BASIS FOR THE DETERMINATION OF ACCESSIBILITY INDICATORS FOR PUBLIC GREENERY: A CASE STUDY OF BENEŠOV AND LITOMĚŘICE

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Received: 17th March 2025, **Accepted:** 18th July 2025

ABSTRACT

This paper presents a methodology for creating an indicator of public green space accessibility on the basis of both quantitative and qualitative analysis. The research is conducted within the framework of the green infrastructure (GI) concept, with a focus on cultural ecosystem services. The study areas are the built-up regions of Benešov and Litoměřice. The green areas and elements of GI are identified using the current ZABAGED database, verified through field surveys and linked to the landscape terminology of green areas and GI elements. The existing qualitative conditions of the green areas and GI elements are subsequently assessed, and indicators of public green space accessibility are evaluated. This paper contributes by expanding the quantitative assessment of green space accessibility to include quality evaluation and by proposing a method for developing accessibility indicators. This approach is intended to support public administrations in preparing strategic documents.

Keywords: green infrastructure, urban green space accessibility, cultural ecosystem services, urban green space assessment, the Czech Republic

INTRODUCTION

Urban greenery is essential for the sustainability of cities, and its effectiveness is enhanced by systemic coherence within spatial and functional linkages. Urban greenery is analysed in the context of the green infrastructure (GI) concept, which represents a complex network of areas and elements of a natural or semi-natural character. This network includes vegetation, water, and water management features, which are typically characterized by a predominantly continuous structure. GI elements are categorized by their importance into three types:

- **Core Elements**: These elements primarily fulfil ecosystem services.
- **Supporting Elements**: These elements serve a different primary function but indirectly contribute to ecosystem services.
- **Complementary Elements**: These elements ensure the connectivity of the GI network (Kučera *et al*., 2023).

The primary function of GI in urban settings is to improve residents' quality of life by delivering fundamental ecosystem services. These services significantly influence residents'

quality of life, urban biodiversity, and the overall viability of urban environments (Gómez-Baggethun & Barton, 2013).

GI plays an indispensable role in producing oxygen, absorbing carbon dioxide, and contributing to nutrient cycling, soil formation, and biomass production (supporting services). It also serves as a source of food, water, timber, fibre, natural medicines, and genetic resources (provisioning services).

GI is essential for mitigating air and water pollution, regulating temperature, and managing stormwater. These functions contribute to reduced urban heat island effects and enhanced water management (regulating ecosystem services). The regulation of microclimates through shading and plant transpiration, which naturally lower urban temperatures and improve air quality, has been highlighted by Escobedo *et al*. (2011). Similarly, the ability of plants to increase air quality has been studied by Nowak & Dwyer (2007), whereas Kaczynski & Henderson (2007) emphasize the role of GI in supporting biodiversity and ecosystem resilience.

In addition to its environmental benefits, GI fosters cultural identity and provides spaces for recreation, spiritual enrichment, aesthetic experiences, and sources of knowledge and inspiration (cultural ecosystem services). Parks and gardens provide significant psychological and social benefits by creating spaces for rest, recreation, social interaction, and community connection. These activities positively impact the mental health of urban residents and contribute to the development of healthy, resilient urban communities (Marselle *et al*., 2014; Jennings & Bamkole, 2019). The quality and accessibility of GI elements to urban populations are central to the realization of these cultural ecosystem services (CESs).

The foundation for defining GI accessibility is a standard (Maier *et al*., 2020, modified), which suggests a maximum physical accessibility of 300 metres for public park green spaces (areas of 0.5–1 ha) within public open spaces. Similarly, the European Common Indicators (CI2, 2013) recommend the same walking distance for public spaces larger than 0.5 hectares. During the development of the new land use plan in Liberec, urban green spaces were categorized into city and local parks, with minimum sizes of 1 and 0.1 hectares, respectively. Moreover, walking accessibility was defined as 30 and 15 minutes, respectively (Hrbková, 2017). The Spatial Analytical Documents of Prague offer a range of walking distances (100–1500 metres) and times (2–25 minutes) for various park categories, including metropolitan, district, locality, and local parks (IPR Praha, 2021).

In addition to accessibility, the quality of GI elements is critical (Lacina & Cetkovský, 2005). Kučera (1999) and Sojková & Šmídová (2011) assess green areas on the basis of the vegetation species composition, the spatial structure, tree health and supporting amenities. Šimek (2001), Šimek *et al*. (2011), and Štefl (2014) provide detailed discussions of indicators for evaluating the quality of basic green areas.

