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ANALYSIS OF THE INTRA-URBAN SUBURBANIZATION WITH GIS METHODS

The case of Debrecen since the 1980s

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Abstract

The issues of intra-urban suburbanization tend to be received increasing attention during the last decades. The rapidly growing possibilities through the GIS-based methods provide new ways to analyse the processes. In the current research, a new methodology of dataset building was implemented in order to cover different types of resources (topographic maps, orthophotos, satellite images) and to create basis for a longitudinal analysis by the example of Debrecen. The resulted parcel level point layers ensured detailed grid-based analyses to discover changes between the early 1980s and 2000 and after the millennium until nowadays. The investigation drew the attention to the different tendencies of intra-urban suburbanization in which some areas proved to be continuously dynamic (some parts of the urban fringe or the external part of the inner areas), some garden zones' role changed and unambiguous decrease was represented by some agricultural territories. The most dynamic territories were characterised by quick densification and by extension of the built-up areas at the fringes. The rapid suburbanization process slowed down after the 1990s, but it has not stopped in Debrecen. These findings tend to be regarded as spatial concentration process within the frame of relative deconcentration of the population (as part of intra-urban suburbanization).

Key words

GIS methods, Great Hungarian Plain, grid, intra-urban suburbanization, long-term changes, urban fringe, urban sprawl

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INTRODUCTION

Urban sprawl and suburbanization are essential research issues during the last decades within urban geography (Schneider and Woodcock, 2008) because this global phenomenon is accelerated by numerous complex processes and outcomes (Knox, 2009). Suburbanization with its social and economic impacts is regarded as the most important spatial processes in the post socialist countries of Central and Eastern Europe (Kubeš, 2013).

The rapidly increasing datasets and analysing methods – including GIS tools – providing intensively extending possibilities for researches (Jakobi, 2014, Taubenböck et al., 2019).

The process of suburbanization gained altering attention within the relating urban studies, but due to the lack of territorially detailed statistical datasets analyses primarily concentrated on the settlement level tendencies. This is the reason why intra-urban suburbanization (Szmytkie, 2021) within the administrative area of a larger town has become important part of the researches (Vasárus, 2022). The intra-urban suburbanization is in relation to the process called 'hidden suburbanization' in which former second homes or summer-homes became the target of migration (Leetmaa et al., 2012; Vasárus and Lennert, 2022).

OBJECTIVES

The objective of the current paper is to introduce a GIS-based methodology, which creates the basis for a longitudinal and spatially detailed database to analyse the intra-urban suburbanization process by the example of Debrecen.

Further aim of the analysis is to discover the spatial pattern of objects within the administrative area of Debrecen (Hungary) except for the main inner area (according to its boundary in 1980).

The analysis makes attempt to represent the changes between the early 1980s and 2000, and from the millennium until nowadays, furthermore to discover some spatial characteristics of these.

Additional objective is to identify the characteristics of the local processes in the context of the suburbanization features of the Great Hungarian Plain.

THEORETICAL FRAMEWORK

After the decades of socialism, the phenomena of suburbanization has become the most dominant part of the urban development in Central Europe (Timár and Váradi, 2001, Timár, 1999, Enyedi, 1992), as the result of fundamental political, societal and economic changes (Beluszky and Timár, 1992, Sýkora and Stefan, 2012). Suburbanization caused a significant restructuring – relative deconcentration – of the population (Enyedi, 2011) and a major alteration of the local societies (Sýkora,

2003, Matlovič and Sedláková, 2007), but its consequences are widespread and comprehensive. The process has generated a rapid and irreversible change in the land cover and use in the surroundings of the cities (Kovács et al., 2019, Vasárus and Lennert, 2022). The complex environmental influences of the urban sprawl have effects on the long-term sustainability of the cities and their hinterlands with decreasing resilience, weakening competitiveness and deteriorating quality of life (Hardi et al, 2020, Lennert, 2020, Mocak et al. 2022; Pachura et al. 2018).

