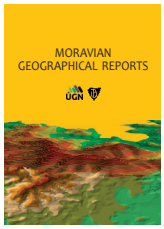

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Dynamics of residential suburbanization in post-socialist countries: The case of the Warsaw Metropolitan Area

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Abstract

In post-socialist countries, in recent years, scientific debate has focused on extensive and uncoordinated suburbanization, which has led to fragmented settlement expansion into rural areas increasingly distant from the core city. Although suburbanization in this part of Europe has intensified, its dynamics have become increasingly differentiated within individual urban regions. The aim of this paper is to determine the dynamics of suburbanization across the entire Warsaw Metropolitan Area and within its internal structure, as well as to identify the probable causes and consequences of the observed changes in the scale of the analyzed processes. It verifies the hypothesis that since the mid-1990s, the initially more extensive spreading of the population in rural areas of Warsaw region has gradually shifted toward greater concentration in a limited number of municipalities. In this study, the k-means classification method was applied. The findings confirmed that the majority of the WMA municipalities remained demographically active throughout the entire study period, however, a more extensive pattern of suburbanization, characterized by smaller differences between units of analysis, is shifting toward a more concentrated form. The most significant turning points that accelerated the change in the character of suburbanization towards greater selectivity were the 2009 economic crisis and the pandemic.

Keywords: Residential suburbanization, dynamics of suburbanization, types of dynamics, Warsaw Metropolitan Area, post-socialist countries

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1. Introduction

In many post-socialist cities, the 1990s initiated residential suburbanization, which is one of the most remarkable and dynamic socioeconomic process and simultaneously a kind of reaction on decades of centrally planned economy (Kotus, 2006; Ouředníček, 2005, 2007; Tammaru et al., 2009; Stanilov & Sýkora, 2014). The political transformation enabled the expansion of residential construction and the fulfilment of individual needs that had previously been suppressed (Schneider-Sliwa, 2006; Leetmaa et al., 2009; Kubeš, 2013). This development was facilitated, among other things, by the transfer of power from the state to local authorities, as well as the rejection of spatial planning in the early stages of the transformation and its significant liberalization in the following years (Stanilov & Sýkora, 2014). This has led to mass suburbanization – understood as the urbanization of the suburban zone in its social, functional, and spatial dimensions – driven by the spatial decentralization of population and economic activity. This process often unfolds in an extensive and uncoordinated manner, resulting in considerable spatial chaos and fragmented settlement expansion into rural areas located increasingly farther from the core city, yet still within its functional sphere of influence.

Previous studies show that suburbanization in some city regions of Central and Eastern Europe (CEE) has intensified. At the same time, within certain urban regions, spatial patterns and internal dynamics have shifted from extensive to more concentrated forms in selected municipalities (Ouředníček et al., 2019; Pénzes et al., 2023). However, there is a lack of analyses that complement the existing body of knowledge with insights into the recent development dynamics of suburban municipalities, particularly following the pandemic period. This paper contributes to a deeper understanding of the suburbanization process in rural areas of the Warsaw Metropolitan Area (WMA), focusing on its long-term dynamics and the most recent trends.

The aim of the study is to determine the dynamics of suburbanization across the Warsaw Metropolitan Area (WMA) as a whole and within its internal structure, as well as to identify the probable causes and consequences of the observed changes in the scale of the analyzed processes. It addresses the following research questions:

1. What are the changes in the pace of deconcentration of population in the long-term perspective in rural areas of the Warsaw Metropolitan Area as a whole and within the region?
2. What potential factors and consequences of shifts in the scale of suburbanization within the WMA can be inferred from the identified spatial and temporal dynamics?

In this paper, the dynamics of suburbanization, as a key term, will be understood as changes in the degree to which the scale of the phenomenon in individual units of analysis deviates from the average for the entire WMA. The methodological aim of the research is to test the applicability of the k-means classification method for

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analyzing long-term changes in phenomena, using an approach that differs from time-series clustering (Kobylin & Lyashenko, 2020; Watanabe, 2022). In this research, instead of analyzing the similarity of changes in the values of individual indicators over time, the focus was placed on changes in the assignment of the studied units to particular clusters across successive periods.

2. Theoretical background and hypothesis

Although suburbanization has become a broadly discussed topic in the literature (Hirt, 2007; Kok & Kovács, 1999; Tsenkova & Budic, 2006; Ouředníček, 2007; Soaita, 2013; Sandu, 2024), we still lack a common methodological approach and a generally accepted definition of the process itself, which obstructs any rigorous comparisons between cities and countries (Ouředníček et al., 2019). Suburbanization is generally defined as a process of deconcentration of population and its activities from the core of metropolitan region to its hinterland (Timár & Váradi, 2001; Tammaru et al., 2013; Ouředníček et al., 2019), where the dominant land use is residential (Simon, 2021). Suburban areas, especially in post-socialist countries, experience dispersed and chaotic residential development, a process known as urban sprawl. The European Environment Agency (EEA) has described urban sprawl as "the physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas" (EEA, 2006, p. 5). Urban sprawl is commonly used to describe the extensive physical expansion of urban areas, often accompanied by a chaotic urban form resulting from weak planning control over land subdivision. Development under urban sprawl is patchy, scattered, and stretched out, often characterized by discontinuity and resulting in numerous negative impacts (Mantey, 2011; Grădinaru et al., 2015; Nagy & Hegedűs, 2016; EEA, 2006; Cocheci & Petrisor, 2023). Despite the negative impacts of urban sprawl, individual residential preferences frequently lean towards lower-density housing areas (Howley, 2009; Mantey, 2021; Huang et al., 2023). In this context, the discussion about extensive *versus* intensive suburbanization gains additional justification.

This paper focuses exclusively on residential suburbanization, understood as a specific aspect of suburbanization that is closely related to population and housing functions. Since it focuses on the scale and dynamics of population inflow rather than on urban or rural morphology, density, livelihoods, or functional ties with the urban core, the article consistently uses the term 'suburbanization', irrespective of the specific zones in which these processes occur.

One of the approaches to defining residential suburbanization delineates the outflow of the population from central parts of the city to its periphery within the functional urban area. This implies that the direction of migration (outward movement) is a key determinant of the process (Tammaru et al., 2009; Kurek et al., 2017; Korwel-Lejkowska, 2021; Szmytkie, 2021). Although most definitions mention core cities as an outflow area, it is highly probable that nowadays, smaller cities also generate decentralization of the residential function to their own hinterlands. The tendency for settlement dispersion therefore applies to cities of all size categories (including even the smallest ones) (Bojarska-Lis, 2024).

The second approach defines suburbanization as a process in which the suburbs grow at a faster pace than the urban core. This implies that the source of migration includes not only the urban core population but also residents of the functional urban region or even individuals from outside this area (Kontuly & Tammaru, 2006; Gnatiuk, 2017; Slaev et al., 2018). Considering the varying definitions and analytical approaches to suburbanization (Kryczka et al., 2025), this article integrates both perspectives and further extends them by incorporating Ouředníček's (2007) view, which considers residential suburbanization as involving not only population relocation but also the development of new housing. Adopting a clear definition of suburbanization is essential when selecting indicators to analyze the scale of demographic processes and their changes over time.

