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LAND USE DYNAMICS IN THE BANAT REGION: A COMPARATIVE ANALYSIS OF FUNCTIONAL URBAN AREAS IN SERBIA AND ROMANIA (2012–2018)

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ABSTRACT

Among numerous global and local challenges, sustainable land use management and spatial planning are crucial for setting a path for human development. Transformations in land use and land cover (LULC) patterns can result from changes in socio-economic systems and policy reforms, which are particularly notable in post-communist countries. This study employs Urban Atlas (UA) data to compare land use changes that occurred between 2012 and 2018 in the Functional Urban Areas (FUAs) of the historical Banat region, specifically Zrenjanin FUA in Serbia, and Timișoara FUA in Romania. The methodological framework comprises two principal components: (1) a comparative analysis of the share of each UA level within the FUAs and (2) the calculation of Land Take (LT) levels, LT ratios, and demographic LT ratios. The results reveal that artificial surfaces cover a third of the Timișoara FUA, and around 5% of the Zrenjanin FUA. Furthermore, during the reference period, almost no changes regarding the shares of UA levels were recorded in Zrenjanin FUA. On the other hand, Timișoara FUA showed an increase in the artificial surfaces by 2.1%, while the share of agricultural areas decreased by the same amount. The LT ratio suggests that the values of Timișoara FUA are 45 times higher than those for the Zrenjanin FUA, while the demographic LT ratio is twice as high in Timișoara FUA. One of the main reasons for this is depopulation in Zrenjanin FUA and urban decline, while the population growth in Timisoara FUA conditions the process of urban expansion. The analysis of local indicators, demographic indicators, LT and LULC changes must be taken into account while planning sustainable land use.

Key words: *Zrenjanin, Timișoara, land use/land cover (LULC), land take ratio*

INTRODUCTION

Land use and the changes of the natural environment are as old as humankind itself (Ellis, 2021). For millennia, humankind went from hunter-gatherer societies, through horticultural, agrarian and industrialized ages, while adapting nature according to their needs (Diaz et al., 2019; Ellis, 2021; Roberts, 2019). Different research suggests that approximately 75–95% of the Earth's ice-free-surface ecosystems were subjected to human-induced land use transformation (Ellis et al., 2021; Kennedy et al., 2019; Riggio et al., 2020). In the last two centuries, due to agricultural and industrial revolutions, as well as the use of fossil fuels, drastic changes in land use were recorded (Dabović et al., 2021; Schirpke et al., 2023; Weith et al., 2020).

In today's world, with local and global challenges, such as climate change, soil degradation, loss of biodiversity, rapid urbanization and industrialization, the need for sustainable land management and responsible spa-

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tial planning has become increasingly important (Dabović et al., 2021; Kalfas et al., 2023; Weith et al., 2020). For this reason, the General Assembly of the United Nations adopted the 2030 Agenda for Sustainable Development in 2015, which was built upon earlier initiatives, such as Agenda 21 or Millennium Development Goals. The agenda comprises 17 goals and 169 targets. Land use and its changes fall into multiple goals and targets, most notably Goal 9, 'Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation' Goal 11, 'Make cities and human settlements inclusive, safe, resilient and sustainable', Goal 13, 'Take urgent action to combat climate change and its impacts', as well as Goal 15, 'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss' (United Nations, 2015). Assessing the trends in land use changes and their dynamics is of great importance for sustainable development and regional planning (Fu et al., 2022).

According to the research conducted by Kuemmerle et al. (2016), LULC dynamics in Europe are diversified across space, highlighting the contrast between Western and Eastern Europe. Social-economic systems and policy reforms can lead to changes in land use patterns, which is particularly notable in European post-communist countries (Bucała-Hrabia, 2024; Dabović et al., 2021; Grešlová et al., 2023; Kovacs et al., 2019; Stoian, Groza, Sandu, 2025).

In order to standardize the LULC data across Europe, the European Commission launched the CORINE (Coordination of Information on the Environment) program, and the first CORINE Land Cover (CLC) dataset was produced in 1990 (European Environment Agency, 2011). Since then, CLC data proved to be a valuable resource for assessing LULC changes in numerous studies in Europe, including Serbia (Ostojić, Fekete, Mesaroš, 2019; Tešić, 2022; Živanović Miljković, Dželebdžić, Čolić, 2022) and Romania (Costea, Nikolin, 2018; Ianăş, Ivan, 2022; Stoian, Groza, Sandu, 2025). Despite the advantages and widespread use of CLC, some research indicates that the resolution of the data is insufficient (Minimum Mapping Unit (MMU) is 25 ha) and spatial details are unsatisfactory, particularly the ones regarding anthropogenic classes (Rosina et al., 2020; Živanović Miljković, Popović, Gajić, 2022).

