FULFILLMENT OF SELECTED ECOSYSTEM FUNCTIONS AND SERVICES AND THEIR SPATIAL RELATIONSHIPS IN OLOMOUC

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Abstract
The paper presents the analysis of selected urban ecosystem services in the city of Olomouc. In the first part of the study, three selected ecosystem functions and services (EF/S) were quantified in biophysical units, and their (i) total value in the city and (ii) contribution to the total value of each city district were determined. Cooling capacity and carbon sequestration functions and biomass production functions were analysed. The analysis was carried out at a detailed scale of 1:5,000 using standardised datasets that cover the entire territory of the Czech Republic, and replication of the approach is possible for any built-up area.

Key words: spatial analysis, urban landscape, GIS

Introduction

Globally, urban development is increasing, and urbanization is one of the fastest growing land uses. Both population growth and socio-economic factors support people moving from rural areas to cities (Liu et al., 2003). The unprecedented rate of global urbanization is considered as an important threat for ability of urban ecosystems to continue delivering main provisioning, regulating, cultural, and supporting services to people (Felappi et al., 2020). An optimization of high efficiency of urban ecosystem services have been recently recognized as a key support tool for adaptation to urban growth (Zhang et al., 2020). Ecosystem services in urban environment are provided by urban green and blue space such as e. g. urban parks, gardens, urban water bodies, and watercourses. These various natural and semi-natural habitats in urban environment are generally denoted as urban green infrastructure (UGI). UGI include numerous types of urban green spaces (urban parks and gardens, green sporting fields, greenways, street trees, green walls and green roofs (Beninde et al., 2015). Ecosystem services are based on biodiversity of urban habitats as a key fundament of ecosystem functioning; thus, we need to understand relationships between urbanization and biodiversity in the frame of emerging field of Urban Ecology (Wu, 2014). The better understanding the ecology of urban habitats should consider how urbanization affects key ecological functions of urban habitats, which rapidly change in time.

Materials and methods

Study area

Olomouc is a statutory and university city in the Olomouc district, the sixth most populous city in the Czech Republic, the regional capital of the Olomouc Region and one of the two historic metropolises of the whole of Moravia. The city of 10,336 hectares is home to approximately 102,000 inhabitants. It is the largest city on the Morava River. Olomouc has many park areas covering a total area of more than 48 hectares. They are based on three historical parks created during the 19th century on the Olomouc fortress's eastern, southern and western outskirts. Gradually, during the 20th century, other areas were added to them to create a continuous green belt around the city's historic core.

Data

For this analysis, digital data (see Tab. 1) supplemented by a field survey in the period June-August 2023 was used.

Tab. 1: Data used

Name	Format	Scale	Datum update	Data producer
Zabaged	Esri geodatabase	1:10000	1.07.2023	Czech Surveying and Cadastral Office
Ortofoto ČR	WMS services	12,5 cm/px	19.6.2022	Czech Surveying and Cadastral Office
Landsat8	GeoTiFF	30m; 100m/px	8.7.2023	NASSA
Detailed combined habitat layer	Esri geodatabase	1:10 000	1.1. 2020	CzechGlobe

In the first step, Olomouc's current land use map was created at the biotope level. The starting basis was the Detailed Combined Biotope Layer, which was gradually updated with newer data from the biotope mapping layer and Zabaged data and revised using orthophotos and our field survey. During the land use map creation, a multi-level classification of occurring segments in terms of naturalness, degradation, and vegetation form was performed and then statistically evaluated. In this work, habitats listed in the Catalogue of Habitats of the Czech Republic (Chytrý et al., 2010) are considered natural habitats. All other habitats are considered habitats influenced or created by humans. Their classification is based on version 6 of the Methodology of Habitat Assessment of the AOPK CR (Seják et al., 2018). Using zonal statistics tools in ArcGIS Pro 3.x environment, absolute and relative proportions of each value were calculated for urban districts or analysed surface types. The degree of fulfilment of the ecosystem function carbon stock and production function was determined using the look-up table method from published data (Seják et al., 2018b) for each occurring habitat. Determination of surface temperature was made from Landsat 8 imagery using the formula according Avdan and Jovanovska (2016). The air temperature for the same day and time of the Olomouc imaging (8.7.2023 at 10h) was read from our semi-professional Davis station located on the university grounds in the centre of Olomouc, recording the air temperature every 30 minutes. The determination of absolute cooling in degrees Celsius for each pixel was calculated from the difference according to the relation: Air temperature - LST(in degrees Celsius). The Cooling Capacity Index was determined in the InVEST Urban cooling module. The study aimed to determine the degree of fulfilment of selected EF/S in the urban environment, using the example of Olomouc.

