main results of the project, carried out in the research area and the realisation of co-creation in practice. It means the support of the traditional combined land use practice of planting fruit trees between the vine rows, the maintenance and re-establishment of floodplain orchards, and an accentuated support for floodplain grazing in particular.

The fourth, closing online workshop in the Sopron–Lake Fertő region summarised the result of the previous communications

and had the purpose of discussing the co-operation and the co-dependence of the two main landscape character areas from three points of view: ecological, functional and visual. The answers reflect again predominantly an activity-related, functional, operational approach, highlighting the vineyards, the road network, transport facilities and the exchange of products. Ecologically, the connecting role of the waters, the possibly far-reaching transport of pollution, and the previously mentioned difference in the subalpine and continental areas arose. The visual aspects had a minor part to play.

The closing workshop at the Tápió-vidék study area was organised at a public swimming pool, with the participation of 20 visitors, primarily applying an interactive board game. The main goal was to involve the previously underrepresented middle-aged locals, focusing on the visions/expectations of the region's future and on the identification of the landscape units with similar characteristics.

The last workshop of Gerecse Mountains study site was organized in a restaurant with a spectacular view of the hilly landscape. The scenery contributed to the success of the discussion. Still, it could have been more motivating for the participants than an event organized on an active hiking day in nice weather outside the landscape.

Evaluating the opinions of the local inhabitants, we can confirm some conclusions from the international literature concerned with our topic:

- The opinions of the respondents about the landscape differ significantly according to their age and profession (Howley, P. 2011; López-Martínez, F. 2017; Šerý, M. and Daňková, M. 2021);
- The favourite places of the local environment are typically near-natural, refuge-like, hidden segments of the landscape (Lowenthal, D. 2007; Hedblom, M. *et al.* 2020; Belanche, D. *et al.* 2021);
- The attitude of the public toward the landscape character prefers the traditionally cultivated, mosaic-like pattern, the open scenery, often with long tree rows (De la Fuente de Val, G. *et al.* 2006; Junge, X. *et al.* 2015; Häfner, K. *et al.* 2018);
- The land use of outdoor recreation modifies the landscape structure increasingly (Butler, A. and Berglund, U. 2012; Silva, L. and Leal, J. 2015);
- The aesthetic value and the quietness of the rural landscape are more and more critical components of an ecosystem service (Angelstam, P. *et al.* 2019; Kaltenborn, B.P. *et al.* 2019).

Conclusions

In addition to the conclusions mentioned above from the Hungarian survey, we have some general remarks. Clichés – though characteristic – originating from the touristic advertisements and national park brochures – water, reed, birds, gentle hills – often appear among the preferences. Local citizens usually have an indisposition for large-scale alterations of the accustomed environment, which leads to less familiar feelings.

The various methods used (e.g., free association drawing, small group guided conversation, community mapping, interactive board game, grouping of study area photographs, ppGIS) are not only suitable for assessing people's thoughts, knowledge and emotions about the landscape but also for providing an experiential, interactive, perceptual program, can also be seen as an educational program. The reverse is also true: in addition to scientific communication, interactive games, playful tasks, and programs can also be suitable for portraying the landscape image of society/local communities. Demographic, economic and social conditions in a given study area significantly influence the selection of possible methods. For this reason, the results obtained in different study areas cannot be perfectly compared.

It should be emphasized that landscape researchers and local residents, as well as local experts, represent three different points of view. Landscape researchers strive for a ho-

listic vision, i.e., they combine measurable and mapable data with information that can be detected based on field visits and experience and use this knowledge to guide the exploration of local people's opinions. Unlike this, the local, layman's view is not spatial, they mostly think in terms of functions and activities: where, what is produced, how does transportation, commuting, trade, and tourism work. They try to link these activities to the spaces. At the same time, in the case of the landscape, vantage points are often mentioned, which means the importance of the view. In addition, point-like objects and values are emphasized. Finally, the experts have a strong sectoral approach and remain within the boundaries of their own field of expertise. They can also 'fit into the landscape' of their own subject area through functional interactions and the landscape.

The most important lesson learned from the study areas was that the workshop "has to be" an event where the locals are actively present. In this case, they behave comfortably, are open for discussion, can form individual or group opinions, and feel more free to speak up from the heart. The organizer should observe the event calendar of the region and join regular ongoing events where people are a priori present and active. An outdoor event is even better since the participants can feel the "landscape perspective" (in a picnic area, near a lookout point, or a rest area of a popular hiking route, etc.). It is not easy to invite laypeople to the office and make them speak than to go to their "desk" and discuss with them. This "desk" may be found at the market, at a fair, at a competition, at a concert, during a community day, at a campsite, in a forest school, on a picnic or any gastronomic event or during a guided landscape tour.

Landscape protection, which means conservation, reshaping or rehabilitation of the visual approach of the landscape, has seen increasing social support recently

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Suburban neighbourhoods versus panel housing estates – An ecological footprint-based assessment of different residential areas in Budapest, seeking for improvement opportunities

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Abstract

In this study, the household consumption-related ecological footprint of lifestyles linked to panel housing estates and suburban neighbourhoods were compared in the case of Budapest and its suburbs. Our results show that the biggest parts of the ecological footprint are in both study areas the carbon, the cropland and the forest components, in line with earlier calculations. On the whole, the ecological footprint values are bigger in the suburban study area (2.63 gha/capita) compared to the panel housing estates (2.29 gha/capita), mainly because of the differences between the carbon uptake and the built-up land components. Beyond comparing the ecological footprint values of different residential areas, the study also contributes to the literature by addressing the improvement options of the respective areas through a rough model calculation on the reduction opportunities in both cases, resulting 36 percent in case of panel housing estates, and 47 percent in the suburban areas. Although these values have to be considered cautiously, they show significant opportunities in ecological footprint reduction in both types of residential areas supported by individual motivations, as well as by policy measures.

Keywords: suburbanisation, urban sprawl, sustainability assessment, housing estates, panel buildings, ecological footprint, Budapest

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Introduction

One of the most spectacular processes in the development of post-socialist cities has been the transformation of the inner-city neighbourhoods and the outskirts. Outside the core city, in the agglomeration zone suburbanisation and urban sprawl have determined the development process in the last decades (Kubeš, J. and Nováček, A. 2019; Spórna, T. and Krzysztofik, R. 2020). Within the administrative boundaries of the city, fragmentation has progressed, with different neighbourhoods occupying different position on the housing market. In Hungary, and also in other post-socialist countries, the position of housing estates has been changing recently due to modernisation and upgrading, as evidenced by the rising dwelling prices and a growing demand for such dwellings (Kalm, K. *et al.* 2023).

There is a growing number of suburbanising towns and cities, which is significantly transforming urban land use, but urbanisation also happens at peri-urban areas. The inevitable corollary of decentralisation, on the

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other hand, is urban shrinkage (Champion, T. 2001), which has led to the re-emergence of the compact city concept in the EU's cohesion and social policy. Analysing the trends of the last almost four decades, a reversal towards the compact city in the development of metropolitan regions can be expected and urban sprawl can be seen as an intermediate stage of long-term territorial development (Taubenböck, J. *et al.* 2019). The expected direction of development is therefore not towards further expansion of these areas, but rather towards networking between increasingly compact, highly urbanised areas (Lang, R. and Knox, P.K. 2009). In this respect, the environmental characteristics of residential areas within the city and in the suburban zone are particularly important issues. Last but not least, there is much to be learned from the question of what ecological, architectural and lifestyle changes would be needed for the resident population to increase the sustainability of cities. Based on Ferreira, J.P. *et al.* (2023), different types of urban structure and population are responsible for significantly different levels of ecological impacts. According to Erdeiné Késmárki-Gally, Sz. and Neszmélyi, Gy.I. (2017), this is highly influenced by the significant differences in the level of urbanisation in the world.

Based on previous research, the aim of this study is to compare the ecological impacts of two very different types of urban structures, (1) densely populated panel housing estates in the compact city, and (2) sparsely populated suburban settlements outside the city, but still close the city boundary. This paper compares two types of neighbourhoods through the example of Budapest, using the concept of the ecological footprint (Wackernagel, M. and Rees, W.E. 1996). The research questions are the followings:

– RQ1. How do the ecological footprints of suburban settlements and panel housing estates differ from each other?
– RQ2. Considering their different built-up characteristics, what are the opportunities to decrease the specific ecological footprint of these two different neighbourhoods?

The intended novelty and added value of this study is related to both research questions. In the literature review section, a research gap is detected. In spite there seems to be a consensus among academics that urban sprawl increases ecological footprint compared to compact cities, there is very little empirical research on comparing different types of residential areas, especially when ecological footprint of consumption habits of the respective lifestyles is also considered. Academic literature mainly focuses on the ecological footprint-based comparison of different construction technologies (Li, H.X. *et al.* 2014; Kumar, A. *et al.* 2021; Ottelin, J. *et al.* 2021), or macro-level (national or regional) comparisons (Kovács, Z. *et al.* 2020, 2022; Yang, Y. *et al*. 2022; Kuzyk, L.W. 2023; Zhang, H. *et al*. 2024), while ecological footprint literature lacks convincing studies comparing different residential areas (even Ottelin, J. *et al.* [2015] compares inner and outer urban areas in terms of carbon footprint).

The calculation presented related to RQ1 contributes to fulfil this gap. The results not only help to better understand the differences between the overall ecological footprint values of the two study areas, but also highlight the key components contributing to both the indirect and the direct parts of the overall ecological footprint.

Another novelty value is the addressing and better understanding of the improvement options in panel building estates and suburbs (related to RQ2, in the discussion section). This can contribute to the further development of both public policies and individual strategies aiming at decreasing ecological footprint related to both study areas.

The rest of the study is structured as follows:

a) Literature review section provides a literature review of the major environmental challenges in residential areas, covering both suburban and densely populated prefab neighbourhoods, as well as a short overview of the concept of the ecological footprint with a special focus on the urban level.

b) Methodology section introduces the study areas as well as the method of the ecologi-

cal footprint calculations mainly based on household consumption.

c) Results section presents the results of comparing the two study areas.

d) Discussion section analyses the opportunities of decreasing the ecological footprint of the different types of neighbourhoods. Finally, the last section concludes the main findings of the research and provides an outlook for further research.

Literature review

Environmental challenges in different residential areas

The environmental challenges of suburban neighbourhoods

Following the recession in the first half of the 1990s, cities of the Central and Eastern European countries have experienced a spectacular development (Enyedi, Gy. 1998). Suburbanisation and urban sprawl became one of the dominant spatial processes in the Budapest urban region, as in other large Central and Eastern European cities (Tammaru, T. *et al.* 2009; Roose, A. *et al.* 2013; Kocsis, J.B. 2015; Csapó, T. and Lenner, T. 2016). Suburbanisation and urban sprawl in the Budapest agglomeration accelerated in the second half of the 1990s triggered by lower land and dwelling prices, lower densities, more attractive environment etc. The target settlements of the accelerating suburbanisation were mainly villages and small towns in the western and northern parts of the urban region, where the hilly and mountainous areas offered an attractive natural environment for the newcomers *(Photo 1).* An uncoordinated and chaotic growth prevailed in the suburban belt of Budapest significantly transforming these areas (Egedy, T. 2012; Kovács, Z. and Tosics, I. 2014). Transport networks have not been developed in line with emerging

Photo 1. Suburban neighbourhood in the Budajenő-Telki area. (Photo taken by the authors.)

needs, typically due to the lack of resources and a focused strategy (Erdeiné Késmárki-Gally, Sz. *et al.* 2020).

Suburbanisation and urban sprawl have led to a dramatic increase in transportation need and the associated car use, and transport problems gradually became the biggest challenge for the city region (Austin, P. and Gregorova, E. 2015). Another major challenge for post-socialist cities is the significant transformation of space and wasteful land use in city regions (Sýkora, L. 2014), as highlighted by *Figure 1.*

The statistics on commuting clearly show that in the post-1990 period, the spatial structure of the metropolitan region of Budapest has gradually transformed towards polycentric development. This process has resulted in an increase in cross-commuting between cities and a sharpening urban-to-rural commuting due to the decentralisation of the economy.

Meanwhile, in terms of land use, the massive conversion of former agricultural land into residential and commercial areas has commenced (Kovács, Z. and Tosics, I. 2014). The consequences of urban sprawl became visible in the region: the share of abandoned land increased, the proportion of agricultural land decreased, and the natural environment became fragmented. The growth of artificial surfaces has significantly accelerated. The post-socialist, post-industrial urban development has increasingly become a victim of ad hoc decisions and development. Investments became often random, making spatial development in the Budapest urban region unpredictable, it became difficult to predict and monitor land use changes. In the last two decades, development has been the result of market processes rather than of well-established development policy interventions (Fazekas, M. *et al.* 2015; Lang, T. 2015). Development has been organised along the lines of weaker resistance and stronger lobbies, reinforced by short-term political interests (Egedy, T. *et al.* 2017). As a consequence of the uncontrolled and unregulated spatial processes, the conflicts and negative environmental and social effects associated with suburbanisation and urban sprawl have intensified (Da Silva Machado, F. 2017).

The most common environmental challenges caused by the rapid development of suburban settlements include transport problems arising from commuting (with the ecological issues arising from car traffic being the main reason), land use problems

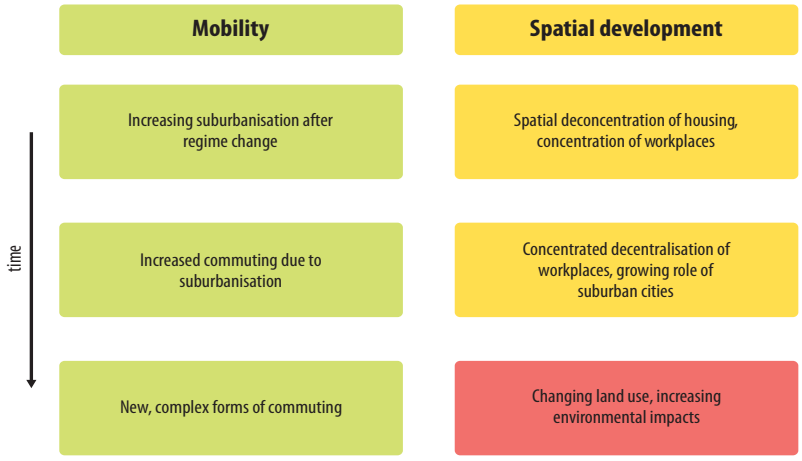

Fig. 1. The interrelationship between mobility and spatial development in the Budapest metropolitan region.
Source: Authors' own design.

linked to land conversion for housing (encroachment on natural landscapes, growth of artificial surfaces, illegal development and circumvention of regulations).

Challenges of panel housing estates from environmental and social perspectives

The reasons behind the construction of housing estates in both Western and Eastern Europe were similar: on the one hand, they were an attempt to address the quantitative housing shortage by cost-effective means, while on the other hand, it was an attempt to fulfil social equality and/or egalitarian political ideology (communist Eastern Europe) based on the theory of modernist architecture (Benkő, M. 2015; Leetmaa, K. *et al*. 2018). One spectacular and – at the time – effective element of this was the emergence and spread of prefabricated housing estates in Europe and in other parts of the world.