In this research, the Urban Atlas (UA) data were used (Copernicus Land Monitoring Service, n.d.). UA represents a component of the EU Copernicus programme, developed as a joint initiative of the Directorate-General for Regional and Urban Policy and the Directorate-General for Growth, with support from the European Space Agency and the European Environment Agency (EEA). In contrast to CLC, which represents the whole country, the UA dataset provides land use information integrated with population estimates for European cities with more than 50,000 inhabitants, including their Functional Urban Areas (FUAs) — defined as a city and its commuting zone. The data is derived from semi-automatically and manually enhanced CORINE land cover datasets. The biggest advantage of UA compared to CLC is 100 times greater resolution, with UA's MMU of 0.25 ha (Batista e Silva, Poelman, 2016). Analyses of LULC changes using UA and FUA data have proven to be significant in scientific research, as demonstrated by numerous studies conducted in Serbia (Živanović Miljković, Popović, Gajić, 2022), Romania (Petrescu, 2019), Turkey (Aksoy et al., 2022), Spain (Domingo, Palka, Hersperger, 2021), and several countries in Central Europe (Kudas et al., 2024; Wnęk, Kudas, Stych, 2021).

This paper aims to compare land use changes that occurred in the period 2012–2018 in the Functional Urban Areas (FUA) of the historical region of Banat, shared among Romania, Serbia and Hungary, with the focus on Romania and Serbia. FUA taken into consideration for this research were Zrenjanin in Serbia, and Timișoara in Romania. Banat was chosen as a study area due to the common historical background that shaped this region (Gaudenyi, Milošević, 2023). The study will also focus on the land take (LT) process in the FUA's, given its relevance to SDG Indicator 11.3.1 and land consumption rate (Botticini et al., 2022; Holobâcă et al., 2022; UNSTATS, 2025; Živanović Miljković, Popović, Gajić, 2022). Studying the changes in recent years can provide valuable insights into LULC trend shifts and contribute to future spatial planning, especially when based on the examples of the cities that have historically shared close ties. Furthermore, to the author's knowledge, no research comparing LULC changes in the Banat region was previously conducted, making this research the first one to address a significant gap in the literature on cross-border urban development.

STUDY AREA

The geographical and historical region of Banat covers around 28,522 km2. Its boundaries are defined hydrographically by the following rivers: the Danube, the Tisza, the Mureș and the Cerna (Gaudenyi, Milošević, 2023). The largest part of the historical region of Banat (about 2/3 of the region) is located in Romania, while around 1/3 is located in Serbia. A territory at the mouth of the Mureș River in the Tisza River (284 km2) belongs to Hungary (Ianăş, Ivan, 2022). In Romania, the Banat region is administratively divided between Timiș and Caraș-Severin counties, as well as 12 and 4 administrative units in Arad and Mehedinți counties, respectively. Serbian Banat is a part of the Autonomous Province (AP) Vojvodina, and is comprised of three counties – North-Banat, Central-Banat, and South-Banat, with a small SW segment that is a part of the City of Belgrade (Gaudenyi, Milošević, 2023).

In the early Common Era (CE), Banat was populated by the Dacians, Samartians, and Germanic tribes, who frequently waged wars against the Roman Empire. In the 4^{th} century, a heterogeneous group of Huns, Goths and Allans started to inhabit the northern Danubian limes. The Avars ruled Banat at the end of the 6^{th} and the beginning of the 7^{th} century (Ivanišević, Bugarski, 2008). At the same time, Slavic tribes inhabited Banat. However, after the arrival of Hungarians to the Pannonian Basin in the 9^{th} and 10^{th} centuries, and the establishment of the Kingdom of Hungary, Banat became a part of the Kingdom (Neumann, 2019).

Between 1552 and 1716, the region was under Ottoman rule, when it was conquered by Prince Eugene of Savoy, and incorporated into the Habsburg Monarchy. Subsequently, the Habsburg Monarchy established the Banat of Temeswar as a new military administrative region, with the capital being the city of Temeswar (Timișoara). In the late 18th century, the Banat of Temeswar was partitioned among three counties: Torontál, Temes and Krassó-Szörény (Gaudenyi, Milošević, 2023). Temeswar remained the capital of Temes county, while Nagybecskerek (Zrenjanin, Serbia) and Lugos (Lugoj, Romania) became capitols of Torontal and Krassó-Szörény counties, respectively.