The process in Central Europe appeared in a delayed form comparing to Western Europe and mostly to North America. However, suburbanization had appeared even before the WWII in Central Europe, in most countries the process froze under the communist era. It became spectacular – mostly in the close proximity of the capital cities since the 1980s (Enyedi, 1992). Numerous studies discovered the characteristic features of suburbanisation especially focused on these cities (Kok and Kovács, 1999, Sýkora et al., 2000, Havryliuk et al., 2021), but cities and towns at lower hierarchical level also faced with considerable restructuring of the population as the result of significant migration (Bajmócy, 2014, Bujdosó et al., 2016; Pachura et al. 2018). Based on the common characteristics of suburbanization in Central Europe models were developed about the spatial features (Sailer-Fliege, 1999, Vasárus et al., 2018, Spórna and Krzysztofik, 2020; Matlovicova, Mocak and Kolesarova 2016). The global economic and financial crisis in 2008-2009 decreased the intensity of the observed processes of suburbanization in Central Europe, although it did not changed their nature (Novotný, 2016). During the last decades, the issues of intra-urban suburbanization gained greater attention (Ouředníček, 2007, Bajmócy, 2014), as this process was significant component of the post-socialist diffusive urban development (Spórna and Krzysztofik, 2020). Relating studies highlighted the outstanding population growth in the urban-rural fringe, in the other inner areas and in the outskirts of large Hungarian towns (Pócsi, 2011, Bajmócy and Makra, 2016). Between 1990 and 2011, 44.1% of suburbanisation was directed towards the separated inner areas and outskirts within the agglomerations and settlement groups in Hungary (excluding the agglomeation of Budapest) (Vasárus, 2022).

The phase of suburbanization is characteristically started during the mid-1990s and turned back by the period of the global financial crisis in 2008-2009, however the declining trend appeared years before (Fig 1). The process of suburbanization not only slowed down in the urban hinterlands of Hungary (the official delimitation is seen in: Tóth, 2014), but it represented reurbanization in given years (Budapest and its agglomeration is not included into this calculation in order to avoid the distortions). The tendencies of the last few years definitely demonstrate a new phase in the internal migration of Hungary (and a new wave of suburbanization) in parallel with the governmental measures in relation to the family and housing policies. Further researches are required to discover the factors behind these trends (covering the effects of COVID-19 lockdowns in the recent years).

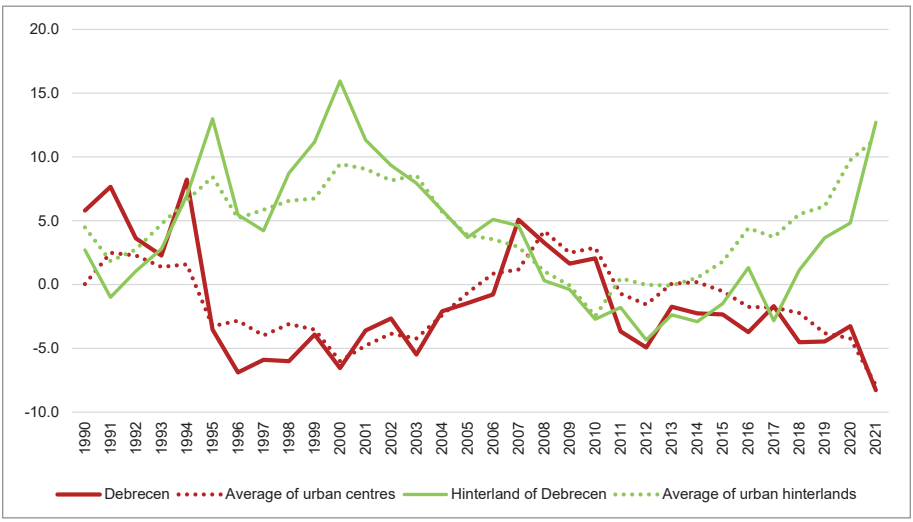

Fig. 1 The average internal migration balance per 1000 residents in the urban centres and in their hinterlands of Hungary (excluding Budapest) between 1990 and 2021, head

Source: edited by the authors, data from the Hungarian Central Statistical office (HCSO) and National Regional Development and Spatial Planning Information System (TEIR)

