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CHARACTERISTICS AND EXPLANATION OF NEW ARTIFICIAL LAND USES ON THE EXAMPLE OF HUNGARIAN SECOND-TIER TOWNS

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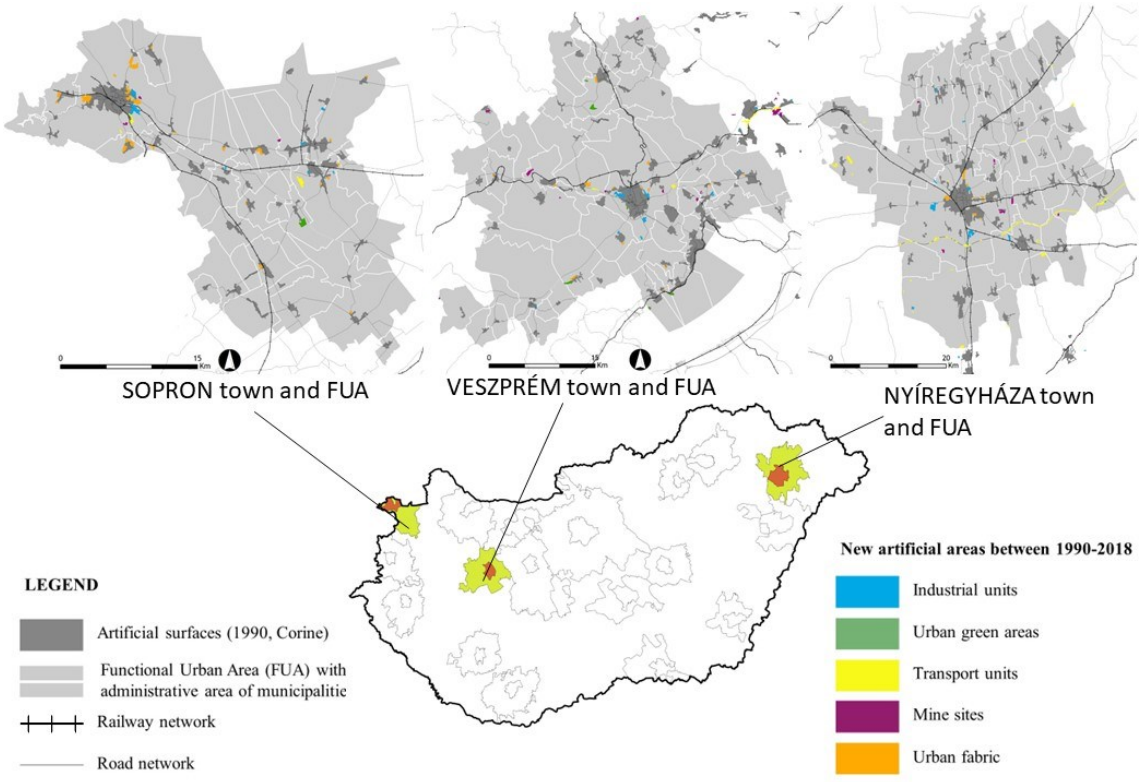
Abstract

The spatial growth of cities and the examination of the appearance of new artificial surfaces have been in the focus of several studies in the last decade. Attention was primarily focused on the metropolitan areas; however, the phenomenon can also be identified in smaller towns, which – at least, in Hungary – can hardly be explained by demographic trends. Urban growth, which is identified in the Carpathian Basin as well, is of concern from a sustainability point of view, so the monitoring and exploration of driving forces is of practical importance. Using the Corine Land Cover Database, the study analyses urban growth between 1990–2018 and looks for explanatory factors to understand the phenomenon. New artificial surfaces have appeared in the surroundings of cities or directly connected to morphological urban areas. Their morphological characteristics are presented on maps and in descriptive form. Those examples are interpreted for which the changes are not related to suburbanization trends or show unique characteristics in case studies. For example, in Sopron a large proportion of new residential areas are constantly appearing, thanks to its location on the border and the multi-centered metropolitan area of Vienna–Bratislava. The role of the ring road in the growth in Veszprém or the motorway construction in Nyíregyháza also determine spatial growth. Although the research approaches the issue of urban growth primarily from the point of view of morphology and land use, policy related conclusions can also be drawn from the results.

Keywords: urban growth, land use change, urbanization, urban morphology, Hungary, Corine

Graphical Abstract



New artificial surfaces between 1990–2018 at the three study areas in Hungary: Sopron FUA, Veszprém FUA, Nyíregyháza FUA (Data source: Corine Land Cover Database)

INTRODUCTION

Urban sprawl is a popular research topic, several and diverse publications deal with different aspects of the phenomenon. While some show uncontrolled growth (Ricz et al., 2009; EEA, 2016), others highlight the importance of car use (Bengston et al., 2004), explain land take increase difference (Fulton et al., 2001), discuss landscape aspects (Csemez, 1996; Jaeger and Schwick, 2014), sustainability (Piorr et al., 2011) or density (Camagni et al., 2002). Land use change is also a popular aspect, and basic professional documents have specifically highlighted the concerns about changes in cities and their environments: the growth of artificial surfaces, urban sprawl in Central and Eastern European cities has accelerated since the 1990s, mainly at the expense of semi-natural and agricultural areas (Antorp, 2004; Feranec et al., 2017; Gutman and Radeloff, 2017; Wnęk et al., 2021).

In Central Europe, most of the studies focus on the capitals (Feranec et al., 2010; Nuissl and ESPON EU-LUPA, 2014; Siedentop, 2021); thus, in Hungary special attention is paid to the Budapest agglomeration (Tosics, 1998; Schuchmann, 2013; Egyedné Gergely, 2014; Cegielska et al., 2018; Kovács et al., 2019; Lennert et al., 2020). However, smaller towns are also affected by urban sprawl (Iváncsics and Filepné Kovács, 2019). An overview study was carried out on Hungarian second-tier towns (Iváncsics and Filepné Kovács, 2021), drawing lessons from former research and using the methodology to formulate the need for a deeper understanding of the changes, background processes, and a more precise overview of the individual cases.