The 1970s was the peak period for the construction of prefab housing estates in East-Central European countries (Ouředníček, M. and Kopecká, Z. 2023), including Hungary (Kovács, Z. *et al*. 2018). Only in Hungary, about 600,000 dwellings were built using prefabricated technology (Benkő, M. and Egedy, T. 2023). Based on the authors, more than half of them has central heating and emerged in the form of greenfield investment. The layout and architectural character of the 1970s housing estates was mainly determined by the Soviet type large-panel technology. Ten-storey high strip houses (slabs) and 15-storey high towers became dominant, mostly with five, sometimes with ten staircases, as illustrated by *Photo 2*. The reduction of costs was only possible with the neglect of the construction of public services, and development of green areas, which became the most serious deficiencies of these housing estates (Kolcsár, R.A. *et al*. 2022). These large-scale, land-intensive, densely built housing estates with medium- and high-rise buildings were usually built on the periphery of large cities, in isolated environments far from the city centre, on open urban land still available for

Photo 2. Typical prefab building built in the 1970s. The "Village House" with 884 dwellings residing 3,000 people built in 1970 in Budapest's 3rd district. (Photo taken by the authors.)

large-scale construction (Petsimeris, P. 2018). The physical characteristics of housing estates: size, design and construction have had a crucial impact on the long-term trajectory and performance of housing estates on the housing market, even if social and housing values have changed over time (Hess, D.B. *et al.* 2018). Monotonous high-rise housing estates located in the periphery with poor accessibility face higher risks for social and physical downgrading than smaller housing estates closer to the city centre (Andersson, R. and Bråmå, Å. 2018).

The 1970s also brought about changes in the social composition of housing estates. Poorer and less educated people got better access to public housing in housing estates, and the average social status of the new estates decreased accordingly. After the change of regime, the wealthier strata who could afford better quality housing moved out of the panel housing estates, and today these neighbourhoods are mainly inhabited by the lower-middle class and the elderly (Egedy, T. *et al.* 2022). At the same time, due to the smaller average dwelling size, prefab housing estates have some potentials as in most European countries (and also in Hungary). They can attract small households composed of young singles, elderly, divorced people, foreign students and temporary workers who seek smaller housing units (Hess, D.B. *et al.* 2018).

The challenges of prefab housing estates can be grouped into three categories: i) challenges caused by the built environment, ii) problems associated with the social environment, and iii) challenges arising from the location (localisation) of the housing estates. The challenges of the built environment include problems of technological origin (problems due to the reinforced concrete construction, poor thermal and acoustic insulation, the single-pipe heating system with its wasteful technology, which did not allow the individual metering and proportional accounting of the energy used per apartment etc.), the lack of services and infrastructure (lack of institutions, shops, public services), the quality of green spaces and parking problems. The social challenges of prefab housing estates include the ageing of the local population, difficulties resulting from the co-existence of different generations (older original population and young newcomers), problems related to segregation, safety and crime. The location and localisation of housing estates (peripheral location in the case of panel estates) and their difficult accessibility often pose significant problems in terms of the lack of proximity and connectivity between the neighbourhood and the rest of the city.

The concept of the ecological footprint in a regionally oriented framework

The ecological footprint indicator measures human demand on nature by showing how much biologically productive land and sea area is needed to sustain a given consumption pattern. The magnitude of the demand, thus, can be compared with the available biocapacity on the supply side. If the demand for land in a certain area (country, region) exceeds the supply of biologically productive land, this results an ecological deficit indicating unsustainability at the longer term.

The concept was originally introduced in the 1990s (Wackernagel, M. and Rees, W.E. 1996), but has since been further developed (Wiedmann, T. *et al.* 2006). The size of the ecological footprint is expropriated through consumption activities is calculated by dividing the amount of resources and services consumed by the yield of the type of land that produces those resources and services. The resulting values are then multiplied by equivalence factors and summed to produce the final ecological footprint values. Meanwhile, biocapacity measures the ecological assets (including forest land, grazing land, cropland, fishing land and built-up land) available within the boundaries of the investigated territory and their capacity to produce renewable resources and ecological services (Galli, A. *et al.* 2020). National footprint calculations are constantly improv-

ing as better data become available and new methodologies are developed (Kitzes, J. *et al.* 2009). However, sub-national calculations are still relatively rare.

One direction for improvement in sub-national calculations is to develop a method to disaggregate national ecological footprints by socio-economic groups or certain territories. This is done by combining existing National Footprint Accounts with input-output analysis (Wiedmann, T. *et al.* 2006; Csutora, M. *et al.* 2011; Zhou, X. and Imura, H. 2011). One specific area of application of the ecological footprint indicator is the calculation of the ecological footprint for cities and city regions, which became popular in the literature recently (Galli, A. *et al.* 2020; Kovács, Z. *et al.* 2020; Swiader, M. *et al.* 2020). The results of a recent publication regarding the ecological footprint calculation of Budapest provides the basis for our current research (Kovács, Z. *et al.* 2022). The concept of ecological footprint has been the focus of much criticism (Galli, A. *et al.* 2016; Harangozó, G. *et al.* 2019), but its versatility has made it one of the most popular sustainability assessment indicators, inspiring many creative applications to address spatial aspects (Kocsis, T. 2014).

Despite the popularity and the methodological development of ecological footprint calculations, there are surprisingly few studies aiming at comparing different types of built-up areas beyond the conventional urban-rural approach. Holden, E. (2004) compared different types of residential areas in Norway and found that suburbs had higher footprint than city centres and argued for 'decentralised concentration' as a future development direction of urban areas, meaning smaller and more compact cities instead of urban sprawl. This study, however, mostly focused on the ecological footprint of housing and commuting, while embedded ecological footprint of consumption (this may vary between different residential areas) was disregarded. There are studies comparing the ecological footprint of different built structures, including prefab buildings (e.g., Solís-Guzmán, J. *et al.* 2013; Husain, G. and Prakash, R. 2019), but these still not cover the ecological footprint aspects of the lifestyles related to them.

An interesting perspective is provided by Hurley, R.E. (2009), suggesting that brownfield development of residential areas is preferred to greenfield ones. This sound to be logical (with the addition, that not exactly the ecological footprint is lower, but the need for – further – bio-capacity is less in case of brownfield investment), however, there is no empirical evidence provided for that. Indeed, Zhang, L. *et al.* (2016) could prove such relationship (brownfield investments are better than greenfield ones also from an ecological footprint perspective, in case of Chinese industrial areas), but not in residential areas.

As existing research does not seem to cover the differences between ecological footprint patterns of various types of residential areas (especially considering respective consumption habits), there is a research gap and need for more empirical studies in the field.

Methodology

Delimitation of the study areas

In our study, the household consumption-related ecological footprint of lifestyles linked to panel buildings and suburban neighbourhoods were compared in the case of Budapest. Following the scope of the research, two study areas were defined:

– Prefab panel buildings within the city borders: these neighbourhoods include multistorey, land-intensive buildings with high population density and relatively low apartment sizes, with little or no green surfaces and with district-heating. On one hand, inhabitants of these buildings have limited individual options on energy efficiency improvement (e.g., insulation) or alternative energy sourcing (e.g., solar panels). On the other hand, panel neighbourhoods are close to the compact city centre and supplied by public transpor-

tation. Altogether there are 57 housing estates within the city limits of Budapest with partly or fully prefab panel buildings. Based on the authors' estimation, this means about 200,000 dwellings with approximately 460,000 residents.

– Suburban neighbourhoods in the agglomeration of Budapest: these are villages and smaller towns, mostly with single family homes with smaller gardens, the size of dwellings is bigger and they are supplied with individual heating. There are more options regarding individual improvements for energy efficiency or use of alternative energy sources, however, such neighbourhoods have limited access to public transportation. For the research, the following seven municipalities were included in our sample: Budakeszi, Dunakeszi, Halásztelek, Pilisborosjenő, Szentendre, Telki and Vecsés. When compiling the suburban sample, villages, small and medium towns were considered, where relatively new and low-rise family house neighbourhoods are dominant. A further aspect was to include towns from various geographical sectors of the suburbs of Budapest. The total housing stock of the selected settlements is about 48,000 dwellings, with a population of 130,000.

The study areas are overviewed by *Figure 2*.

Fig. 2. Overview and location of the study areas. *Source:* Authors' own compilation.

Data and method

The process of calculating the household-related ecological footprint (associated with both goods and services), was conducted using an input-output model, supplemented with environmental data. Input-output models (based on the seminal work of Leontief, W. in 1936) unveil the interdependence among sectors within an economy and quantify how a unit of output in one sector relies on resources drawn from various other sectors. To illustrate, consider the inputs required for the consumption of a kilogram of potatoes, including the agricultural, energy, transport, and retail sectors etc.

The integration of environmental data into input-output models (environmentally extended input-output analysis – EEIO), it becomes possible to quantify the ecological footprint related to household consumption. This type of ecological footprint calculation is considered as a top-down approach. The input-output model was first used to calculate the ecological footprint by Bicknell, K.B. *et al.* (1998), and Ferng, J.J. (2001). The first application in Hungary was by Csutora, M. *et al.* (2011), who used it to determine the ecological footprint of household consumption. In this study, we extended the application of this methodology to a regional context, following the methodological guidelines set by Wiedmann, T. *et al.* (2006). Similar methodology was used by Córcoles, C. *et al.* (2024), using an environmentally extended multiregional input-output model and the Spanish Households Budget Survey to extract expenditure microdata by municipality size.

The household consumption spending related methodology is highly appropriate to address micro-level differences between the study areas in many aspects. For example, differences in household energy spending address the differences between prefab

panel and suburban family house dwellings, spending on transportation and vehicle fuel address the spatial aspects of the study areas, while spending on various goods and services indicate the differences between lifestyles representing the study areas. The ecological footprint embedded in household consumption can be expressed through the formula:

$$EF = EF_{dir} \cdot (I\text{-}A)^{-1} \cdot FD, \quad (1)$$

where EF represents the ecological footprint, EF_{dir} stands for the direct ecological footprint vector of specific sectors (in gha per million HUF). The term $(I\text{-}A)^{-1}$ corresponds to the Leontief-inverse matrix derived from the input-output model, showing the interdependencies among sectors. Finally, FD stands for the household-related final demand vector indicating the extent of consumption along the products of various sectors during the study period.

The data for the EF_{dir} vector were obtained from the Global Footprint Network (GFN) database, specific for Hungary, for 2019, the latest dataset provided by GFN. The household FD consumption vectors are calculated based on the EU Statistics on Income and Living Conditions (EU-SILC) database, data were obtained from the Hungarian Central Statistical Office (HCSO). Data were available for 2019, the last year before the Covid-19 pandemic. For the first case area (Budapest panel building neighbourhoods) data on households from Budapest with district heating were used as a proxy, while for the agglomeration case area, households from the respective municipalities in the Hungarian SILC database were used. Economy level input-output tables are developed in every five years for Hungary by the HCSO, so we applied the latest version, representing 2020.

Beyond the ecological footprint of the embedded consumption (indirect part), calculated as above based on Wiedmann, T. *et al.* (2006), we also estimated the direct components, originating directly from households. These components have been quantified along two domains of the ecological footprint:

– Carbon related component: This results from carbon emissions directly from residential heating and vehicle fuel usage. Examples include emissions from burning natural gas and gasoline or diesel during private car use. However, it excludes factors like electric heating, as electricity usage generates carbon emissions elsewhere (in power stations and during production and transportation of boilers, already covered by the EEIO-based calculation above). Similarly, the usage of bus transport accounted when acquiring transport services. (The burning of firewood for home heating, relevant for the agglomeration is not quantified in ecological footprint accounts, as it is considered as carbon neutral. However, in practice it is not necessarily the case [Gunn, J.S. *et al.* 2012], not considering other pollution caused by firewood heating.) Quantifying the household's direct carbon footprint involves the following four steps:
a) Identifying expenditure on fuels (piped natural gas, bottled gas, liquid fuels, coal, briquettes, coke) and vehicle fuels (petrol, diesel) based on the HCSO consumption survey data.
b) Determining consumption quantities based on average prices.
c) Calculating annual per capita carbon-dioxide emissions using calorific values (GJ/unit of volume) and specific carbon-dioxide emissions (t CO_2/GJ) of different fuels.
d) Deriving the carbon footprint per capita (gha/person) based on the coefficient of carbon dioxide from the (GFN data).
– Built-up land related component: This is associated with the physical area of residential properties and roads, in proportion to household utilization. As a proxy, properties are estimated to cover 1,000 square metres per households in the agglomeration (accounting for 0.25 gha – 0.12 gha/capita – considering that both built-up land and arable land have an equivalence factor of 2.51 gha/ha). For panel building apartments in multi-storey blocks, this component was neglected. There was no proxy to estimate the household use related part of

road surfaces, so this component is somewhat underestimated.

Beyond comparing the per capita ecological footprint values of the study areas, the study goes further. Based on literature and own considerations, specific improvement options are presented and discussed through a model calculation for the study areas.

Results

Table 1 provides an overview of the per capita household-related ecological footprint values for the two study areas, including both indirect (in household consumption embedded) and direct components.

Data show that the biggest components of the ecological footprint are in both study areas the carbon, the cropland, and the forest components, in line with earlier calculations (see Kovács, Z. *et al.* 2020, 2022). Altogether, the ecological footprint values are bigger in the suburban study area (2.63 gha/capita) compared to the panel housing estate neighbourhoods (2.29 gha/capita), mainly because of the differences between the carbon uptake and the built-up land components.

In spite of the clear differences between the two study areas (the overall per capita footprint value in the suburban sample is 15% higher than in the panel housing estate sample), there are major differences, if the direct and indirect parts of the ecological footprint values are considered. The indirect (embedded in the life-cycle of purchased goods and services) part of the household consumption related footprint is 14 percent higher in case of panel housing estates (2.13 gha/capita versus 1.83 gha/capita in the suburbs) and the values of panel housing estates outnumber suburbs related all of the three most influential component (cropland, carbon and forest land). Indeed, the higher overall ecological footprint values of the suburbs emerge based on the major difference between the direct components (0.76 gha/capita in the suburbs), 4.75 times bigger than the 0.16 gha/capita values of the panel housing estate sample. The respective carbon component is much larger in the suburban sample because of heating with natural gas. This component is not relevant in the panel housing sample, because those households use district-heating (and, thus, count into the indirect component), their natural gas consumption is very low (used mainly for heating water and cooking) compared to suburban households. The direct built-up land component is also bigger in the suburban sample (see the details of the respective methodological considerations in the previous section).

*Table 1. Per capita household consumption related and total ecological footprint as well as bio-capacity by land use types**

Land use types	Household-related ecological footprint						Ecological footprint (national, total)	Bio-capacity (national)
	Budapest panel buildings			Suburbs				
	indirect	direct	total	indirect	direct	total		
Cropland	0.93	–	0.93	0.82	–	0.82	1.11	1.68
Grazing land	0.06	–	0.06	0.05	–	0.05	0.11	0.08
Forest	0.35	–	0.35	0.31	–	0.31	0,40	0.67
Fish	0.02	–	0.02	0.01	–	0.01	0.02	0,02
Built-up land	0.04	–	0.04	0.03	0.12	0.15	0.13	0.13
Carbon	0.73	0.04** +0.12***	0.89	0.65	0.48** +0.15***	1.28	2.23	–****
Total	*2.13*	*0.16*	***2.29***	*1.87*	*0.76*	***2.63***	***3.97***	***2.57***

*In gha/person, 2019, household related data. *Source:* Authors' own calculation, national level data: GFN.
**Natural gas related (heating, cooking, hot water; only cooking and hot water in district heated panel buildings.
***Transport related. ****As a fictive land type, not applicable in bio-capacity accounts.