After the First World War, Banat was divided among the Kingdom of Serbs, Croats and Slovenes, Romania and Hungary. Although this marked the end of its shared political history, the centuries of unity left a lasting mark on the region. Banat remained the center of multiculturalism, ethnic and cultural diversity (Neumann, 2019). Following the Second World War, both Romania and Serbia came under communist rule, once again placing the Banat region on a parallel historical path. In the late 20th and early 21st century, after the fall of communist regimes, both countries faced the challenges of the social-economic transition. This period was characterized by significant land use changes and diverging development paths of the countries, particularly after Romania acceded to the European Union in 2007 (Dabović et al., 2021; Ianăş, Ivan, 2022; Stoian, Groza, Sandu, 2025). The complex historical background and dynamic patterns of development form the basis for selecting Banat as the study area (Figure 1), with particular attention given to the cities of Timișoara and Zrenjanin, the historic centers of the region.

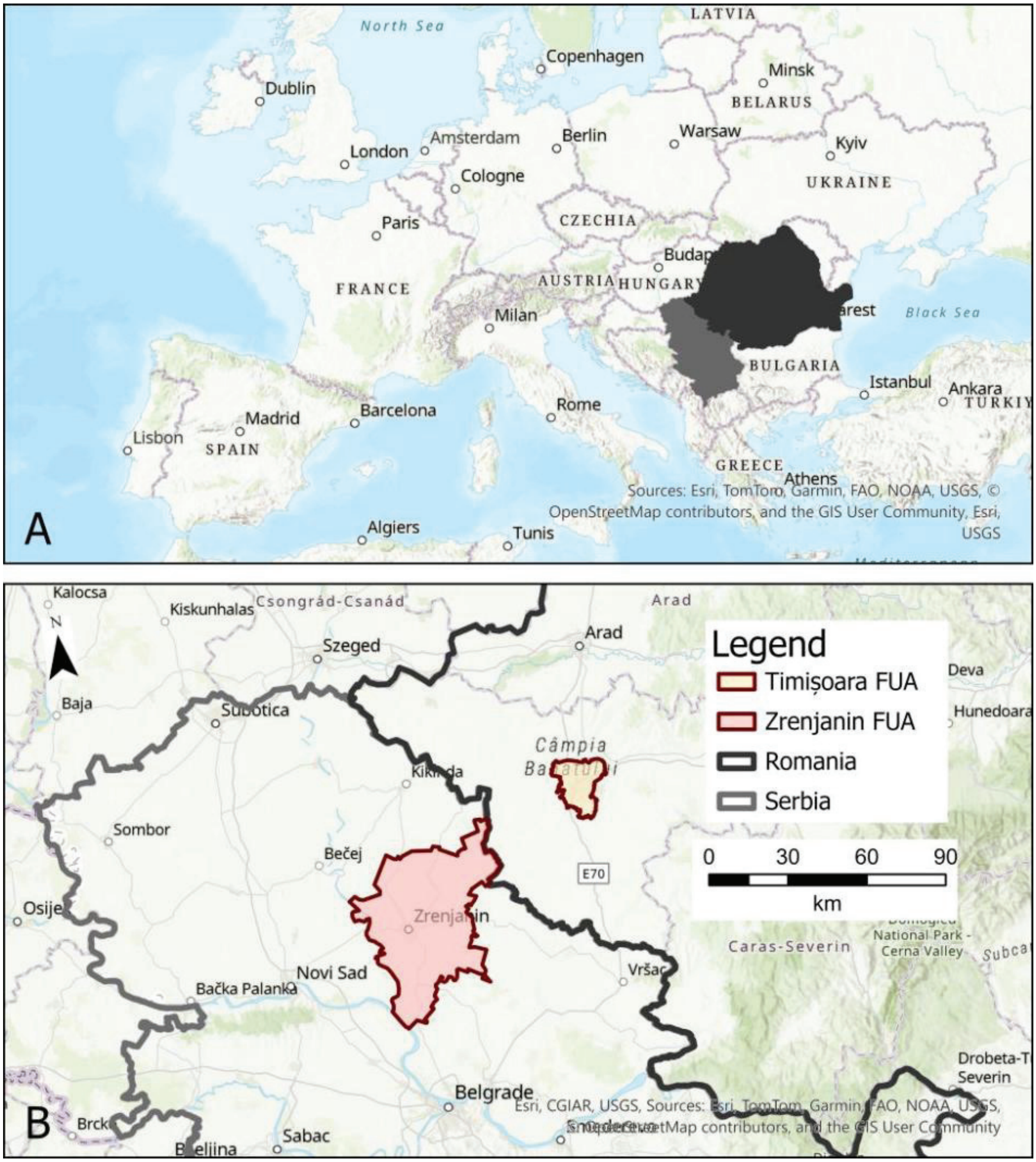

Figure 1. Study area: A – Serbia and Romania in Europe; B – FUAs in Serbia and Romania