This paper aims to develop an indicator for assessing the availability of public green spaces that incorporates not only quantitative aspects but also their capacity to provide CESs. This research integrates GIS analyses with field surveys, offering a robust tool for strategic planning and enhancing urban quality of life.

MATERIALS AND METHODS

To determine the indicator of the accessibility and quality of GI in settlements, the focus was placed on public green areas larger than 0.5 hectares. Private greenery, such as gardens, was excluded from the assessment despite its significant share in settlement greenery and its

provision of CESs (e.g., individual recreation). This exclusion was due to the inaccessibility of private greenery, which precludes field evaluation of its qualitative parameters.

The areas of interest within the GI were identified using orthophoto maps, ZTM10 (Basic Topographic Map of the Czech Republic at a scale of 1:10,000), and the modified ZABAGED 2021 (The Fundamental Base of Geographical Data of the Czech Republic). The monitored areas included spaces larger than 100 m² from the following ZABAGED categories (edited):

- Reserved green areas
- Decorative garden, park
- Publicly accessible orchards and gardens
- Permanent grassland
- Forest ground
- Water areas
- Arable land
- tree avenues or rows of trees

These areas were verified through field surveys, during which each area was checked and, if necessary, corrected. Green spaces not recorded in the mapping documents were added and assessed. Each identified GI area was categorized according to a modified version of the Czech State Standard 83 9001 Horticulture and Landscape Architecture classification system (see Tab. 2) and was qualitatively evaluated. The evaluation included parameters such as operational design and amenities, the vegetation structure, suitability of the plant selection, quality of vegetation, quality of maintenance, intensity of use and stability in terms of function and significance (based on Sojková & Šmídová, 2011, modified). Each parameter was scored on a scale of 1 to 3 (1 = best, 3 = worst).

Table 1: Method for qualitative assessment (based on Sojková & Šmídová, 2011, modified)

Factor	Assessment		
Vegetation Structure	1	**Appropriate**	the spatial configuration of the individual elements of the landscape composition (trees, shrubs, …) is consistent with the functional requirements and corresponds to the designated type of greenery.
	2	**With spatial deficiencies**	the spatial configuration of the individual elements of the landscape composition exhibits certain shortcomings or inconsistencies.
	3	**Inappropriate**	the spatial configuration is inadequate, failing to meet functional requirements and disregarding the intended type of greenery.
Suitability of the Plant Selection	1	**Appropriate**	the selection of woody plant species fully aligns with the type of greenery, functional requirements, and the character of the landscape design, as well as with the surrounding environment and site conditions.
	2	**Partially inappropriate**	the selection of woody plant species only partially reflects the type of greenery, functional requirements, character of the landscape design, surrounding context, or site conditions.
	3	**Inappropriate**	the selection of woody plant species fails to consider the type of greenery, functional

			requirements, character of the landscape design, surrounding environment, and site conditions.
Quality of Vegetation	1	**Very high**	includes highly valuable specimens or individuals of above-average quality.
	2	**Average**	consists primarily of specimens of average quality.
	3	**Very low**	includes predominantly below-average or minimally valuable specimens.
Operational Setup And Amenities	1	**Appropriate**	fully meets the operational requirements of the space and its functional integration with the surrounding environment, particularly in terms of path layout, placement of seating areas, etc. The amenities support the intended use of the space and align with current user needs.
	2	**With deficiencies**	only partially meets the operational requirements of the space and its connections to the surrounding environment; amenities are basic, partially fulfilling current user needs and only partially supporting the intended use.
	3	**Inappropriate**	fails to meet the operational requirements of the space or its integration with the surrounding environment; amenities are either insufficient or entirely absent.
Quality of Maintanance	1	**Appropriate**	maintains greenery in good condition and contributes to the enhancement of its overall quality.
	2	**With deficiencies**	exhibits shortcomings in maintenance practices that may affect the condition and development of the greenery.
	3	**Inappropriate**	maintenance is inadequate and fails to support the health or quality of the greenery.
Intensity of Use	1	**Utilized**	the area is actively used by visitors or residents in a manner consistent with its intended function.
	2	**Partially utilized**	the area is only occasionally or selectively used; usage is limited in scope or intensity.
	3	**Not utilized**	the area shows minimal or no signs of use, indicating a lack of functional engagement by users.
Stability	1	**Stable**	management requires only a review of the suitability of current maintenance practices.
	2	**Partially stable**	management involves implementing measures without altering the overall maintenance concept
	3	**Unstable**	management requires conceptual changes and a reconstruction or redevelopment project.