The Great Hungarian Plain represented some characteristic features in a Central European comparison. These are reflected by the agricultural dominated land cover, the settlement structure, the delayed and insufficient local infrastructural networks and even by the rural activities (e.g. supplementary farming) and heterogeneous social status of residents (Timár, 1993). The urban-rural fringe – primarily at the edges of the main (or central) inner area – faced with complex and altering transition due to economic reasons (besides the population movements the expansion of the retail stores, transportation network amd greenfield industrial and recreational investments are highlighted) (Vasárus et al., 2018, Csatári et al., 2013; Brunn et al. 2018). These processes triggered profound changes inter alia in the land use, the cover of artificial areas and the social decomposition of the separated inner areas and outskirts of large towns (Vasárus and Lennert, 2022).

In the current study, the characteristics of intra-urban suburbanization is analysed by the case of Debrecen. The trends of suburbanization in Debrecen and in its hinterland correlated the most significantly out of the larger towns with the average tendencies of the urban areas of Hungary (in the mirror of migration balances) – see Fig. 1. At the same time, some of the inner areas (Józsa) and outskirts (Biczó István-kert and Bayk András-kert) of Debrecen demonstrated the most dynamic population growth among these group of territories after 1990 (Bajmócy, 2014).

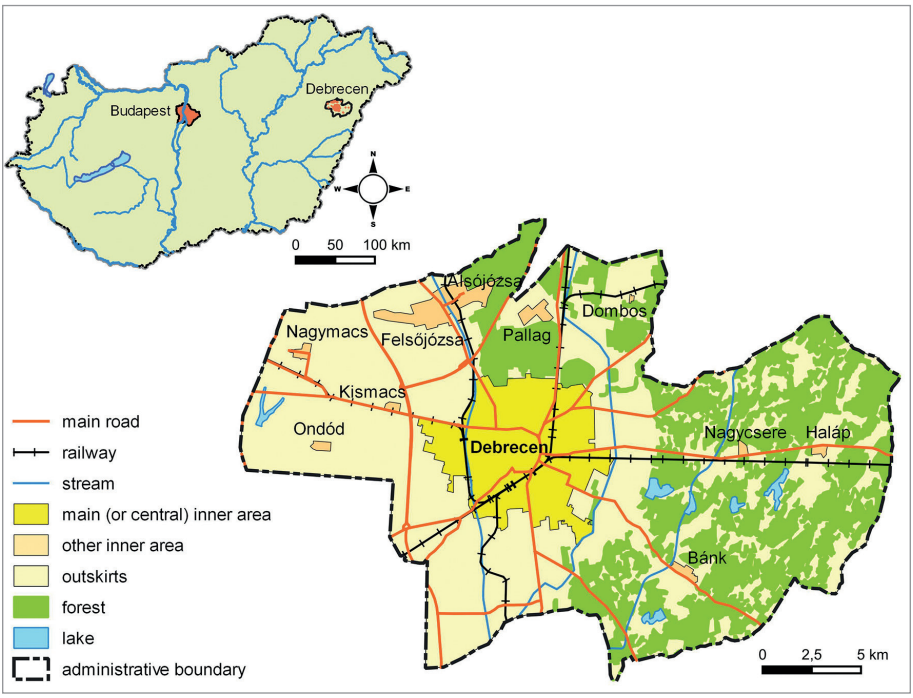

Fig. 2 The location of Debrecen and its inner areas
Source: edited by the authors, with the usage of OpenStreetMap and Corine Land Cover 2018 database

Tab. 1 Population of Debrecen and its areas between 1980 and 2020

Areas	1980	1990	2001	2011	2020*
main inner area	180,372	195,414	188,924	181,859	166,289
other inner areas	9,606	10,362	13,745	15,137	17,347
*from which Józsa***	*6,701*	*7,293*	*9,541*	*10,944*	*11,886*
outskirts	8,217	6,459	7,686	14,127	15,651
Debrecen together	***198,195***	***212,235***	***210,355***	***211,123***	***199,287***