Results and Discussion

For the entire area of interest (the city of Olomouc), three ecosystem functions and services (EF/S) were analysed, the essential characteristics of which are presented in Tab. 2.

Tab. 2: Summary values of assessed EF/S for the whole city

Ecosystem function and services (EF/S)	Value	Units	Note
Absolute surface cooling (dLST)	8,16 C	Celsius degree	Absolute value in C; difference between surface temperature (LST) and air temperature measured at 2m, 8.7.2023
Cooling Capacity Index (CCI)	0,55	ratio value (0-1)	Methodology according to InVEST
Biomass production (Biomas)	3153140,14	tons / year	Gross increment is considered
Carbon storage function (Carbon)	124138,23	tons Carbon / year	Value is the sum of 3 carbon pools - above ground, below ground and dead biomass

The summarized information can be used to compare similarly sized cities, but given the large size and heterogeneity of the city, not for a detailed analysis of the situation in a town. For this reason, individual town districts' contribution (rate of fulfilment) to the overall figures was analysed. The values

obtained show that the highest absolute values of cooling (dLST) are achieved in the Povel (12.1°C), Nové Hodolany (11.8°C) and Staré Hodolany (11.7°C) town districts. The lowest absolute values are reached in Svatý Kopeček (4.1°C), Lošov (3.6°C) and Radíkov (3.3°C). It should be mentioned here that the relatively low values are not a manifestation of non-functioning vegetation. On the contrary, these town districts are predominantly forested, have scattered buildings, and do not overheat the surface here.
In the case of the cooling capacity of occurring vegetation (CCI) assessment, the highest values are achieved in the urban districts of Radikov (0.584), Svatý Kopeček (0.58) and Týneček (0.576). On the other hand, the districts with the minimum green areas are Olomouc-Střed (0.527), Povel and Staré Hodolany (0.526), and the lowest are Nové Hodolany (0.517). In the case of the carbon storage function (Carbon), the highest values of fixed carbon are achieved in Lošov (25.52% of the total stock), Radíkov (10.9% of the total stock) and Droždín (9.9% of the total stock). On the other hand, Tabulový vrch (0.46 % of total stocks), Pavlovičky (0.4 % of total stocks) and Povel (0.29 % of total stocks) show the lowest values. In the case of EF/S biomass production (BIOMASS), the municipal districts of Holice, Lošov and Droždín contribute the most to the total biomass production. On the other hand, the lowest values are achieved in Olomouc-West, Tabulový vrch and Povel. The overall values achieved are, of course, influenced by the different sizes of the urban districts and the size of the individual segments. It is, therefore, appropriate to use a standardised expression per 1 ha area when comparing them (Tab. 3).

Tab. 3: Calculated values of selected EF/S for town districts. Normalized values

Town District	**Area (ha)**	**Area (%)**	**Relative share of the total population (%)**	**dLST**	**Carbon 1**	**Carbon 2**	**Biomas 1**	**Biomas 2**
Černovír-Hradisko	592,43	5,74	1,4	0,00996	382,9	7,19	13,1	6,27
Droždín	670,61	6,49	1,3	0,0079	465,6	9,9	13,6	7,36
Hejčín	139,63	1,35	2,3	0,05944	211,4	0,94	11,7	1,32
Holice	1472,6	14,26	3,7	0,00509	97,1	4,53	9,2	10,95
Chomoutov	403,08	3,9	1	0,01538	280,8	3,59	13	4,21
Chválkovice	608,96	5,9	1,4	0,011	215	4,15	12,3	6,02
Lazce	129,24	1,25	5,6	0,07351	192,6	0,79	13	1,36
Lošov	792,36	7,67	0,7	0,00454	1015,8	25,53	15,7	10,04
Nedvězí	333,51	3,23	0,5	0,02249	115	1,22	15,1	4,04
Nemilany	618,92	5,99	1,3	0,01066	143,8	2,82	11,2	5,56
Neředín	369,52	3,58	7,2	0,0249	174,3	2,04	16,4	4,89
Nová Ulice	361,96	3,51	5,9	0,03122	137,3	1,58	8	2,32
Nové Hodolany	149,63	1,45	8	0,07886	104,3	0,49	7,3	0,88
Nové Sady	321,95	3,12	15,3	0,03137	157,6	1,61	11,5	2,99
Nový Svět	255,76	2,48	2,6	0,03949	180	1,46	11,1	2,29
Olomouc-střed	241,51	2,34	8,7	0,0443	130,9	1	5,6	1,08
Olomouc-západ	123,36	1,19	7,6	0,08268	200,8	0,79	7,3	0,73
Pavlovičky	84,96	0,82	0,9	0,12359	148,7	0,4	12,6	0,86
Povel	65,08	0,63	6,6	0,18593	138,5	0,29	7,7	0,41
Radíkov	269,17	2,61	0,4	0,01226	1277	10,9	18,2	3,95
Řepčín	530,34	5,14	1,1	0,01395	168,4	2,83	13,7	5,86
Slavonín	430,26	4,17	2,6	0,01859	170,6	2,33	11,9	4,12
Staré Hodolany	357,14	3,46	4,2	0,03276	155,5	1,76	6,3	1,83
Svatý Kopeček	201,11	1,95	0,8	0,02039	1258,3	8,03	20,1	3,25