The field survey data were digitized using Microsoft Excel and GIS software, allowing for detailed qualitative and quantitative analyses. Areas larger than 5 000 m² that were publicly accessible were selected for further analysis of availability and quality in the context of CESs. These areas were subsequently divided into two (or three) categories on the basis of their potential to fulfil CESs:

- **Areas providing cultural ecosystem services**: Parks, small park areas, greenery of residential buildings, greenery of civic facilities, greenery of recreational and sport facilities and greenery for special purposes.

- **Areas potentially providing cultural ecosystem services**: Others greenery, close-to-nature greenery, greenery of recreation buildings, agricultural greenery and neglected greenery, greenery of commercial areas.
- **Areas not providing cultural ecosystem services**: Greenery of commercial areas, agricultural greenery and greenery of recreation buildings, which were excluded from further analysis.

The quantitative evaluation focused on parameters such as the total area of green spaces, their proportion within the city, the total number of green spaces, and the largest, smallest and average sizes of the evaluated areas. Additional parameters included the number of green spaces larger than 5000 m² and the representation and accessibility of different types of green areas. For linear elements such as tree avenues and rows of trees, qualitative parameters (completeness, based on Kučera, 1999; and the quality of woody vegetation elements, based on Bulíř, 2008) and the quantitative parameter of the number of lines were assessed.

The GI concept was analysed from the perspective of CESs to provide a foundation for creating an indicator of public green space accessibility. The supporting and complementary elements of the GI were identified through field survey data:

- **Core elements**: Publicly accessible areas larger than 0.5 ha that fulfil CESs (e.g., parks (Ps), greenery of residential buildings, greenery of civic facilities, greenery of recreational and sport facilities and greenery for special purposes).
- **Supporting elements**: Areas smaller than 0.5 ha or inaccessible, such as small park areas (SPs), greenery of residential buildings, greenery of civic facilities, greenery of commercial areas, agricultural greenery and greenery for special purpose.
- **Potential GI elements**: Neglected greenery, others greenery and close-to-nature greenery.
- **Complementary elements**: Linear features such as tree avenues and rows of trees, which strengthen GI connectivity.

Table 2: Types of urban greenery. On the basis of these classifications, a GI framework was developed that connects key areas of interest via pedestrian routes lined with linear elements and integrates recreation into the broader landscape.

Type of urban greenery	Characteristic
Park	A landscaped area meticulously designed into a distinctive compositional entity, spanning over 0.5 hectares with a minimum width of 25 meters. This category includes urban parks, historical parks, and spa parks.
Small park area	A smaller, landscaped space, typically up to 0.5 hectares, crafted according to horticultural principles but not meeting the full criteria of a park. This encompasses various types of mini-parks, greenery around public transport stops, public buildings, playgrounds, etc.
Greenery of civic facilities	The green spaces surrounding civic amenities, including schools, healthcare facilities, hotels, stations, shopping areas, public buildings, banks, churches, cemeteries, monuments, etc.
Greenery of commercial areas	The green areas within or around commercial, industrial, and storage facilities, areas of commercial premises, factory compounds, agricultural buildings, logistics centers, and dumps.

Greenery of recreational and sport facilities	The areas dedicated to recreation and sports, including park forests, leisure complexes, playgrounds, swimming pools, campsites, and zoological gardens.
Greenery of recreation buildings	Green spaces associated with leisure and relaxation, such as cottages, lodges, and allotment gardens.
Greenery of residental buildings	The verdant spaces within residential settings, including housing estates, courtyard blocks, terraced houses, and detached homes - Publicly available.
Others	This includes scattered greenery and reserved green spaces not categorized elsewhere.
Special Purpose Greenery	Exclusively designated green spaces, including botanical gardens, arboretums, and dendrological parks.
Agricultural Greenery	The expanses of green dedicated to agriculture, such as forests, fruit orchards, nurseries (both ornamental and turf), vineyards, hop fields and grass lands.
Neglected Greenery	The green spaces that have been abandoned or neglected, including wastelands, fallows, brownfields, quarries, and landfills.
Close-to-nature Greenery	Green areas that are close to the nature environment.

For the accessibility indicator, publicly accessible settlement green areas larger than 0.5 ha that provide CESs were considered. Areas requiring interventions to support their recreational function (e.g., vegetation revitalization, improved accessibility, road network reconstruction, and the addition of amenities) were identified as potential areas for improvement.

Accessibility Indicator Development

The accessibility indicator was developed at multiple levels. The first or basic level is defined as a zone with a maximum aerial distance of 300 metres from the edge of the respective green areas, processed using the Buffer tool in the GIS software (ArcMap, ArcGIS Pro). The second level calculates accessibility as areas originating from nodes (entry points to the green areas), considering the attached line layer—in this case, the road network created from the corresponding ZABAGED layers. This calculation utilized the Service Area tool from the Network Analyst toolset. Both approaches were combined with data from the Czech Statistical Office, which provides population data at the address level (Czech Statistical Office, 2022).