The current article focuses on and summarizes the results for three study areas, which were selected because of their special character, and gives further morphological analysis to understand the nature of changes and trends. The article deals with towns and their neighborhood, using the Functional Urban Area (FUA) delineation of OECD (2012). The most specific study area was Sopron FUA with its special situation at the Hungarian–Austrian border surrounded by national reserves of Lake Fertő Nyíregyháza FUA is on eastern part of Hungary with a relative late development and special settlement character around. Veszprém FUA is surrounded with national reserves of Bakony Mountains and Lake Balaton, well known recreation areas of Hungary.

From the experience gained in former research the following research questions arose: Are new artificial surfaces, and within these new residential areas typical for the whole metropolitan area in the neighbourhood of Sopron FUA? How can the outstanding quantity of new artificial surfaces be explained regarding Nyíregyháza FUA? What is the explanation of the diffuse and in parallel compact development of new artificial surfaces in Veszprém FUA?

STUDY AREA

All three study areas are situated in the Carpathian Basin, in Hungary. Sopron is in the Western part of the country, in the Alps Foothills (Alpokalja) region, very close to the Vienna Metropolitan Region. Nyíregyháza is in the Eastern part of the Great Pannonian Plain, in the neighborhood of Slovakia, Ukraine and Romania. Veszprém is situated in the middle of Transdanubia, near the popular recreational areas of Lake Balaton and Bakony Mountains (Fig. 1).

Sopron and its region

Sopron is located next to the western border of Hungary, in the Alps Foothills region, 60 km from Vienna, Austria and 220 km from Budapest, Hungary. The population of Sopron is about 60% of the whole FUA (Table 1). The city was built between the Sopron Mountains and the Balf Hills near Lake Fertő, in the Sopron Basin, at the confluence of the Ikva and Rák Streams, right at the narrowest point between the Vienna Basin and the Little Plain (Kisalföld) region. Lying at the foot of the hills, in an area of moderate relief compared to the surroundings, Sopron funnelled all of the roads running from north to south and from north-west to south-east. Sopron profits from its location on transport routes. Additionally, its economy is based on timber from the Sopron Hills, vines produced in the area of the Lake Fertő with slopes of the Balf or Rust–Kroisbach Ridge, the excellent construction material quarried here (Baden-Leitha limestone), the reeds, fish and game of the Fertő and in a greater distance, the Hanság (Wasen) area (Vadas, 2010).

The area of Sopron has been inhabited since prehistoric times, as it was significant as a castle during the time of the Romans, and after the Conquest Period, it was known as a royal city in the Middle Ages. Despite the wars, it developed continuously, and the settlement had administrative powers covering the whole Transdanubia. After World War I, in a vote, the citizens decided to belong to Hungary and not to Austria. Although after World War II, significant industrial development took place in Sopron as well, and the former commercial role was partly lost. However, tourism and holiday opportunities, as well as textile industry provided new sources of income. The “iron curtain” separated Sopron and its surroundings from Austria. In the 1960s and 1970s, significant monument protection works were carried out in the town, and the Baroque image of the city was preserved. Thanks to the excavations in this period, the development of the town is also well documented in terms of settlement morphology.
The urban development during the political transition at the endo of the 1980s, which has been largely private, resulted in the explosion of building private houses. An enormous demand appeared, utilising outskirt areas, although many people also moved out of the town, resulting in a transformation of the surrounding villages (suburbanization) (Vadas, 2010).

Nyíregyháza and its region

Nyíregyháza is in the vicinity of Slovakian (ca. 70 km), Ukrainian (ca. 60 km) and Romanian (ca. 85 km) border at the north-eastern part of Hungary (Fig. 1). The population of Nyíregyháza is about 50% of the whole FUA. It's territory is the largest comparing Sopron and Veszprém FUAs area (Table 1). Today it is a livable and increasingly colorful town with stable economy, a developed institutional system, and versatile culture.

The town was founded at the meeting point of agricultural fields with excellent quality and important roads, and it was known as an agricultural town (Csapó, 2011). Nyíregyháza has a special morphological pattern, as grouped farmsteads of agricultural buildings ("bokortanya" in Hungarian) became the centre of living. Due to the shape of the the arable lands and pastures that belonged to the town, it caused a lot of trouble for the population that the part of the land under cultivation fell far from the centre of the village / town. Therefore, those whose plot was very far away decided to set up lodgings / ranches (so-called "szállás"). These ranches later became settlement units used periodically for the village's animal husbandry and, later, for farming. Relatives and closely related families got their plots of land next to each other, and in order to minimize damage to the cultivated area, they built their