Furthermore, there may be another element to be considered in the carbon component in the suburban study area, the impact of the firewood heating. In the ordinary ecological footprint accounts, biogenic emissions are not considered (based on the assumption that dead wood would decompose anyway), however, Gunn, J.S. *et al.* (2012) debate this approach. It is not the scope of this study to dig deeper in this debate, so a further 0.15 gha/capita carbon uptake land component (based on firewood consumption) was not added to the suburban ecological footprint, but still mentioned as a potential fictive element.

Household consumption-related ecological footprint data for both types of study areas are smaller than the national total values (but this is not very surprising as the latter also involves footprint components beyond the household consumption, such as governmental and third sector activities). If we, however, compare the results to the national bio-capacity (the 'supply' of biologically productive land), it is obvious that the household-related ecological footprint itself approaches (in case of the panel buildings) or even outnumbers (in case of the suburban study area) it, raising serious sustainability concerns.

Table 2 goes further and provides a summary on the ecological footprint data according to consumption (COICOP – Classification of Individual Consumption According to Purpose, United Nations 2011 categories) (UN 2011).

If consumption categories are considered, the most important components are the food, housing (mainly heating) and transportation related ecological footprint components. The food component is somewhat bigger in the panel housing neighbourhoods, that can be the result of higher spendings on food

*Table 2. Household related ecological footprint along COICOP consumption categories**

Budapest and neighbourhoods	Categories	01 – Food and beverages	02 – Alcohol, tobacco and narcotics	03 – Clothing and footwear	04 – Housing, water, electricity, gas, fuels	05 – Furnishings, household equipment	06 – Health	07 – Transport	08 – Communication	09 – Recreation and culture	10 – Education	11 – Restaurants and hotels	12 – Miscellaneous goods/services	*Total*
Budapest panel buildings	indirect	0.87	0.19	0.04	0.31	0.05	0.03	0.18	0.01	0.15	0.02	0.22	0.05	*2.13*
	direct	–	–	–	0.04	–	–	0.12	–	–	–	–	–	*0.16*
	total	0.87	0.19	0.04	0.35	0.05	0.03	0.30	0.01	0.15	0.02	0.22	0.05	**2.29**
Suburbs	indirect	0.74	0.16	0.04	0.31	0.07	0.03	0.11	0.01	0.09	0.02	0.25	0.04	*1.87*
	direct	–	–	–	0.61	–	–	0.15	–	–	–	–	–	*0.76*
	total	0.74	0.16	0.04	0.79	0.07	0.03	0.26	0.01	0.09	0.02	0.25	0.04	**2.63**
Difference (suburbs versus Budapest panel buildings in %)	indirect	-14.5	-14.4	3.3	-2.0	30.0	-13.6	-39.8	-15.0	-36.8	4.3	12.4	-14.1	*-11.9*
	direct	–	–	–	142.5	–	–	25.0	–	–	–	–	–	*37.5*
	total	-14.5	-14.4	3.3	122.4	30.0	-13.6	-13.9	-15.0	-36.8	4.3	12.4	-14.1	*15.0*

*In gha/person, 2019. *Source:* Authors' own calculation.

product, which can be further decomposed along product categories using the coefficients of the Global Footprint Network Database *(Table 3).* The most dominant components are bread and cereals (because of their high quantity consumed) and meat products (based on their per unit ecological footprint impacts). The biggest difference between the panel housing and the suburban neighbourhoods are related to the housing component, where the latter has more than double values (0.79 gha/capita versus 0.35 gha/capita), mainly because of the larger average size of appartments and the individual buildings as opposed to panel apartments. The transportation related footprints are relatively similar (higher commuting impacts in the suburban lifestyle may be balanced by more leisure related monility among residents of panel buildings).

If differences between suburbs and panel housing estates are considered, it can be seen that footprint components related to most consumption categories are smaller in case of suburbs, but the large surplus related to housing (mainly related to energy consumption and physical land use) makes the overall value outnumber panel housing estates by 15 percent.

Results comparing the ecological footprint values of different residential areas are not only interesting in themselves, but also serve as the basis of our model calculation on how to reduce them, discussed in the following section.

*Table 3. Household-related food consumption footprint according to main food categories**

Food categories	Panel buildings	Suburbs
Bread and cereals	0.240	0.210
Meat	0.180	0.160
Fish	0.023	0.020
Milk, cheese, eggs	0.064	0.054
Oils/fats (plant-based)	0.100	0.089
Oils/fats (animal-based)	0.037	0.032
Fruit	0.078	0.066
Vegetables	0.077	0.066
Sugar, jam, honey, chocolate	0.039	0.033
Food n.e.c.	0.022	0.018
Total	*0.870*	*0.740*

*In gha/person, 2019. *Source*: Authors' own calculation based on GFN coefficients.

Discussion

Based on the results, it seems that compact, high density, high-rise housing estates are better than low-rise, sprawling, suburban areas, when ecological footprint is considered. It is important to note here, that results emerged as the aggregation of three major influencing factors, covered in the results section: building characteristics (influencing housing related footprint components), spatial aspects (responsible for commuting related footprint) and consumption patterns (influencing a major share of indirect – in the supply chains of products and services consumed).

Although the lack of extensive literature coverage of comparing the ecological footprint of specific residential areas, the results can still be discussed from different angles. If regional urban-rural aspects are considered, the current results are in line with recent calculations (Swiader, M. *et al.* 2020; Kovács, Z. *et al.* 2022), however, the study areas in those calculations are not specified and address only the differences between city and suburban neighbourhoods (disregarding the heterogeneity of those study areas).

Literature focusing on the construction aspects of buildings from an ecological footprint perspective (Solís-Guzmán, J. *et al.* 2013; Husain, G. and Prakash, R. 2019) highlight the benefits of modern apartment blocks. This is partly in line with the results of this study, as panel building neighbourhoods seemed to have lower housing-related footprints, but this is not necessarily because of the modernity of those buildings, but rather related to the lower per capita areas and the detached nature of such dwellings.

The findings of Holden, E. (2004) – an advocate of 'decentralised concentration' based on a Norwegian case study – show similarities with the results of this study, but the current two study areas (panel building estates within a major city and suburbs out of the city, but still linked to it) are far from his ideal settlement, compact and small towns with low travel needs. Very few studies go beyond the aspects mentioned in this section so far

and consider general consumption patterns when comparing the ecological footprint values of different residential areas. Gao, X. *et al.* (2024) analysed Chinese households and found that footprint inequality increased both in urban and rural areas. The results are hard to be explicitly compared to this study, but it supports the current finding that footprint related to consumption patterns play a key role in the overall footprint.

Based on the results, it seems that the geographical location of the dwelling, its size, architectural character, the basic communal infrastructure and the consumption patterns of residents are all key determinants of the magnitude of the ecological footprint and the potentials for reducing it. Beyond discussing the results of the two study areas of this paper, maybe an even more important field is to look for options decreasing ecological footprint specific for the different neighbourhoods. In this section, some ideas are presented based on literature, with a special focus on the major footprint components.

Literature differentiates top-down and bottom-up measures to decrease ecological footprint in the different residential areas. The first follows a macroeconomic approach through policies developed and financed by the states or state-level authorities, while the latter, a microeconomic perspective, means locally initiated and realised interventions (Tilov, I. *et al.* 2019; Saunders, H.D. 2000). The measures themselves can cover several fields: energy consumption (housing and transportation), products related to housing and clothing and food consumption (Shinde. R. *et al.* 2022).

Su, B. *et al.* (2022) highlight the significant potential in reducing food-related footprint by consuming less meat or even going vegan. Vávra, J. *et al*. (2018) draw the attention to food self-provisioning, even though such opportunities seem to be limited even in suburban conditions. There is a huge body of literature on how housing-related footprint can be radically decreased. Among them many researchers advocate refurbishing the buildings (Mir, A. *et al.* 2022; Kazemzadeh, E. *et al.* 2023), improving energy efficiency (Li, R. *et al*. 2022), promoting renewable energy in residential use (Shabir, M. *et al.* 2023), developing the electricity grid (Kuzyk, L.W. 2023) or promoting low-carbon technology innovation already at the planning phase of buildings (Gao, X. *et al.* 2024).

Based on these ideas, as a basis of a model calculation, the following measures are quantified here: 1) going totally vegan by avoiding meat, fish and dairy product consumption, 2) giving up totally harmful habits of smoking and alcohol consumption, and 3) transforming household-related energy use totally to renewable energy (and, thus, eliminating the indirect and direct carbon footprint elements) and giving up individual car usage with combustion engines(eliminating the direct carbon component of transportation related footprint). Based on the earlier outcomes of *Table 2* and *3*, this would result in decreased per capita ecological footprint values, as summarised by *Table 4.*

Estimates based on *Table 4* indicate a 0.83 gha/capita (36%) reduction in the panel housing estates and 1.25 gha/capita (47%) in the suburban sample area. An important insight is that suburban neighbourhoods not only have higher potential for reduction, but if the total theoretical potential could be achieved, the remaining per capita ecological footprint would be even lower compared to panel building neighbourhoods (1.38 gha/capita versus 1.46 gha/capita respectively). Additionally, in case the fictive 0.15 gha/capita firewood would also have been accounted, based on Gunn, J.S. *et al.* (2012), as derived in the method section) this could be a further reduction potential.

If our assumption for the number of residents of panel housing estates (450,000) holds true, the overall reduction potential accounts for 373,500 gha for this study area, 8.4 percent of the total footprint value of Budapest based on the most recent related calculation (Kovács, Z. *et al.* 2022). The respective reduction potential for the suburbs may vary between 10.9 and 15.9 percent of the total ecological footprint of the agglomeration of Budapest. Although it is very hard to estimate the population in the suburbs living

*Table 4. Possibly achievable household related ecological footprint along COICOP consumption categories**

Budapest and neighbourhoods	Categories	01 – Food and beverages	02 – Alcohol, tobacco and narcotics--	03 – Clothing and footwear	04 – Housing, water, electricity, gas, fuels	05 – Furnishings, household equipment	06 – Health	07 – Transport	08 – Communication	09 – Recreation and culture	10 – Education	11 – Restaurants and hotels	12 – Miscellaneous goods/ services	*Total*
Budapest panel buildings	indirect	0.87	0.19	0.04	0.31	0.05	0.03	0.18	0.01	0.15	0.02	0.22	0.05	*2.13*
	direct	–	–	–	0.04	–	–	0.12	–	–	–	–	–	*0.16*
	theoretical reduction potential	*0.27*	*0.19*	–	*0.25*	–	–	*0.12*	–	–	–	–	–	*0.83*
	total (potential)	0.70	–	0.04	0.10	0.05	0.03	0.18	0.01	0.15	0.02	0.22	0.05	***1.46***
Suburbs	indirect	0.74	0.16	0.04	0.31	0.07	0.03	0.11	0.01	0.09	0.02	0.25	0.04	*1.87*
	direct	–	–	–	0.61	–	–	0.15	–	–	–	–	–	*0.76*
	theoretical reduction potential	*0.23*	*0.16*	–	*0.70*	–	–	*0.15*	–	–	–	–	–	*1.25*
	total (potential)	0.51	–	0.04	0.22	0.07	0.03	0.11	0.01	0.09	0.02	0.25	0.04	***1.38***

*In gha/person, 2019. *Source:* Authors' own model calculation based on considerations in the text.

in similar neighbourhoods as in our respective study area (small towns that are different from urbanised suburbs or rural areas in the suburbs of Budapest), the range estimated here is based on the assumptions that the whole agglomeration has the *same amount* (higher end of the range) or *same ratio* (lower end of the range) of residents falling into our suburban sample. However, as the considerations of the decreasing potential apply also to the whole Budapest or agglomeration population, the numbers estimated in this passage can be understood as underestimation of the total reduction potential.

Although these estimations are very rough (not taking into account the emerging needs for additional vegan food, public transportation etc.), clearly indicate huge opportunities for ecological footprint reduction. While current values are higher in the suburban areas, the outcome of the reduction options also seems to be higher (also proportionally); this can also be considered when limited governmental resources or funding options are allocated for such purposes. The better understanding of the differences between core-periphery patterns (studied also from a different perspective by Péti, M. *et al.* (2024) can enable more case specific reduction actions.

In some cases, ecological footprint reduction does not need financial investment (in case of going vegan or giving up harmful habits. In other cases, however, improving the energy efficiency of buildings or transportation, monetary resources are essential and modernisation funds indeed play a major role. According to Bajomi, A.Z. *et al.* (2022), in countries, like Hungary and others, where the state provides very little funding and support for modernisation and energy efficiency programmes of

residential buildings compared to other EU member states, this is clearly a limiting factor. If the benefits of such programmes are highlighted from properly from multiple angles (including the results of this study, as well), more convincing recommendations for policymakers can be formulated. Furthermore, if also at an international context, state subsidies are scarce or limited, even the disposable income and savings of the local residents can be a basis, when investment is needed for ecological footprint reduction measures (Shinde, R. *et al.* 2022). As the authors studied residential areas in Switzerland, the availability of financial resources of local residents can also be a limitation factor if major refurbishment of buildings is considered, even though this would pay back over time.

In case of both top-down and bottom-up measures to decrease ecological footprint, the rebound effect (savings and, thus, ecological footprint reduction achieved in one area can lead to increased spending, an again larger ecological footprint, in other fields) needs to be considered (Chitnis, M. *et al.* 2013). For example, savings on energy bills may be spent on larger distance driven as leisure activity, partly or fully decreasing the achievement in ecological footprint reduction. This phenomenon draws the attention for the need of a complex, environmentally conscious approach, when promoting measures to decrease ecological footprint. Considering the results of this study as a rough model calculation on how ecological footprint could be reduced in different types of residential areas, several limitations need to be mentioned:

Comparing two lifestyles is obviously artificial – in reality, there are many different lifestyles living side by side. The aim was to illustrate that different neighbourhoods with populations following different lifestyles have different potentials to reduce the level of the current ecological footprint.

This research is based on sample-based statistical data, from which individual differences cannot be identified due to the nature of the research.

The research relates to a single point in time, so comparisons over time, which would be the most meaningful application of ecological footprint calculations, are hence not possible.

The model calculation oversimplifies at some points (not considering the increased need for public transportation or vegan food if higher ecological footprint intensive patterns – such as carnivorous diet or individual driving of combustion-engine vehicles – are given up).

The limitations suggest that the results have to be interpreted with caution. However, the results still show, that a more detailed understanding of ecological footprint of different urban neighbourhoods and related lifestyles can enable both individuals and policy makers to find alternative opportunities on how to launch programmes to decrease local ecological footprints.