Zrenjanin FUA is comprised of two Serbian municipalities - the City of Zrenjanin and Žitište municipality. It covers 1851.39 km² (Figure 2). According to FUA population estimations, Zrenjanin FUA had 136,609 inhabitants in 2012, and 133,056 in 2018. The population density was 73.79 inhabitants/km² in 2012, and 71.87 inhabitants/km² in 2018 (Copernicus Land Monitoring Service, n.d.).

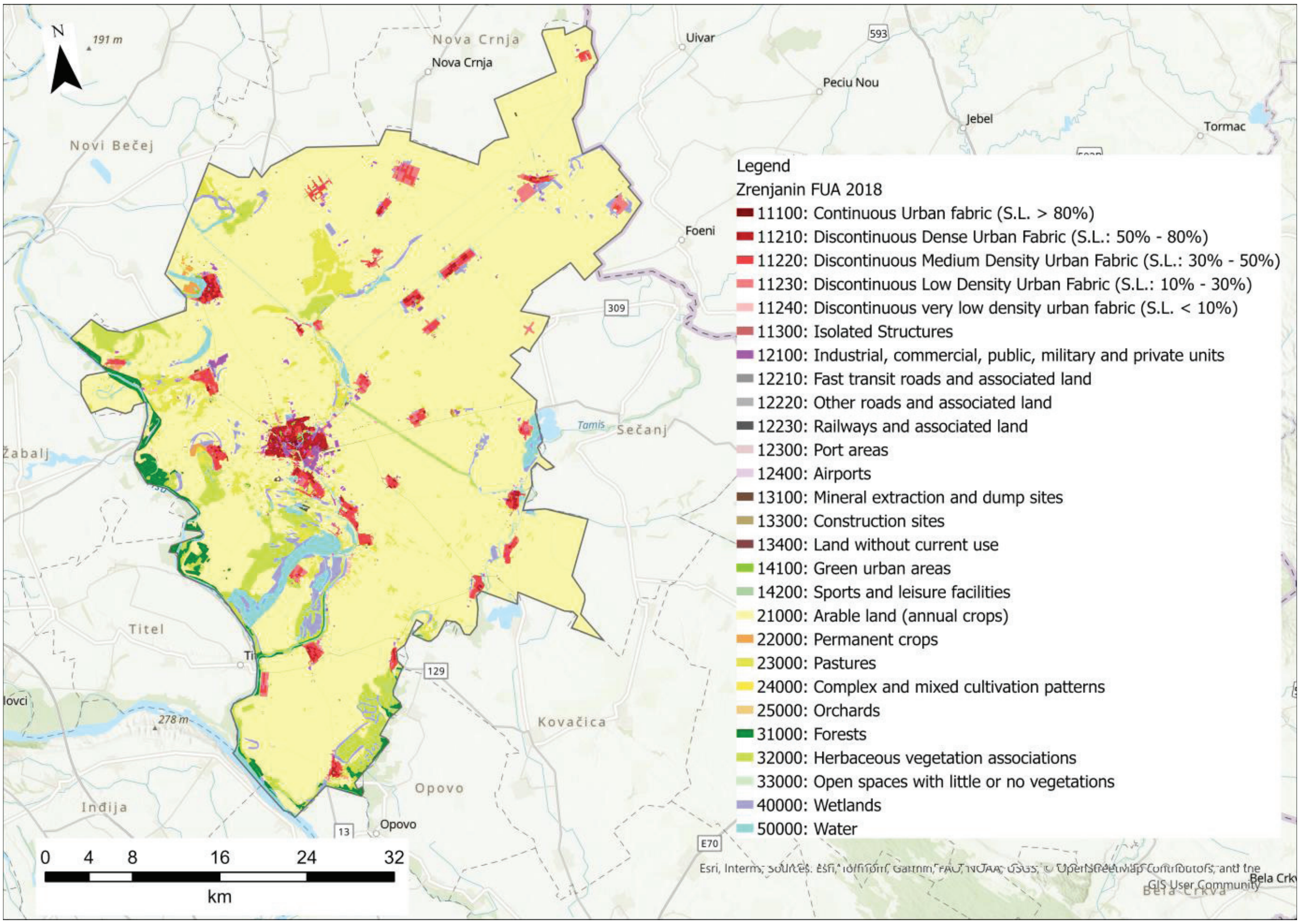

Figure 2. Zrenjanin FUA in 2018

Timișoara FUA covers an area of 237.41 km², and consists of four local administrative units: the municipality of Timișoara and the communes of Dumbrăvița, Ghiroda, and Giroc (Figure 3). The 2012 FUA population estimates amount to 332,806, while in 2018, the population growth was observed, with the estimates suggesting the number of inhabitants to be 340,404. Population density in 2012 was 1401.82 inhabitants/km², and in 2018, 1433.82 inhabitants/km² (Copernicus Land Monitoring Service, n.d.).

