Settlement and green infrastructure characteristics in dynamically growing urban areas

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1. Abstract

One of the determining tendencies worldwide in recent landscape change is urbanization that reflects at the same time the transformation of human lifestyle and settlement space, the growing expansion of urban areas in line with the increasing urban concentration of population. It is also important to map these settlements in terms of the evolution of the landscape-settlement relationship and the character of the green space network within the settlements.

In Hungary in the second half of the 20th century, the number of settlement areas – that significantly changed in size, in structure and in building stock – was under fifty. The largest of those towns, which are roughly evenly distributed throughout Hungary's settlement network, are the „patches" defined as independent landscape character types, settlement landscapes, in the landscape character research project (KEHOP-4.3.0-VEKOP-15-2016-00001) (Web ref. 1).

In this research, we analysed urbanised settlements and their associated built-up areas as a continuation of the landscape character research project (KEHOP-4.3.0-VEKOP-15-2016-00001) (Web ref. 1). We typified the spatial structure of the analysed settlements and defined the green space character, the degree of built-up areas and the relationship between the built-up areas and the green spaces.

Based on the results, we determined that the role of green space areas within the structure of settlement areas is always significant in some ways, but at the same time the character of them is different:

- the majority of the settlement areas analysed, despite being the most urbanised at national level, are loosely built-up with significant green space,
- the smaller, more densely built-up areas, on the other hand, have a high proportion of green spaces bordering the built-up areas.

In addition to the spatial typology of the urbanised settlements and their territories, this study illustrates in detail through three settlements with different structure the characteristics of the spatial structure and the networks of green infrastructure elements.

2. Introduction

The quality of the green infrastructure network and its services will certainly have a significant impact on the liveability of the increasingly populated cities in the future. Green spaces are integrated into the urban spatial structure, so mapping the overall spatial structure of settlements is

essential for the determination of effective green infrastructure development strategies. However, relatively little is known about the spatial structure of Hungarian urbanised settlement spaces.

The analysis of settlement areas was started within the framework of the landscape character research KEHOP-4.3.0-VEKOP-15-2016-00001 (Web ref. 1.). During the research, we identified the Hungarian settlements with high growth based on statistical data from the last 70 years – such as population and housing stock. The results indicate above-average values for 41 analysed settlements, which can be considered as hotspots of urbanisation.

The characteristics of the green spaces integrated into the urban spatial structure were analysed based on the map database from the KEHOP-4.3.0-VEKOP-15-2016-00001 (Web ref. 1.) project – used as a tool in the landscape character project. In this research, we considered green spaces with and without trees within the urban structure, forests, grasslands dominated by herbaceous plants, and wetlands that are also part of the blue infrastructure as parts of the coherent green infrastructure system of the settlements. We analysed settlement spatial structure in terms of the areas containing built-up areas and artificial surfaces, which contains beside built-up areas and pavements the non-biologically active modified surfaces.

In relation to these results, we focused on the analysis and typification of the spatial characteristics of the highly urbanised settlements. The results are illustrated in detail through Nyíregyháza, Mosonmagyaróvár and Zalaegerszeg by presenting their spatial structure and green space characteristics.

3. Background and Literature Review

The most important source of literature and research for defining the urban spatial structure types in Hungary is the National Ecosystem Mapping and Assessment of Hungary (henceforth NÖSZTÉP) (Web ref. 1), which was established as a result of the framework of the landscape character research project KEHOP-4.3.0-VEKOP-15-2016-00001 (Konkoly-Gyuró, 2021). This map is considered as the primary data source for this research as well. Another primary source of literature is the research section on settlement spatial patterns within the landscape character research project, where several publications on settlement spatial patterns have been published (Illyés et al., 2019 (1-2)).

International research, such as „A novel concept to assess human-nature interrelations, nature conservation and stewardship in cities" (Elands et al, 2019), provides important aspects for the assessment of interdependent urban and green space structures, and a detailed analysis of the planning office of Gerhard Curdes, which provides the basis for urban development (Curdes, 1997) informed the methods used in this research.