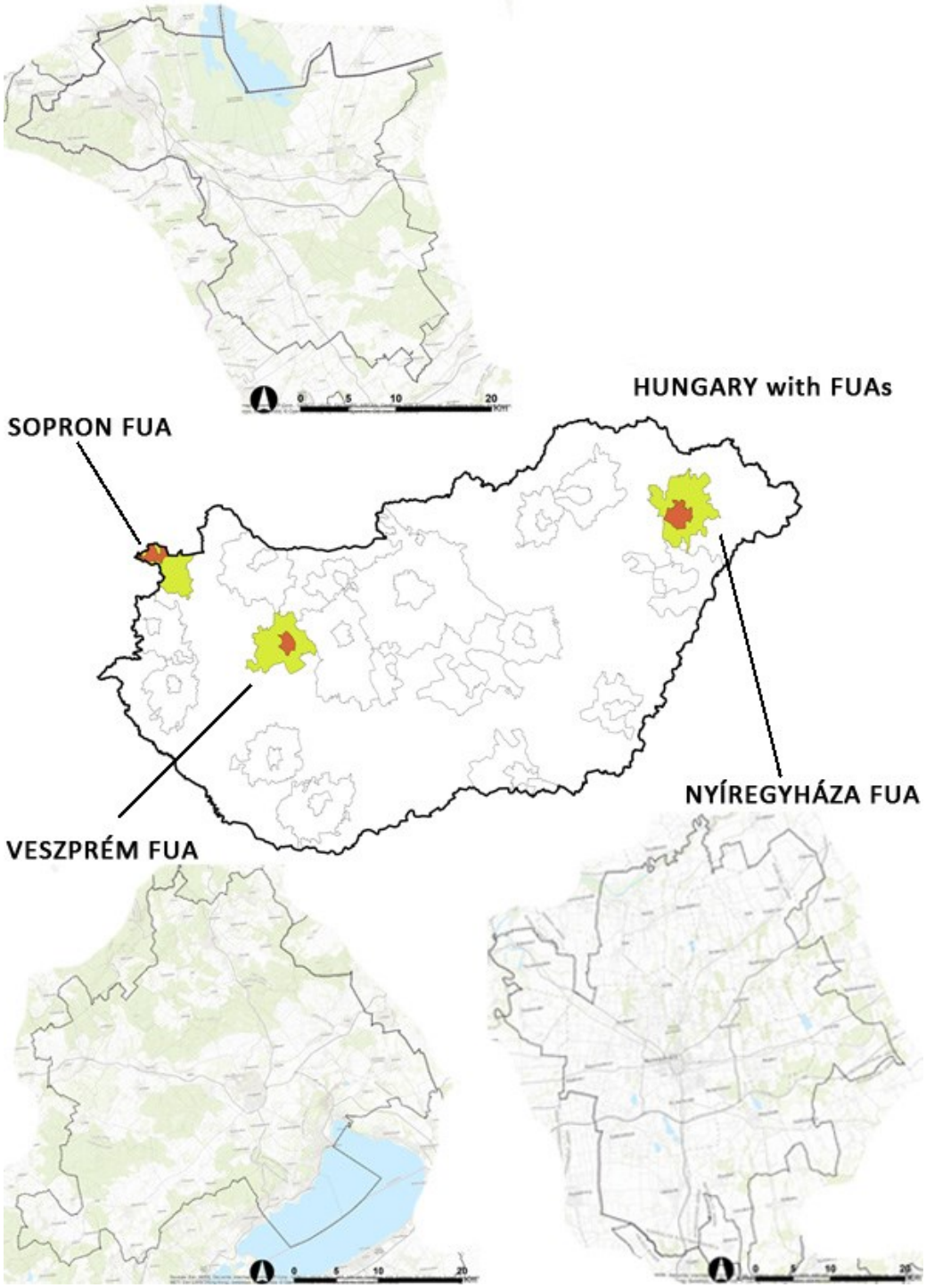


Fig.1 The situation and topography of Nyíregyháza, Sopron and Veszprém Functional Urban Areas (FUA) within Hungary.

Table 1 The area and population of Nyíregyháza, Sopron and Veszprém Functional Urban Areas (FUA) and central town (Source: KSH 2020)

Central town	FUA area (ha)	Central town area (ha)	FUA population (2020)	Central town population (2020)
Sopron	46,220	16,900	96,394	58,053
Nyíregyháza	112,800	27,450	242,999	119,765
Veszprém	77,360	12,690	137,584	55,247

gardens close to each other by mutual agreement. As a result, a specifically grouped farmstead structure was formed, which became the basis of the settlements in the farming area (Bácskainé Pristyák 2014). In the area of the town, 61 grouped farmsteads are present. In the development of the area, an important milestone was the establishment of railway connection to Budapest (1858). However, industrial development slowed down during the socialist era (Rechnitzer and Berkes, 2021). The population of the town doubled after railway constructions, thus, industrial-style housing construction started, which meant a new type of morphological pattern in addition to the previous mainly one-level buildings. As a result, the proportion of built-in areas in the northern and eastern half of the settlement increased significantly, and the former outer areas of Sóstóhegy, Borbánya and Oros became integral parts of the town. During this period, the industrial area was connected to the railway station, and the Sóstó green area was formed, considered as the lung of the city (Csapó, 2011).

After the regime change at the end of the 1980s, several international companies settled in the town, which were organically integrated into the county's economy and labour market. Peripheral shopping centres appeared, mostly along the roads leading out of the town. Urban sub-centres are typically located closer to the central city than in other studied towns. The centre transformed into a business district, and two types of living area were formed: an inner residential area, within the ring road, with mixed morphology, and an outer residential area, with homogenic family houses. Nyíregyháza established the first industrial park in the region in the 1990s (Rechnitzer and Berkes, 2022).

Veszprém and its region

Veszprém is situated in Central Transdanubia (Fig. 1). The town has a specific topographic location, as it is in the vicinity of Lake Balaton, at the foot of Bakony Mountains, on the Séd Creek. The population of Veszprém is about 40% of the whole FUA (Table 1).

The natural geographical features are more prevalent in Veszprém compared to Nyíregyháza and Sopron. Veszprém extended to Várhegy (Castle Hill) and the six settlements around it (Váralja in Hungarian) until the end of the 15th century. The special characteristic of the settlement structure of Veszprém, which can be traced back to the early Middle Ages, is that its downtown streets are aligned to the varying ground level height; thus many of them are narrow, steep and fragmented. This street network later gradually expanded outwards. The settlements of Váralja were later formed at the junction of the geological fault lines (valleys) crossing at Bakony Mountains and its eastern exit. In these fault lines in the past, there were particularly important routes that connected the Southern Bakony and the Balaton Uplands. Veszprém is settled at the meeting point of these routes, and the Veszprém Plateau became an important marketplace of the region. This market, expanding from the southern end of the Castle towards the southeast, became the backbone of the town's road network. The Séd Creek, as the only major watercourse on the Veszprém Plateau, also strengthened the handicraft and commercial functions (Csapó and Lenner, 2012).

However, the old character changed during the 18th century: the Váralja was surrounded by houses and expansion has been continued to south-eastern direction. In 1861, the Southern Railway connecting Buda with Nagykanizsa was built, which bypassed Veszprém, which affected the town adversely. Later, the Székesfehérvár–Celldömölk railway line, built in 1872, passed 4 km from the town. By then, the town had lost its commercial role, the distance was not conducive to the spatial development of the Veszprém. In the 19th century, thanks to the multi-storey buildings, the centre got an urban character. Many public buildings were built, and Veszprém's role in public administration and education was strengthened.

The socialist period, however, radically changed the morphology of Veszprém. Multi-storey block houses were built, primarily in the eastern and southern parts of the city, and neighborhoods with extensive detached and terraced houses were constructed (Csapó and Lenner, 2012). At the same time, as a victim of socialist urban development and construction ideas, a part of the centre's rows of closed houses were demolished and replaced by a modern style centre. The town's former administrative and educational character has changed. A new technical university was founded, and several industrial sites were opened. The population grew from about 20 500 (1949) to about 63 000 (1990) during the socialist era.