Conclusions and outlook

Central and Eastern European cities are undergoing concurrent processes of suburbanization and densification, characterized by ongoing urban sprawl alongside efforts to increase compactness, particularly evident in major capital cities. This trend is particularly pronounced in cities experiencing a transition from a period of shrinking in the 1990s to a recent phase of growth, known as reurbanization. In such cities, strategies are needed to address challenges related to vacant properties, brownfield sites, transportation infrastructure, and overall quality of life for new residents (Wolff, M. 2018). Suburbs face various social and environmental issues, including inadequate infrastructure, increasing social polarization, and growing commuting pressures, contributing to congestions, and impeding residents' daily lives (Buzási, A. and Jäger, B.S. 2020; Mobolaji, D. *et al.* 2022). Therefore, it is key to better understand and measure the environmental challenges related to these areas.

This study compares the ecological footprints of two very different residential areas: panel building housing estates and suburban neighbourhoods through the examples of

Budapest. Based on the literature, this study not only contributes to the ecological footprint-based comparison of the study areas (RQ1), but also provides a novel model calculation to address the improvement potential specific to the study areas (RQ2). The findings and the explicit answers to the research questions can be summarised as follows:

Panel housing estates exhibit a slightly lower per capita ecological footprint, attributed to building-related and spatial differences as well as assumably slightly lower per capita income compared to suburban areas, 2.29 gha/capita versus 2.63 gha/capita respectively. Beyond these factors, differences in food and transportation-related footprints were less pronounced (RQ1).

In addition to absolute footprint values, the study suggests a rough model calculation for estimating opportunities to decrease ecological footprint, as well. Findings show a 36 percent reduction potential for panel housing estates and 47 percent for suburban areas, meaning that suburbs may even achieve lower footprint values than panel housing estates (RQ2).

Although these figures have to be interpreted cautiously, the specific details presented in this study indicate that numerous individual initiatives and policy interventions can be suggested that align with both urban development and ecological objectives. As a new insight offered by this study, such measures to decrease ecological footprint may be structured and scaled along the major aspects influencing the ecological footprint of the study areas:

Related to the energy efficiency characteristics improvement of dwellings, suburbs offer a bigger and more flexible opportunity, as not only large-scale, policy driven refurbishment projects can be implemented, but smaller scale, individual, even do-it-yourself ones. However, newly built, or refurbished panel housing estates can provide comfort and high energy efficiency at the same time (Hess, D.B. *et al.* 2018), a major driver of conscious reurbanization.

Regarding the spatial aspects, different pathways can target the idealistic 'decentralised concentration' (Holden, E. 2004). Panel housing estates within the city perform already right well in this perspective, while the compact municipality approach as a future development stream could contribute to the reduction of ecological footprint in suburbs, as well.

The consumption patterns related to both study areas are important, also from an ecological footprint perspective. To avoid the rebound effect (Shinde, R. *et al.* 2022), environmental education and consciousness should be fostered, so that ecological and financial savings related to the previous aspects are not spent on further ecological footprint intensive goods and services.

Beyond these measures, the limitations of this study presented before also highlight new research directions:

As there are very few research and comparison of the ecological footprint of different residential areas available at this time, further studies are needed to go beyond the urban-rural comparison and assess and compare specific neighbourhoods.

Beyond input-output modelling-based studies, bottom-up ecological footprint assessment and comparisons would be very useful, considering local conditions even more specifically.

This study is based on a single point in time, but temporal comparisons, quantifying the possible differences over time of different residential areas would also add new insights to the better understanding of the ecological footprint aspects of territorial development.

To overcome the simplifications used in this model calculation on the ecological footprint reduction potential of different residential areas, more research is needed to specify and quantify the trade-offs related to specific measures (e.g., switching between transportation modes, diets, habits), also from an ecological footprint perspective.

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Socio-economic characterization of Portuguese kiwi growers: Facing current social and sustainability challenges

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Abstract

This paper reports a socio-economic characterization of the Portuguese kiwifruit sector. A survey was applied between 2019 and 2020 to a sample of 94 kiwifruit farmers (males 76%, females 24%). 72 percent of the participants declare that kiwi cultivation is a complementary occupation characterized by an intergenerational pattern (25.6%). Almost 70 percent of the orchards are under 5 ha, and 26.8 percent declare that their company does not have a positive turnover. The labour force is mainly seasonal. Regarding the challenges, 21.1 percent struggle with disease control in their orchards and 19.0 percent have difficulty in finding workers. The findings contribute to a nuanced understanding of the socio-economic dynamics underpinning kiwifruit cultivation in Portugal, offering insights for policy interventions and sectoral development strategies.

Keywords: kiwifruit growers, challenges, sustainability, socio-economic characterization, Portugal

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Introduction

The cultivation of *Actinidia deliciosa*, commonly known as kiwifruit, has a rich history dating back to the 12th century during the Song dynasty in China (Ward, C. and Courtney, D. 2013). Over time, this fruit spread from its native region to New Zealand (Morton J.F. 2013), where it underwent commercial development, transforming into a significant agricultural commodity (Costa, G. *et al.* 1992; Bano, S. and Scrimgeour, F. 2012). The subsequent introduction of kiwifruit cultivation in Portugal during the 1970s marked a significant expansion of the industry (Antunes, M.D. *et al.* 2018), particularly in regions like Entre Douro e Minho and Beira Litoral (Moura, L. *et al.* 2015).

However, despite its historical significance and growing importance, the Portuguese kiwifruit sector faces various challenges, particularly concerning sustainability and socio-economic factors. One of the most pressing issues is the decline in productivity due to the prevalence of *Pseudomonas syringae pv. actinidiae* (*Psa*), which causes bacterial canker disease. This pathogen poses a significant threat to both the viability of kiwifruit cultivation and the livelihoods of growers.

While previous studies have shed light on aspects of kiwifruit production in Portugal (Cruz, L. *et al.* 2004; Antunes, M.D.C. *et al.* 2007; Antunes, M.D. 2008a; Antunes, M.D. *et al.* 2018; Castro, H. *et al.* 2021, 2022; Abreu, C.C. 2022), there remains a dearth of information regarding the socio-economic profiles of

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those involved in the industry. Understanding the challenges faced by kiwifruit growers is essential for devising strategies to enhance the sector's resilience and sustainability.

Therefore, this study aims to fill this gap by conducting a comprehensive socio-economic characterization of Portuguese kiwifruit growers. Through a questionnaire survey, we seek to delve into the social and economic dynamics shaping kiwi production in Portugal, with a focus on the unique geographical, environmental, and social challenges encountered by growers. By examining the interplay between geography, socio-economic factors, and sustainability challenges, this study not only contributes to the existing literature but also provides valuable insights for policymakers, stakeholders, and practitioners involved in the Portuguese kiwifruit industry. Rather than viewing geography as a deterministic factor, we employ relational thinking to unravel the complex web of influences, including natural conditions, market relations, and policy frameworks, that mould kiwifruit cultivation practices and outcomes.

Understanding the socioeconomic dynamics of the Portuguese kiwifruit industry necessitates a multifaceted approach that transcends traditional disciplinary boundaries. At its heart, agricultural economics provides insights into the economic behaviour of kiwifruit growers, such as production decisions, input selection, and market interactions (Fuglie, K.O. 2012). The idea of farm size and its implications for economic performance, as demonstrated by the prevalence of small-scale kiwifruit farms in Portugal, is consistent with agricultural economics principles (Thirtle, C. *et al.* 2003). Furthermore, market structure and market power theories give light on the difficulties that producers confront when negotiating appropriate prices for their produce in the face of volatile market conditions. Rural sociology complements the economic approach by providing useful insights into the social aspects of kiwifruit growing (Bebbington, A. 2000). The sociographic profile of Portuguese kiwifruit growers, which is dominated by male, relatively young adults with high levels of education, mirrors broader demographic trends in rural communities (Marsden, T. and Smith, E. 2005). Furthermore, familial involvement in kiwifruit growing demonstrates the intergenerational transmission of agricultural knowledge and practices, emphasizing farming's social embeddedness (Bebbington, A. 1999). Drawing on sociological theories of social capital and networks, kiwifruit growers' strong associative linkages, as indicated by membership in industry associations, highlight the necessity of collective action and collaboration in tackling common challenges (Pretty, J. and Ward, H. 2001). In the context of sustainability research, the socioeconomic character of kiwifruit farming overlaps with broader environmental and societal concerns (Pretty, J. *et al.* 2005). In terms of sustainability, the emphasis on small-scale farming practices and familial involvement in kiwifruit cultivation is consistent with agro-ecology and community-based natural resource management ideas. Furthermore, the investigation of problems connected to bureaucratic complexities and legal compliance highlights the necessity for institutional arrangements that enhance agricultural systems' resilience and adaptive capacity (Lele, S. *et al*. 2013).

In addition to these established disciplines, recent advances in geography provide unique analytical frameworks for understanding the intricacies of kiwifruit production. Notably, the burgeoning fields of food geographies and economic geography of food provide new lenses through which to examine the intricate webs of commodity chains, labour geographies, and food system complexities (Kneafsey, M. *et al.* 2021; Joassart-Marcelli, P. 2022; Moragues-Faus, A. *et al.* 2023). By diving into the spatial features of agricultural operations, these pioneering publications shed light on the geographical complexities of kiwifruit cultivation and distribution networks. Furthermore, the emerging area of more-than-human geographies provides a paradigm-shifting viewpoint on the interactions between human agents, non-human ac-

tors, and the environment in kiwifruit agroecosystems (Hinchliffe, S. and Whatmore, S. 2006; Lorimer, J. 2015; Aldeia, J. 2023). These interdisciplinary investigations challenge standard anthropocentric narratives by emphasising the agency of non-human species and highlighting their critical role in changing agricultural landscapes (Aldeia, J. 2022, 2024). Set against this background, this paper is organized as follows: first, we provide an overview of the historical significance and global spread of kiwifruit cultivation, followed by an exploration of international and Portuguese trends in kiwifruit production. We then delve into the associative patterns of Portuguese kiwifruit farmers. Subsequently, we detail the materials and methods employed in our study, outlining our research question, objectives, and methodology. Next, we present our findings and engage in a comprehensive discussion of the socio-economic profiles of Portuguese kiwifruit growers, drawing implications for the sector's sustainability and viability. Finally, we conclude with reflections on the broader implications of our research and avenues for future inquiry.

International and Portuguese trends of kiwifruit cultivation

The presence of *Actinidia* is not recent, since it exists in Chinese historical records for centuries (Huang, H. and Ferguson, A.R. 2001; Ferguson, A.R. 2004; Franco, J. 2008; Meingassner, L. 2011), but it was until the beginning of the 20th century, mostly found in the wild. Although in the 19th century, specimens of this plant already existed in Europe, they were very few and only intended for botanical study, with *Actinidia* being botanically classified in 1845 (Ferguson, A.R. 2004). Nevertheless, the taxonomic distinction between the two main species of *Actinidia* – *A. deliciosa* and *A. chinensis* – is much more recent, accomplished in 1984 (Ferguson, A.R. 2004). The development of an agricultural sector devoted to the cultivation and commercialization of kiwifruit followed from the arrival of this species in New Zealand in 1904 (Ferguson, A.R. 2004). It was in the 1920s in New Zealand that the "Hayward" cultivar (*A. deliciosa*) was the world's most widely planted female variety, becoming predominant in almost all countries with significant crop size (Huang, H. and Ferguson, A.R. 2001; Ferguson, A.R. 2004; APK, 2007; Antunes, M.D. 2008b; Neves, N. 2008), including Portugal (APK, 2007; Antunes, M.D. *et al.* 2018). The international success of the New Zealand kiwifruit industry led companies from other countries including Portugal to enter this emerging sector from the 1970s onwards, planting orchards of *Actinidia deliciosa* and, though on a smaller scale, of *A. chinensis*, with increasing expansion (Huang, H. and Ferguson, A.R. 2001; Ferguson, A.R. 2004; APK, 2007; Franco, J. 2008; Antunes, M.D. *et al.* 2018). From the 1990s, a commercial success history began in most national and transnational markets dedicated to the domestic commercialization and export of *Actinidia*, with a significant increase of the planted area, the volume of production and the volume of capital generated.

According to FAOSTAT (2020) between 1988 and 2018, the world production of kiwifruit increased more than seven times, from 554,175 to 4,022,650 tons, representing a positive variation of ca. 200 percent *(Table 1).* Portugal also followed this international trend.

The global kiwifruit industry is controlled by a few primary producing countries, with annual production levels shifting depending on climate conditions, market demand, and agricultural policies. According to the most recent data available from the Food and Agriculture Organisation of the United Nations (FAO), China produces the most kiwifruit, accounting 2,380,304.47 tons in 2022 (FAO, 2024). Iran is close behind, with 294,571.01 tons in 2022. Portuguese kiwifruit producers face competition from both domestic and international suppliers, particularly in key markets such as Portugal and Spain. Understanding the competitive landscape is essential for Portuguese producers

Table 1. Evolution of kiwifruit plantation area with Actinidia and percentage change, 1988–2018

Area	Cultivated area, ha				Change of cultivated area, %		
	1988	1998	2008	2018	1988–1998	1998–2008	2008–2018
World	51,282	53,901	162,037	247,109	+5.1	+200.6	+52.5
Portugal	600	1,133	1,464	2,736	+88.8	+29.2	+86.9

to strategically position their products and maintain market share. In Portugal, native kiwifruit production competes with imports from other kiwifruit-producing countries, particularly during the off-season or when domestic supply is low. Countries such as Italy are important kiwifruit exporters to Portugal, providing customers with a variety of alternatives throughout the year. Italian kiwifruit, in particular, is well-known for its quality and frequently competes directly with Portuguese kiwifruit on the Portuguese market (Testolin, R. and Ferguson, A.R. 2009).

Portugal and Spain consume 95 percent of Portuguese kiwifruit production, which can be linked to historical preferences, market dynamics, and supply chain ties (Gallego, P.P. 2018). The dominance of Portuguese consumption in Portuguese kiwifruit production is determined by both historical and current market conditions. Historically, Portugal and Spain have been important kiwifruit eaters, with a predilection for locally grown cultivars (Antunes, M.D. *et al.* 2018). The proximity of kiwifruit-growing regions to consumer markets in Portugal and Spain, combined with favourable climatic conditions for production, has resulted in high domestic consumption rates. Furthermore, cultural considerations, nutritional choices, and culinary traditions may have influenced the appeal of kiwifruit in certain countries over time (Panagopoulos, T. and Antunes, M.D.C. 2011).

According to FAOSTAT (2020), there were 247,109 ha planted with *Actinidia* worldwide in 2018, generating an aggregate production of 4,022,650 tons. Portugal was the 10th largest producer, with 1.1 percent of the world's planted area (2,736 ha), and 0.85 percent of the world's production, namely 34,057 tons (INE, 2019; FAOSTAT, 2020).

This was the second year with the highest production of kiwifruit in the country, only surpassed by 2017. The *Actinidia* plantations are mainly concentrated in two agrarian regions: Beira Litoral (central region) and, above all, Entre Douro e Minho (north of Portugal). According to the agricultural statistics published by Statistics Portugal (INE, 2019), in 2018, of the 2,736 ha occupied by this agricultural crop, 1,916 ha (70.0%) were located in the north, and 799 ha (29.2%) in the central areas, representing 99.2 percent of the total national area planted with *Actinidia*. The same pattern was already observed in 2006 (INE, 2007), where 76.9 and 20.7 percent of the national area planted with *Actinidia* were located in the Entre Douro e Minho and Beira Litoral regions, respectively. These two agrarian regions are also responsible for almost the entire national production of kiwifruit. Of the 34,057 tons produced in Portugal in 2018, 27,097 tons came from orchards located in the northern area of the country (79.6%) and 6,711 tons in the central area (19.7%). Together, these two areas are responsible for 99.3 percent of national production this year (INE, 2019).