4. Method and Data

The first step of the research was to delimit the contiguous settlement areas directly linked to the built-up areas of the 41 settlements[1] defined as development hotspots. The digital delimitation was

[1] The 41 settlements defined as development hotspots are the following: Budapest, Sopron, Gödöllő, Keszthely, the south shore of Lake Balaton, Tatabánya, Lake Velence, Székesfehérvár, Dunaújváros, Kecskemét, Cegléd, Dabas,

based on the NÖSZTÉP map using GIS methods (ArcGis 10.4 software). This map is a new tool, established at national scale, with a pixel resolution of 20x20 m, which detects surface quality in great detail and with a high degree of accuracy, and therefore provides a number of additional data for the representation of present land uses and for the definition of land surface quality.

In order to obtain realistic built-up area contours from the built-up areas, the pixels containing the built-up areas were first expanded by 100m and then shrunk by 100m. Thus, the built-up pixels merged. Then, by aggregating the built-up areas by 300m, contiguous settlement areas were created. The contiguous settlement areas around the hotspot settlements cover 113 administrative units. (**Figure 1**)

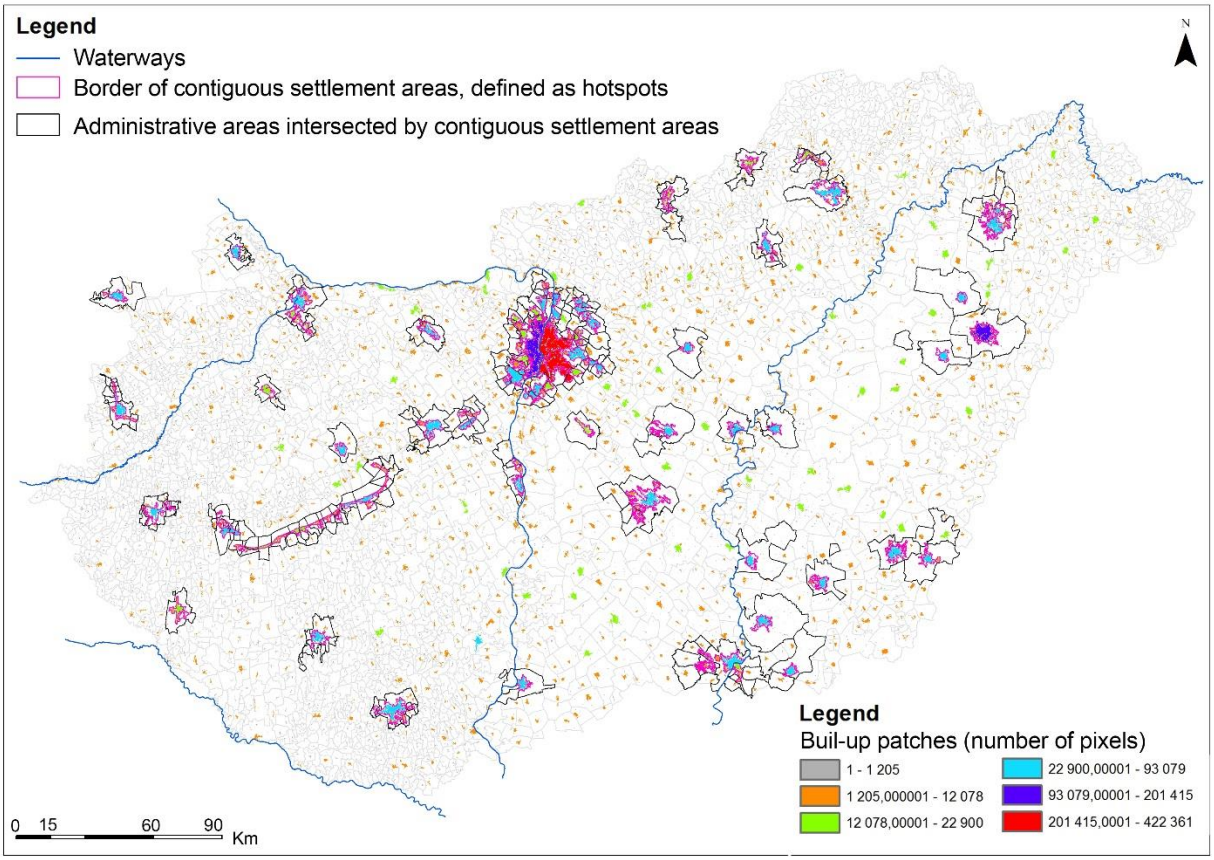

Figure 1. Location of contiguous settlement areas in Hungary (own edited figure)