Assuming that suburbanization is a process shaped by migration patterns, it is important to note that suburban municipalities are subject to migration flows, differing in terms of the types of both source and destination settlements, which in both cases can be a city, suburb, or countryside. The net population growth or decline results from the balance of nine distinct urbanization processes occurring simultaneously, e.g., urbanization as a migration from the countryside to cities and suburbs, suburbanization as a migration from the city to its suburbs, and counterurbanization as a movement from cities and suburbs to rural areas (Ouředníček et al., 2019). However, migration from the core city to the suburban hinterland does not necessarily involve the construction of new residential buildings. There are four special migration streams according to types of housing: (i) suburbanization (migration to a new house); (ii) migration to older houses (former rural villages); (iii) elderly migration to social care institutions; and (iv) migration to recreational houses (cottages) (Ouředníček et al., 2019). In CEE countries, the expansion of urban functions increasingly includes the development of shopping centers, logistics facilities, and industrial zones (Sýkora, 1999; Matlovič & Sedláková, 2007). However, non-residential suburbanization was not the subject of this analysis.

Post-socialist city regions continue to experience significant in-migration, which has transformed their sociodemographic structure, economy, and spatial organization. However, the pace of development across individual municipalities is becoming increasingly differentiated. Studying the internal differentiation of suburbanization processes within city regions is important from both a cognitive and practical perspective, as it enables more effective transport management and more rational allocation of public funds. Some municipalities that have entered a phase of slower development – reflected in a slowdown in suburbanization processes – have typically exhausted their available resources or lost their attractiveness for other reasons (Dudek-Mańkowska et al., 2024). Other units continue to grow dynamically, although the so-called 'new suburbs', described in the literature as functionally diverse subcenters primarily focused on employment (Hall, 2001; Sieverts, 2003, 2011; Young & Keil, 2014; Young et al., 2011), have not yet emerged in this part of Europe. The formation of such subcenters, often described as polycentric post-suburbanization and exemplified by forms such as edge cities (Garreau, 1991; Aguilera & Mignot, 2004; Derudder et al., 2022) or suburban downtowns (Hartshorn & Muller, 1989), remains characteristic of global city-regions. Residential suburbanization in the former socialist countries is generally taking place at a lower rate compared to the United States or Western Europe, since in Central and Eastern Europe, the most intense phase of residential deconcentration coincides with slow or negative population growth and limited municipal resources to extend infrastructure to outlying areas (Dinić Branković et al., 2016).

Regarding the transformation of Polish urban regions, issues related to the rapid and uncontrolled spread of urban development in Poland began to gain momentum in the mid-1990s and have since become the subject of numerous studies and expert analyses (Lorens, 2005; Kozłowski, 2006; Lisowski & Grochowski, 2008; Mantey, 2011), which initially focused on the spatial, social, and economic consequences of suburbanization around major cities. However, it quickly became evident that suburbanization is widespread across all categories of cities, not just the largest ones (Śleszyński et al., 2021), although the most intensive suburbanization processes are observed around the biggest urban centers. Between 1995 and 2021, the zones surrounding the 'big five' cities (Warsaw, Krakow, Poznań, Tricity and Wrocław)

experienced particularly strong demographic growth, with the population increasing by 60% (*ibid.*). However, the development of each urban region is internally diverse. According to Dudek-Mańkowska et al. (2024), the rate of suburbanization in municipalities within the Warsaw Functional Area is influenced by various factors, with land rent and transport accessibility having the greatest impact on the popularity of individual municipalities. Bogusz et al. (2024) identified pull factors that positively correlated with the number of migrants. They confirmed that migrants tend to choose urbanized municipalities with good institutional amenities (such as kindergartens and nurseries) and those located within a shorter driving distance to Warsaw. Migrants are also guided by social affiliations, such as income (reflecting municipal wealth) and support for the socially and economically liberal KO (Koalicja Obywatelska) party. The somewhat surprising positive association between the number of migrants and the median parcel price probably also reflects the social status, as the municipalities bordering Warsaw are typically inhabited by relatively affluent populations. A study of the Mazowieckie Voivodeship (Ajdyn et al., 2023) indicates that municipalities in suburban zones experiencing significant population growth are characterized by a younger age structure, a higher fertility rate, and are generally 'demographically younger'. Consequently, their demographic situation is substantially more favorable compared to areas that are far less attractive for settlement. In the future, this may exacerbate disparities in suburbanization dynamics, further increasing differences between individual municipalities within the WMA.

Building on previously discussed analyses of suburbanization dynamics in CEE urban regions and in the WMA, this study tests the hypothesis that, since the mid-1990s, the initially more extensive spreading of the population in rural areas of the Warsaw region has gradually shifted toward greater concentration in a limited number of selected municipalities. In the context of suburbanization, extensiveness refers not only to the widespread population growth and low-intensity development across a wide area, but also to more evenly distributed development expressed in smaller differences between the analyzed rural units. In this study, the focus is primarily on the latter interpretation of this concept.

3. Materials and methods

3.1 Study area

The area of study is the Warsaw Metropolitan Area (WMA) according to the EU NUTS2 division. It covers an area of 6,000 km^2 and consists of 9 counties and 70 municipalities located within them, including Warsaw; 14 urban municipalities whose boundaries coincide with those of a city (regardless of its population size or administrative role); 22 urban-rural municipalities that encompass both a city and surrounding villages; and 33 rural municipalities consisting exclusively of villages. In 2023, the WMA was inhabited by over 3.3 million people, marking a significant increase from 2.6 million eighteen years earlier. During the same period, Poland's population decreased from 38.6 million in 1995 to 37.6 million in 2023. The WMA is one of the most dynamically developing agglomerations in Europe.

Assuming that suburbanization primarily affects rural areas, the study used data for rural municipalities and the rural parts of urban–rural municipalities (both categories will hereinafter be referred to as units). Municipalities that changed their status from rural to urban–rural between 1995 and 2023 (Cegłów, Halinów, Latowicz, Mrozy, Tarczyn, Jadów) were excluded from the analysis, as this status change affected the way data were aggregated by Statistics Poland. The exclusion of cities from the study area was a deliberate decision, based on the research objective, which focuses exclusively on suburbanization in rural areas rather than across the entire metropolitan region. Similarly to rural areas, satellite cities also attract many migrants from the core city, yet they are simultaneously subject to suburbanization processes themselves. Moreover, cities are primarily subject to densification and intensification of land use, whereas suburbanization involves the development of new residential and service areas, often on formerly agricultural land. This distinction is well illustrated by population density data. In 2023, the median population density for cities within the WMA was 1,063 people per km^2 (with values ranging from 157 to 4,130 people per km^2), while for rural municipalities or the rural parts of urban-rural municipalities, the median was 131 people per km^2 (ranging from 24 to 560 people per km^2) (Fig. 1). For these reasons, the study area has been