Most Portuguese kiwifruit farmers manage small orchards (INE, 2011). Therefore, and also because of the low profitability of these small-scale orchards, most of the kiwifruit farmers do not have the required logistical conditions to store their production after harvesting (e.g., refrigerated chambers) during the period necessary for the fruit to ripen to the point where it can be consumed (APK, 2007; Antunes, M.D. 2008c). The warehouses are, thus, central actors in this sector, receiving the annual harvest from various producers, storing it and controlling its maturation. There are six largest Portuguese warehou-

ses[3], that receive most of the national production. Most companies do not sell directly to retail, to major international brands or other production destinations but rather sell their annual production to warehouses, which subsequently sell the stored production.

As in most other kiwifruit-producing countries, the cultivar "Hayward" (*Actinidia deliciosa*) is the predominant female cultivar in Portuguese orchards (APK, 2007; Franco, J. 2008; Antunes, M.D. *et al.* 2018), although farmers have diversified the planted cultivars, either with *Actinidia deliciosa* or other varieties (especially *Actinidia chinensis*, but also a small amount of *Actinidia arguta*). Slightly less than half of the national production of kiwifruit is exported. Nevertheless, a considerable amount of this fruit is also imported. According to INE (2019), in 2017, the year in which the sector produced 35,411 tons of kiwifruit, of which 15,751 tons (44.5%) aimed at the international market. In 2018, this value reached 49.2 percent, corresponding to 16,747 tons. To meet Portugal's domestic market demand, 9,466 and 9,706 tons of kiwifruit were imported in 2017 and 2018, respectively. Although almost half of the national production of kiwifruit is exported, according to Antunes, M.D. *et al.* (2018), 95 percent of the production is intended for the Portuguese and Spanish markets, the latter being the main destination of exports.

Portuguese kiwifruit farmer's associative patterns

The kiwifruit market has grown both nationally and internationally. According to the available data, the Portuguese sector has consistently managed to be responsible for more than 1 percent of the world's kiwifruit production's gross value, approaching or surpassing the 2 percent barrier in several years, decreasing to only 1.3 percent in 2016 (APK, 2007).

The growth of kiwifruit production in Portugal has been economically positive for the actors in the sector. Some farmers fear that this upward trend, especially when framed within the world's growing trend in kiwifruit production, may saturate the Portuguese market, as well as Portugal's export markets for this fruit, leading to a drop in the price. In this scenario, the activity in the sector could become less profitable, especially the most recent business actors, who would have more significant difficulties in recovering the relatively high investment necessary to start their activity, since an orchard can take about three years post-planting to become commercially productive. In light of this, the Kiwifruit from Portugal Association (APK) was created in 2004 to promote the national kiwifruit sector (APK, 2007). By the end of 2020 APK had about 200 associates and it develops various activities to promote the sector, from participating in scientific research projects on the culture of the *Actinidia* to developing commercial strategies that bring together the actors in the sector, highlighting the creation of the brand "kiwifruits from Portugal".

Together with several kiwifruit farmers and warehouses, APK has sought to develop commercial strategies that ensure the economic sustainability of the sector. Among these strategies is the diversification of planted cultivars, such as *A. deliciosa, A. chinensis*, or *A. arguta* (on a smaller scale). This diversification of cultivars is accompanied by a commitment by several farmers to obtain agricultural and commercial certifications for their activity, such as the GLOBAL G.A.P. (a global reference framework for good agricultural practices) or the organic production method. Alongside these strategies, there is also emphasis on exporting national production, strengthening its presence in markets where it is already present, and entering new markets. Among other communication and marketing strategies, the brand "Kiwis de Portugal" was created by APK, intended to

[3] Frutas Douro Ao Minho, S.A.; Kiwicoop – Cooperativa Frutícola da Bairrada CRL; Kiwi Greensun – Conservação e comercialização de Fruta, S.A.; Kiwi Life, Lda.; Prosa – Produtos e serviços agrícolas, S.A.; e Terras de Felgueiras – Caves de Felgueiras CRL.

be a common banner under which the sector can organize itself with business success in national and international markets. While these efforts have been instrumental in advancing the interests of Portuguese kiwifruit producers, the role of European guidelines and frameworks have been pivotal in shaping this market.

The European Union's (EU) agriculture regulations and policies have a significant impact on the operating environment for Portuguese kiwifruit farmers. These policies include a wide range of issues, including agricultural subsidies, market access, environmental standards, and food safety laws, all of which have a substantial impact on the kiwifruit industry. The EU's agricultural subsidies under the Common Agricultural Policy (CAP) (European Commission, 2024a) have a direct impact on the financial viability of Portugal's kiwifruit farms, namely in influencing production decisions, investment strategies, and overall farm profitability. However, the distribution of subsidies across different agricultural sectors and locations in Portugal may not always reflect the special requirements and goals of kiwifruit farmers, providing hurdles to sectoral development (European Commission, 2024b). Alongside, market access is another important factor controlled by EU rules. The EU's internal market and trade agreements with other nations govern the circumstances under which Portuguese kiwifruit can be sold domestically and exported internationally. Tariffs, quotas, and sanitary and phyto-sanitary regulations set by the EU and its trading partners can have an impact on the competitiveness of Portuguese kiwifruit in foreign markets, as well as the sector's export plans.

Materials and methods

Research question and objectives

This study was guided by the following research question: What are the socio-economic dynamics shaping kiwifruit production in Portugal, and how do they impact the sustainability and viability of the kiwifruit sector? To answer this research question, the following objectives were established:

- To comprehensively characterize the socio-economic reality of the kiwifruit sector in Portugal;
- To elucidate the key socio-economic factors influencing kiwifruit production in Portugal, including but not limited to land tenure, farm size, labour force characteristics, income sources, and marketing strategies;
- To assess the challenges and opportunities faced by Portuguese kiwifruit growers in the current socio-economic landscape, with a particular focus on issues such as disease control, labour availability, market access, and sustainability practices.

With these objectives it is expected to provide a comprehensive understanding of the socio-economic characteristics of Portuguese kiwifruit growers and to identify key challenges and opportunities faced by kiwifruit growers in Portugal, along with recommendations for addressing these issues and enhancing the sustainability of the sector.

Methodological approach

To meet these objectives, a questionnaire survey was applied to producers/farmers and companies that planted *Actinidia* orchards. The questionnaire survey drew upon a combination of previous research, field observations, and expert input to ensure its comprehensiveness and relevance to the study objectives. Initially, before finalizing the questionnaire, we conducted an extensive review of existing literature on kiwifruit farming practices, socio-economic factors influencing agricultural activities, and the broader context of Portuguese agriculture. This literature review served as the foundation for identifying key themes and topics that warranted exploration in our study. Several significant topics concerning kiwifruit farming practices, socioeconomic

factors influencing agricultural activities, and the broader environment of Portuguese agriculture were identified: socio-demographic characteristics of growers; farm management practices and infrastructure; economic aspects such as income sources and market access; environmental considerations and sustainability practices; and social dynamics including family involvement and community networks

Moreover, we supplemented our literature review with field observations and informal discussions with kiwifruit growers, industry experts, and agricultural extension officers. These interactions provided valuable insights into the day-to-day realities and challenges faced by kiwifruit farmers, helping us to refine and prioritize the themes to be addressed in the questionnaire. We conducted direct observation during the winter and summer of 2018 to gain insights on relevant practices in the kiwifruit industry. Specifically, we attended a number of occasions where Portuguese kiwifruit growers met with the APK to address the obstacles of marketing their products. We also visited kiwifruit orchards in Entre Douro e Minho and Beira Litoral, Portugal's two key agricultural regions for the kiwifruit sector. During these visits, we accompanied specialists working in the orchards, obtaining first hand knowledge of their operations and witnessing the subtleties of kiwifruit production procedures. These direct observations provided vital insights into the daily reality and issues faced by kiwifruit growers, supplementing the quantitative data gathered through our questionnaire study. While the exact number of stakeholders who participated in these informal discussions was not systematically recorded, our goal was to collect a variety of viewpoints and experiences from the kiwifruit industry.

While existing research gave useful insights into these problems, our study sought to fill gaps and address unresolved issues. For example, there has been little research into the specific socioeconomic dynamics affecting kiwifruit production in Portugal, particularly in terms of land tenure arrangements, labour force characteristics, and marketing techniques unique to the Portuguese context (Eurostat, 2017). Furthermore, there was a paucity of detailed assessments of the challenges and opportunities faced by Portuguese kiwifruit growers, particularly in light of changing market conditions and sustainability concerns (Malla, S. *et al.* 2022; Zhang, X. *et al.* 2023; Gurbuz, I.B. *et al.* 2024).

We conducted a preliminary pilot survey with a small sample of kiwifruit growers to test the clarity, relevance, and feasibility of the questionnaire items. During this phase, numerous changes were made based on their feedback, including clarifying language, simplifying complex questions, removing repetition, rephrasing for clarity and precision, providing response choices, such as explanatory comments or examples, and improving visual layout and structure. For example, the term "sustainability practices" underwent refinement to delineate whether it pertained to environmental, economic, or social sustainability, thereby ensuring respondents understood the intended scope of inquiry. The feedback received from participants during this pilot phase allowed us to fine-tune the wording of questions, identify potential ambiguities, and ensure the comprehensibility of the survey instrument.

Questionnaire development and application

Drawing on this multi-faceted approach, the finalized questionnaire was designed to capture a comprehensive range of themes deemed crucial for understanding the socioeconomic dynamics of Portuguese kiwifruit farming. These themes included but were not limited to:

1. Socio-demographic characteristics of growers;
2. Farm management practices and infrastructure;
3. Economic aspects such as income sources and market access;

4. Environmental considerations and sustainability practices;

5. Social dynamics including family involvement and community networks.

Between the summer of 2019 and the spring of 2020, the questionnaire was available for an online response, duly anonymized, through the Google Forms platform. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964. There was informed consent, the study aims were explained to participants, and they received guarantees of confidentiality and anonymity. The email address was made available to representatives of the kiwifruit companies and farmers thanks to the help of the six national warehouses (mentioned earlier), and APK. The same questionnaire survey was also made available in a printed version (also anonymized) and distributed to farmers who preferred to fill it in this way.

A convenience sample was used to obtain as many responses as possible (Parker, C. *et al.* 2019). This was the best possible way to characterize socio-economically the kiwifruit farmers in Portugal, especially given the lack of reliable aggregate data on their numbers (Bornstein, M.H. *et al.* 2013), and also the actual numbers.

In 2019 the data available regarding this sector was most likely outdated by the 2009 Agricultural Census (INE, 2019) (the latest public data available at the time of the study), given the growth that the sector had been experiencing. An exhaustive agricultural census operation is held every 10 years and since the Covid-19 outbreak delayed the application of the 2019 Agricultural Census it was impossible at the time to secure the necessary figures by a representative sampling of the kiwifruit farmers. Thus, the search for the greatest possible number of answers appeared to be the best methodological alternative to carry out the socio-economic characterization of the sector.

Although it cannot be considered a representative sample of the kiwifruit producers' sector, this study makes a first attempt to provide some insights and trends in the sector based on producers' opinions about their activity and some of the main problems in the sector. From 100 answers, 94 were obtained online, and 6 were in printed format. Only 94 answers were considered valid since six were answered by non-owners of the companies in the sector (i.e., employees of these companies) or because the respondent did not explicitly consent to the processing of data (1 answer). It was considered more relevant for the socio-economic characterisation to work only with data from these 94 questionnaires answered directly by business owners.

Some reasons may be pointed out for the small number of answers: (i) the first may be related to the length of the questionnaire, whose 57 questions took at least about 20 minutes to answer; (ii) secondly, this questionnaire survey began to be made available at a time close to the harvest season, which is an unfavourable period to answer requests like this questionnaire because of the high workload that characterizes the season for the farmers; (iii) the third and, perhaps, most relevant, is that this study was conducted, in part, at the beginning of the current outbreak of Covid-19, which limited the possibilities of meeting face-to-face with national kiwi growers to make them aware of the importance of their participation in this study.

After the anonymization of the answerers, they were subsequently processed using the IBM SPSS Statistics ® software (IBM, 2018) through descriptive analysis.

Although our study attempted to cover some of these gaps with a questionnaire survey and descriptive analysis, certain subjects were left unaddressed due to methodological constraints and limitations. For example, the impact of EU agricultural policy on kiwifruit production in Portugal is an interesting subject of future research. While this topic was somewhat uncovered throughout the literature analysis, it was outside the scope of the current study to investigate further. Future research could investigate the connection between EU policies, socioeconomic dynamics, and the sustainability of Portugal's kiwifruit sector, providing additional insights into policy implications and prospective sectoral growth strategies.

Results and discussion

Sociographic profile

Regarding the sociographic profile of the sample, where males prevailed (76%), it reflects the typical gender composition of the agricultural sector. Agriculture has historically been seen as a male-dominated profession due to cultural norms and traditional gender roles, which may explain why males are overrepresented in kiwifruit production (Maman, M. and Tate, T.H. 2012). 64.9 percent are under 50 years old, which expresses a trend of a younger population since they are mainly concentrated in the 30–39 (33%) and 40–49 (26.6%) year-old age groups *(Figure 1).* At the time of the questionnaire survey application, the youngest respondent was 24 years old, and the oldest was 87 years old. Despite this youthfulness of the sample, it should be made explicit that some companies have more than one business partner and that only one was responding to this questionnaire on behalf of the other. Also, this trend can be ascribed to a number of factors, including generational succession within family-owned farms, greater interest among younger people in sustainable agriculture, and the adoption of contemporary agricultural techniques that appeal to a younger audience (Widiyanti, E. *et al.* 2018; Girdziute, L. *et al.* 2022; Srinivasan, S. and White, B. 2024). Regarding marital status, 81.9 percent are married or in de facto union, followed by single (12.8%), divorced (3.2%), and widow (2.1%).

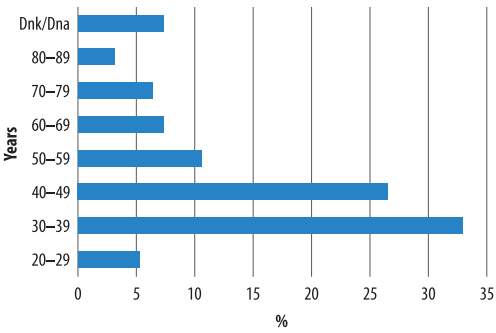

Fig. 1. Sample distribution of kiwifruit producers by age group. Dnk/Dna = Do not know / Do not answer.*Source*: Authors' own elaboration.

Of the 94 respondents, 61.7 percent were APK associates (N = 58), and 90.4 percent were associates of one of the national warehouses (N = 85), revealing that the actors of the Portuguese kiwifruit sector have strong associative links, which can be explained by the centrality of the warehouses as mediators between producers and retailers. Since the APK had 189 members when this survey was applied, this study sample represents 30.7 percent of its members. The sample revealed a high level of education *(Table 2)*, with approximately 60.7 percent of the respondents having completed at least one degree in higher education, to which must be added 8.5 percent of respondents who have attended higher education without completing any degree which may be related to the youth of the sample. Literature reveals that educated growers are likely to be more keen to adopt innovative technologies, implementing sustainable farming practices, and adapting to changing market dynamics, thereby enhancing the overall productivity and competitiveness of the kiwifruit sector (Klerkx, L. and Leeuwis, C. 2009).