*Source: Hungarian Central Statistical office (HCSO) census; Kozma (2016) and population registry data. *Estimated numbers **Alsójózsa and Felsőjózsa together*

Debrecen is the second largest town in Hungary with 200,000 inhabitants in the Great Hungarian Plain. The administrative area of Debrecen is 461.7 km^2 and besides its central inner area, there are 10 other inner areas and 22 named outskirts (Fig. 2). Population growth appeared during the 1980s in the neighbouring settlements of Debrecen (Süli-Zakar, 1996) that accelerated after the mid-1990s (Bajmócy, 2014), but as the result of its large extent administrative area intra-urban

suburbanization took place ensured stable number of residents in the case town (Süli-Zakar, 1994, Kozma, 2016). However, significant spatial restructuring of the population could be detected as the population number of the main inner area started to decline after 1990 (Tab.1). In the case of the other inner areas (including the largest one – Józsa, that is indicated on the map as Alsójózsa and Felsőjózsa) increasing numbers of residents have been observed since 1980 (Eke, 1994). At the same time, the outskirts became attractive only after the political transition with outstanding increase during the 2000s. The financial and economic crises slowed this process down even in the surroundings of Debrecen (Pósfai and Nagy, 2017), but the recovery and revival of the construction sector (primarily due to the state subsidy of families for housing) accelerates the intra-urban suburbanization in the last few years again.

DATA AND METHODS

In the last decades, the rapid development of GIS techniques provided several possibilities to discover the detailed spatial characteristics of the built environment. Analysis of the urban sprawl – and within this the low-density suburbanization – is often based on land use data (Zévl and Ouředníček, 2021). The CORINE and Urban Atlas database (Lennert et al., 2020, Vasárus and Lennert, 2022) provide good basis for large-scale territorial analysis. Satellite images, scanned and digital orthophotos mean possibility to process them with GIS methods and impressively precise vector data can be achieved to analyse the built-up area (Schlosser et al., 2020). Spatial attributes are also integrated into some of the grid datasets available in the last decade in which the cell size is 100*100 metres provide detailed data about the population number (Csomós et al., 2020). The combination of traditional maps and new datasets provide a perspective combination to discover the tendencies with a precise resolution.

In the case of different input spatial datasets and layers, data aggregation or even disaggregation might be necessary in order to find the most appropriate forms of territorial units to analyse. The grid or lattice model is a raster model in which the regular system of cells stores single attributes of the representing points – or other features. This fact might mean significant loss of information according to the initial state but through the bottom-up method of data aggregation the methodology provide appropriate solution to process the point-like spatial features (with point-in-polygon operations) (Jakobi, 2015, Fotheringham et al., 2000) or to compare significantly different spatial divisions (Netrdová et al., 2020) even in longitudinal analyses (Papp et al., 2021). Additional aggregation techniques are also applied to analyse the different territorial processes – including urban sprawl and suburbanization (Verma et al., 2017).

Current analysis is part of our multistep research project targeting to discover the transport access of different services in the light of the population changes in Debrecen during the last decades. Based on this objective and according to the constraints of the limited number of detailed population datasets before 2010 and because of the heterogeneous territorial data resources specific methodology must have been developed. For this reason, the Urban Atlas has been regarded as not appropriate because of its limited time frame (available only from 2006). The CORINE Land Cover database is a good basis for longitudinal analyses (as it is available since 1990) but its resolution and content are not detailed enough to discover those fine changes in the case of the built-up areas which were expected to be identified.

The creation of the territorial dataset was accomplished in a retrospective form in which the recent situation was vectorised with the help of the Google Satellite Hybrid layers (for 2019-2020) and OpenStreetMap (OSM) layers and we validated it by the digital building plan of the Local Authority of Debrecen (maintained by the ERDA Kft. company). In order to create the dataset of the second period (year of 2000), we vectorised orthophoto layers provided by the former FÖMI (Institute of Geodesy, Cartography and Remote Sensing – nowadays it is maintained by the Lechner Knowledge Centre) with the usage of Quick Map Services (QMS) plugin of the Quantum GIS 3.16 „Hannover". In order to improve the accuracy of the digital map, the primarily created dataset was modified according to the orthophotos. Vector layers were not available about the early 1980s, for this reason the scanned and geo-referred topographic maps of Hungary (scale 1:10,000) were vectorised by the authors on the basis of the previously created digital layers. Paper format cadastral maps (scale 1:4,000) were used to the validation on the level of parcels (these were recorded during more years in the early 1980s – in order to simplify, we refer to this as 1980 in the followings).