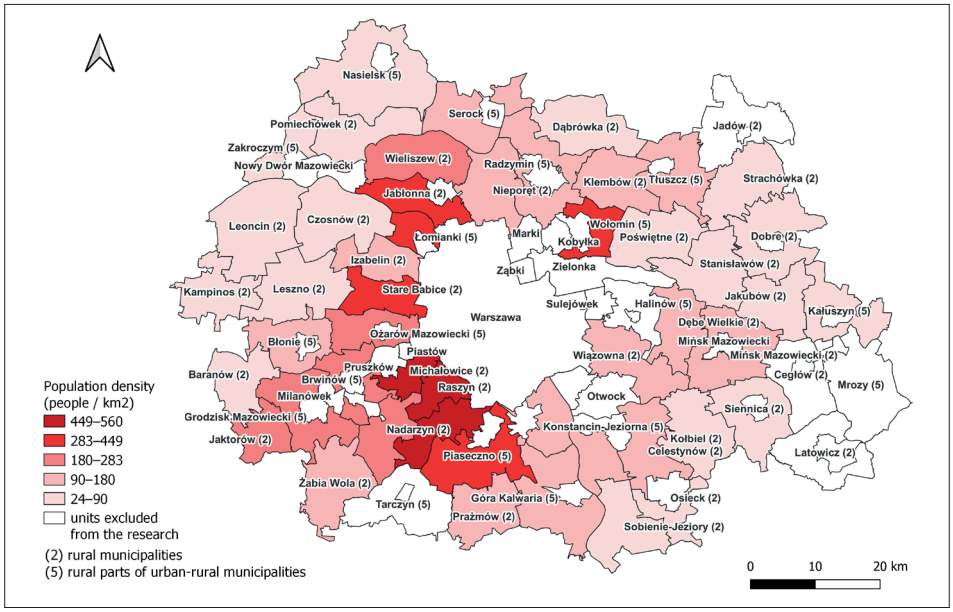

Fig. 1: Rural units covered by the study and their population density in 2023[1]. Source: Author's elaboration

[1] Rural municipalities of Siennica and Dobre changed their administrative status from rural to urban-rural in 2024. However, they were included in the analysis because the last examined four-year period ends in 2023. On the map, these municipalities are marked with the code (2), indicating their rural status during the study period, while the boundaries of the newly designated towns are also outlined.

limited to rural municipalities and the rural parts of urban-rural municipalities, particularly exposed to the negative consequences of more extensive development, which is conditioned by the availability of open land – a resource that cities possess only to a limited extent.

Taking the above assumptions into account, a total of 49 municipalities were ultimately included in the study: 33 rural municipalities and rural parts of 16 urban-rural municipalities (Fig. 1).

While the findings presented in this article are based on data from municipalities within the WMA – a unique and dominant urban region in Poland – the article is aimed at identifying the general trend of change in the process of suburbanization. The spatial patterns and directions of suburban development around Warsaw may help explain the dynamics of suburbanization. The verified tendency of making suburbanization more concentrated may be relevant to other metropolitan contexts regardless of structural and functional differences between urban regions.

3.2 Methodology

For the purposes of this paper, the concept of suburbanization dynamics in individual units is understood as temporal changes in the values of the analyzed indicators relative to the average for the entire study area. Suburbanization dynamics were measured using three variables obtained from the Local Data Bank of Statistics Poland (GUS):

- net migration balance – both internal and international (X),
- permanent residence registrations from cities (Y),
- number of dwellings put into use (V).

The selection of indicators was primarily dictated by the adopted definition of suburbanization, which includes both the population growth in the suburban area and the direction of migration, as well as the construction of new houses. With regard to permanent residence registrations from cities, it should be noted that GUS provides data on inter-municipal migration flows in three categories: total, from villages, and from cities. Consequently, it is not possible to isolate migration streams originating specifically from Warsaw. Nevertheless, because suburbanization processes are driven by inflows from cities of various sizes, for the purposes of this study it is sufficient to know that migration originated from a city, without distinguishing which one.

Despite the strong correlation between the indicators (correlation coefficients were statistically significant at the 0.01 level for each period of analysis), all three variables were included in the study because they relate to different aspects of suburbanization. Moreover, correlated indicators enhance differences between groups and facilitate the interpretation of clusters.

A second criterion in selecting indicators was the possibility of ensuring the longest possible time series and maintaining methodological consistency. The empirical part of the study relies on data from 1995 onwards, as this is the first year when the analyzed indicators are systematically and consistently provided in digital form by Statistics Poland (GUS). The year 1995 marks not only the beginning of coherent digital data availability from GUS, but also coincides with the period when suburbanization processes began to intensify. Although the origins of post-socialist suburban development date back to the early transformation period, it can be assumed that these processes only started to gain real momentum in the mid-1990s.

Due to significant variations in the data for individual years, the analysis was based on the aggregated values for seven four-year periods: 1995–1998, 1999–2002, 2003–2006, 2007–2010, 2011–2014, 2016–2019, 2020–2023. According to Statistics Poland, due to the insufficient quality of data on permanent international migration for the year 2015, these data were not published. This means that information on the net migration balance, which includes both internal and international migration, is unavailable. For this reason, the year 2015 was excluded from the analyses. The subsequent four-year period following 2011–2014 is 2016–2019.

For the purpose of the analysis, absolute values of the indicators were chosen. While relative indicators are more often employed in demographic comparisons, this study focuses on the scale of suburbanization, which generates varying pressures on municipalities. Relative measures do not reflect the actual magnitude of suburbanization effects, nor do they allow for an adequate assessment of their impact on infrastructure, public services, or spatial planning. Local governments, irrespective of their size, are responsible for providing public services and infrastructure based on the absolute number of inhabitants. Absolute figures make it possible to capture these demands more accurately, although this approach may limit the comparability of findings across different urban regions. It is not the relative growth rate but the actual increase in population that determines whether a new school, road, or water supply system needs to be developed. Relative measures may highlight local dynamics, but only absolute values reflect the real pressure on municipal services and infrastructure. In suburbanization research, making a clear distinction between the intensity (relative measures) and the actual scale (absolute magnitude) of the phenomenon in each self-government unit is essential for understanding its real impact and spatial consequences.

The overview of the basic characteristics of the analyzed variables (Tab. 1) shows a very wide range of values for individual indicators in relation to their medians, as well as high positive skewness of the distributions, which indicates the presence of values significantly higher than most of the others. In such cases, median-based statistics are more appropriate for capturing central tendencies. To assess the internal variability of the analyzed variables, the interquartile range (IQR), relative IQR, and skewness were used. Relative IQR is a measure of variability which – unlike the coefficient of variation (CV) – does not require a normal distribution or positive values (as is the case with net migration, which may include negative values), and is resistant to outliers. This coefficient provides a useful alternative for asymmetric distributions containing negative values. Relative IQR indicates what percentage of the median is covered by the values spread between the 25^{th} and 75^{th} percentiles. For all analyzed variables, the values of the relative IQR exceed 100%, which indicates a high degree of internal differentiation and dispersion of data. This proves (together with skewness) that the distributions are highly skewed and heterogeneous, with significant differences in the magnitude of the phenomena across municipalities.

To identify the dynamics of the scale of suburbanization in the WMA, a non-hierarchical classification method in the form of the k-means algorithm was used. This technique involves dividing a particular set of observations into a given number of homogeneous subsets called clusters or groups. The main goal of k-means is to maximize cluster dissimilarity while minimizing variation within each cluster. The k-means clustering method is directly based on arithmetic means, both in determining cluster centroids (i.e., their 'center') and in assigning objects to clusters – the algorithm minimizes the sum of squared Euclidean distances between the points and the centroids. The main advantage of the k-means algorithm is its low complexity, which is especially important when dealing with a large number of units. On the other hand, the key drawbacks of the method include the lack of a clear way to choose the optimal number of clusters and the randomness in selecting the initial cluster centroids (Derda, 2023).