Regarding the income from this activity, it can be stated that it represents a complementary economic activity and that, in most cases (72.3%), it accounts for half or less of the respondents' annual income. In fact, 26.6 percent of the respondent stated that their complementary occupation is related to intellectual and scientific activities, and 12.8 percent represents legislators, executive bodies, officials, directors, and executive managers. The complementary occupations of the sample is somewhat linked with the highly educated level of those working in the kiwifruit sector. This diversification of revenue sources may act as a risk mitigation technique, protecting growers from volatility in kiwifruit prices or yields and increasing their overall economic resilience (Lagerkvist, C.J. *et al.* 2007). The intergenerational profile of this activity shows that although not the majority, many of the respondents have family members who are also dedicated to kiwi-

Table 2. Sample distribution of workers by educational level

Educational level	Number	%	Educational level	Number	%
4th grade	3	3.2	University degree	39	41.5
6th grade, 2nd cycle	5	5.3	Post-graduate	4	4.3
5th year of high school*	2	2.1	Master's degree	12	12.8
7th year of secondary school**	7	7.4	Doctorate	2	2.1
12th year of secondary school	11	11.7	Other levels of education	1	1.1
Higher education***	8	8.5	*Total*	*94*	*100.0*

*9th grade, 3rd cycle, **11th year, secondary, *** But not completed.

fruit culture (43.6%). This study also finds couples where both spouses are kiwi growers (25.6%). These familial links not only allow knowledge transmission and skill development, but also help to ensure the sustainability and continuity of kiwifruit farming practices throughout generations (Chiswell, H.M. 2018; Sheridan, A. *et al*. 2021). In examining the sociographic profile of our sample, it's essential to recognize the multifaceted nature of kiwifruit farming. While traditional metrics such as age distribution and marital status offer insights into the demographics of growers, relational thinking prompts us to delve deeper into the intergenerational patterns and familial ties that underpin kiwifruit cultivation. Our findings reveal not just individual farmers, but families and communities engaged in this agricultural endeavor, shaping and shaped by socio-economic forces.

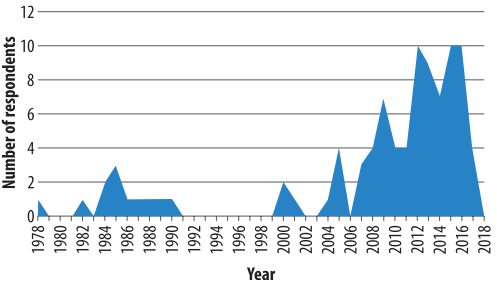

Fig. 2. Year of the beginning of the professional activity of respondents in kiwifruit producing. *Source*: Authors' own elaboration.

Socio-economic profile

Because kiwifruit production is concentrated in the Portuguese agrarian regions of Entre Douro e Minho and Beira Litoral (INE, 2019), most company headquarters are located here (97.8%). Based on the respondents' answers, the majority claim to work in kiwifruit culture either as an individual entrepreneur (58.5%) or as part of a limited liability company (29.8%). *Figure 2* shows that most respondents started producing kiwifruit in recent years, with 69.1 percent starting in the last decade (2010–2018), which is aligned with the youth of the sample. In relation to the progressive increase of the area planted with *Actinidia* in Portugal, it appears that this significant number of recent beginners to kiwifruit culture supports the growth of the sector in the last decade.

Concerning the size of the farms, the sample confirms the profile of the kiwifruit sector already identified by FAOSTAT (2020), Statistics Portugal (2019), and Antunes, M.D. (2008c). Almost 70 percent of these companies exploits farms under 5 ha, and 87.2 percent exploit up to 10 ha. In the entire sample, only two farms are bigger than 30 ha. This confirms the small scale of the farmers (97.9%), who do not have the conditions to store and mature their production after harvest. The predominance of small-scale farms in the kiwifruit sector reflects historical land distribution patterns, land availability, and economic considerations, but also sociocultural characteristics since small farms are characteristic of family-based agriculture and

may face challenges in accessing resources and markets compared to larger operations (Antunes, M.D. 2008a).

Observing companies' annual sales in 2018 reveals a significant number did not invoice or presented a reduced invoicing, in some cases, insufficient to cover the company's operating costs and/or to recover the investment made to start the activity. About 27 percent of the companies did not have a positive turnover (at least +1 EUR) in 2018. It was also found that half of the companies in the sample (52.4%) registered a turnover that did not exceed 5,000 EUR.

The recent data on orchards plantations of several companies (the sample contains 29 companies whose orchards were planted between 2016 and 2019) shows that a significant percentage of companies in the sector have reduced or non-existent turnover (INE, 2019). Furthermore, the small size of the farms in the sample demonstrates the difficulty in generating better turnovers unless these orchards were extraordinarily productive, which they are not. Despite this, it was found that some companies presented a turnover of several hundred thousand euros in 2018. Only 7 companies indicate that they have exceeded 100,000 EUR in their turnover for that year. Moving beyond surface-level measurements, our analysis reveals the complex socioeconomic framework in which kiwifruit growers operate. Rather from viewing farm size and turnover as discrete indicators, this analysis identified the underlying structures and power dynamics that shape these outcomes. A more comprehensive knowledge of the constraints and opportunities that kiwifruit growers face by contextualizing farm sizes within broader economic frameworks and investigating turnover in light of market changes and policy interventions is provided (Mishra, A.K. *et al.* 1999).

Since the companies are small, most farmers do not have permanent workers or only have one or two, and farming companies with 15 and 21 permanent workers are statistically rare in the sample (2 companies). The respondents reported considerable variations in the use of seasonal workers *(Figure 3)*: 81.9 percent had, in 2018, a maximum of 10 seasonal workers. Some companies use comparatively high numbers of seasonal workers (three companies used 20, and one company used 30). Additionally, thirteen companies did not use any seasonal workers in 2018.

In the case of the earnings received by the permanent workers, it was observed that the average wages of agricultural workers tend to be lower than those with administrative and/or management functions *(Table 3)*. Of the 33 companies with permanent agricultural workers, most pay monthly salaries close to the national minimum salary (at that time), and 11 companies pay their permanent agricultural workers between 750 and 999 EUR. As for the 18 companies that indicate they have permanent workers with administrative and/or management functions (in addition to the owner/s), the latter continue to earn salaries ranging between 500 and 999 EUR. But, three companies indicate that workers with such functions earn salaries above 1,000 EUR, and in one case, above 1,500 EUR.

Permanent workers with both types of functions receive less than 499 EUR (N = 2), assuming that, in such cases, these are part-time contracts, although this could not be confirmed by the respondents. On the other hand, more companies do not have permanent workers with administrative and/or management functions (N = 67) than com-

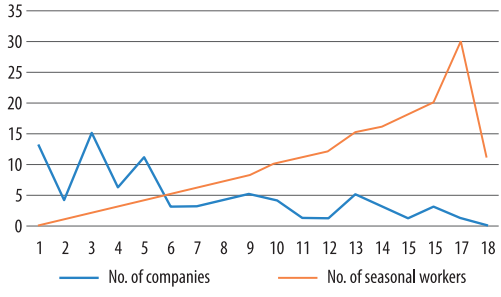

Fig. 3. Relation between the maximum number of simultaneous seasonal workers (axis y), and the number of companies (axis x). *Source*: Authors' own elaboration.

Table 3. The average salary of permanent workers

Salary, EUR	The approximate average salary of permanent agricultural workers		The approximate average salary of permanent workers with administrative and/or management functions	
	Number	%	Number	%
No workers for the role other than the owner	50	47.0	67	63.0
under 500	2	1.9	2	1.9
500–749	20	18.8	7	6.6
750–999	11	10.3	6	5.6
1,000–1,449	0	0.0	2	1.9
1,500 or more	0	0.0	1	0.9
Do not know/Do not answer	11	10.3	9	8.5

panies that do not have permanent workers with agricultural functions (N = 50), indicating that, in several of these companies, landowners primarily perform administrative and/or management functions. The amounts paid per hour of work to seasonal agricultural workers in this sample vary between 3 and 9 EUR *(Figure 4)*.

21 companies indicate that they paid these workers 5 EUR/hour (which is higher than the hourly wage corresponding to the national minimum wage). There were, however, companies that, plausibly, due to difficulties in finding workers, paid significantly higher amounts per hour of work (5 companies indicate paying 8 to 9 EUR per hour). On the other hand, 9 companies in the sample indicated that they paid less than 4 EUR/hour to seasonal agricultural workers, which is lower than the national minimum wage. While traditional assessments may focus exclusively on wage rates and workforce demographics, the relational approach applied in this study requires us to include the larger socioeconomic context that influences labour availability and remuneration. Factors such as urbanization trends, societal attitudes of agricultural work, and seasonal fluctuations in employment demand all interact to shape labour dynamics in the sector.

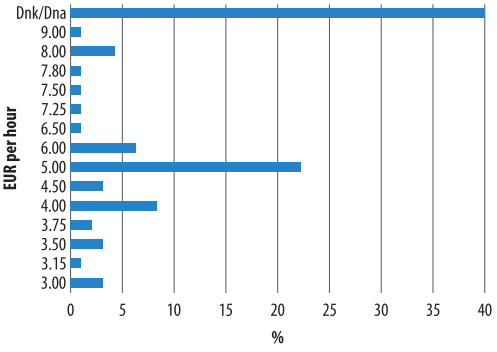

Fig. 4. Approximate average salary of permanent workers in EUR per hour. Dnk/Dna = Do not know / Do not answer. *Source*: Authors' own elaboration.

Exploratory mapping of the main current and future challenges

One of the most relevant pieces of information for the sector is to know which current and future challenges are perceived by these actors. Therefore, each respondent was asked to identify their company's top three challenges *(Table 4)*.

It is significant, from the outset, that the most frequent response was disease control in the orchards (N = 50). When this problem is combined with the challenges (mentioned less frequently) that are weed control in orchards (N = 26) and/or pest control (N = 12), we see that, agriculturally and economically, kiwifruit farmers are notoriously concerned about these issues. It is also significant that the second most frequently mentioned challenge is to find workers (N = 45). Plausibly, this difficulty explains why most of the companies in the sample pay seasonal workers remunerations higher than

Table 4. Main challenges the company faces

Challenge	Number	%
Disease control in the orchard	50	21.1
Difficulties in finding workers	45	19.0
Kiwi sale price lower than necessary to maintain the financial viability of the company	37	15.6
Weed control in the orchard	26	11.0
Difficulties with bureaucratic issues within the scope of investment projects	26	11.0
Difficulties associated with complying with legislation*	15	6.3
Pest control in the orchard	12	5.1
Logistical issues**	8	3.4
Day-to-day management difficulties of the company's employees	4	1.7
Competition from foreign companies	4	1.7
Competition from Portuguese companies	2	0.8
Other	8	3.4

*Social security, health and safety at work, etc. **Storage of production during harvest, transportation of production, etc.

the national minimum wage (in the case of some companies, more than twice as high).

A broad framework of the fluctuations of the Portuguese economy in recent decades would be necessary to adequately understand the difficulties of several companies in the sector to find workers. A discussion on employment in the primary sector would be necessary since this difficulty is extended to other agricultural sectors. The increasing urbanization that the country has experienced in recent decades (Fernandes, J.A.R. and Seixas, J. 2018), as well as the dominant social representations of what agricultural work means (when comparing country and city life), causes a significant depreciation and critical evaluation (Naiff, D.G.M. *et al.* 2009; Bonomo, M. *et al.* 2017), and may be relevant factors in understanding this challenge. Promoting fair and attractive payments to farmers is essential to enhance their willingness to stay (May, D. *et al.* 2019). Despite these reasons, the seasonal nature and inconsistency of the work, and the labour intensiveness should be also considered. The industry is perceived as low paying (despite it being found that these companies pay significantly higher amounts per hour of work to these workers) and is not particularly seen as safe (Hutchison, G. 2021).

Still, the third most mentioned challenge is the significant concern with the price at which their companies can sell their agricultural production (N = 37). There are several companies whose turnover in 2018 indicates that they had financial losses in that year, despite considering that there are other driving factors, such as the recent date of planting, which leads to the fact that they do not yet have marketable production. However, this does not invalidate that, for a significant part of the sample, kiwifruit culture was, in 2018, an activity that did not (yet) paid off the investments.

The recent date of many of the plantations that are not yet productive does not allow us to understand why, for 37 respondents, one of the challenges was the selling price of fruit, which they consider to be lower than the amount needed for their business activity to be economically viable. Other firms with older and more productive orchards also indicate difficulty in ensuring financial viability.

The national kiwifruit industry has generated an increasing overall gross production, which has benefited many of its actors. This sample seems to indicate that these economic benefits are not experienced by all, with some companies claiming to be, or at least fearing to be, in financial difficulties. It is also significant that several respondents indicate that their companies experience difficulties in administrative tasks, namely in situations where they must deal with bureaucratic and legal issues. 15 respondents mention a challenge to compliance with legislation, such as social security or

health and safety at work. At the same time, 26 say that it is a challenge to deal with bureaucratic issues in the scope of investment projects.

At this level, two possibilities are unveiled: On the one hand, these difficulties may be motivated by the obligation to comply with extensive sets of rules, sometimes not very flexible and not always easily decipherable for those without legal training. On the other hand, dealing with bureaucratic-legal issues in a business context increasingly requires full-time professional dedication or the existence of employees (or owners) permanently dedicated to administering such tasks. It is plausible that small companies, whose owners are not exclusively dedicated to the business activity and without administrative staff, as are many of the companies in the sample, experience more pronounced difficulties in this area.

Finally, our examination of the constraints and opportunities facing kiwifruit growers demonstrates the need of relational thinking in understanding complex socioeconomic events. Rather of addressing problems like disease control, labour shortages, and market prices as discrete issues, we see them as interwoven manifestations of larger socioeconomic factors. Using a relational view, it was possible to uncover underlying systemic causes and devise targeted interventions to improve the resilience and sustainability of the kiwifruit sector.

Conclusions

Data on kiwifruit sector is stills scarce at national level which limits the possibility to design and implement tailored and effective policies. To fill this gap, we conducted the first socioeconomic analysis of the Portuguese kiwifruit sector using a comprehensive questionnaire survey. While we recognise that our sample may not be statistically representative, our findings indicated tendencies consistent with indicators of the sector's economic expansion in previous decades. Given the presence of respondents with these characteristics in the sample, the data shows that several companies in 2018 did not have commercial production or positive turnover (at least not with significant values and capable of immediately ensuring the financial sustainability of these companies).

Some challenges may be pointed out, being the control of *Actinidia* diseases the currently severe problem leading to losses of plants and fruits, as well as having negative financial impacts. Equally relevant are two other challenges: the difficulties in securing workers to carry out crucial tasks in the orchards and the administrative complexities/bureaucracy that must be addressed mainly associated with investment projects, and complying with legal requirements (e.g., social security, health and safety at work). Although these are distinct problems, none of them can be solved through the actions of individual companies but rather, require coordinated collective actions. Problem resolution requires the establishment of recurrent dialogues with actors and entities outside the kiwifruit chain, such as state agencies.