The original data were revised to exclude populations not relevant to the accessibility calculation methodology, such as those residing in government buildings or correctional facilities. Only potential residents who were realistically capable of utilizing public spaces and green infrastructure were included in the final accessibility computation.

Study Area

The model areas were two medium-sized towns, Benešov in Central Bohemia and Litoměřice in the Ústí nad Labem region of the Czech Republic.

Benešov, situated in the Benešov hills 30 km southeast of Prague, has a history dating back to the second half of the 12th century. The oldest part is the Karlov hilltop with an early Gothic church, under which a Minorite monastery was founded and a sub-castle with

a market. Later, at the crossroads below Karlov, there was a town with a rectangular square and a network of streets. At the beginning of the 18th century, a Piarist college with a church was built in the southwest corner of the square; it is still a prominent landmark today. The Benešov suburbs grew in street form along all transit routes. At the end of the 19th century, new constructions began to develop towards the station and around the whole of the inner city. By the mid-1940s, the agricultural character of the town had persisted. In the 1970s, redevelopment of the town began. In place of the small, low-rise town houses, a housing estate grew up, significantly disturbing the historic buildings in the town centre (Malé náměstí) (Kuča, 1996; Procházková, 2005).

Litoměřice is located on the northern edge of the Elbe Lowland at the confluence of the Elbe and Ohře Rivers. The town was founded in the 13th century at the crossroads of important trade routes near an older Přemyslid stronghold with the Church of St. Stephen, which was located on Dómský Hill. The new central market square of the town (today's Peace Square) is still one of the largest squares in the Czech Republic, which testifies to the importance of the royal town of Litoměřice at that time. In the 17th century, the town was rebuilt in the Baroque style, and a bishopric was established (St. Stephen's Cathedral, deanery, bishop's residence, etc.). The development of the town was significantly influenced by the Industrial Revolution, which, among other things, brought the railway to the town. Also progressive in the 20th century was the establishment of a residential area north of the railway, following garden city principles. During World War II, the town of Litoměřice was annexed by the Nazi German Reich, and the largest concentration camp in the Czech Republic, Richard, was established there; at the end of the war, the town was damaged by air raids. The post-war development was connected with the construction of prefabricated housing estates (Kocanda, Cihelna, Svornost, Družba, Střed, Severozápad, Pokratice), which took place partly in the former historical districts. After the Velvet Revolution in 1989, new neighbourhoods of satellite houses and commercial, industrial, and logistics complexes were established on the other side of the Elbe River (Kuča et al., 2020; Kotyzová and Kotyza, 2011; Kotyza et al. 1997; Kraus, 2017; Kuča, 2011; Landa, 2012).

RESULTS

Quantitative Analysis

Benešov

Benešov contains 105.6 hectares of green space, 54 % of which (57.8 ha across 48 areas) provide CESs. These include parks, small parks, greenery of residential buildings, greenery of civic facilities, greenery of recreational and sport facilities, greenery of commercial areas and greenery for special purposes. Green spaces account for 20 % of the town's total area, with an average size of 1.3 hectares. The largest green space is 10.1 hectares (arable land in Pomněnice), whereas the smallest is 0.06 hectares (a garden at the “Sovička” kindergarten). Forty-six areas exceed 5000 m². As of 2023, Benešov has a population of 16.875, equating to 30.6 m² of green space per resident.

The largest proportion of public greenery comprises civic facilities (15.4 %), greenery of residential buildings (12.6 %) and greenery of recreational and sport facilities (12.5 %), while parks and small parks account for 8.4 %. Greenery of civic facilities and greenery of residential buildings are the most common, with 16 and 11 areas, respectively. Close-to-nature greenery, neglected greenery and others greenery account for 45.2 % of the total green area but are typically small and peripheral (see Fig. 1). Sporadically, the city has green areas of recreation buildings, greenery of commercial areas and neglected greenery. Each of these types of green areas is represented in a maximum of 2 areas. The largest share