The data was first standardized to eliminate the effect caused by different scales and measurement units. For each of the analyzed four-year periods, it was assumed that the maximum number of

	Variable	Min	Max	Median	IQR	Relative IQR [%]	Skewness
1995–1998	X	– 134	1,308	94	236.0	251.1	1.7
	Y	35	1,739	270	344.5	127.6	1.9
	V	10	451	75	88.5	118.0	1.9
1999–2002	X	– 95	2,711	187	469.0	250.8	2.5
	Y	34	3,034	342	513.5	150.1	2.3
	V	2	969	103	160.5	155.8	2.5
2003–2006	X	– 118	3,884	360	587.0	163.1	2.7
	Y	32	4,586	554	688.5	124.3	2.6
	V	16	1,396	225	291.5	129.6	2.1
2007–2010	X	– 101	3,412	378	853.0	225.7	2.1
	Y	28	4,372	564	941.0	166.8	2.2
	V	15	1,882	273	381.5	139.7	2.4
2011–2014	X	– 35	2,611	381	690.5	181.2	1.9
	Y	32	3,671	604	835.5	138.3	2.0
	V	21	1,293	248	345.5	139.3	1.5
2016–2019	X	– 58	3,172	248	684.5	276.0	2.2
	Y	58	3,760	543	889.0	163.7	2.0
	V	19	2,134	196	301.0	153.6	2.6
2020–2023	X	– 42	4,586	419	951.0	227.0	2.1
	Y	46	4,285	634	1,103.5	174.1	1.8
	V	37	4,081	343	621.0	181.0	2.8

Tab. 1: Basic characteristics of variables used in the classification
Notes: X – net migration balance [people]; Y – migrants from cities [people]; V – dwellings put into use [units]
Source: Author's elaboration based on Local Data Bank, Statistics Poland (https://stat.gov.pl/)

groups that suit the research purposes is 4, and then, the final cluster centers and their frequences were determined. The same number of clusters (4) in each four-year period was intended to ensure comparability over time. Using a consistent number of clusters makes it possible to track and interpret the dynamics of suburbanization across periods in a more structured way. This approach enables a systematic comparison of characteristics of the same number of clusters at each point in time. It shows not only changes in cluster internal parameters such as the rising centroid values (with a few exceptions discussed later), which point to a growing scale of suburbanization, but also transitions of specific units (municipalities) between clusters, which reflects real changes in the development dynamics. In practice, however, this means that with a fixed number of clusters, some clusters may be small (containing only 1–2 municipalities). This is statistically acceptable, as certain municipalities may exhibit a significantly different scale of suburbanization. These small clusters represent outliers or extreme cases, which are both functionally relevant and analytically valuable. Forcing more balanced clustering would artificially suppress real variation in the data. At the end, an analysis of variance (not presented in this article) confirmed the statistical significance of the differences between the individual clusters.

The dynamics of suburbanization were described based on the assignment of the units under study to individual clusters in successive periods as well as the centers of individual clusters. All calculations were performed using PS IMAGO PRO, which is powered by the IBM SPSS Statistics analytical engine.

4. Results

The analysis of the medians of the three examined indicators for all 49 units (Figs. 2–4) reveals a systematic increase between the periods 1995–1998 and 2007–2010. This upward trend was interrupted during 2011–2014, reflecting the impact of the global financial and banking crisis that peaked in 2008–2009. In the subsequent period, 2016–2019, a rebound and further growth were observed, which significantly accelerated in recent years, despite the onset of the COVID-19 pandemic at the beginning of the 2020–2023 period. The varying dynamics are also illustrated by the year-over-year median dynamics index (previous year = 100), which indicates that the scale of suburbanization has been steadily increasing, albeit at different rates, with a slowdown between 2003–2006 and 2016–2019, followed by faster growth in the most recent four-year period (Fig. 5).

Medians of the studied indicators are rising, and individual values are becoming increasingly dispersed toward higher levels. This trend has accelerated significantly in the most recent four-year period. The widening upper quartiles indicate that certain units are becoming dominant suburbanization poles, which is reflected

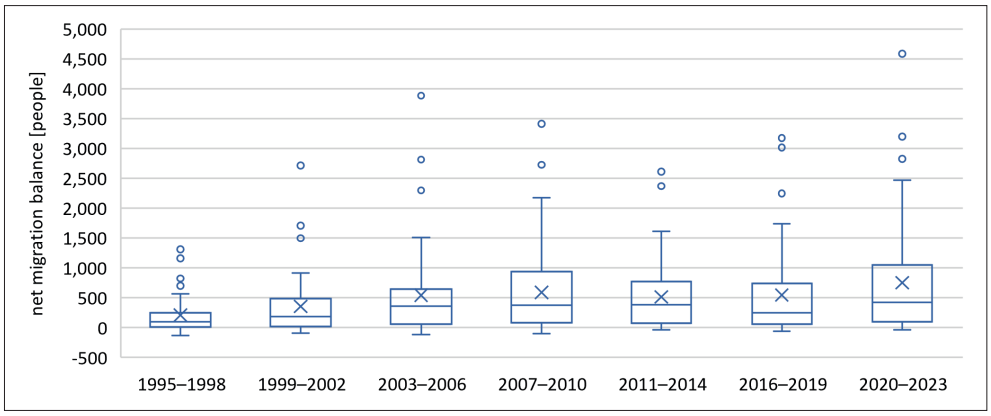

Fig. 2: Distribution of net migration balance across 49 units in successive four-year periods
Source: Author's elaboration based on Local Data Bank, Statistics Poland (https://stat.gov.pl/)

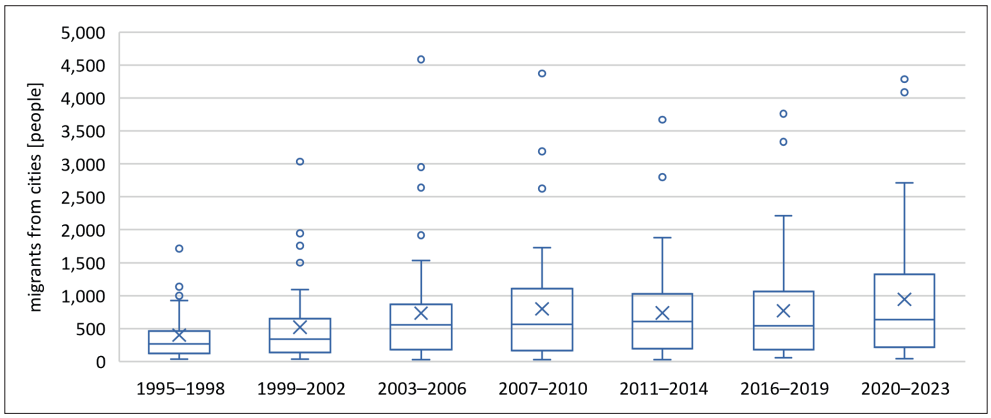

Fig. 3: Distribution of migrants from cities across 49 units in successive four-year periods
Source: Author's elaboration based on Local Data Bank, Statistics Poland (https://stat.gov.pl/)