We analysed the contiguous settlement areas („patches") to define their spatial structure based on the NÖSZTÉP map. For the spatial structure classification, the following data were determined:

- the settlements (regarding as administrative units) intersected by the boundaries of the contiguous built-up area
- the total area and number of built-up areas within the analysed settlement „patches"

Jászberény, Törökszentmiklós, Szolnok, Salgótarján, Ózd, Kazincbarcika, Eger, Miskolc, Hajdúszoboszló, Hajdúböszörmény, Debrecen, Békéscsaba, Gyula, Szeged, Hódmezővásárhely, Makó, Orosháza, Szentes, Baja, Pécs, Kaposvár, Nagykanizsa, Veszprém, Pápa, Szombathely, Zalaegerszeg, Mosonmagyaróvár, Nyíregyháza, Győr

regarding to the inlot areas[2], the periphery areas and the areas under complex cultivation (typically vineyards, orchards, gardens)
    - the number and size of individual built-up areas within the above „patches”
    - the number and size of the areas under complex cultivation and other built-up areas in the periphery area within the above „patches”

The following data have been identified for the classification of urbanisation and green surfaces:

- the area of high and low (below 12 m) built-up areas within the total built-up area
- the area of artificial (paved surfaces, roads, railways) surfaces (including built-up areas)
- the area of green surfaces, and within this, their area in artificial surfaces
- areas dominated by woodstock and areas dominated typically by herbaceous vegetation within green surfaces
- the area of water surfaces
- the area of arable agricultural surfaces
- the area of surfaces under complex cultivation

The databases used were extended by calculations of distribution, ratio and average size and the results were categorised into average, above average and below average groups.

5. Results

National results

On the basis of the results obtained using the method described above, we classified those settlement areas that are considered as urbanisation hotspots into 7 different spatial structure types. (**Table 1, Figure 2**)

Table 1. Spatial structure types of urbanising settlement areas

1. Category	
non-agglomerating settlement areas with compact boundaries, with sparsely subdivided, compact structure, with one or more merging centres	
Settlements: Hajdúböszörmény, Jászberény, Törökszentmiklós, Mosonmagyaróvár, Pápa, Hajdúszoboszló	
2. Category	
non-agglomerating settlement areas with compact boundaries, with a looser internal structure, with one or more merging centres	
Settlements: Baja, Makó, Szentes, Hódmezővásárhely, Debrecen, Békéscsaba	

[2] Outlying and inlot areas are administrative classifications of parcels of land according to their location in Hungary. Regarding to Government Decree No. 321/2012 (XI. 16.) on spatial planning, the inlot areas of the settlements' administrative area are defined as typically comprising the historically developed, contiguous, built-up or intended to built-up areas of the settlements, while outlying areas are defined as areas primarily used for agriculture, forestry, water management, or special purposes (e.g. mines, water reservoirs, waste disposal sites) or are not under cultivation. Hungarian settlements do not typically have a single contiguous inlot area (there are central inlot and separate inlot areas).

3. Category	
non-agglomerating settlement areas bounded by small units, with less compact, loose structure and with fragmented centre	
Settlements: Dabas, Veszprém, Szolnok, Salgótarján, Ózd, Cegléd, Sopron	
4. Category	
non-agglomerating settlement areas with units of various sizes, with loose structure, with sub-centres	
Settlements: Nagykanizsa, Orosháza, Székesfehérvár, Gyula, Kaposvár, Szeged	
5. Category	
agglomerating, non-compact settlement areas with loose structure, with units of various sizes, with sub-centres	
Settlements: Eger, Keszthely, Dunaújváros, Zalaegerszeg, Kecskemét, Nyíregyháza, Gödöllő, Győr	
6. Category	
agglomerating, less compact settlement areas bounded by small units, with loose structure, with fragmented centre	
Settlements: Kazincbarcika, Miskolc, Velencei-tó mente, Tatbánya, Szombathely, Pécs	
7. Category	
extensively agglomerating, non-compact settlement areas with units of various sizes, with loose structure, with sub-centres	
Settlements: Balaton déli partja, Budapest	