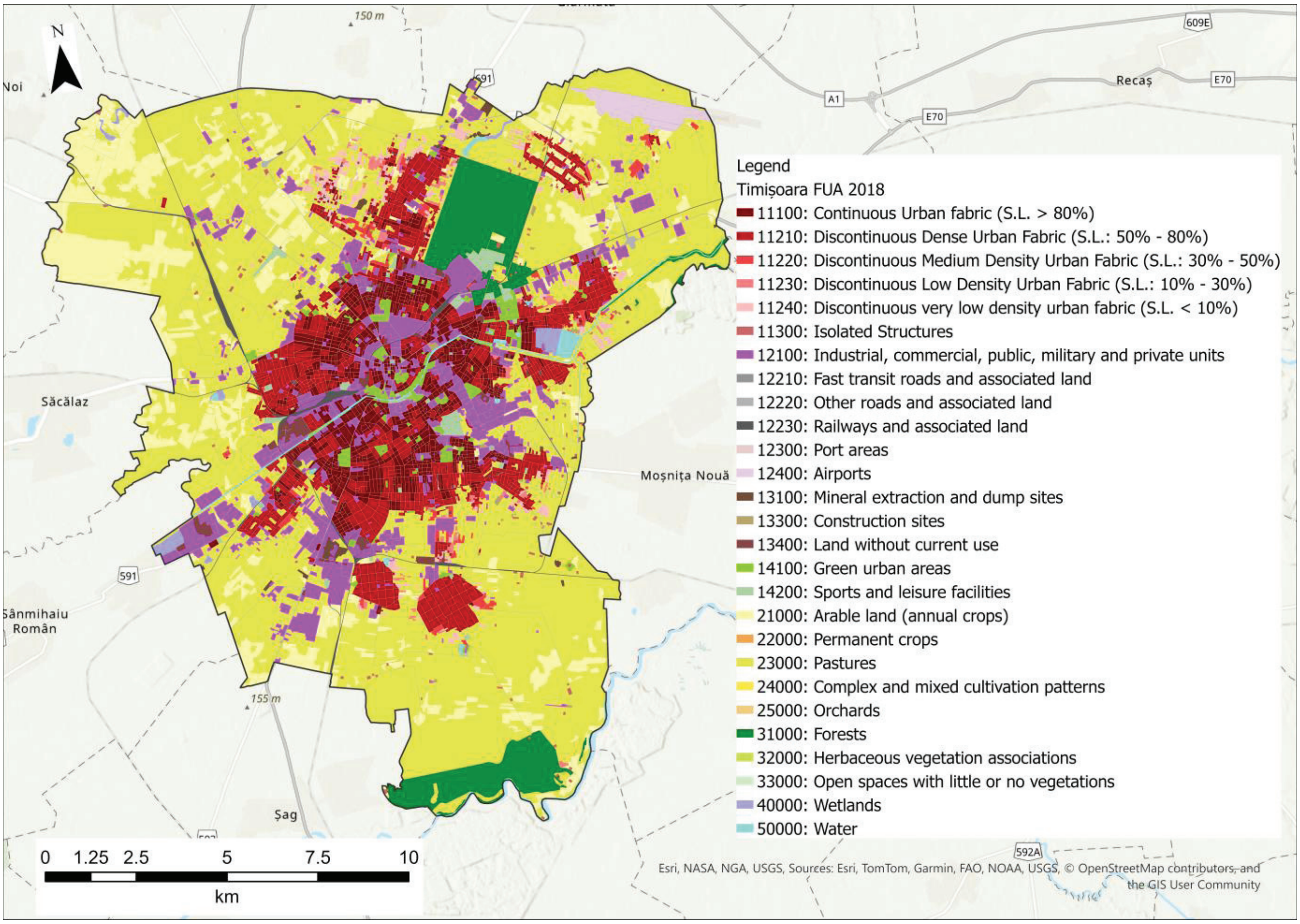

Figure 3. Timișoara FUA in 2018

METHODOLOGY

After thorough structuring and reasoning for using UA data in the Introduction, this section gives a description of the specific methodological steps applied in processing and analyzing the LULC data for the selected FUAs. This paper compares LULC, its changes and the land take process in the two FUAs in the period 2012–2018. The period was selected based on the availability of the UA data – the data for EFTA countries is available since 2012, and the data from 2006 covered EU member states (Copernicus Land Monitoring Service, n.d.).

UA data are classified into 5 levels, which are further divided into 27 classes. The five levels are: (1) artificial surfaces; (2) agricultural areas; (3) natural and semi-natural areas; (4) wetlands; and (5) water. Each class is defined by a unique 5-digit code, with the first digit corresponding to the level the class belongs to (Copernicus Land Monitoring Service, n.d.). In order to determine LULC change, the data from UA for both FUAs in 2012 and 2018 were imported into ArcGIS Pro 3.2. software. The layers were dissolved according to their codes, and the area of each class was calculated. In the following step, the data were exported from ArcGIS Pro as an Excel table, where they were further processed statistically according to the five levels (Tešić, 2022). Detailed information on changes between the two reference years was extracted from the UA documentation (Copernicus Land Monitoring Service, European Environment Agency, SIRS, 2018a; Copernicus Land Monitoring Service, European Environment Agency, SIRS, 2018b). The map visualizations were produced using ArcGIS Pro 3.2 software.

Urban LT represents the topic of scientific debate, due to different definitions and geographic boundaries of the terms, such as "urban agglomeration" among the countries (Botticini et al., 2022; Živanović Miljković, Popović, Gajić, 2022). Based on the definition given in SDG indicator 11.3.1, the land consumption rate is described as “the percentage of current total urban land that was newly developed” (UNSTATS, 2025). In the European context, the description of LT given by the EU suggests that it is usually interpreted as all land use aside from agriculture, natural and semi-natural areas, and water bodies (Botticini et al., 2022; European Union, 2013). When linked to the UA data, land take (LT) indicators can be calculated based on the first thematic level – artificial surfaces. In this research, the methodology for the calculation of the LT level, LT ratio and demographic LT ratio was adopted from Botticini et al. (2022).