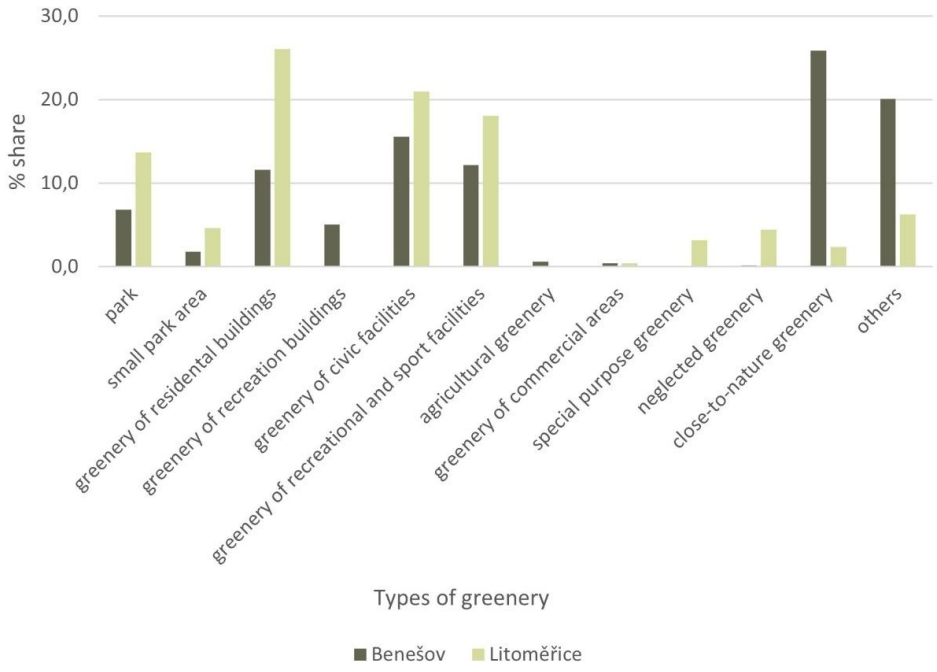
of these areas is green areas of recreational development, which account for 4.9 % of the total area (see Fig. 1). This development is located on the outskirts of the city and is not publicly accessible.

Litoměřice

Litoměřice features 126.17 hectares of green space across 109 areas. Of these, 86.9 % (109.6 ha across 97 areas) provide CESs. Green spaces represent 17 % of the town's total area, with an average size of 1.16 hectares. The largest green area is 9.5 hectares (forest park Mostná hill), whereas the smallest is 0.03 hectares (area near a chapel). Fifty-four areas exceed 5000 m². As of 2023, Litoměřice's population is 23.124, providing 47.2 m² of green space per resident.

The most significant green spaces are greenery of residential buildings (26 %) and greenery of civic facilities (21 %), followed by parks and small parks (19 %) and greenery of recreational and sport facilities (18 %). The most frequent types are greenery of civic facilities (37 areas) and small parks (24 areas). Close-to-nature greenery, neglected greenery, and other greenery account for 13.1 % of the total green area but are less prominent (see Fig. 1).

Fig. 1: Share of types of greenery in the total green area in the cities of Benešov and Litoměřice



Comparison of green spaces in Benešov and Litoměřice

When the representations of individual types of public green spaces in Litoměřice and Benešov are compared, it is clear that there are significant differences between the cities. In Benešov, other and close-to-nature greenery predominate; in Litoměřice, the share of other green spaces is barely one-third, and the share of close-to-nature greenery is significantly lower than that in Benešov. In Litoměřice, the largest share of greenery of residential buildings (almost double that in Benešov) is attributed to the urban structure and the high share of housing development. The greater share of parks and small park areas is due to the greenery around the castle ring, the vast Jirásek Park and the cultivation of greenery around the Elbe for park improvements. In Benešov, the only park is Na Klášterce Park.