Tabulový vrch	77,67	0,75	8,3	0,13647	184,9	0,46	7,2	0,45
Topolany	477,44	4,62	0,3	0,01424	75,9	1,15	10,9	4,19
Týneček	247,46	2,4	0,5	0,02182	283,5	2,23	13,9	2,77

Carbon 1 - normalised value (t / ha), Carbon2 - Relative share (%) of the total absolute carbon stock; Biomas1 -normalised value (t/ ha), Bimas2 - Relative share of the total absolute production in the city

The above table shows that Povel, Tabulový vrch and Pavlovičky have the highest values of the cooling function per hectare. On the other hand, the lowest values of performance are in Droždín, Holice and Lošov. Radíkov, Svatý Kopeček and Lošov have the highest values of carbon stock per hectare. On the other hand, the lowest values are shown by Nové Hodolany, Holice and Topolany. The highest biomass production per hectare is reported by Svatý Kopeček, Radíkov and Neředín. On the other hand, the lowest values are found in the urban areas of Tabulový vrch, Staré Hodolany and Olomouc-střed.

The realisation of these functions depends on the quantity and quality of green areas. *Is it proper for all the monitored functions that the more greenery there is in a district, the higher the value (contribution) of the function?*

The greenest districts are Lošov, Holice, Droždín, Černovír-Hradisko and Radíkov, which have more than 5% of green areas. In these districts, 42.2% of the city's green areas are located. The last green parts of the city have less than one per cent of green areas. They are Topolany, Pavlovičky and Povel. The distribution of LULC categories in urban areas is strongly influenced by their location within the city. The rural parts in the wider area have higher areas of green space and less built-up and other areas. The inner parts of the city have the opposite ratio, i.e. more built-up and other areas and less green space. Town district Topolany has the highest representation of other areas, followed by Nedvězí, Nemilany, Chválkovice and others. The lowest values are shown by Svatý Kopeček, Olomouc-centre, Olomouc-západ and Tabulový vrch.

The highest representation of non-natural greenery is in Svatý Kopeček, Radíkov, Lošov, as well as in Tabulový vrch, Lazce, Staré Hodolany. The lowest values are in Holice, Nemilany, Nedvězí and Topolany. The highest values of the representation of natural greenery are found in Černovír-Hradisko, Holice, Lošov and Chomoutov. The lowest values are also found in Staré Hodolany and Týneček and Slavonín and Svatý Kopeček. It can be seen that it is not true that in town district where there is relatively the greenest space, the EF/S contribution is the largest. The findings are consistent with those of similar studies in other Czech cities (e.g. Včeláková et al., 2023).

Conclusion

The value (fulfilment) of the analysed ecosystem functions and services in the urban environment depends on the quantity and quality of the green spaces. Our results show that the assumption that the more greenery in a metropolitan area, the higher the contribution to the total EF/S value for the whole city is not valid. The quality and type of green spaces play a significant role. This dependence is variable to individual kinds of selected functions. Individual urban districts' contribution to total value is variable in the town, too.

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Souhrn
Plnění analyzovaných ekosystémových funkcí a služeb v městském prostředí závisí na množství a kvalitě zelených ploch. Výsledky ukazují, že předpoklad více zeleně v metropolitní oblasti zvýší příspěvek k celkové hodnotě EF/S pro celé město, neplatí. Významnou roli hraje kvalita a typ zeleně. Tato závislost je variabilní na jednotlivých typech vybraných funkcí. Podíl jednotlivých městských částí na celkové hodnotě je také ve městě proměnlivý.

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