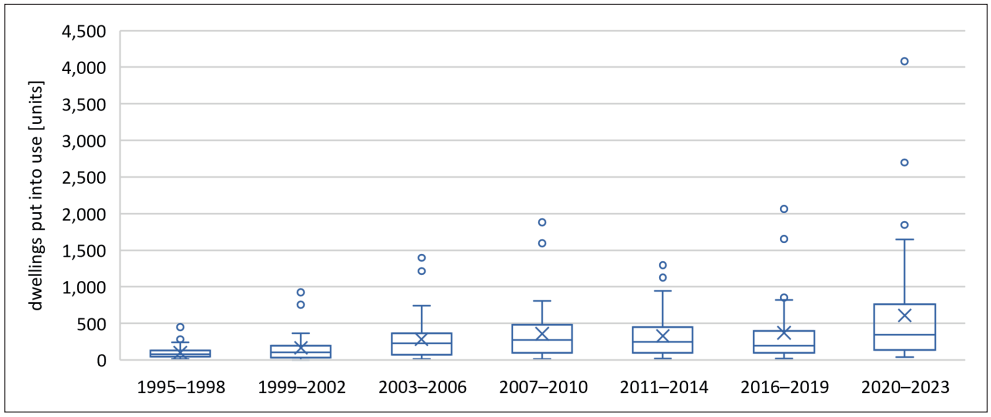

Fig. 4: Distribution of dwellings put into use across 49 units in successive four-year periods
Source: Author's elaboration based on Local Data Bank, Statistics Poland (https://stat.gov.pl/)

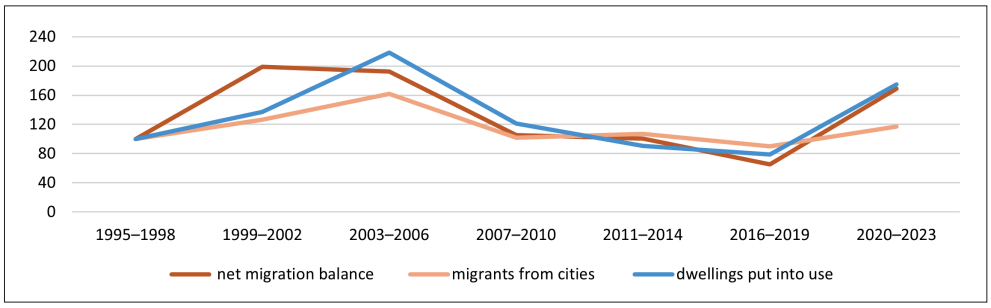

Fig. 5: Median dynamics indexes (previous four-year period = 100)
Source: Author's elaboration based on Local Data Bank, Statistics Poland (https://stat.gov.pl/)

in the increasing distance between them and the remaining units. Additionally, for dwellings put into use, the number of outliers has not grown substantially, but they are consistently reaching values increasingly higher than the median.

During k-means clustering, convergence was achieved in fewer than 10 iterations for each analyzed period. Table 2 presents the cluster centers for each indicator and four-year period, calculated both from the original values (Mean) and the standardized values (Z, expressed in standard deviations, SD). In each four-year period, the centroids of the largest cluster in terms of the number of units, computed from standardized variables, were below 0, indicating that the average values of all three analyzed indicators in this cluster were lower than the overall mean for all municipalities during the respective period. The centers of the remaining three less numerous clusters were above the mean, indicating that larger-scale suburbanization is confined to a smaller subset of units.

There are significant disparities between clusters in terms of mean values and frequencies (Tab. 2). Clusters with centroids considerably above the mean for the entire population were very small, in some cases consisting of only a few units or even a single one. The analysis revealed an increase in the number of units classified into the cluster with centroids below the average for the entire rural area of the WMA from 25 units in 1995–1998 to 33 units in 2020–2023. Moreover, a comparison of the first and last four-year periods shows that the distances between both the means and the standardized values for the two extreme clusters has widened. This suggests that a more extensive suburbanization characterized by smaller differences between municipalities is gradually giving way to increasing disparities in the scale of ongoing suburban development.

A comparison of the centroids for clusters with the highest and lowest values (Max Mean–Min Mean) shows that the differences between the average indicator values (ΔMean) for these two

		Clusters ordered by centroid values* (frequency)								ΔMean (Max Mean – Min Mean)
		Mean	Z	Mean	Z	Mean	Z	Mean	Z	
1995–1998		1 (N = 25)		3 (N = 16)		4 (N = 6)		2 (N = 2)		(2-1)
	X	– 2.0	– 0.639	213.9	0.019	725.5	1.572	1,234.0	3.115	1,237.0
	Y	146.7	– 0.630	410.2	0.024	989.0	1.461	1,727.5	3.294	1,580.8
	V	46.5	– 0.617	104.7	0.036	228.0	1.420	383.5	3.165	337.0
1999–2002		1 (N = 35)		2 (N = 9)		3 (N = 4)		4 (N = 1)		(4-1)
	X	101.5	– 0.473	609.4	0.472	1,420.3	1.981	2,711.0	4.383	2,609.5
	Y	235.9	– 0.484	830.8	0.523	1,701.0	1.998	3,034.0	4.257	2,798.1
	V	69.1	– 0.451	248.4	0.377	649.8	2.230	923.0	3.491	853.9
2003–2006		1 (N = 34)		2 (N = 13)		3 (N = 1)		4 (N = 1)		(4-1)
	X	202.8	– 0.443	991.2	0.592	2,813.0	2.984	3,884.0	4.390	3,681.2
	Y	338.1	– 0.462	1,297.2	0.661	2,949.0	2.596	4,586.0	4.513	4,247.9
	V	146.7	– 0.482	479.9	0.702	1,213.0	3.307	1,396.0	3.958	1,249.3
2007–2010		1 (N = 29)		3 (N = 17)		4 (N = 2)		2 (N = 1)		(2-1)
	X	160.3	– 0.602	937.2	0.487	2,451.5	2.610	3,412.0	3.957	3,251.7
	Y	303.6	– 0.585	1,190.1	0.459	2,909.0	2.481	4,372.0	4.204	887.0
	V	137.0	– 0.553	501.8	0.354	1,609.0	3.108	1,882.0	3.787	1,745.0
2011–2014		1 (N = 28)		3 (N = 14)		2 (N = 5)		4 (N = 2)		(4-1)
	X	147.3	– 0.641	746.4	0.407	1,124.6	1.068	2,489.5	3.453	2,342.2
	Y	301.1	– 0.611	1,005.9	0.376	1,429.4	0.970	3,234.0	3.498	2,932.9
	V	135.2	– 0.665	428.6	0.352	765.4	1.519	1,209.0	3.056	1,073.8
2016–2019		1 (N = 30)		3 (N = 16)		2 (N = 1)		4 (N = 2)		(4-1)
	X	135.8	– 0.566	881.4	0.470	2,247.0	2.367	3,092.5	3.541	2,956.7
	Y	308.3	– 0.581	1,199.2	0.540	2,214.0	1.816	3,546.0	3.492	3,237.7
	V	136.4	– 0.503	515.9	0.309	1,655.0	2.746	2,099.5	3.696	1,963.1
2020–2023		1 (N = 33)		4 (N = 13)		2 (N = 2)		3 (N = 1)		(3-1)
	X	267.6	– 0.516	1,342.9	0.627	3,010.5	2.401	4,586.0	4.076	4,318.4
	Y	423.1	– 0.537	1,637.1	0.712	3,398.0	2.523	4,285.0	3.436	2,974.9
	V	254.3	– 0.478	988.5	0.510	2,272.0	2.238	4,081.0	4.674	3,826.7