LT level was first quantified as the absolute amount of urbanized land, and then normalized by calculating its proportion in relation to the total administrative surface (Equation 1).

$$\text{LT level} = \frac{\text{UL}_{\text{tn}}}{\text{AS}} \times 100 \tag{1}$$

LT level [%] – Percentage of land take up to the administrative surface;
UL [km²] – Urbanized Land (obtained from UA data);
t_n – reference year;
AS [km²] – Administrative Surface.

The LT ratio is calculated as the amount of newly urbanized land (in m²) divided by the total administrative area (in km²) (Equation 2). It reflects the intensity of land consumption within a given territory, showing how much land was converted to artificial surfaces relative to the entire area under analysis.

$$\text{LT ratio} = \frac{(\text{UL}_{\text{tn}} - \text{UL}_{\text{t0}})}{\text{AS}} \tag{2}$$

LT ratio [m² / km²] – Urbanized land consumed in the reference period up to the total surface;
ULt_n [m²] – Urbanized land at the end of the reference period (obtained from UA data);
ULt_o [m²] – Urbanized land at the beginning of the reference period (obtained from UA data).

The demographic Land Take Ratio measures the amount of newly urbanized land per inhabitant per year (Equation 3). It is obtained by dividing the change in urbanized land area by the product of the total population at the end of the period and the number of years observed.

$$\text{DLT ratio} = \frac{(\text{UL}_{\text{tn}} - \text{UL}_{\text{t0}})}{\text{Inh}_{\text{tn}} \times (\text{tn} - \text{t0})} \tag{3}$$

DTL ratio [m² / (inhabitants year)] – Urbanized land consumed in the reference period up to the demographic variation in the reference period;
Inh_{tn} – inhabitants at the end of the reference period.

The described indicators enable a comprehensive assessment of the land use dynamics within the selected FUAs. The results aim to highlight the scale, intensity, and direction of land transformation within each FUA between 2012 and 2018.