After the regime changed at the end of the 1980s, no more Soviet style housing estates were built, but residential parks and sophisticated detached houses appeared. Historically, most of the settlements in the Veszprém FUA have agricultural or forestry tradition (e.g. at Szentgál, Zirc). However, during the socialist era, industrialization also caused significant changes (in Balatonfűzfő, Papkeszi) (Dövényi, 2010). Also, a military training field of European importance was located here, with regular international military exercises. From an economic point of view, the political transition brought a stagnation; however, today Veszprém is an economical focus point of Western Hungary thanks to several companies which have chosen

Veszprém as new location. Tourism is also important here, as the area features popular holiday destinations around Lake Balaton and in the Bakony Mountains. The whole region won the title of European Capital of Culture for the year of 2023.

METHODS

In the last decades, the toolbox of research on land use and land use changes in the current sense has turned towards remote sensing and related indicators (for a comprehensive literature review, see e.g. Farkas et al. 2023). In Hungary, some basic studies have also been published. These generally dealt with the analysis of land use patterns relying on the Urban Atlas, Corine Land Cover (CLC), Landsat or Sentinel databases or other documentation (Mari, 2010; Mucsi, 2011; Henits et al. 2017; Szilassi, 2017; Mezősi et al., 2019; van Leeuwen et al., 2020). The current study relies on the Corine Database for the following reasons.

- It is widely used and accepted.
- Its nomenclature fits to answer the research questions.
- The scale is suitable for regional analyses (25 ha /100 m, after 2000: 5 ha, changes documented with 5 hectares);
- The time frame is suitable for analyses after 1990 in contrast to the Urban Atlas (Corine available for the following periods: 1990–2000, 2000–2006, 2006–2012, 2012–2018, Urban Atlas for 2012–2018).
- Risks and deficiencies are well documented, such as errors due to scale, size of the smallest mapping unit, generalization rules (Diaz-Pacheco and Gutiérrez 2014; Mari 2010).

The recent research focuses on the period after the regime change, from 1990 to 2018. For the purposes of this study, the nomenclature has been restructured to focus on artificial surfaces and further categories within. Five different land use functions were developed within the artificial surfaces, which meant the regrouping of the existing categories: (i) Urban fabric, (ii) Industrial units, (iii) Transport units, (iv) Mine sites (v) Urban green areas. The regrouped categories are listed in Table 2.

To avoid the risk of generalisation rules and error due to scale, validation has been made in the database, all polygons were checked manually and corrected according to the corresponding Google Earth orthophotos. The subcategory of the polygon was corrected according to the final status of the area. As a result, several transport units were modified as non-artificial areas, because of misclassification of Corine, and the Construction sites (1.3.3.) were classified according to the final status of the area.

Although all the results rely on the Corine Database, for deeper understanding and comparison, the Corine Database CHA was also used to calculate the surfaces belonging to different categories.

In this study, *artificial surfaces* are understood as areas with buildings of different functions or incorporated areas for urban use, like urban parks or other recreational areas. During the morphological analyses, the focus was on the pattern of artificial surfaces and non-artificial

Table 2 The applied land use categories of the analyses, based on Corine nomenclature (source: Heymann et al., 1994; Bossard et al., 2000)

Code	Corine nomenclature			Simplification and terms in this study	
	Class 1	Class 2	Class 3	Main categories	Subcategories
1.1.1	Artificial surfaces	Urban fabric	Continuous urban fabric	Artificial surfaces	Urban fabric
1.1.2			Discontinuous urban fabric		
1.2.1		Industrial, commercial and Transport units	Industrial and commercial units		Industrial and commercial units (abbr. industrial units)
1.2.2			Road and rail network and associated lands		Transport units
1.2.3			Port areas		
1.2.4			Airports		
1.3.1		Mine, dump and construction sites	Mineral extraction sites		Mine, dump sites (abbr. mine sites)
1.3.2			Dump sites		
1.3.3			Construction sites		Manually categorised according to the satellite photo from Google Earth 2020.
1.4.1		Artificial, non-agricultural vegetated area	Green urban areas		Artificial, non-agricultural vegetated area (abbr. urban green areas)
1.4.2			Sport and leisure facilities		
2.	Agricultural areas			Agricultural surfaces	
3.	Forest and semi natural areas			Natural, semi natural surfaces (abbr. natural areas)	
4.	Wetlands				
5.	Water bodies				

Table 3 The proportion of three main land use categories within the Functional Urban Areas (FUA) of Sopron, Nyíregyháza and Veszprém in 1990 and 2018. (Source: Corine)

	Sopron FUA		Nyíregyháza FUA		Veszprém FUA	
Land use / year	1990	2018	1990	2018	1990	2018
Artificial surfaces	6%	7%	7%	9%	5%	6%
Agricultural surfaces	41%	40%	81%	74%	54%	51%
Natural or semi-natural surfaces	53%	54%	12%	16%	40%	42%

surfaces (agricultural and natural surfaces together). The terms *built-in* or *urbanised areas* are regarded as synonymous to *artificial surfaces*. *New artificial surfaces* arise if the former non-artificial surfaces became artificial during the examined period. *Urban fabric* is a subcategory of artificial surfaces with residential function.

The *central settlement* is the centre of the FUA, given by the data source of shape files from OECD (2023). The central settlement is a town in all mentioned cases with a clearly visible concentration of artificial surfaces. As a cognate term, *morphological urban area (MUA)* is also applied, which is defined as "a territorially contiguous settlement area that can be distinguished from low-density peripheral and rural hinterlands" by Taubenböck et al. (2019). In the Corine Database, the MUA is delineated as a continuous, concentrated area of artificial surfaces (class 1 in Table 2) within the administrative area of central settlement / town in our case.

The spatial pattern of new artificial surfaces was described according to the categories of Inostroza et al. (2013): infill, isolated and axial.

- *Infill*: new artificial surfaces appearing in previously non-artificial areas surrounded by the existing urbanised area.
- *Isolated*: new artificial surfaces created separately from the already existing urbanised area, without connection.
- *Axial*: the clearly visible design of the artificial surfaces that appear in a characteristic longitudinal shape.