Tab. 2: Final cluster centers calculated from original values (Mean) and standardized values (Z)
*Notes: * the order of clusters based on centroid values does not correspond to the numerical order; X – net migration balance [people]; Y – migrants from cities [people]; V – dwellings put into use [units]*
Source: Author's calculations based on Local Data Bank, Statistics Poland (https://stat.gov.pl/)

extreme clusters have been increasing across successive four-year periods. However, there are some exceptions showing declines between 2003–2006 and 2007–2010, and between 2007–2010 and 2011–2014, probably reflecting the immediate or delayed impact of the 2009 economic crisis. The observed tendency indicates that the disparity between the cluster with below-average suburbanization scale, encompassing the majority of municipalities, and the cluster with the largest suburbanization scale is widening. When interpreting these findings, it should be noted that each successive cluster is smaller, with the one having the highest centroid containing only one or two units. Overall, these findings point to a tangible shift toward a greater concentration of population growth and development in selected municipalities.

The analysis of suburbanization dynamics at the level of individual units is reflected in cluster transitions across successive four-year periods (Fig. 6). The most significant changes were observed in rural areas within the first ring around Warsaw. From the outset of the transformation, higher dynamics were noted in the southwestern corridor, and since the early 2000s, also in the northern sector. However, the most intense and sustained changes are still observed in municipalities directly south of Warsaw. Interestingly, in some municipalities within the highly urbanized southwestern corridor, suburbanization dynamics have slowed in recent years. Furthermore, Konstancin-Jeziorna was the only first-ring municipality where suburbanization in rural areas was persistently below the WMA average.

The transition of units between clusters made it possible to distinguish ten types of rural units based on the sequence of changes observed within each type (Tab. 3, Fig. 7). The assignment of a municipality to a particular type reflects its suburbanization dynamics, understood as changes in assignment to clusters across successive four-year periods, described by standardized centroids.

From the mid-1990s onwards, half of the municipalities have exhibited consistently below-average (22 units, Type I) or predominantly below-average (5 units, Type II) suburbanization dynamics across all three indicators. Despite increasing scale of suburbanization, no significant increase in its pace was observed – the dynamics of suburbanization remained below the average in each or most of the four-year periods. Most of these units are located in the second or more distant rings around Warsaw. In four units, the scale of the phenomenon remained above average for most of the study period (up to 0.712 SD) but declined to below-average level in the post-pandemic period (Type III). In six municipalities, a steep decline was observed from a high or very high level of suburbanization dynamics in the 1990s to a very low level (below average – Type IV) or moderately low level (up to 0.712 SD above average – Type V) throughout most or all subsequent periods.

Three municipalities maintained a stable, moderately above-average level of suburbanization dynamics (0.019 to 0.712 SD above the mean) across all periods (Type VI), while three others exhibited variable dynamics, fluctuating over time, with the latest period (2020–2023) reaching above-average values, though still below 0.712 SD (Type VII). In one municipality, suburbanization dynamics increased from a moderately low level (0.019–0.712 SD) to a high level (0.970–3.307 SD), before returning to the 1990s levels in the period preceding the pandemic (2016–2019) (Type VIII). Only one municipality experienced a sustained increase from a moderately low level (0.019–0.712 SD) to a high level (0.970–3.307 SD) starting in 2011–2014, which persisted through the most recent period (Type IX). Finally, two units have shown consistently high (0.970–3.307 SD above the mean) or very high (3.056–4.674 SD above the mean) suburbanization dynamics since the mid-1990s (Type X).

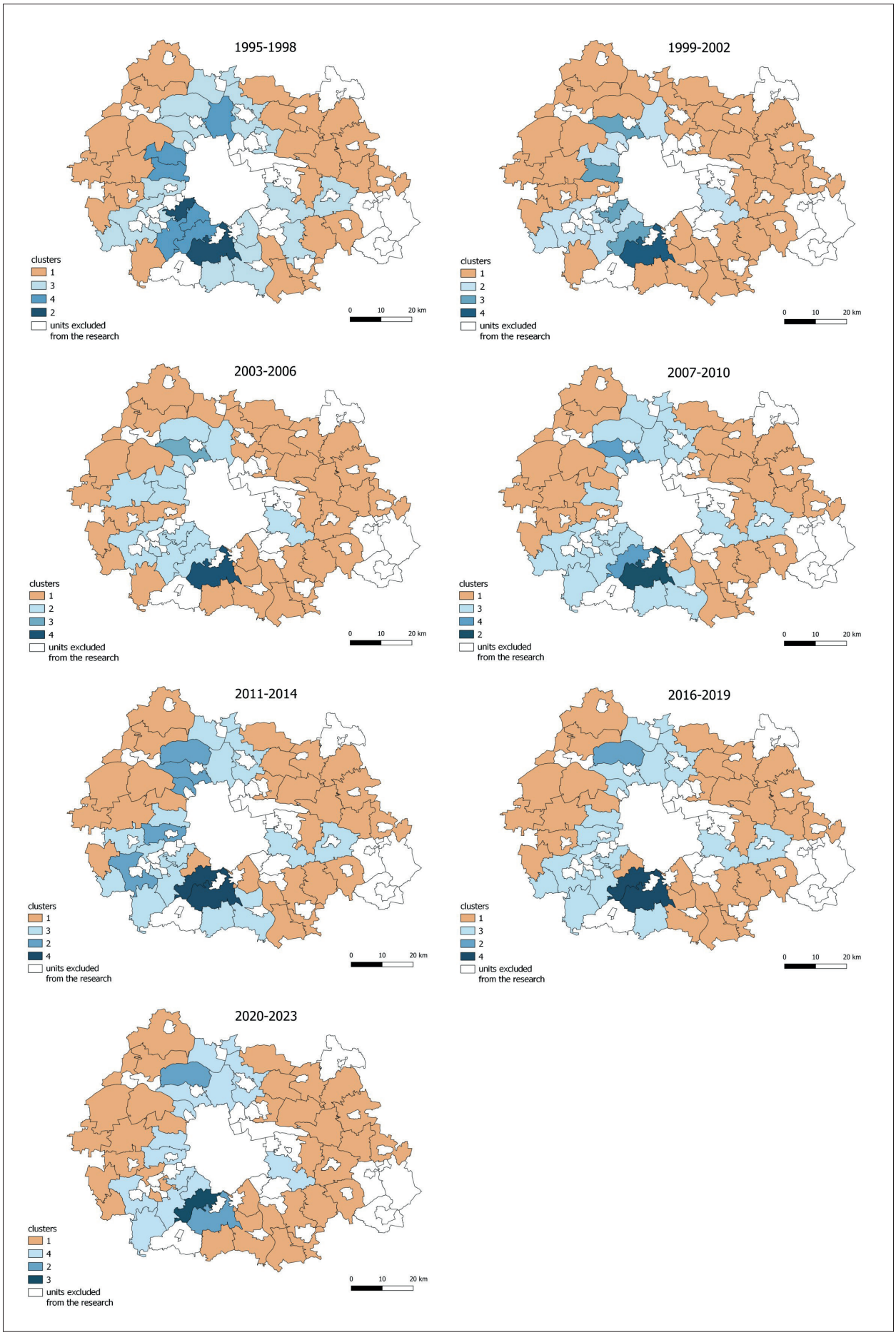

Fig. 6: Assignment to clusters in successive periods
Source: Author's elaboration