RESULTS

In order to provide an initial overview of LULC structure in the selected FUAs, Table 1 presents the relative share of the five UA levels for the reference years. The comparison highlights the differences between the FUAs, as well as the shifts occurring in each FUA in the period 2012–2018.

Table 1. Share (%) of each UA level area in the FUAs in the reference years

	Timișoara 2012	Timișoara 2018	Zrenjanin 2012	Zrenjanin 2018
Artificial area	31.5	33.6	5.4	5.4
Agricultural areas	62.5	60.4	83.4	83.5
Natural areas	4.9	4.9	5.7	5.8
Wetland	0.4	0.5	2.4	2.4
Water	0.7	0.6	3.1	2.9

Based on the data from Table 1, numerous comparisons may be made. The most notable difference between Timișoara FUA and Zrenjanin FUA is in their share of artificial surfaces. While artificial surfaces cover a third of Timișoara FUA, their share in Zrenjanin FUA is just around 5%. On the other hand, agricultural areas cover more than 80% of Zrenjanin FUA, and around 60% of Timișoara FUA. Another significant finding is that in Zrenjanin FUA, there were almost no changes regarding the shares of UA levels in the reference period. In contrast, the share of artificial areas in Timișoara FUA increased by 2.1%, while the share of agricultural areas decreased by the same amount. The UA product report for Timișoara FUA implies that 89.6% of the changes between 2012 and 2018 are due to urban expansion and the uptake of agricultural areas. Loss of artificial surfaces and other changes account for 4.7% and 5.7% of the changes, respectively (Copernicus Land Monitoring Service, European Environment Agency, SIRS, 2018a). In Zrenjanin FUA, urban expansion and uptake of agricultural areas comprise 10.3% of the changes, simultaneously with agricultural development and the uptake of natural areas, which make up 9.1% of the changes. All other changes account for less than 5% of the total changes each (Copernicus Land Monitoring Service, European Environment Agency, SIRS, 2018b). The changes in the shares of natural areas, wetlands and water are minimal in both FUAs.

To quantify and analyze the extent and nature of urban expansion in the FUAs, Table 2 shows the LT indicators, alongside other important indicators, such as population density per urbanized land and urbanized land per capita. These metrics provide a more nuanced understanding of the efficiency of land use and the relationship between demographic and spatial dynamics. Together, they enable comparisons between FUAs and help identify patterns of urban development.

Table 2. LT indicators for the FUAs

FUA	Indicators	Unit of Measure	Value
Zrenjanin	Administrative surface	Sq km	1851.39
	Urbanized land (2018)	Sq m	100,290,000
	Urbanized land (2012)	Sq m	99,440,000
	FUA population estimation (2018)	inhabitants	133,056
	LT level (2018)	%	5.42
	LT level (2012)	%	5.37
	Population density per urbanized land (2018)	Inh/sq km	1326.71
	Urbanized land per capita (2018)	Sq m/inh	753.74
	Land take ratio (2012–2018)	Sq m/sq km	459.11
	Demographic land take ratio (2012–2018)	Sq m/(inh years)	1.06

Timișoara	Administrative surface	Sq km	237.41
	Urbanized land (2018)	Sq m	79,700,000
	Urbanized land (2012)	Sq m	74,730,000
	FUA population estimation (2018)	inhabitants	340,404
	LT level (2018)	%	33.57
	LT level (2012)	%	31.48
	Population density per urbanized land (2018)	Inh/sq km	4271.07
	Urbanized land per capita (2018)	Sq m/inh	234.13
	Land take ratio (2012–2018)	Sq m/sq km	20934.25
	Demographic land take ratio (2012–2018)	Sq m/(inh years)	2.43

Although the total surface of Zrenjanin FUA is almost 8 times larger than Timișoara FUA, the absolute sizes of their urbanized zones remain relatively similar. However, Timișoara FUA has a much larger population in a smaller urbanized area, resulting in a significantly higher population density per urbanized land. On the other hand, Zrenjanin FUA shows a greater amount of urbanized land per capita, due to its more dispersed urban fabric and smaller population.

The LT ratio results further underline this divergence – Timișoara FUA has the value approximately 45 times higher than Zrenjanin FUA. Correspondingly, the DLT ratio is more than two times higher in Timișoara FUA. These findings indicate not only a greater extent of urban expansion, but also a greater demographic pressure on land resources, which likely reflects more dynamic development patterns and denser growth of urban areas in the Romanian context.