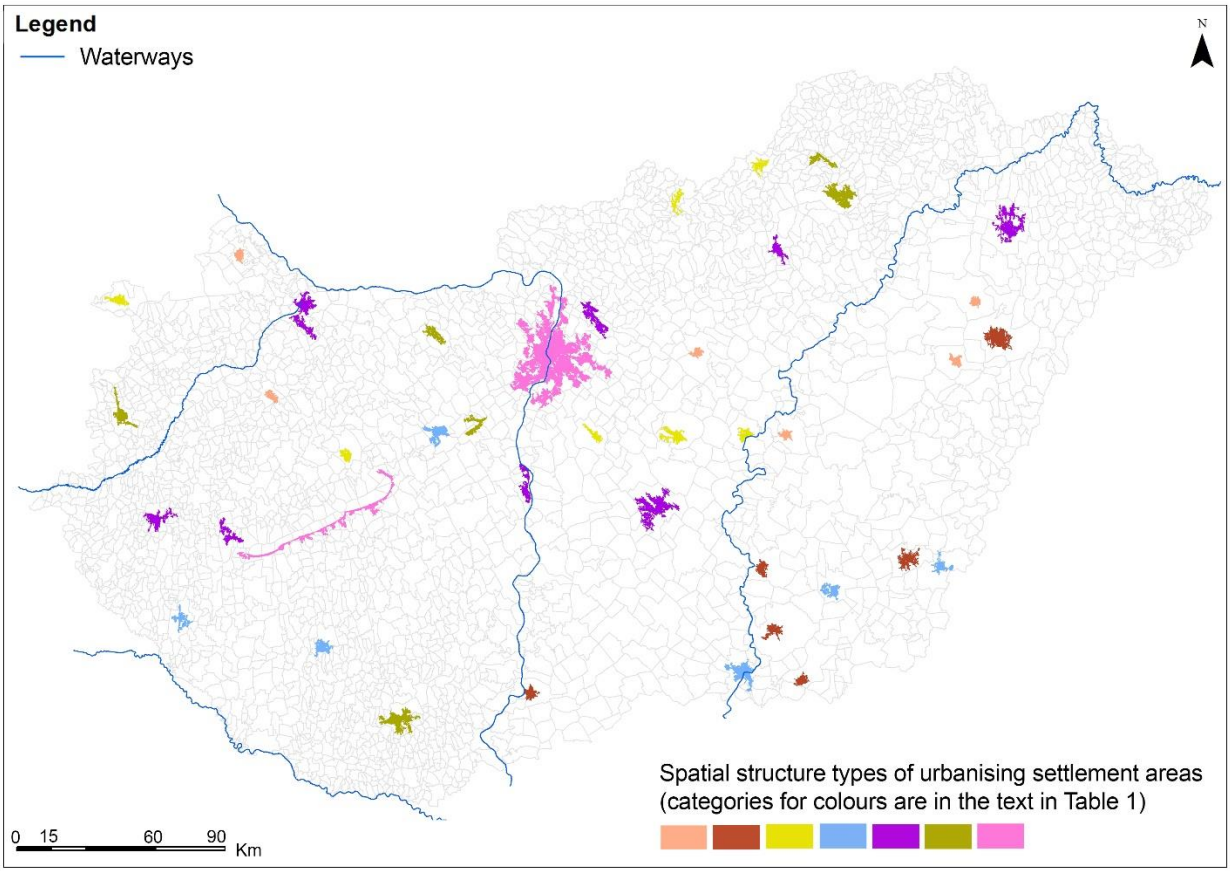

Figure 2. Location of urbanising settlement areas categorized by their spatial structure (own edited figure)

An important result is that our analysis has also revealed spatial structural relationships that are beyond administrative boundaries. In 16 of the urbanised settlement areas, the built-up structure forms an agglomerating, merging structure with neighbouring settlements. In this relation, the merging built-up areas from the peripheries have a significant role within connection. Agglomerating settlement areas that are growing to a significant extent through their built-up structure of their peripheries are Jászberény, Törökszentmiklós, Pápa, Hajdúszoboszló, Hódmezővásárhely, Debrecen, Orosháza, Zalaegerszeg, Nyíregyháza, Gödöllő, Szombathely, Kazincbarcika.