Type	Transformation (clusters in successive periods)	N	Units representing a given transformation: (2) rural municipality; (5) rural part of an urban-rural municipality	Description of the type
I	1 1 1 1 1 1 1	22	Baranów (2), Czosnów (2), Dąbrówka (2), Dębe Wielkie (2), Dobre (2), Jakubów (2), Kałuszyn (5), Kampinos (2), Karczew (5), Klembów (2), Kołbiel (2), Leoncin (2), Nasielsk (5), Osieck (2), Pomiechówek (2), Poświętne (2), Siennica (2), Sobienie-Jeziory (2), Stanisławów (2), Strachówka (2), Tłuszcz (5), Zakroczym (5)	no signs of increasing suburbanization dynamics – still below the average for the entire WMA
II	1 1 2 1 1 1 1	1	Leszno (2)	dynamics of phenomena mostly below the average for the entire WMA, individual periods with a slight increase in dynamics, followed by another decline, currently dynamics below the average
	1 1 1 1 3 1 1	1	Błonie (5)	
	3 1 1 1 1 1 1	3	Celestynów (2), Konstancin-Jeziorna (5), Wołomin (5)	
	3 1 1 3 3 1 1	1	Góra Kalwaria (5)	
III	3 1 1 3 3 3 1	2	Mińsk Mazowiecki (2) Prażmów (2)	dynamics of phenomena mostly slightly above the average for the entire WMA, in the recent period a decline to a level below the average
	3 2 1 3 3 3 1	1	Jaktorów (2)	
	3 2 2 3 3 3 1	1	Brwinów (5)	
IV	4 2 2 1 1 1 1	1	Izabelin (2)	rapid decline from the high dynamics of phenomena in the 1990s to a level below the average for the entire WMA that has been maintained for almost two decades
V	4 2 2 3 1 1 4	1	Raszyn (2)	transition from high or very high dynamics of phenomena in the 1990s to slightly above the average for the entire WMA, possibly with a short period below the average in the past
	4 2 2 3 3 3 4	2	Nadarzyn (2), Nieporęt (2)	
	4 3 2 3 3 3 4	1	Stare Babice (2)	
	2 3 2 3 3 3 4	1	Michałowice (2)	
VI	3 2 2 3 3 3 4	1	Wiązowna (2)	dynamics of phenomena consistently slightly above the average for the entire WMA, with possibly one period of significant acceleration in the past
	3 2 2 3 2 3 4	2	Grodzisk Mazowiecki (5), Łomianki (5)	
VII	3 1 1 3 3 3 4	2	Radzymin (5), Serock (5)	considerable fluctuations in dynamics of phenomena over time, in the recent period, dynamics slightly above the average for the entire WMA
	1 1 1 3 3 3 4	1	Żabia Wola (2)	
	3 1 1 1 2 3 4	1	Ożarów Mazowiecki (5)	
VIII	3 3 3 4 2 3 4	1	Jabłonna (2)	transition from low to high dynamics of phenomena, and in the pre-pandemic period, a return to dynamics slightly above the average for the entire WMA
IX	3 1 2 3 2 2 2	1	Wieliszew (2)	increase in the dynamics of phenomena from slightly above the average for the entire WMA to a high level that has been maintained for over a decade
X	2 4 4 2 4 4 2	1	Piaseczno (5)	dynamics of phenomena still very high or high
	4 3 2 4 4 4 3	1	Lesznowola (2)	

Tab. 3: Characteristics of types of units according to dynamics of suburbanization. Source: Author's elaboration

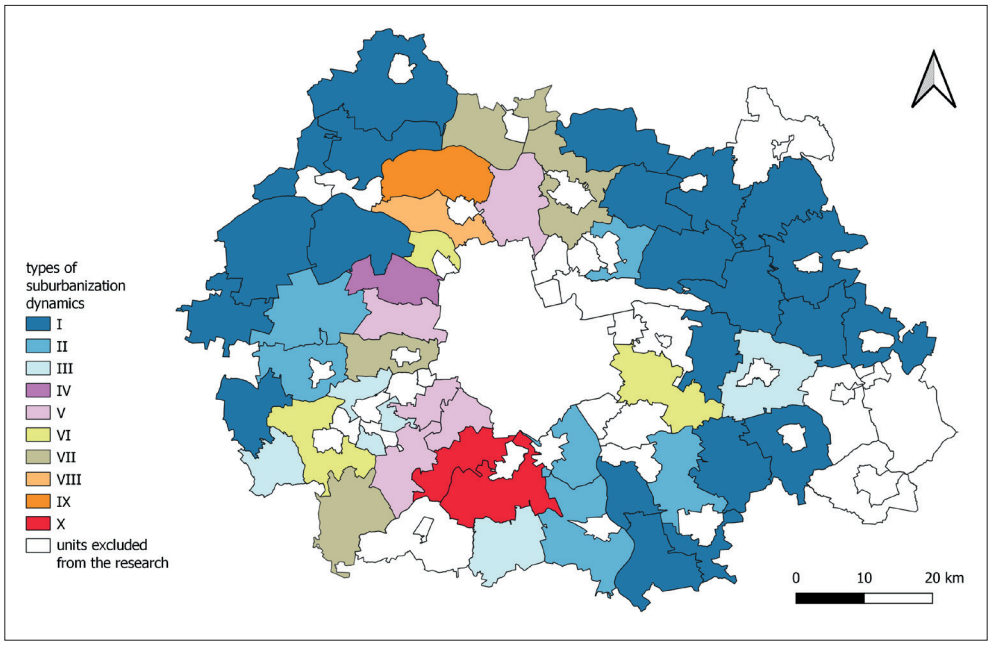

Fig. 7: Types of units according to dynamics of suburbanization. Source: Author's elaboration

The spatial distribution of unit types (Fig. 7) shows that municipalities in the second and subsequent rings around Warsaw largely exhibited similar suburbanization dynamics throughout the analyzed period, with the exception of Wieliszew, located north of Warsaw in the second ring, where dynamics systematically increased. At the same time, municipalities in the first ring showed considerable variation in suburbanization dynamics. This group includes units that experienced a sharp decline in dynamics (Types IV and V), located west of Warsaw, as well as units where the values of the analyzed indicators substantially exceeded the average for all studied municipalities (Type X). Within the entire WMA, the northern belt stands out, where dynamics showed large fluctuations (Type VII) but currently slightly exceed the WMA average, as well as the south-western belt, where dynamics have declined (Type V) yet still remain above the average.

5. Discussion

The study confirmed that a real 'post-socialist suburban revolution' began after 2000 (Sýkora & Stanilov, 2014), when mortgages became available even for middle-income households. After the rapid suburban growth in the first decade of the new millennium, residential suburbanization weakened in the second decade due to the previous strong development, the ongoing economic crisis, and the end of population decline in cities (Haase & Rink, 2015; Kubeš, 2015). While some pre-pandemic studies suggested that, by the second decade, suburbanization had reached its spatial limits and that new housing construction would not extend to more distant settlements (Ouředníček et al., 2019), the WMA study indicates that suburbanization has regained momentum after the pandemic, though the process is now more spatially selective.