DISCUSSION

The observed LULC changes within the studied FUAs represent the outcomes of a complex interplay of historic changes, socio-economic transitions, spatial planning policies, and demographic trends in Serbia and Romania (Dabović et al., 2021; Ianăş, Ivan, 2022; Stoian, Groza, Sandu, 2025). In an effort to better understand these changes and their patterns, this section discusses the potential drivers of land transformation.

Dabović et al. (2021) identify six main drivers of LULC change in Serbia for the period 1990–2012: political-institutional, economic, natural-spatial, demographic, cultural, and technological. According to their research, the period 1990–2000 represents a period of regression, 2000–2006 a period of progression, and 2006–2012 a period of stagnation. These findings align with the study by Tešić (2022), which analyzed LULC dynamics in Serbia and Bosnia and Herzegovina over the 2000–2018 period. In addition to the conclusions drawn by Dabović et al. (2021), Tešić (2022) argues that the period 2012–2018 was a period with lower intensity changes, and that the reason behind it is the population crisis in recent years. This trend may be observed in Zrenjanin FUA as well – the FUA is affected by the long-term depopulation process, which is the main reason why the urbanization process is almost non-existent in the period 2012–2018.

Research conducted in Romania reveals similar drivers of LULC change after the fall of the communist regime as those identified in Serbia – political, economic, technological, and demographic (Ianăş, Ivan, 2022). In the period 1990–2012, the built-up area almost doubled in Romania, but the differences in annual rates within this period are significant. Until 2000, the built-up area increased by 33.8%, with the annual rate of 49,045 ha. The second half of the period was characterized by a 13.1% increase in built-up area, and the annual rate of 21,142 ha. Furthermore, the regional disparities can be observed. The West Development Region, where Timișoara FUA is located, shows intra-regional disparities between Timiş County and three less developed counties (Grigorescu et al., 2018). The process of urbanization in Romanian Banat is most prominent in Timișoara Plain, as Timișoara represents the demographic and economic center of the region (Ianăş, Ivan, 2022). In the period 2006–2020, the highest increase rate of built-up areas in Timișoara was recorded between 2009 and 2015 (Holobâcă et al., 2022). In contrast to the depopulation process in Serbian Banat, Zrenjanin FUA, and the majority of Romanian Banat, Timișoara FUA has a steady population growth, since it offers education and job opportunities (Costea, Nicolin, 2018).

Contemporary cities find themselves in a number of challenges. The goal of making sustainable cities, capable of withstanding global crises, demands finding a balance between minimizing ecological footprint, economic development and societal well-being (Szaja, 2024). If the ecological footprint is assessed only through spatial changes and urbanization, Zrenjanin FUA has much higher sustainability than Timișoara FUA, with fewer LULC changes, lower pressures of urbanization. However, if demographic parameters are taken into consideration, Zrenjanin FUA is in a significantly worse situation than Timișoara FUA. Depopulation brings numerous problems, such as weakening of the local economy, reduced local economic innovations and investments, degradation of urban space, social fragmentation and inequalities, etc. (Szaja, 2024). When the city is undergoing a process of decline, it becomes substantially more difficult to make it more sustainable. The issue of sustainable development and sustainable cities is one of the most important contemporary concerns, which requires a multidisciplinary and systematic approach in decision-making and land use planning.

CONCLUSION

This study has shown how different development paths in the Serbian and Romanian Banat regions have produced distinct land use dynamics within comparable functional urban areas. While Timișoara FUA is characterized by urban expansion and the uptake of agricultural areas, Zrenjanin FUA reflects a period of stagnation. The main reasons for the differences are institutional and demographic in nature. Due to the long-term depopulation within the Zrenjanin FUA, LULC changes have been minimal. Conversely, the Timișoara FUA has experienced population growth, resulting in increased spatial pressure and a greater demand for construction and urban expansion.

Reduced LULC changes and urbanization do not necessarily imply sustainable development. Demographic decline must be taken into consideration when assessing LULC changes in the context of sustainability, since the reductions in changes may be the result of depopulation, rather than effective land management. The planning and management of cities in expansion and in decline require substantially different approaches. Therefore, LT indicators and LULC changes must be interpreted through local context in order to ensure the most sustainable and realistic path of development.

The main limitation of UA data is the lack of more recent data, as well as the lack of data for Serbia before the year 2012. Nevertheless, further research may utilize satellite imagery from earlier and more recent years in order to track changes more accurately. Furthermore, the research on spatial planning documentation and regulations, as well as several socio-economic indicators (percentage of population with higher education, percentage of population employed in agriculture, etc.), through the years may also reveal underlying patterns of land transformation.

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