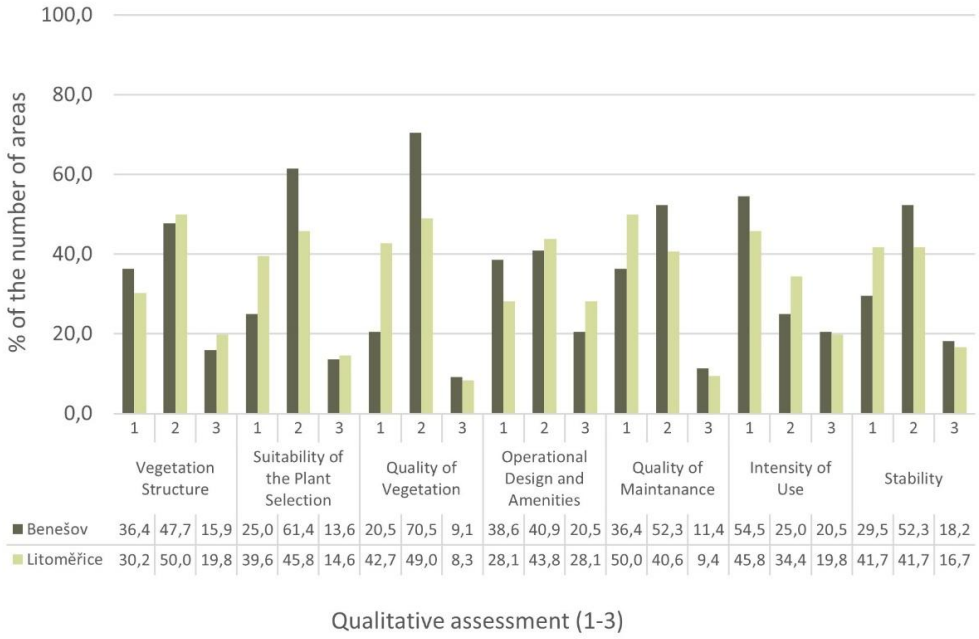
Green Infrastructure

Benešov

The green infrastructure concept has been developed. The ability to provide CESs and connectivity of the GI were a major consideration in the delineation. The largest share and the most frequent are the supporting elements of green infrastructure in Benešov. They occupy a total of 37.1 % of the area and are in a total of 41 distinct units.

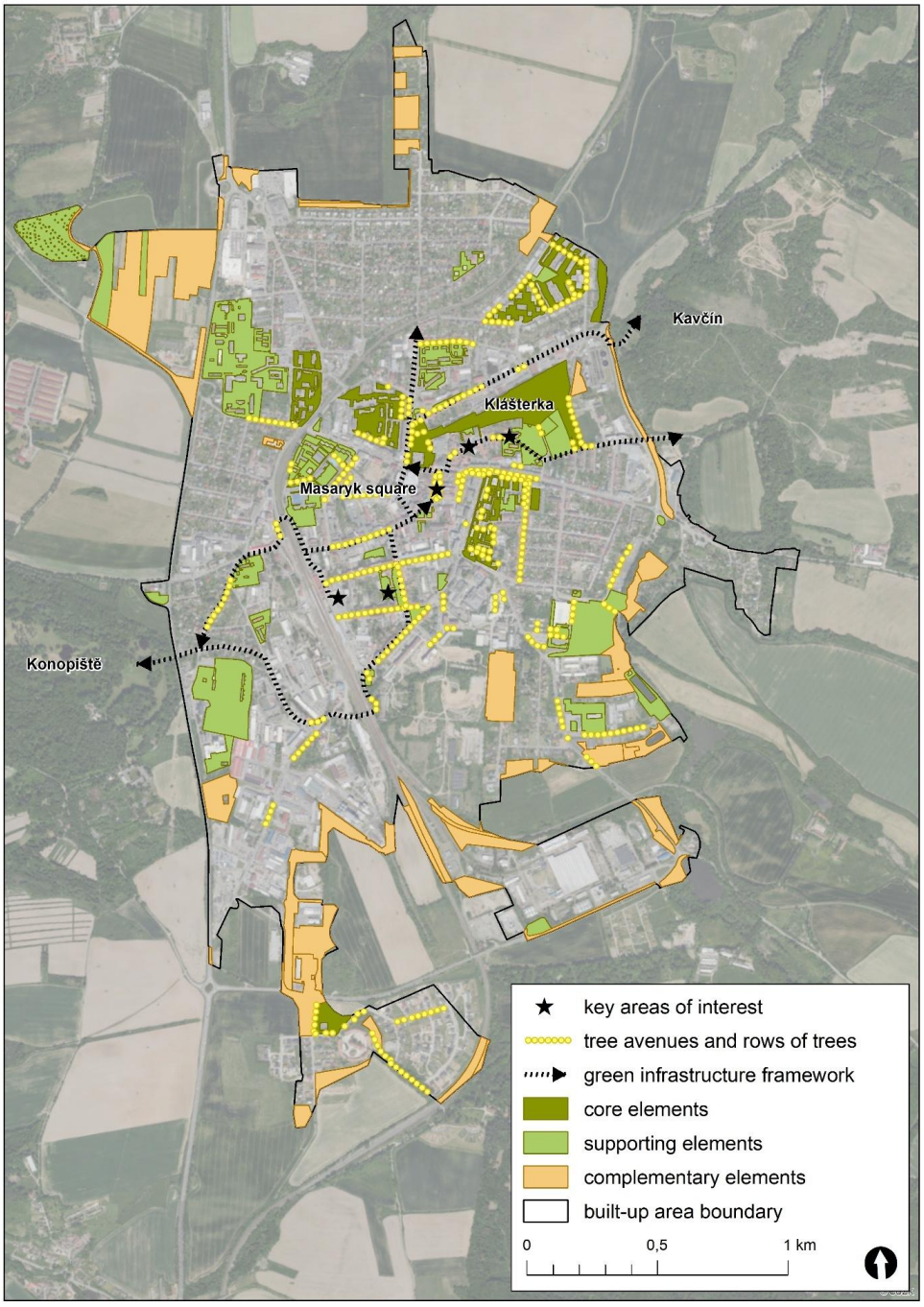
The core elements of green infrastructure that are publicly accessible and larger than 0.5 ha account for 17.7 % and include 7 areas - "Na Klášterce" park and 6 areas of greenery of residential buildings: at Bezručova and Zappova Streets, at Jiřího Horáka, Jana Švermy and M. Kudeříkové Streets, at Kpt. Nálepky, Spořilov II Streets - Pražského Povstání Street, 5. at Na Tržišti and Na Spořilově – Ladova Streets. Areas of other greenery, close-to-nature greenery and neglected greenery are considered potential elements of GI in terms of ecosystem recreational services (45.2 % of green areas). For follow-up measures to increase not only the area but also the capacity to provide ESs, a qualitative assessment was carried out on parks, small parks, greenery of recreation buildings**,** greenery of civic facilities, and greenery of recreational and sport facilities, which are core and supporting elements of GI. The evaluation did not include some supporting elements, such as agricultural greenery, greenery of recreation buildings and greenery of commercial areas, which could not be evaluated according to the established criteria. Greenery with CESs had an average score of 1.81 out of 3. The intensity of use was rated the best: 54.5 % of the areas are fully used (53.4 % of the assessed area of greenery with CESs). Only one-fifth of the areas are unused; these areas have a perspective for the future. The quality of maintenance is rated good, with 52.3 % of the areas (53.2 % of the area) having deficiencies and more than one-third of the areas rated 1. Operational design and amenities are deficient in 40.9 % of the areas (65.3 % of the area), whereas 38.6 % of the areas (21.6 % of the area) fully respect operational requirements. The suitability of the plant selection and the quality of vegetation are closely related, with the average rating prevailing: 61.4% (67.5% of the area) were of partially unsuitable assortment, and 70.5 % (78.1 % of the area) were of average quality. One-quarter of the plots had a suitable mix of species, and one-fifth of the plots had very valuable species. The vegetation structure was suitable in 36.4 % of the plots (32.1 % of the area), with minor deficiencies in 47.7 % (56.5 % of the area) (see Fig. 2).