Because of the great heterogeneity of the available resources and the final objective of the research project one single point was vectorised in every individual parcel with at least one visible building apart from its function or size. This approach is not appropriate to detect the changes in neither the built-up areas nor the number of population – because the points are not able to represent these features. The decision about this major simplification was primarily made under the constraint of limited possibility to identify objects and functions in the case of older layers and maps. Nevertheless, in our opinion this approach is regarded as sufficient to discover the most characteristic territorial processes of the intra-urban suburbanization of Debrecen.

According to the research topic, the vectorised area covered the whole administrative area of Debrecen except for the main (central) inner area – included the other inner areas and the outskirts. The main inner area was delineated according to its boundary in the early 1980s, because some parts of the territories

influenced by the suburbanization later became the main inner area (almost 10 percent growth occurred since than in the extent of the main inner area from 45.524 km^2 to 49.749 km^2).

To process the point-based layers with the other spatial datasets grid cells were used to ensure the common basis. The grid network with the attributes of the population number created by the GeoX Ltd. were available for our research but only about those territories in which at least one citizen lived. A grid network was drawn with 100*100 meters cell size and fitted to the existing one. In order to test the similarity of the point-based datasets and the population numbers, point densities were calculated in the cells – except for those cells which were inside the main inner area of Debrecen (according to the boundary in the early 1980s). On the basis of the point density values in the cells, the different temporal stages became comparative and the changes could have been detected (see on Figure 3 depicting an exampling area in the case of Józsa – one of the most populous other inner areas of Debrecen). The changes of the point densities were discovered during the periods (between the early 1980s and 2000; between 2000 and 2020) and the whole timeline too.

The city centre (Kossuth square in Debrecen) was tagged on the layers and it was a reference point to measure the distance from centre in the comparative analysis. The centres of the grid cells were used in this analysis and the attributes of the cells (point densities) were used to calculate. Special territorial aggregation – similarly to the method used by Verma et al. (2017) – were applied to combine the compass directions and the distance from city centre.

RESULTS AND DISCUSSION

The significant spatial restructuring of the population was demonstrated by the census and the estimated population data (Tab. 1). The objective of the current research is to analyse this process based on the created spatial datasets with some GIS methods.

The special approach of the current investigation resulted in point maps (representing those parcels with at least one completed building or structure) in the case of the administrative area of Debrecen (excluding the main inner area in 1980) from three years. The number of objects increased dynamically – almost doubled during the investigated period (the value rose from 10,304 to 16,087 between 1980 and 2000 and it reached 18,155 by 2020). These values clearly represented the period of intensive growth during the 1990s, however certain parts of the administrative area of Debrecen showed significant increase in the density of points.

In order to discover the changes in the number of objects, at the same time the changes in the extent and density of these units, spatial aggregation of data

was implemented. 42,588 grid cells (100*100 meters size) were created in the field of Debrecen excluding the main inner area in 1980 – 46,901 grid cells covered the whole administrative area. 5,278 grid cells were inhabited with at least one resident in 2020, from which approximately one half (2,597 grid cells) was located outside the inner main area of Debrecen.

The correlation between the number of objects (represented by points) and the number of population was r = 0.439 based on the grid cells in 2020. This fact drew the attention to the different character of the layers correlated and it means that the number of objects should not been regard as a substituting data of the number of population. This difference is reasonable as the vectorised points (so called objects) do not represent the size or the function of the building on a given individual parcel (one point can represent even an agricultural warehouse or a school building or a detached house or a whole block of flats). This limit of the investigation was a necessary consequence of the longitudinal research due to the impossible reconstruction of the mentioned characteristics especially for the 1980s. Keeping these limits in mind, the transforming or unchanging character of the territories in the administrative area of Debrecen (except for the main inner area in 1980) could be investigated (see by the example of Alsójózsa – Fig. 3).