It must also be stressed that several companies in the study sample declare to be concerned with their financial viability, stating that the price at which they sell their production may not be sufficient to guarantee the financial health of their companies. Even supposing that several of them will be in a more solid financial situation in a few years when their orchards have higher fruit production, the concern with the financial viability does not go unnoticed in the sample. It would also be relevant to obtain statistically representative information about the sector that would allow us to reach more reliable conclusions than those possible from this work and to conduct a more robust monitoring of the sector's evolution which could contribute to assure its socioeconomic and environmental sustainability.

The sociographic picture of Portuguese kiwifruit growers provided in this study, including demographic trends, educational levels, and family involvement in kiwifruit growing is uncommon in the previous research, which frequently focuses on larger agricul-

tural trends rather than specific subsectors such as kiwifruit cultivation. Our study fills a critical vacuum in the worldwide literature by providing researchers with a multifactorial understanding of the human components of kiwifruit farming, which may be applied to comparable studies in other geographical situations, facilitating tailored policy interventions and stakeholder engagement. While similar assessments exist for other agricultural sectors, our research provides fresh insights specific to the kiwifruit industry, such as disease management issues and labour limitations. By highlighting these sector-specific characteristics, our findings contribute to a better understanding of the socioeconomic landscape of kiwifruit production, expanding the international agricultural economics literature and informing comparative research across various agricultural sectors around the world, which may inspire similar analyses to uncover nuanced economic realities, informing strategies for enhancing sectoral resilience and sustainability.

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The authors declare no conflict of interest.

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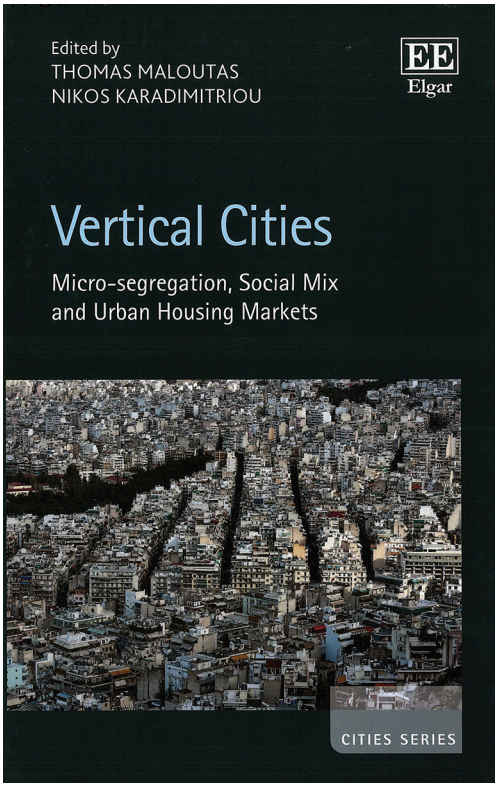
BOOK REVIEW SECTION

Maloutas, T. and Karadimitriou, N. (eds.): Vertical Cities. Micro-segregation, Social Mix and Urban Housing Markets. Cities Series, Cheltenham, Edward Elgar, 2022. 378 p.

In the book *Vertical Cities*, Thomas Maloutas and Nikos Karadimitriou explore social differentiations and micro scale segregation through several lenses. The key aspects covered in the book are: the constantly shifting social mix, which is reconfigured with changes in the housing market; micro-segregation in compact and socially mixed cities; and hierarchies and social inequalities often reproduced by processes taking place in urban spaces. The book is intended to address the question about the form, size, history, and location of micro-segregation; the social actors engaged in the process; the policies regulating the micro-segregated housing stock; the relation between micro-segregation, neighbour segregation, and gentrification; and the impact of micro-segregation on socio-spatial inequalities.



The publication has 340 pages and is divided into six major sections, with thematically grouped chapters describing cities from Europe, Africa, the Americas, and Asia. Drawing from a variety of case studies, of different geographical positioning and socioeconomic assumptions, described by 53 different authors, the volume provides a rich overview of the phenomenon of micro-segregation, its origins, typology, and projected future development. Research shows that social interplay is derived from class stratifications and reinforces these stratifications, which are embodied in regulatory grids and market forces, and that they lie at the centre of the micro-segregation existence. The book can be perceived as a continuation of research paying attention to the contextual approach to segregation (e.g., Maloutas, T. and Fujita, K. 2012; Hess, D.B. *et al.* 2018; Van Ham, M. *et al.* 2021). It enriches our knowledge about the conducted contemporary research and promotes awareness among decision-makers about the diverse meanings, appearances, and factors of the development of segregation.

In the introductory Chapter 1, the two editors indicate that the phenomenon of micro-segregation has not attracted much attention in ongoing research in urban studies until recently and needs to be introduced. Micro-segregation is studied in areas of high population density, where the city develops not only horizontally, but also vertically. The micro level refers to units smaller than the neighbourhood, and as with other forms of segregation, it is assumed that people living in spatial proximity have unequal positions according to their socioeconomic status or ethno-racial identity. Thus, groups with more resources have access to more desirable properties, while those with fewer resources are delegated to housing that offers lower standards. The examples described in the book show that social hierarchies are constantly being remodelled in space, even in individual buildings, and that social mix is not an alternative to neighbourhood segregation. Socio-spatial hierarchies, even in a socially diverse neighbourhood, are being reconstructed again at the micro level. Therefore, living in one block but on different floors may be subject to social valorisation or evaluation. The authors emphasise that processes standing behind the micro-segregation are difficult or even impossible to compare because of existing contextual differences due to historical conditions (institutional heritage), local housing market

structures, and the sorting function of the housing market. This chapter provides a great introduction to the issues covered in the tome.

The first part (*Hierarchies in Negotiated Social Mix*) concentrates on examples from Europe and Africa. In Chapter 2, Nick Dines and Cristina Mattiucci present historically conditioned vertical stratification in apartment blocks in Naples, Italy. The authors illustrate how perceptions of segregation have changed over time. They begin by showing the traditional division between social strata in tenements, where the lowest social classes occupied the lowest floors, the first and second floors belonged to people of the highest status, and the upper floors belonged to the middle class. The formation of such an arrangement resulted from the horizontal underdevelopment of the city, which contributed to the concentration (densification) of diverse functions in cities and to the diversification of existing housing stock. Although formerly existing social complexity was seen as an example of underdevelopment or deprivation in the city, today, this social complexity is considered exceptional and should be protected. The authors point out that today, this diversity is threatened by the growing importance of tourism and short-term rentals. Housing prepared for tourists is a resource that is no longer accessible to vulnerable groups, and they are being moved out of the centre, thus, diversification can diminish. In Chapter 3, Apolline Meyer and Thomas Pfirsch use two apartment-building case studies to explore micro scale residential differentiation in disadvantaged neighbourhoods in central Marseille, France. They analyse the interplay of the individual strategies of city residents, public policy, and the resilience of the urban fabric, which interact to produce new spatial patterns of social stratification at the very local scale (vary from one apartment to the next). Moreover, they show that the pattern is extremely fluid, which is a typical feature of the central 'arrival neighbourhood' and the area shaped by 'marginal gentrification'. What I found interesting is that the authors identify two ways of managing proximity between socially distant groups: 'urbanity of convenience' in buildings where residents share a community of interest over local issues rather than a common social position and 'micro-segregation' produced between more affluent resident owners and other inhabitants when the condominiums are suitable for gradual spontaneous gentrification built upon property investments.

In Chapter 4, Jihad Farah and Salah el-dinn Sadeck take us to Beirut, Lebanon, where special emphasis is placed on informal forms of housing in inner-city neighbourhoods. Most informal neighbourhoods are on the outskirts of the city, but to escape the problems of stigmatisation or the cost and time involved in commuting, migrants choose to live informally in formal neighbourhoods. These are often so-called micro-houses on rooftops, added parts to the back of the house, or apartments divided into smaller ones. What seems noteworthy is that they are often part of informal constant negotiations that lead to decisions about what practices are considered legal and socially acceptable (authors call it 'different forms of inclusion of the margins'). Adopting such a strategy based on informal relationships contributes to increased vulnerability and insecurity for some groups, which, according to the authors, should be taken into account in urban policies. In the next two chapters , the authors deal with Athens, Greece, where research has long been conducted on the vertical dimension of segregation (Maloutas, T. and Karadimitriou, N. 2001). Chapter 5, written by Ifigeneia Dimitrakou, Dimitris Balampanidis, Nikolia Myofa, Iris Polyzou, Dimitra Siatitsa, Stavros Spyrellis, and Konstantinos Vakalopoulos, provides an introduction to segregation research conducted in Greece and introduces the concept of '*antiparochi*' – a market-based mechanism of housing production associated with the massive densification of housing in city boundaries and '*polykatoikia*' = which is a typical Athenian post-war residential building. *Polykatoikia* is seen as a unit in which the social mix and diverse relations between residents are visible, but also which, in everyday life, do not at all imply socio-spatial equality but rather replicate segregationist behaviour on a micro scale. In Chapter 6, Thomas Maloutas, Stavros Spyrellis, and Nikos Karadimitriou, in turn, propose a new way to study segregation based on microdata. This is the only chapter in the volume that concentrates on methods. It is worth attention, as proposed solutions allow for separating the city space into areas in which segregation is more or less visible. The method is promising and indicates in a more precise way the intensity of vertical segregation and the social context within which it is developed.

Chapter 7 opens Part II, called *Spatial Patterns of Ethnic Proximity*. Issues of segregation based on ethnicity or being of migrant origin are often addressed in studies of segregation (e.g., Anderson, H.S. 2019), but less so in micro-segregation. In Chapter 7, Marinus Cornelis Deurloo, Sako Musterd, Bart Sleutjes, and Jeroen Slot deal with Moroccans living in Amsterdam, the Netherlands, and present what seems very thought-provoking, that within a single nationality group, the level of segregation can vary, and spatial segregation does not necessarily mean lack of integration, quite the opposite, better integration. The authors' observations indicate that the social structure is much more complicated than the picture we get using segregation indicators.

In Chapter 8, Jesus Leal and Daniel Sorando point out the divisions between migrants and native Spaniards and the diversity among migrants themselves in Madrid, Spain. Particularly apparent is the segregation of migrants from low-income countries,

who are concentrated in lower-floor apartments in older buildings in central locations. Here, it turns out that affordability plays a significant role, and the cheapest apartments are right in the ground-floor apartments and are used by migrants from poorer countries, while migrants from richer countries have more opportunities to be active players in the real estate market and rent apartments offering better housing conditions.

Chapter 9, by Juan Jose Natera-Rivas, Remedios Larrubia-Vargas, and Susana Navarro-Rodriguez, takes us to the Haza Cuevas, one of the neighbourhoods in Málaga, Spain. The authors show that the number of migrants has been increasing since 2010, and the sorting function of the housing market is apparent, as in, for example, Madrid (Chapter 8) or Tel Aviv (Chapter 18). More affordable apartments on floors in buildings without elevators are occupied more often by migrants from low-income African and Latin American countries. These apartments are unpopular and less expensive; hence, they are more accessible to this group of migrants. This arrangement appears to be a natural adaptation to existing housing market conditions. We can observe here an increase in social mix, which does not imply equality in access to resources but rather reflects existing divisions of groups or social classes.

In the next section (Part III, *Hierarchical Proximity in Segmented Housing Markets*) the authors discuss case studies beyond Europe, where housing relations are even more diverse. In Chapter 10, Sainan Lin and Zhigang Li examine the three largest cities in China (Beijing, Shanghai, and Guangzhou), showing the differences in access to housing between urban residents and migrants from rural areas. Negative vertical segregation particularly affects the latter group, and existing regulations push migrants into the informal sector. The authors describe basement apartments (which were supposed to serve as air raid shelters) in Beijing, group rental ('shared rental') strategies in Shanghai, and the process of development of urban villages in Guangzhou. The chapter may be of great interest to European readers. The authors described the complex social and urban fabric of very dense areas well. The occupation of basements and sub-standard housing in Beijing and Shanghai is often invisible to the residents of the other (upper) floors, and its residents of informal housing constitute an 'invisible population of the city', without human agency. In the case of Guangzhou, informal self-building in urban villas has increased density, creating the so-called 'hand-shaking buildings' or 'a glam of sky buildings' wherein one can shake hands with neighbours in the next house or can only see a gleam of sky when standing in the alley. In Chapter 11, Vinicius M. Netto, Camila Carvalho, Maria Fiszon, and Yasmin Couto analyse the case study of Rio de Janeiro, Brazil. The authors present a very good study of the overlapping of social disparities. The researchers point out the relationship between property type, income, skin colour, political, sexual, and religious orientation and overlay this with issues of the formal and informal housing market. They also show that the process of social 'sorting' occurs within informal neighbourhoods ('segregation within segregation'), and these neighbourhoods are far from homogeneous. Micro-segregation also in the case of favelas reveals complexities, with internal inequalities that are echoes of inequalities found in the city as a whole.

Part IV (*Social Mix in Recommodifies State Socialist Cities*), as the name suggests, takes us to post-socialist Europe. In Central Europe, which is considered a region with low segregation rates, vertical segregation does exist, although it has a different basis than in the countries discussed in earlier chapters of this book. In Chapter 12, Szymon Marcińczak and Daniel Baldwin Hess deal with the two capitals of Bucharest, Romania, and Budapest, Hungary. The authors aptly demonstrate that despite the existing stereotype and prevailing ideology about egalitarianism in socialist cities, access to housing and location varied and reproduced, in part, existing social divisions. During the socialist era, housing was distributed according to status and the role of the household in the economic system. Later transformations, including those involving the privatisation of the housing market, overlaid earlier divisions. In Central Europe, within different neighbourhoods and types of housing, vertical segregation and micro-segregation take different forms (Jaczewska, B. and Grzegorczyk, A. 2017, 2018). Generally, what seems to be common also in other post-socialist countries is that the higher-status and wealthier households tend to live on intermediate floors (1st-2nd floors) and, thus, do not experience problems with the availability of higher floors or excessive noise on the first floor.

In Chapter 13, Zoltán Kovács, Judit Székely, and Balázs Szabó prove that in post-socialist countries, vertical segregation is linked to the period in which the building was built. Based on research in Budapest, Hungary, they indicate that vertical micro-segregation is more often seen in buildings that were constructed before 1945 than in those built during socialism and afterward. Moreover, new divisions are created in the newest buildings built after 1990, where the level of segregation is not significant, but strong differences related to the occupation of the most attractive apartments by those with higher incomes are visible. It is worth noting that the chapter very well describes how the approach to the study of segregation and how the historical conditions of Budapest's development have changed, making it a valuable case study.

Similarly, broadly described in Chapter 14 are conditions shaping the Dorćol, a central neighbourhood in Belgrade, Serbia. Ivan Ratkaj, Aljoša Budović, and Nikola Jocić illustrate the historical conditions of the

neighbourhood's formation, its changing status over time, and the evolution that has been taking place in recent years. With a spatially limited scope of formal urban development, Belgrade's urban landscape has always expressed horizontal differentiation, with higher socio-economic strata living in central areas and lower strata in the informal housing in the periphery. This pattern continued under socialism, and only post-socialist privatisation erased public renting versus private owning differences and shaped a housing market with high rates of homeownership. In recent years, commodification and gentrification have changed the face of the Dorćol neighbourhood and the area is becoming attractive for urban redevelopment and less socially diverse.