The compactness of the growth of cities in relation to the central settlement and the entire territory of the FUA was also reviewed. Based on the location of the new artificial surfaces that appear, two categories were defined:

- more than 50% of the new artificial surfaces appear in the central settlement;
- more than 50% of the new artificial surfaces appear outside the central settlement.

With these two parameters the spatial pattern of the new artificial surfaces is described and illustrated.

RESULTS

The results are discussed for each FUA separately, discussing the distribution of land use according to three main categories: (i) artificial, (ii) agricultural and (iii) natural or semi-natural surfaces. Then, the most important conclusions from former research (Iváncsics and Filepné Kovács 2021) will be discussed on new artificial land uses and its subcategories in the different periods between 1990–2018, especially for the three study areas. As a further step, the spatial character of these land uses is examined.

Sopron and its region

Based on the Corine data, the Sopron FUA belongs to the regions with significant natural surfaces based on the domestic comparison. Compared to the situation in 1990, the ratio of artificial surfaces and natural surfaces increased to the detriment of agricultural surfaces (Table 3).

In terms of the appearance of new artificial surfaces and the change in population, Sopron's situation is unique, as both indicators increased the most between 1990 and 2018, comparing 12 Hungarian second-tier towns (Iváncsics and Filepné, 2021). In addition, Sopron FUA is unique because of a significant increase of urban fabric in each of the studied periods. In terms of artificial surfaces, industrial and transport units are dominant in the period 1990–2000, and areas with residential and additional functions in the period 2000–2006.Calculating the ratio of new artificial surfaces during the period of 1990–2018, the distribution between the central town and its surroundings is balanced. 46.3% of new artificial surfaces are situated outside Sopron's administrative boundaries.

The pattern of new artificial surfaces follows the infill pattern around the MUA of Sopron. The function of these areas is residential in most cases (Fig. 2). Also, at the settlements in Sopron FUA new urban fabric is typical and organised around the MUA of these settlements. However, as the road network and railway lines also pass through the settlements, some axial character is visible. There are some plots that are isolated, some of them is urban fabric, other spots are urban green areas.

To give on overview about the situation of new artificial surfaces around the Sopron FUA, it is visible, that the country border, the neighbouring towns (e.g. Győr, Szombathely) and capitals (Vienna, Bratislava) are also affected by urban sprawl. Also, there is a strong axial pattern of new artificial areas in the line of roads: South direction from Vienna A2 and A3 motorways, from Győr to Vienna M1, and from Győr to Sopron M85 motorways and railway network (Fig. 3).

Nyíregyháza and its region

Based on the Corine data, Nyíregyháza can be considered a region with an outstanding agricultural surface, where the proportion of artificial surfaces is 9%, the proportion of agricultural surfaces is 74% and the proportion of natural surfaces is 16% in 2018. Between 1990 and 2018, an increase in artificial surfaces and natural surfaces could be seen parallel to the decrease of agricultural surfaces (Table 3).

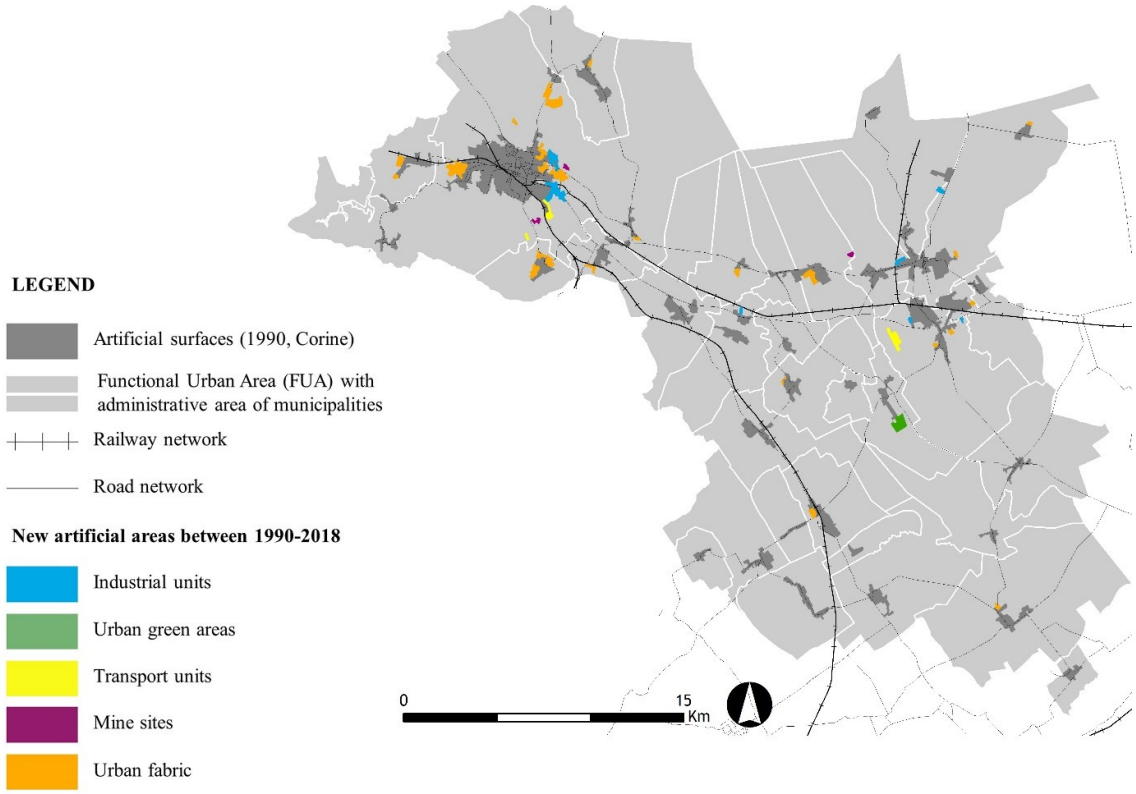


Fig.2 New artificial surfaces by categories between 1990 and 2018 in the Functional Urban Area (FUA) of Sopron (Source: Corine)