Results of the sample settlement areas

To illustrate the structural characteristics of the settlement areas, we selected three settlement areas that are defined as different types in relation to the results of national analysis. Within the category named „non-agglomerating settlement area with compact boundaries, with sparsely subdivided, compact structure, with one or more merging centres" Mosonmagyaróvár is selected. Two of the analysed settlement areas, Zalaegerszeg and Nyíregyháza belong to the category named „agglomerating, non-compact settlement areas with loose structure, with units of various sizes, with sub-centres". The two latter settlements have similar spatial structure, but differ in the aspect that Zalaegerszeg is linked to its neighbours by merging its complex cultivated areas, while Nyíregyháza is linked to its neighbours by densely scattered farmlands. The urbanised settlement areas of Nyíregyháza (119,767 inhabitants), Zalaegerszeg (57,513 inhabitants) and Mosonmagyaróvár (32,454 inhabitants), which are linked to their centres, also differ significantly in terms of their size, population and historical settlement structure. However, they are similar in that aspect, that their population almost doubled over the last 70 years, while population inflows have stagnated or reversed over the last 10 years. The dynamic population growth has been served by the different spatial structures of the settlement areas.

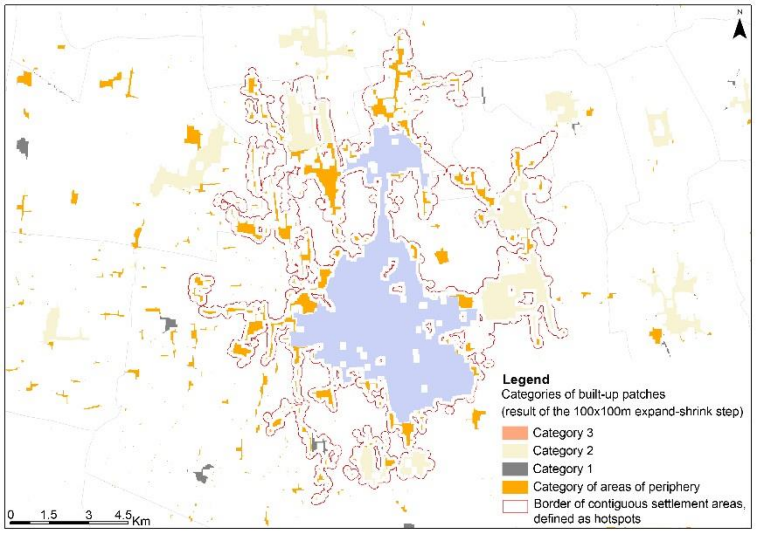

Figure 3. The built-up structure of Nyíregyháza (own edited figure)

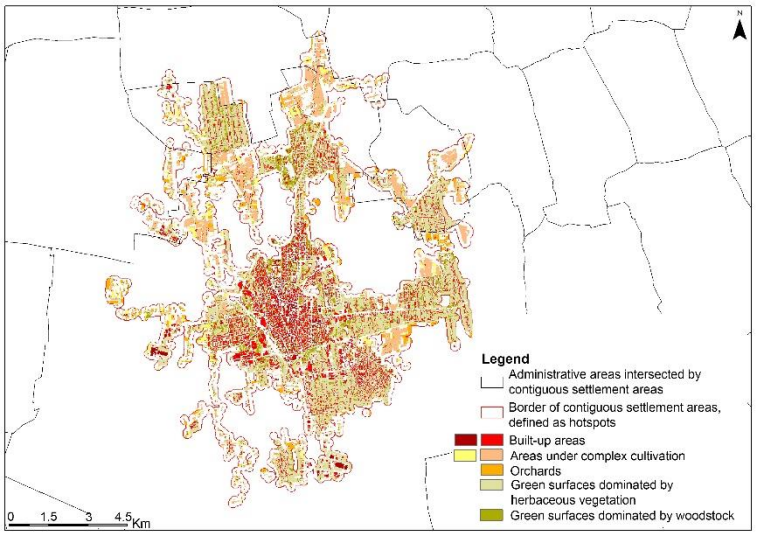

Figure 4. Settlement structure of Nyíregyháza (own edited figure)