Fig. 3 The location of the objects in three periods with the grid network by the example of Alsójózsa

Source: authors' edition by the topographic maps of Hungary (1980s), by the orthophoto layers (2000), by the Google Satellite Hybrid, and by the OpenStreetMap layers

The grid cells provided an illustration with appropriate resolution about the disparities of the objects and through this about the extent of the Debrecen with its areas and outskirts (Fig. 4). According to the spatial distribution of the objects, the most densely effected (but at the same time densely built and populated) area is at the eastern peri-urban zone of Debrecen. At the time of the regime change these streets were opened and became built-up. Later, significant parts of these directly connected zones were attached to the main inner area.

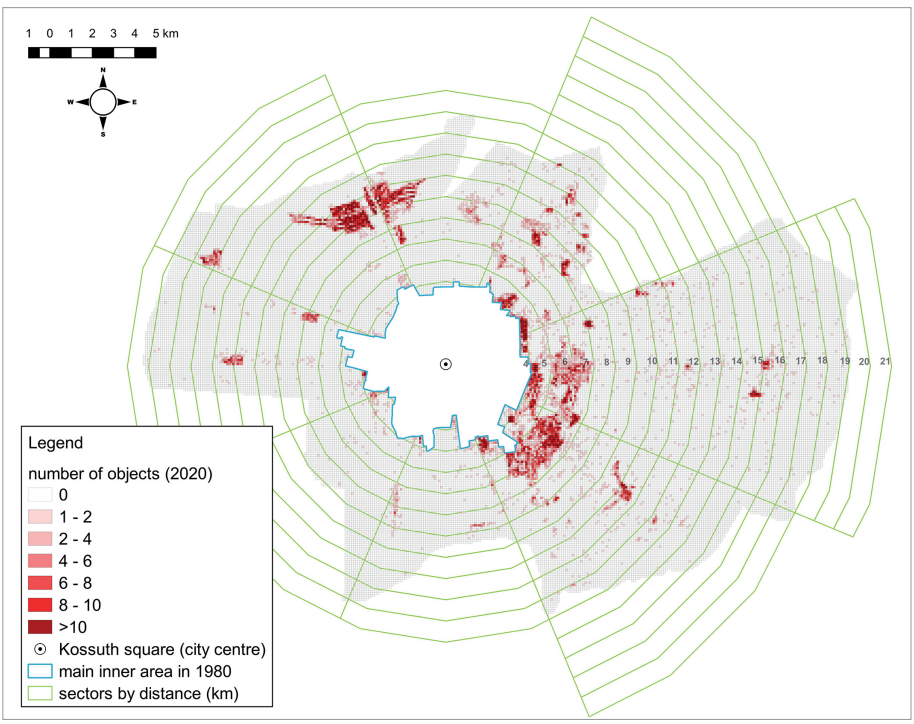

Fig. 4 The density of objects by the grid network in 2020 with the sectors from the Kossuth square
Source: authors' edition by the Google Satellite Hybrid

The zone to the east-southeast from the main inner area is between 5 and 7 kilometres distance from the city centre represents spectacular density of objects. However, this territory has dominantly agricultural and residential function (mainly with small hobby gardens), but these areas – namely the Biczó István-kert and the Bayk András-kert – represented outstanding population growth after 1990 (Bajmócy, 2014). These areas are typically characterised by the features of the suburbanization in the Great Hungarian Plain (Timár, 1993, Pócsi, 2011). The

population is mixed regarding their social status and this type of suburbanization is primarily motivated by the lower costs of living and the possibility of household level agricultural production (Kozma, 2016). According to the experiences (personal field visits and the satellite images), the number of population living in this area tends to differ from the official register data (these garden areas are sometimes called as 'grey zones' due to the illegal activities) (Vasárus, 2022). These zones were dynamic not only in the first period but also after the millennium (Fig. 5 and 6).