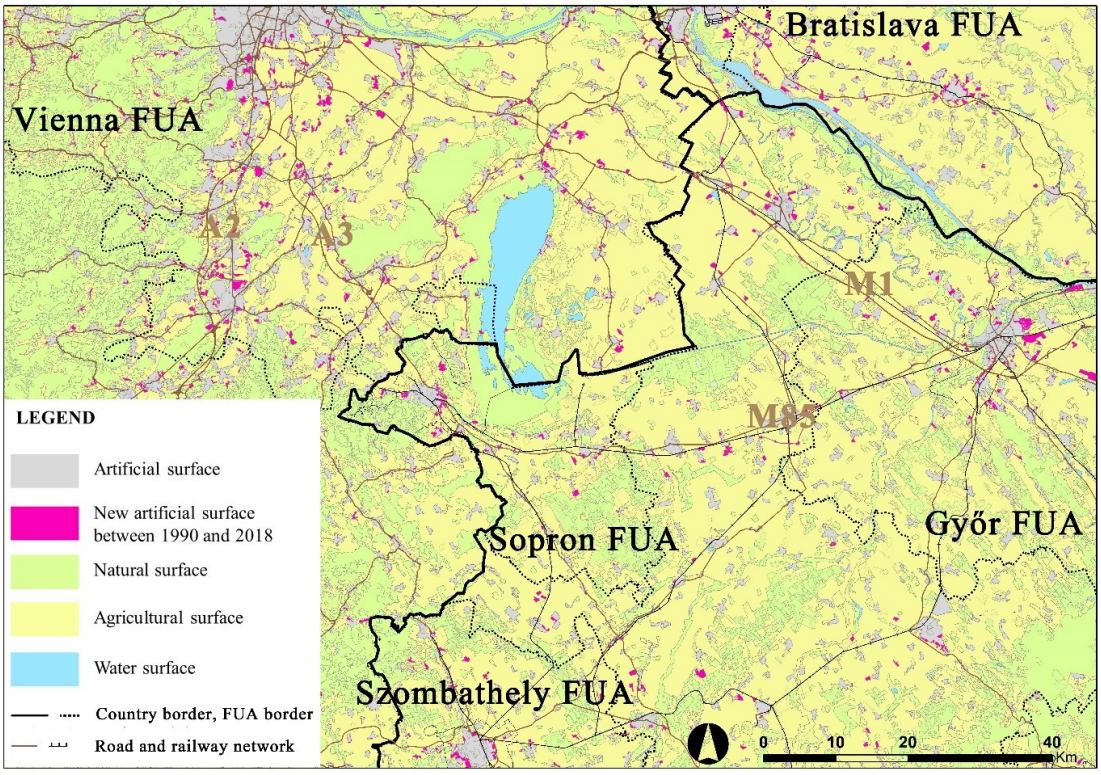


Fig.3 The pattern of new artificial surfaces in the neighborhood of Sopron Functional Urban Area (FUA) (Source: Corine)

In the case of the Nyíregyháza FUA, the proportion of new artificial surfaces is slightly higher than it was experienced in other Hungarian settlements, but this can be said in general for regions affected by highway construction. The extreme increase of new urban fabric in 2000–2006, the exceptionally high number of new transport areas in 2006–2012, and the proportion of new industrial units in the period 2012–2018 show the highest values out of the three examined areas (Fig. 4).

Calculating the ratio of new artificial surfaces during the period of 1990 and 2018, the distribution between the central town and its surrounding is balanced. Most (54%) of the new artificial surfaces are situated outside Nyíregyháza's administrative boundaries.

Based on the overview of the maps, it can generally be stated that the new artificial surfaces in Nyíregyháza FUA are arranged around the central settlement, infilling the MUA, which is typical of new urban fabric. Developments along the axis include industrial and transport units. However, separate from the already existing MUA, isolated new urban fabric is also detected (Fig. 5).

Veszprém and its region

Based on the Corine data, Veszprém FUA belongs to the regions with significant natural surfaces based on the comparison among 12 Hungarian towns (Iváncsics and Filepné 2021). In Veszprém FUA the proportion of artificial surfaces is 7%, the proportion of agricultural surfaces is 40% and the proportion of natural surfaces is 54% in 2018. Compared to the situation in 1990, the proportion of artificial surfaces and natural surfaces increased to the detriment of agricultural surfaces, but the change is small (Table 3).

Veszprém FUA has average values in terms of the appearance of new artificial surfaces among the previously examined regions. The peak period of the appearance of new industrial units here falls earlier, in the period 1990–2000, after which residential areas dominated in the period 2000–2006, in line with suburbanization in Hungary. The period 2006–2012 brought the peak period of new transport units. The same can be said of the more intense period of the appearance of new urban green areas, which appeared to the highest extent in Hungary

Calculating the ratio of new artificial surfaces during the period of 1990 and 2018, the distribution between the central town and its surrounding is diffuse. Almost two-thirds (61.6%) of new artificial surfaces are situated outside Veszprém's administrative boundaries. But, within the central town, the results show concentration of new artificial surfaces.

The new artificial surfaces are organised along the road network, especially new urban fabric. Industrial sites are situated within the motorway ring around and infill the MUA of Veszprém, at northern part, near the railway station and in the south, as developments of the Industrial Park (Fig. 6).