The analysed settlement area of Nyíregyháza (98 km2) intersects the administrative borders of 6 settlements. The landscape surrounding the settlement area is characterised by the mosaic arrangement of sandy areas, water-influenced flats and sand ridges. The spatial structure of the settlement area is characterised by extreme values. Within the built-up area, there are a large number of small settlements and a significant centre (28 km2), and the presence of dense, built-up patches of the periphery is also significant. The proportion of green space is moderately high: about 30% within the analysed area. In terms of shape, the built-up area is interspersed with a loose but networked structured zone around the centre, in which internal, non-built-up areas have developed. The urbanised area is mostly openly connected with arable lands to the landscape. The built-up spatial system is complemented by a mosaic green infrastructure network, including larger blocks. (**Figure 3, 4, Table 2**)

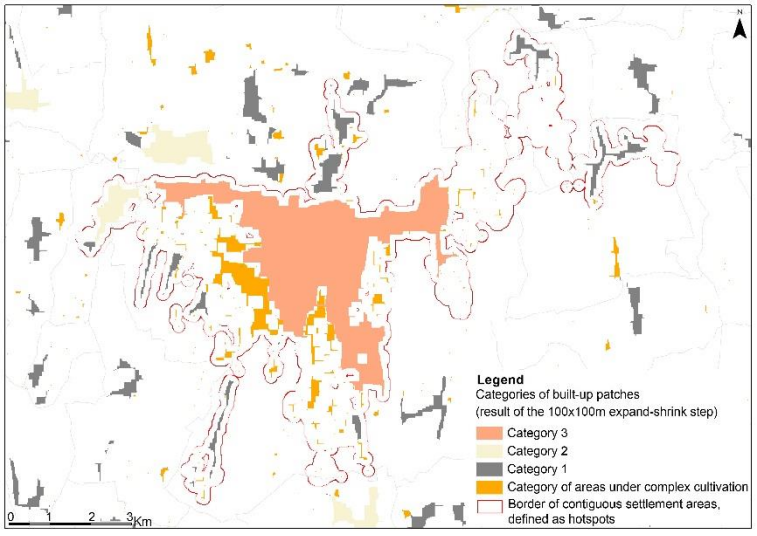

Figure 5. The built-up structure of Zalaegerszeg (own edited figure)

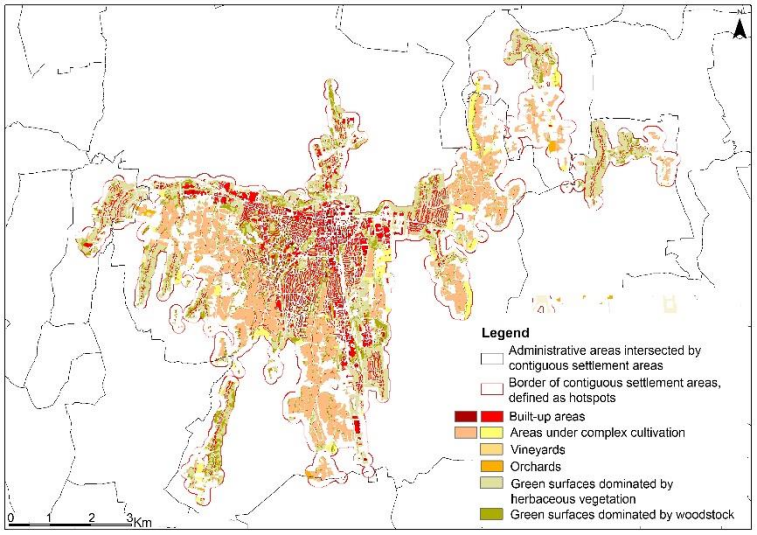

Figure 6. Settlement structure of Zalaegerszeg (own edited figure)