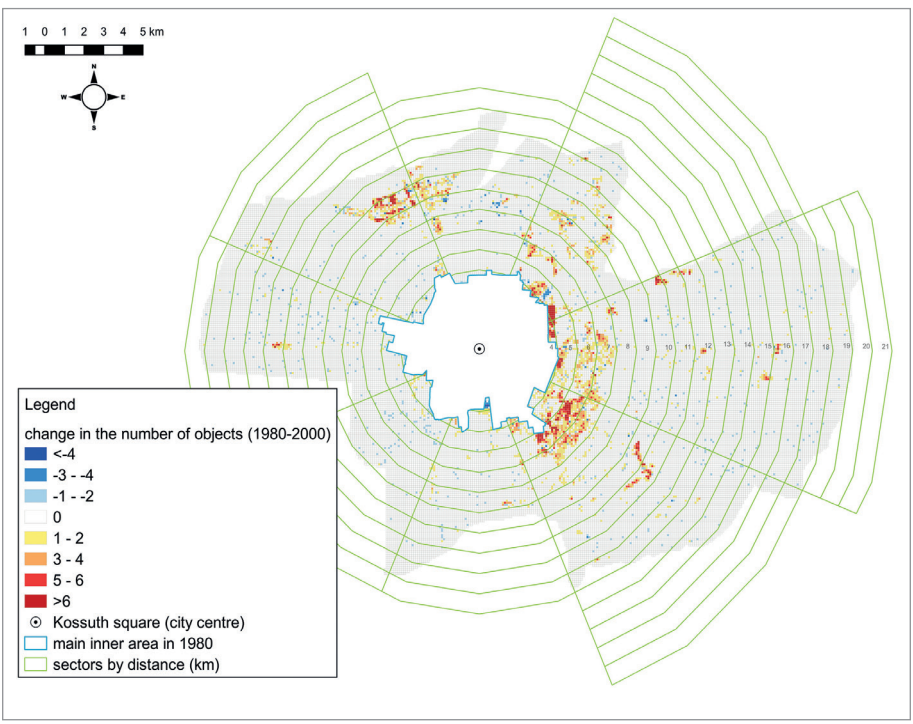

Fig. 5 Change in the number of objects in the grid cells measured from the city centre, between 1980 and 2000
Source: authors' edition by the topographic maps of Hungary (1980s), by the orthophoto layers (2000), and by the OpenStreetMap layers

The other group of garden zones of Debrecen (e.g. Gáspár György-kert) to the northeast from the main inner area is between 7 and 10 kilometres distance from the city centre showed intensive growth in the first period (Fig. 5) that completely finished after 2000 (Fig. 6).