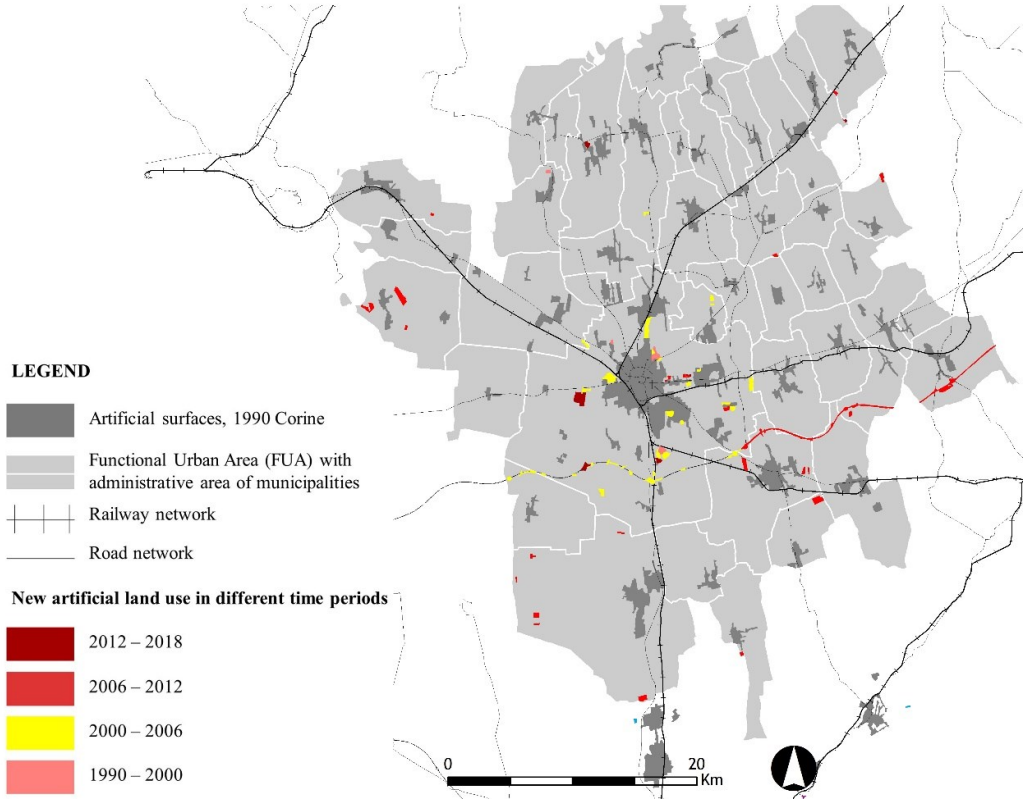


Fig.4 New artificial surfaces by time periods of 1990–2000, 2000–2006, 2006–2012, 2012–2018 2018 in the Functional Urban Area of Nyíregyháza (Source: Corine)

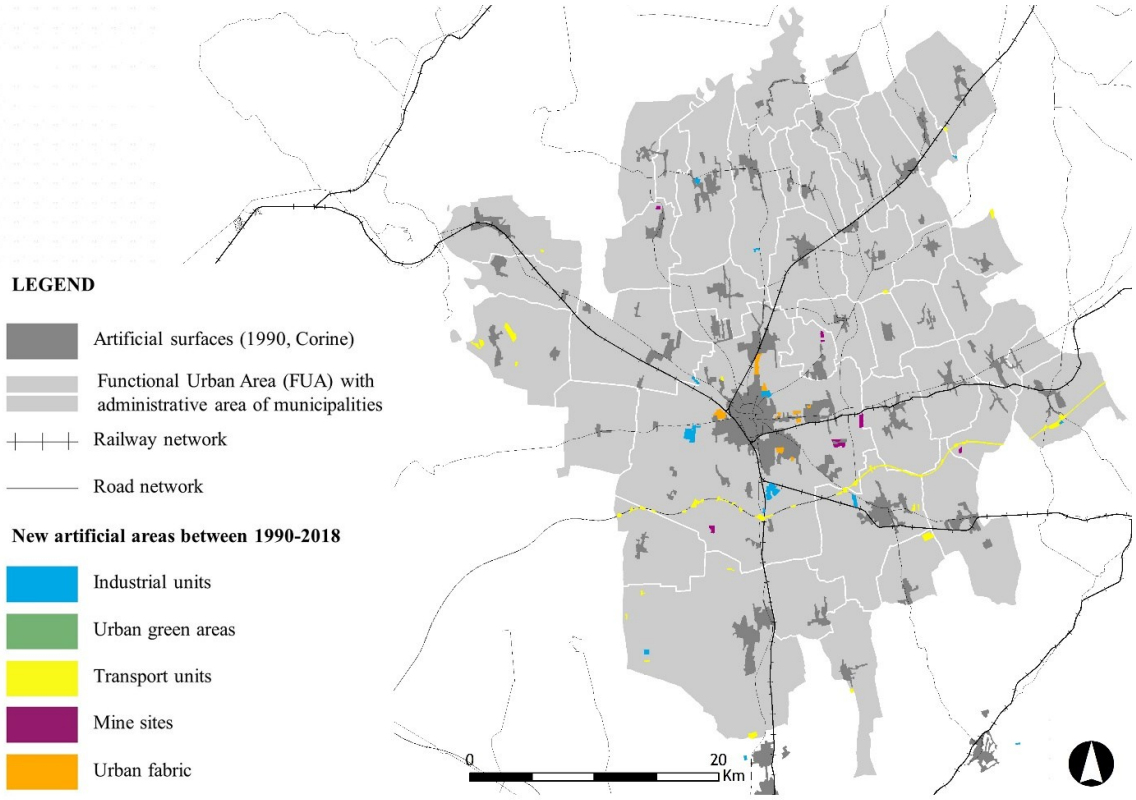


Fig.5 New artificial surfaces by categories between 1990 and 2018 in the Functional Urban Area of Nyíregyháza (Source: Corine)