The analysed settlement area of Zalaegerszeg (47.1 km2) intersects the administrative borders of 6 settlements. The landscape surrounding the settlement area is hilly with a dense valley system. The built-up area is extremely dispersed, with a relatively small central area of 11.2 km2 in addition to the many and small-sized built-up units. The proportion of buil-up patches of the periphery is high, mainly involving complex cultivated areas with patch sizes in the same size range as the inlot units. The proportion of green areas is particularly high within the analysed area (51%). In terms of shape, the built-up area is structured and fragmented, with built-up complex cultivated areas connected to the inlot area in the NE and NW sectors, and a direct connection to forested areas is also common. The built-up area system is connected to a network of green infrastructure, often also dividing the central unit, and the proportion of green areas within the built-up areas is high due to the integrated traditional land structure. (**Figure 5, 6, Table 2**)

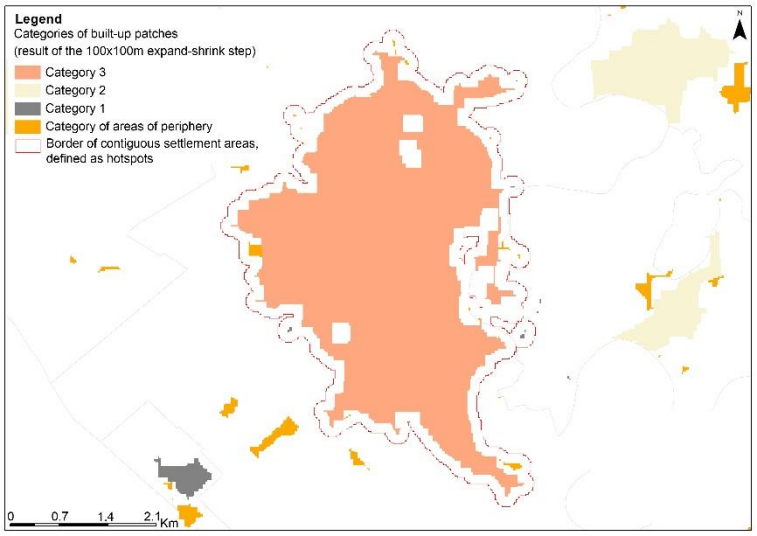

Figure 7. The built-up structure of Mosonmagyaróvár (own edited figure)

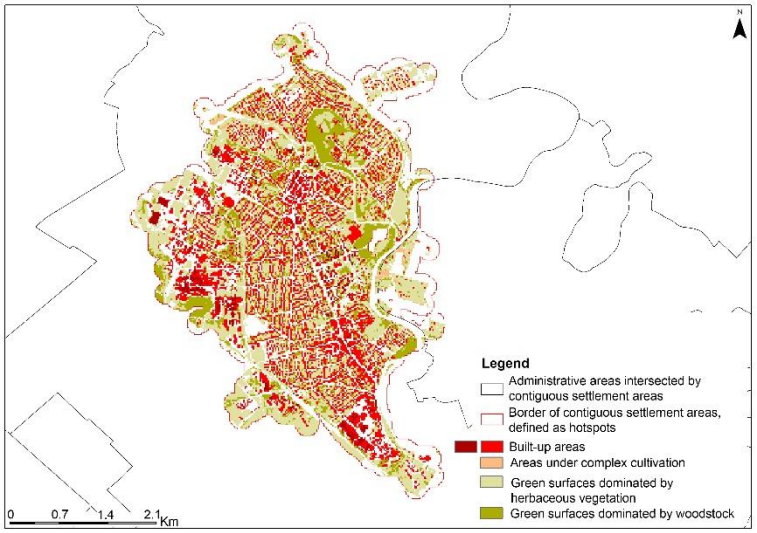

Figure 8. Settlement structure of Mosonmagyaróvár (own edited figure)