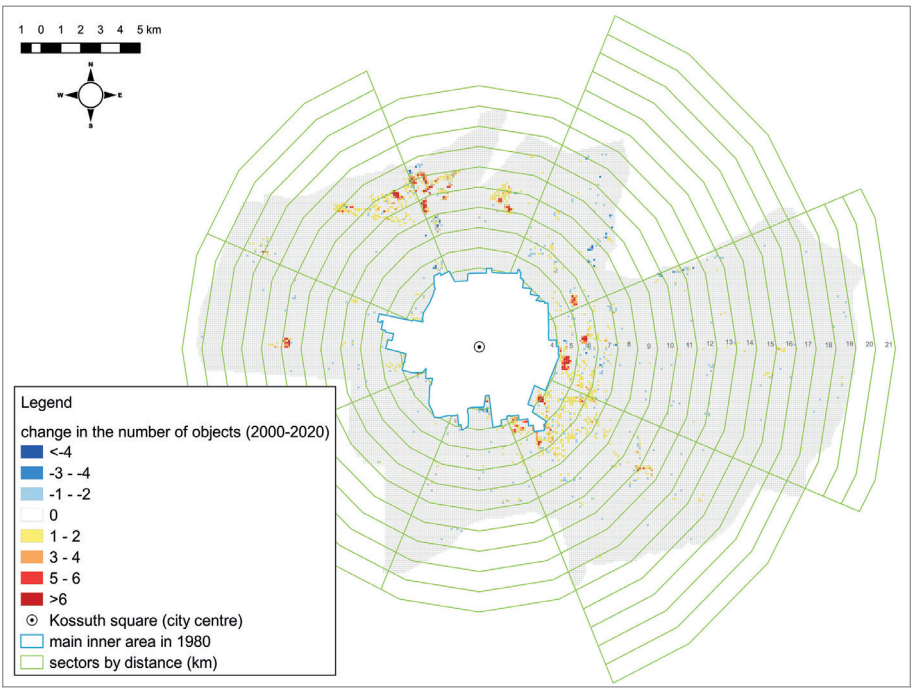

Fig. 6 Change in the number of objects in the grid cells measured from the city centre, between 2000 and 2020
Source: authors' edition by the orthophoto layers (2000), by the Google Satellite Hybrid, and by the OpenStreetMap layers

The most emblematic areas of growth are to the north and northwest from the city centre in the 7 and 10 kilometres distance sectors. These sectors include the characteristic suburban other inner areas of Debrecen (Alsójózsa, Felsőjózsa and Pallag). These areas are typically target for families in the middle and upper class to move there. The intensive construction of buildings with dominantly residential function resulted almost continuous increase in the number of objects. As the territorial changes of Alsójózsa demonstrates (Fig. 3), more types of growth can be identified with the precise analysis of objects. The altering agricultural character is also confirmed by the intensive decrease of the average size of parcels. For instance, new street was established at the contiguous boundaries of the parcels which were cut into half by the owners and sold to be built in. New detached houses were constructed on the empty parcels and several large parcels were separated for investment purposes. Besides of this densification process, the definite territorial sprawl of Alsójózsa is also confirmed through the extension of this other inner area, but similar tendencies can be detected in the attractive other inner areas (Felsőjózsa and Pallag).

Decreasing values are also observed in the sectors to the west and southwest and in the distant sectors to the east and southeast from the main inner area before 2000. After the millennium, decrease could have been detected in some of the north-eastern and eastern sectors, and at the southern fringe of Debrecen. The disappearance of former individual farms primarily on the territory of extensive agricultural cultivation is regarded as a long-term process. At the same time, the intensive industrial investments in Debrecen (e.g. BMW, Continental, Krones, Thyssenkrupp, CATL, Semcorp) will have significant influence on the land use of the surrounded areas as well in the near future (Molnár et al., 2018).

CONCLUSIONS

The investigation primarily focused on the situation of Debrecen, but some findings can be regarded as general and confirm the previous results published by dominantly Central European authors. In order to contribute to the existing researches, some GIS-based methodological attempts were accomplished. As part of the method developed significant generalization was implemented in order to integrate the different resources – topographic maps, orthophotos and satellite images with the grid-based datasets of population number. Parcels with buildings – apart from their function – were identified and were represented with one point as objects. This approach resulted in comparable and precise territorial datasets which are appropriate to detect the changes from the early 1980s to 2000 and after the millennium until nowadays.

In the light of the tendencies discovered the intra-urban suburbanization is continuous after the change of regime in the case of Debrecen – confirming the trends observed in Central Europe –, however there are more intensive and less intensive periods. The general tendency of the population's spatial restructuring was similar during the whole investigated period (between 1980 and 2020), but considerable spatial disparities were detected. The main inner area of Debrecen extended intensively (1) after the change of regime. The garden zones became important target to reside (2) after the political transition (but different status groups of population moved there for different purposes), though some of the distant garden areas became less attractive after the millennium (3). The most prospering other inner areas are transforming quickly as the result of the intensive population increase. Two forms of these were observed; first of all, the former village character is disappearing with the quick densification of the residential areas (4), and on the other hand, the built-up areas are extending at the fringes (5). At the same time, the significant part of the territorially dispersed individual farms disappeared (6) during the investigated period. These findings tend to be regarded as spatial concentration process within the frame of relative deconcentration of the population (as part of intra-urban suburbanization).

Current analysis should be continued in the future focusing on several aspects of the spatial and social changes in the surroundings of the urban centres.

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