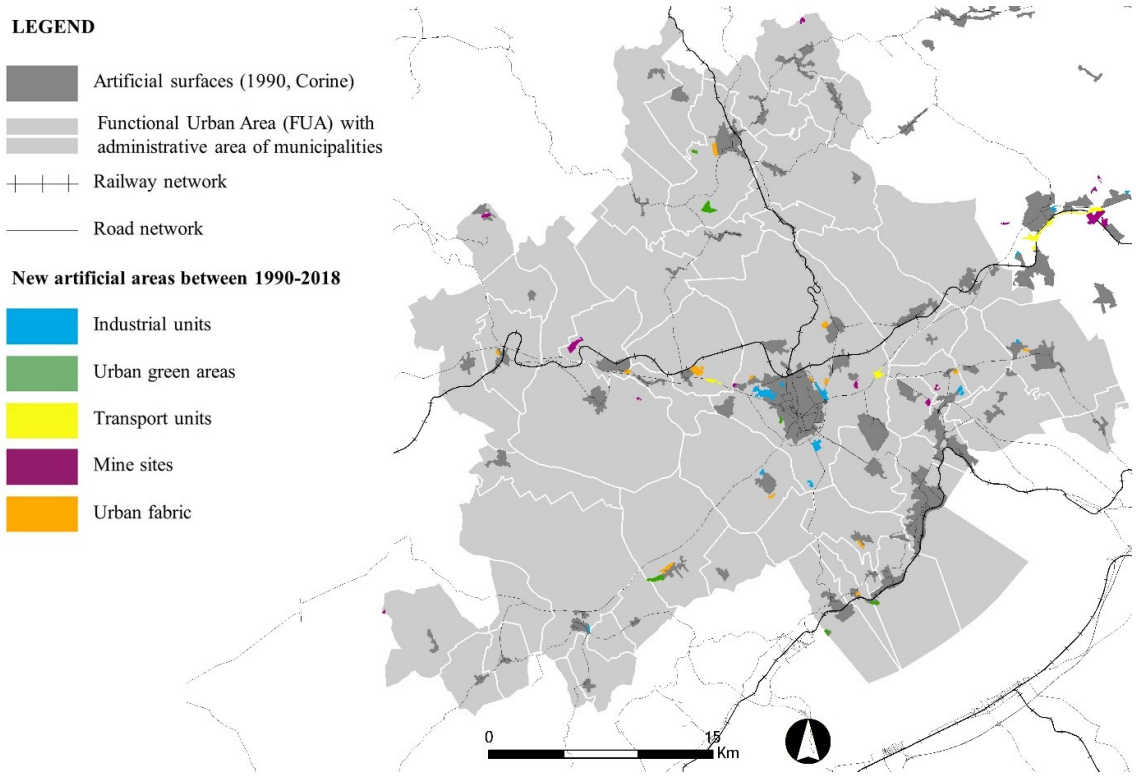


Fig.6 New artificial surfaces by categories between 1990 and 2018 in the Functional Urban Area of Veszprém (Source: Corine)

DISCUSSION AND CONCLUSIONS

Hungarian second-tier towns are affected by urban sprawl, despite the demographic tendencies. However, there are well known trends in Hungarian urbanisation, like suburbanization and its further effects, likepopulated garden-plots, increasing property prices at agglomeration settlements, lack of adequate infrastructure and regulation that does not follow the processes or achieves one-sided benefits (Németh, 2011; Bajmócy, 2014; Kovács, 2017). The examples discussed in the study confirm the well-known trends.

- Suburbanisation: in all three studied FUAs the intensive growth of urban fabric areas was witnessed between 2000 and 2006;
- The late development of Nyíregyháza FUA, compared to Sopron and Veszprém FUAs confirms de East–West division discussed by Beluszky and Győri (1999);
- The growth of artificial areas is typical at strongly agglomerating or geographically special settlements (for example at Sopron, Mosonmagyaróvár or settlements around Lake Balaton) according to Bazsóné Bertalan (2018). Németh (2011) added to this list regions with a recreational role.

Also, there are unique tendencies, depending on the geographical situation, the economic environment, national investments on infrastructure and the inherited or planned settlement structure of the region. To give a brief summary of Iváncsics and Filepné Kovács (2021), the above factors play the most important role of new artificial surfaces.

Sopron's situation is outstanding at the edge of the border Austria and Hungary, next to the former "iron curtain". A similar situation is found at the German–Polish border, where the boom of new artificial areas, especially with residential and economic function was documented (Cieślak et al., 2020). However, from a broader perspective, Sopron and its region are affected by the economic concentration of Vienna and Bratislava. The new artificial areas are concentrated near the main motorway lines at these neighbourhood regions. Some areas that are distant from these networks are not affected by urban sprawl. Furthermore, new urban fabric, novel residential areas are connected to the existing artificial area of other settlements in Sopron FUA. Inside Sopron, the infill pattern of new artificial areas was recorded due to the topographic situation and land cover: Sopron Mountain and forests is an obstacle of rapid growth).

The quantity of new artificial areas is outstanding in the Nyíregyháza FUA. The character is varied, depending on the function: new urban fabric is typically of the infill category, new transport units are axial, while industrial units and some urban fabric areas are isolated. Besides that, the town is situated near of the border of Slovakia, Ukraine and Romania at the north-eastern part of the Great Plain, three explanations are found for the growth pattern of artificial areas. The first is the inherited settlement structure, called grouped farmsteads around the towns. These became residential from the time of history and became the evident direction of urban growth. The road network, that connects grouped farmsteads is also the destination of new industrial, in this case, commercial developments. The motorway M3 was constructed around the town between 2004 and 2014. The third reason is the industrial development. Although the first Industrial Park in the whole region was opened here in the 1990's, according to the results of the study, new industrial units appeared mostly in the period of 2012 and 2018, probably due to the infrastructural development and attractive economic environment.

For the Veszprém FUA, a balanced distribution of artificial surfaces is typical between the central town and its surroundings. However, the spatial pattern is different. (i) Around the central town the pattern of new artificial surfaces, mainly urban fabric, is organised axially, according to the most important primary and secondary road network. Several plots are isolated, these are urban green areas. It is a typical arrangement for this FUA, because of the holiday function of Lake Balaton and Bakony Mountains. These urban green areas were usually established for recreational purposes. (ii) Within the area of Veszprém town, the new artificial surfaces, mainly industrial sites, are situated around the town along with motorway ring and in dedicated Industry Parks at the northern and southern parts. As the result of the organizing power of the ring road, Veszprém's MUA is the most compact town comparing 12 second-tier towns in Hungary, and this compactness seems to be stable during the examined period of 1990 and 2018 (Iváncsics and Filepné, 2021).

Also, important conclusions can be drawn regarding the effects of infrastructural investments. From history it is well known that railway infrastructure development was determinant for long years. This effect is reflected in the spatial distribution up to this day. A similar investment can be an Industrial Park, which influences the industrial development of the future. From the distribution of new artificial areas, the road network, especially the motorway and the primary roads, have the same role. Furthermore, a ring road can be the tool of control urban sprawl, as the example of Veszprém shows (Iváncsics and Filepné Kovács 2019).

The plans for future development of the study leads in two directions. First, it would be important to know the morphological characteristics of new artificial surfaces regarding the already existing urban fabric. Do these fit into the existing urban fabric or environment? What was the motivation of the regulation of urban development plans? To explore this, further methodologies would be useful, for example field studies and interviews. Second, the change of the overall landscape character of the towns and their neighbourhood requires further research: How had the ecosystem services been changed? The answer should be given focusing on regulation and cultural services, like maintenance or air quality, climate and water regulation aesthetics, recreation etc.

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