It is argued by some scholars that, since 2009, residential suburbanization has evolved from a more dispersed, extensive form toward a more spatially concentrated pattern. As noted by Ouředníček et al. (2019), intensification has occurred closer to regional centers, where integration into the daily urban systems of the wider metropolitan region is possible. This trend was also observed by Pénzes et al. (2023), who confirmed that in this part of Europe, the initially dynamic growth and extensive expansion of built-up areas during the transition period, up until around 2000, continued, but gradually slowed and became more spatially concentrated after the turn of the millennium. These findings align with Smutek's (2016) systematization of changes in the intensity of suburbanization in Poland during its peak period, from 2002 to 2010. He noted that only a limited number of suburban municipalities, mainly those located in close proximity to large cities and functionally integrated with them, experienced very intensive suburbanization. However, many of these municipalities were urban rather than rural. The peripheral group, which was the largest, consisted of municipalities where no suburbanization was observed, due to little or no change in the analyzed set of indicators. In contrast, the study by Dudek-Mańkowska et al. (2024), which covers a much longer time series, shows that the majority of the WMA municipalities were demographically active between 2003 and 2020. However, when both natural increase and net migration are considered, in 70% of the municipalities included in the study, the positive natural increase was smaller than positive net migration, or positive net migration, with a surplus, compensated for a negative natural increase. According to Statistics Poland (GUS), by 2040 the majority of municipalities within the WMA are expected to continue experiencing population growth, whereas most municipalities in the rest of the Mazowieckie Voivodeship are projected to undergo population decline. Among the analyzed units, the largest population increases are anticipated in Lesznowola, Wieliszew, and Żabia Wola. Population decline is forecasted to occur only after 2040.

When looking for the reasons behind the varying dynamics of suburbanization, it is worth mentioning the increasing influx of migrants into suburban cities (excluded from the analysis), intensified developers' activity on the outskirts of big cities, rising daily commuting expenses due to higher energy prices, as well as the model of the small family that has spread from the inner city to suburban zones, and the increase in the number of single-person households (Kurek et al., 2017). The liberal spatial policy pursued for years by some municipalities may also be an important stimulus of intensive suburbanization. The municipality of Lesznowola exemplifies this type of approach. According to its spatial policy, as much as 93% of the total area has been allocated for residential, commercial, industrial, infrastructural, and transportation purposes (Mantey, 2016). The increasing selectivity of suburbanization may also stem from changing housing preferences, reflected in a growing demand for locations with good access to infrastructure, services, employment opportunities, and diverse housing options. This change may also indicate that new social groups are increasingly driving suburbanization, as it is financially easier for them to settle outside the central area. To some extent, this phenomenon is shaped by the form of residential development. While investors initially focused on constructing single-family houses in suburban areas, multi-family housing has become increasingly common in recent years. The spatial distribution of such developments within suburban areas varies and largely reflects the spatial policies of individual municipalities. Multi-family projects are primarily located near the core city limits (first ring of municipalities) in well-connected areas, where they can serve as a competitive alternative to housing within the city (Ciok & Leśniak, 2015). However, among the first-ring municipalities, there are some where high-density multi-family housing was not permitted in rural areas. These municipalities either chose not to develop at the same pace (Michałowice, Konstancin-Jeziorna) or were unable to do so (Izabelin) following the first slowdown caused by the 2009 global economic crisis. Although demographic growth is still observable, it has decelerated.

All of this suggests that suburbanization will increasingly be driven by the development of relatively smaller and more affordable apartments, primarily in multi-family buildings (Hubbard, 2025), with good access to the central city. This will further reinforce 'urban villages' (e.g., Józefosław in Piaseczno municipality or Mysiadło in Lesznowola municipality), which Zimnicka and Czernik (2007) already described in the early 2000s as rural settlements featuring highly diverse architecture, including zones of high-density multi-family housing. Among the suburban municipalities of the WMA, some exhibit relatively stable suburbanization dynamics compared with the overall urban region. This means they experience a systematic demographic increase, but at a moderate pace consistent with the dynamics of the entire WMA. The future of suburbanization in this group of municipalities remains uncertain. The expansion of remote work, improved infrastructure, and locally available services that reduce the need to commute to the city could help sustain their demographic growth. Conversely, since suburbanization does not contribute to population rejuvenation or increased fertility as part of the second demographic transition (Kurek et al., 2017), these municipalities may experience a slowdown and might never enter a phase of intensified suburbanization.

As suburbanization continues to advance throughout the WMA, growing disparities between municipalities in the scale of this process are unlikely to prevent the ongoing spread of development. Localities where developer-driven housing is expanding most rapidly, often already referred to as urban villages, will increasingly resemble cities rather than suburbs. This will also increase demand for public services and the expansion of public transport. At the same time, rising property prices in Warsaw and its neighboring municipalities, the spread of remote work, and improved transport

accessibility in more peripheral areas may encourage people to settle increasingly farther from the city, including areas where agricultural activity is still ongoing.

Awareness of the increasing spatial selectivity of suburbanization, combined with the inevitability of depopulation and population aging, should encourage a more thorough reflection on the spatial policies of suburban municipalities and investment strategies for both technical and social infrastructure across the metropolitan region. This trend may also signal a shift toward retrofitting strategies and more compact suburban development.

6. Conclusions

The study of rural areas in the WMA indicates that, despite similarities in suburbanization trends across city regions in CEE countries, the processes differ in both scale and dynamics within each region. In the WMA, some rural municipalities have consistently exhibited low migration balances and limited construction activity, remaining below the WMA average throughout most or all of the study periods. In other municipalities, following periods of intensified residential suburbanization, the process slowed, either stabilizing above or falling below the average. Only a few rural units displayed consistent dynamics over the entire study period or a gradual increase, and in just two municipalities suburbanization has remained at a consistently high level since the mid-1990s. These results highlight the evolving nature of suburbanization, which is shifting from a more extensive to a more concentrated pattern, not in the sense of reduced widespread population growth across a large area, but rather through increasing disparities between individual rural units. The most significant turning points that accelerated changes in the character of suburbanization toward greater selectivity were the 2009 economic crisis and the COVID-19 pandemic, along with its consequences, such as changes in housing preferences. The former slowed the influx of population to suburban municipalities, while the latter accelerated it. In recent years, the growing interest in suburban municipalities has also been accompanied by rising housing prices in CEE cities, including rents, partly driven by the influx of migrants from Ukraine following Russia's aggression.

The proposed methodology for examining suburban dynamics proved effective in capturing the variability of interrelated phenomena over an extended period across numerous and diverse spatial units. It could also be applied to other metropolitan regions. However, its main limitation lies in the relative nature of the approach. The indicator values used in the standardization process are specific to a given city region, particularly because absolute values were employed. The study aimed to assess individual spatial units within the WMA rather than to compare them directly with other metropolitan areas. What can be compared are general trends, rather than the magnitude of change. Within the context of the WMA, these results provide a foundation for further analysis of the drivers behind the observed transformations and the dynamics of other phenomena accompanying demographic shifts.

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