Chapter 16 tells the story of Tallinn, Estonia. Kadri Leetmaa, Elina Maarja Suito, Kadi Kalm, Ingmar Pastak, and Tiit Tammaru point out that the city's situation today is also linked strongly to its history. Almost half of the housing stock was destroyed during the war, and new housing in line with socialist ideas was built after the war. This contributed to a significant diversification of the housing stock in the city centre as well, and reinforced social differentiation. The authors additionally indicate that modern changes resulting from commodification and increasing social differentiation have not contributed to a decrease in the social mix but have actually strengthened it. Diversified housing stock is occupied by representatives of different social groups according to their demands. Nevertheless, at the micro level, segregation is growing, and we can speak of an increase in the polarisation and fragmentation of the city because the processes of reconstruction, revitalisation, or gentrification are occurring at points and not in the entire city centre.

In Part V (*Proximity in Gentrified Urban Spaces*) the impact of gentrification on urban areas is investigated. In Chapter 16, Eftychia Bournazou examines the transformation of the social mix in Mexico City, Mexico, and points out that, in the case of this city, the problem is not a lack of social diversity, which is very high, but a pre-division of poverty and inequality in access to public services. The author points out that state policies that support elite interests, with inadequate controls on housing investment and little state involvement in social housing, mean that gentrification processes are taking place spontaneously, with the most vulnerable groups experiencing further problems with access to housing, relegation to peripheral areas with poorer access to services, and further impoverishment.

In chapters 17 and 18, the authors focus on neighbourhoods in Tel Aviv, Israel. In the former, Tal Shamur and Haim Yacobi give an interesting description of the Gan Hahashmal neighbourhood's history and its evolution from a neighbourhood inhabited by the upper class, then turning into a neighbourhood in decline, and in recent years transforming again under the influence of gentrification. The district's central location means that it has a very diverse social and functional structure. On the one hand, you will find a luxury commercial and leisure hub, a central bus station, gentrifiers, and, on the other hand, members of the lower class. There is also an area where marginal activities, such as drug trafficking and prostitution at night, take place. The authors show the complicated relations between different social groups and how the social mix created by gentrification deepens social differentiation (social hierarchies). Chapter 18, written by Shlomit Flint Ashery and Rinat Steunlauf Millo, describes the changes taking place in the Neve-Sha'anan neighbourhood, which has been transformed by the influx of refugees and immigrants over the past 30 years. As in the case of Málaga, Spain newcomers with irregular status occupy small commercial units on the first floors of residential buildings or the upper floors of buildings without an elevator, i.e., apartments that are less attractive and more affordable. The changes that take place and a substantial social mix are not seen as positive and raise questions about the relationship between representatives of different social groups living side by side.

Part VI (*Hierarchies in Housing Towers*), addresses the divisions observable in high-rise buildings. In Chapter 19, Yu-Min Joo shows the considerable dynamics of transformation in Seoul, South Korea (the author called Seoul 'the capital city of the republic of apartments'). Numerous housing developments subdivide the fact that buildings offering different housing conditions exist side by side; hence, micro-segregation is evident more between housing types than within each type of building. Again, the author points out that despite the increase in social differentiation and the reduction in the level of social polarisation, it has not been possible to integrate individual social groups, despite their clearer spatial proximity. A similar situation is described in the case of Hong Kong in Chapter 20. The city is characterised by significant social differentiation and overlapping social divisions, with representatives of different groups living close to each other due to a lack of land and the influence of local housing policies. Hand Kei Ho and Maurice Yip point out that the social mix is provided by the existence of different types of real estate side by side, where at two opposite ends are luxury apartment buildings offering exclusive services and subsidised housing. This chapter describes the housing strategies adopted by representatives of the upper, middle, and working classes. What seems interesting is that the issues of family relations and family support in accessing housing are here important, which, although not analysed widely in this book, are significant for housing strategies in tight housing markets, e.g., in Central Europe.

In Chapter 21, Ernesto López-Morales and Ignacia Arce Abarca describe the pull and push forces in high-rise developing neighbourhoods in Santiago, Chile. The authors compare how density is perceived by residents of the four housing types, and they indicate that pressures are contributing to pushing especially home renters to move out of the inner city. In Chapter 22, we return to Europe. Using the example of recently built high-rise buildings in Vienna, the authors Walter Matznetter and Robert Musil show that even in a city with excellent social housing policies, isolated units of social privilege can arise.

The book *Vertical Cities* provides an original approach to an under-researched topic, making it a vital resource for academics, researchers, practitioners, and policymakers. Urban sociologists, housing experts, and those interested in urban studies and geography will find the book's insights valuable. The undoubted value of the book is that the authors were tempted to provide detailed descriptions of case studies and pay attention to the context and peculiarities affecting the formation of socio-spatial differentiation. The book, as I tried to show above, contains many interesting characteristics of social stratification and, importantly, comes from different parts of the world. In the book, we will find analyses of various aspects, but no suggestions for practical solutions or actions. It is also difficult to get an assessment of whether vertical segregation is a positive or negative phenomenon. It challenges us to rethink our urban narratives and invites us to explore the hidden layers of urban social co-existence.

In my opinion, the volume illustrates the socio-spatial diversity and complexity of contemporary cities well. Even if the analyses are not always very detailed, the authors examined how the housing market perpetually reconfigures the social mix, how the structure of the housing stock shapes social dynamics, and how policies are deployed to manage these effects. The book also delves into micro-segregation, and the authors investigate the form and content of social and ethno-racial hierarchies within the socially mixed and dense centres of compact cities worldwide. It sheds light on how these hierarchies have evolved over time. Moreover, it examines how the materiality of these hierarchies significantly impacts the reproduction of social inequalities in today's large cities. It underscores the delicate balance between social cohesion and fragmentation, urging practitioners or policymakers to engage critically with the discussion about the diversification of the social mix that defines our cities.

The content of the tome makes an important contribution to scientific research on segregation. This book offers a fresh perspective on the complex dynamics of urban living and the challenges faced by vertical cities. Certainly, the publication enriches our knowledge of the research being conducted and promotes our knowledge of the diverse shapes of segregation. Whether you are an academic, practitioner, or simply curious about urban complexities, *'Vertical Cities'* is an interesting and thought-provoking read, and it is for you.

Barbara Jaczewska[1]

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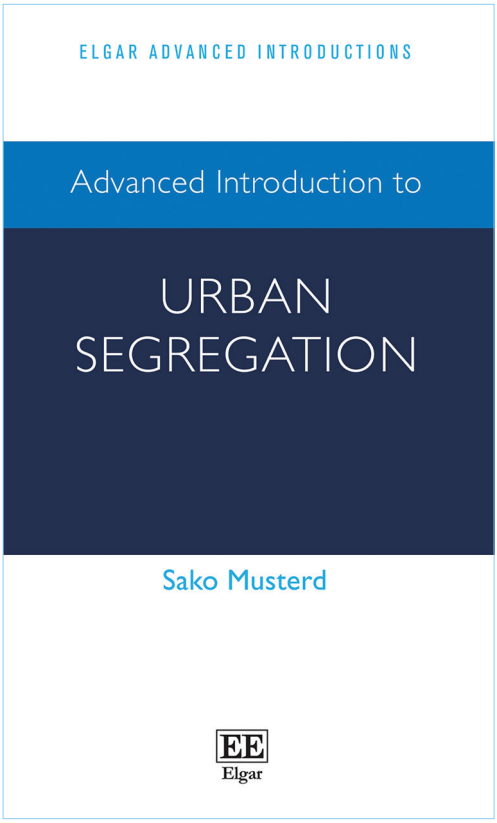
Musterd, S.: Advanced Introduction to Urban Segregation. Cheltenham, Edward Elgar, 2023. 194 p.

Collecting, analysing and summarising the essence of more than a hundred years of research on segregation is not an easy task. Myriads of authors have examined this topic from several angles (e.g., education, income, religion, etc.), on different territorial scales and with several qualitative and quantitative (mathematical and statistical) methods, and have developed concepts on social inequalities and their spatial formations (Maloutas, T. and Karadimitriou, N. 2001; Reardon, S.F. and O'Sullivan, D. 2004; Simpson, L. 2004; Maloutas, T. and Botton, H. 2021). This book is seminal in the literature on urban segregation and a basic reading for those who are interested in the subject. Sako Musterd, the author of the book from the University of Amsterdam has been working on segregation for three decades and has collected ample experiences and international reputation (Musterd, S. 2005, 2022; Musterd, S. and Andersson, R. 2005).



In addition to his own professional experience, he presents in this book the results of several well-known researchers in the field from many different countries of the world thereby helping the reader navigate the abundant literature. The book discusses various dimensions of socio-spatial separation and helps us understand this complex process via eight chapters, and by the end of the book readers can gain a comprehensive picture of urban social segregation.

In the first chapter, the author introduces basic terms and concepts, the knowledge of which is essential when it comes to segregation research. Within urban segregation, there is a specific focus on ethnic segregation in the literature, but in this regard, there are also marked differences between European and American segregation research. The most important studies in the field published in the 20th century are introduced and discussed mainly in this chapter.

After the general picture of urban segregation, the second chapter answers the questions that often come to the fore regarding segregation, and also indicated in the title: *Contemporary debates on urban segregation: 'why', 'who' and 'what' questions*. Musterd points out that there is a stigmatisation of segregation both within the society and in politics, but we cannot scientifically distinguish between good and bad segregation, and we should not lose sight of this. In this chapter, segregation is portrayed and discussed as a result of personal choices and social constraints. Although everyone is free to choose their place of residence, the guiding principle is to be close to specific income or social groups (e.g., people with the same high income are concentrated in urban areas), but urban policy aimed at social and cultural mixing is also at play. The degree of segregation in urban space varies widely, and the author raises the question of whether it is necessary to address the degree of segregation. Even if it is only present to a small extent, it still causes problems and challenges, and needs to be addressed.

In the third chapter, the author uses European and American examples to present concepts and dimensions related to urban segregation. Four spatial forms come to the fore: dispersal, colony, enclave, and ghetto. In each case, the term explores the relationship between immigrants and the host society.

The fourth chapter (*Measuring segregation: 'how' questions*) provides guidance on how such a diverse phenomenon as segregation can be measured. First, the relevance of the size of the study area is considered, since irrespective of what scale it is on, the smaller units we study, the higher value we can get, and this is demonstrated by the example of the dissimilarity

index. Furthermore, the author draws the attention of the reader to the fact that existing censuses carry the gerrymandering effect, i.e., units are separated that can produce results suitable for the given municipality or party in an election. Musterd walks through the evolution of computational indices related to segregation, but he also briefly criticises them. Mathematical and statistical calculations can provide a general picture of urban segregation, but qualitative research is essential to gain a deeper understanding of the causes of social segregation. The author also draws attention to the need to be critical of statements that are deemed acceptable, as this is the key to progress. After the classic measurement methods, Musterd presents the new trends of the 21st century, which he briefly calls the next generation of methods. What makes it different from previous approaches is that they dynamically explore the phenomenon of segregation. Research no longer looks only at where certain groups of people live, but also pays attention to people's daily activities, which has been made possible by the availability of Big Data approaches. Another contemporary innovation is the emergence of a new scale in segregation research, namely the micro scale, which puts the small-scale mechanisms and forms (units below the level of the neighbourhood) in the focus of investigation. In this chapter, readers may feel a sense of lack because there are fewer examples behind the statements, at least compared to the previous chapters.

Although the book as a whole is intended to help the reader understand the complexity of segregation, Musterd devotes a chapter to making urban segregation understandable. In the fifth chapter, the author uses European examples to demonstrate how different forms of segregation look like. The differences may arise from the size and characteristics of the study area or the investigated groups. In addition, the chapter deals with the interpretation and degree of assimilation, showing urban examples of why a group can or cannot assimilate into the majority society. After this, the reader may legitimately ask how urban segregation should be interpreted and, last but not least, understood. In this chapter, the author answers this question, highlighting some aspects that play a role in the fact that urban segregation appears in different ways in different countries of the world. One aspect Musterd points out is the proximity of social groups to each other or even their distance. In addition, the behaviour of individuals is linked to territorial segregation. Finally, he highlights the historical development of cities and cultural factors, which all influence the development of segregation.

The sixth chapter is about synthesising the knowledge acquired so far and bringing the neighbourhood level to the fore. The neighbourhood level has already been mentioned, but in this chapter, the author connects and elaborates on the importance of the territorial level in general in segregation research. Furthermore, he discusses the methodological problems in segregation research that may influence the results produced.

The first part of the book, including six chapters, is about segregation research, the main results achieved in the field, and in what direction it is currently developing. In the seventh chapter, however, the solution options are discussed that have been born on the side of decision-makers. Musterd cites Esping-Andersen's work and use it to show how the three categories of the welfare state (liberal, conservative-corporatist, social democratic) relate to and manage urban segregation. The author presents social mixing at the neighbourhood level as a possible solution to overcome social and spatial inequalities and separation. This approach aims to bring social groups together within a given geographical area, thereby ensuring equality between groups (e.g., in access to health or education). There have been certain criticisms in the literature about mixing neighbourhoods, which the author also presents here. Musterd's presentation of multiple sides provides an overall picture of how difficult it is to understand and handle segregation. Although it can be stated that the initiative of the mixing neighbourhood or even the Danish Ghetto is solution-oriented and has a positive vision, they often have some negative consequences as well.

In the last (eighth) chapter of the book, the author reflects on the emerging questions and problems discussed partly in earlier parts of the book but have not been elaborated in detail. First, the issue of micro-level segregation research is discussed. Research results on this aspect of segregation have been published in the past two decades, but the phenomenon had existed well before. The process of motorisation and suburbanisation has reduced the degree of and attention to micro-segregation, and the study of social separation is increasingly concentrated on larger territorial units. The city centre has become the residence of the lower and middle classes, which, for example, did not show any differences between social groups at the district level. Research on a micro scale (e.g., at street level), however, offers a new opportunity to present areas that previously appeared socially homogeneous as heterogeneous, seen from a different perspective. As a result, previously unknown social tensions and conflicts that determine urban dynamics can be revealed. The exploration of conflicts between social groups in cities is necessary because it can reveal the existing gaps between them. Another message of this chapter is the geographical study of segregation. Residential segregation is often studied and statistically interpreted at the macro scale as the spatial separation of groups within society. In segregation research, however, the use of public spaces or mobility and related conflicts are less frequently discussed, and according to the author, more attention should be paid to these aspects as well. Finally,

Musterd formulates a critique of nomenclature, i.e. that the term ethnic and immigrant segregation, even by its formulation, implies opinion and feeling. The author encourages interested readers to create a neutral demographic indicator of the topic.

Overall, this book is a great overview of urban segregation and fulfils all expectations of potential readers. The author presents social separation and its myriad faces through Asian, American, and European examples. The book can be recommended not only for university students but also for those who are interested in urban social geography, the history and contemporary forms of urban segregation. The most important milestones of segregation research are introduced and discussed in the volume, but it can also serve as a starting point for those who are interested in the topic and want to explore the basic literature.

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