Mosonmagyaróvár's 17.6 km2 municipal area is the smallest of the analysed settlement areas, with only two municipal administrative areas being involved in its development. The landscape surrounding the settlement area is one of the most valuable agricultural areas in Hungary. The built-up area is characterised by its block-like structure, dominated by an undivided 12 km2 inlot centre, to which five small-scale built-up patches are attached on the peripheries. The proportion of green areas within the analysed settlement area and within the built-up area is low in national term, and the structure is compact and densely built-up. The built-up area is characterised by narrow green corridors (mainly along watercourses) and green islands of the blocks in built-up areas. The settlement area is mostly embedded in large-scale arable land, devoid of green space elements, and only borders on a small stretch of block-like green space along the Moson-Danube. (**Figure 7, 8, Table 2**)

Table 2. Analysation aspects of settlement structure of the three sample areas

Analysation aspects	Mosonmagyaróvár	Zalaegerszeg	Nyíregyháza
Area of contiguous built-up structure (km2)	17.67	47.11	98.05
Number of administrative units intersected by contiguous settlement areas	2	6	6
Number of individual inlot built-up areas	6	40	26
Average size of inlot built-up units (km2)	6.15	2.23	17.90
Built-up area within inlot areas (%)	0.70	0.28	0.37
Proportion of high buildings (above 12 m) within the total inlot built-up area (%)	0.03	0.04	0.05
Built-up area within periphery (%)	0.004	0.05	0.03
Proportion of artificial surfaces (%)	0.20	0.13	0.13
Proportion of green surfaces (%)	0.49	0.51	0.30
Proportion of areas dominated by woodstock within green surfaces (%)	0.16	0.25	0.10
Proportion of areas dominated typically by herbaceous vegetation within green surfaces (%)	0.33	0.26	0.20
Proportion of agricultural surfaces (%)	0.051	0.26	0.07
Proportion of surfaces under complex cultivation within agricultural surfaces (%)	0.003	0.18	0.01
Proportion of arable lands within agricultural surfaces (%)	0.05	0.07	0.05
Proportion of vineyards, orchards within agricultural surfaces (%)	0.00	0.09	0.003

6. Discussion and Conclusion

By examining and defining the Hungarian urban settlement spatial system, we have determined the categories of spatial structure and green infrastructure system of the settlement areas. The analyses have shown that some of the highly urbanised settlement areas are surrounded by agglomerated areas in terms of built-up areas, therefore the development of green infrastructure elements in connection with the built-up processes requires spatial cooperation. So, it is proposed to classify the settlement areas – delimited in this research – as areas that can be planned together.

Urban growth may involve the integaration of built-up patches of the peripheries or the merging of nearby inlot areas, but may also be achieved through compact growth and internal transformation. Areas that are integrated by growth influence the resulting internal spatial structure, while restricted areas that cannot be integrated (e.g. forests) become the dividing elements of the coherent settlement space. Both national and sample area results have shown that suburbanisation processes, extensive urbanisation and the growth of urban areas are dominant by the agglomeration of non-urban areas in our country. At the same time, this spatial phenomenon implies that the proportion of green space within urban areas remains very high (49% on average). At least half of the built-up area remains unbuilt and remains as green surface and is covered with a varying but also very high percentage (20%) of woodstock coverage. The detailed analyses revealed that green

infrastructure also forms different, but typifiable, settlement spatial systems in terms of internal spatial structure and the connectivity to the landscape. The typified spatial systems provide an opportunity for the specific design of spatial green infrastructure development strategies and the differentiated definition of support targets.

The morphological assessment of urban settlement areas shows that the green space pattern in the settlement fabric is both based on the initial or integrated built-up patterns and on a form of a pattern of fragmenting patches adapted to the environmental conditions of the host landscape. In areas with arable lands of poor productable soil conditions (Nyíregyháza and its surroundings), the potential for green space is considerable. On the other hand, excellent soil conditions, which are an obstacle to built-up tendencies, impoverish the green infrastructure of the settlement area (Mosonmagyaróvár and its surroundings).

It is a Hungarian characteristic that the most typical built-up categories of urban areas are suburban, with a green, wooded character. This also implies that the ecological development of private green spaces has a high potential for the development of green infrastructure within settlements.

7. References

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