Fig. 2: Qualitative assessment of settlement greenery with cultural ecosystem functions in the towns of Benešov and Litoměřice



The GI framework has been created. The axis runs in a north–south direction from the development of family houses between residential units, where there is a turn around the "Klášterka" Park, which leads into the landscape—the "Kavčín" recreational area. The axis continues southwards past the main "Masaryk Square", with a turn to "St. Nicholas Church" and cemeteries, then southwards past schools with a turn to the railway station and to the landscape "Konopiště" entrance (see Fig. 3).

Fig. 3: Green infrastructure of Benešov



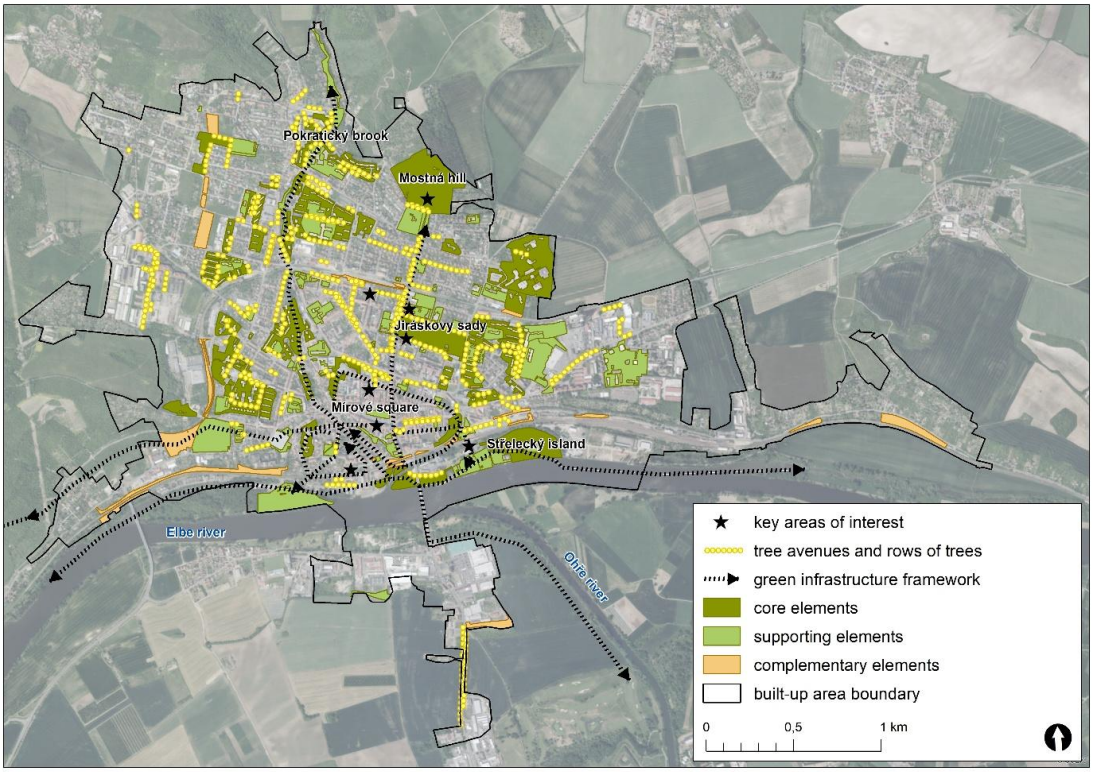
Litoměřice

Green infrastructure in the city was also assessed. The largest area share in Litoměřice is occupied by core elements of green infrastructure (66 % of the total area), of which the largest share is composed of core existing elements of green infrastructure, i.e., areas larger than 0.5 ha and publicly accessible, which are evaluated as a type of green infrastructure: parks, greenery of residential buildings, greenery of civic facilities, greenery of recreational and sports facilities and greenery of special purposes (these account for 20 % of the total number of green areas and 54 % of the total green area). The supporting elements of green infrastructure are the most numerous (71 % of the total number of green areas) but account for only 34 % of the total green area. The existing supporting elements of GI are represented by 33 % of the total green area (parks, small parks, greenery of residential buildings, greenery of civic facilities, greenery of recreational and sport facilities, and greenery of special purposes, i.e., areas larger than 0.5 ha reserved or smaller than 0.5 ha reserved and publicly accessible, as well as agricultural greenery, greenery of recreation buildings and greenery of commercial areas). Potential green infrastructure elements represent 10 % of the total green space. These are the types of green space: other greenery, close-to-nature greenery and neglected greenery greater than 0.5 ha of publicly accessible.

When the quality of green areas with cultural ecosystem functions in Litoměřice was evaluated, the green areas were rated as average quality (grade 1.77 out of 3). The indicator of the quality of maintenance was the best, with 50 % of the green areas with cultural ecosystem functions identified as green areas with appropriate maintenance (60 % of the area of green areas with cultural ecosystem functions). Maintenance with deficiencies was found in 41 % of the areas (37 % of the area), and inappropriate maintenance in only 9 % of the areas (2 % of the area). Furthermore, the intensity of use was assessed as mostly positive, with 46 % of the number of areas (57 % of the area) assessed as used, 34 % of the number of areas (40 % of the area) as partly used and 20 % of the areas (4 % of the area) as unused. For the other indicators (i.e., the vegetation structure, suitability of the plant selection, quality of vegetation, operational design and amenities, and stability), the most frequent rating was average. The greatest deficiencies were found in operational design and amenities (average score of 2 out of 3), where 28 % of the plots (27 % of the area) were rated as unsatisfactory, but even with this indicator, the predominant rating was good, i.e., satisfactory operational design and amenities (28 % of the area), or average, i.e., operational design and amenities with deficiencies (46 % of the area) (see Fig. 2).

Subsequently, the framework of GI was developed. The main axis runs in a north–south direction from “Mírové square” northwards along “Novobranská and Osvobození” Streets to the largest park “Jiráskovy sady”, then along “Sokolovská” Street to Mostná hill. To the south, it continues along the “Mácha’s Steps” to the recreational area along the Elbe River (the swimming pool, the park under the Tyrš Bridge, the park on Střelecký island), across the bridge and along the Ohře River. Another important axis is the Pokratický brook (Pokratická, Masarykova, and Katovny Streets), which heads north towards the recreation area towards Bílá stráň. To the east from “Mírové square”, the stroke heads past “Mariánské square” along Michalovická Street past the cemetery to Radobýl, a significant hill behind the city. A significant circuit runs through “Václav Havel Park”, through the park landscaping along the walls and down Vodní Street. This circuit around “Mírové square” is followed by the western circuit along Zahradnická Street (Rybářské square, Dómské square) (see Fig. 4). A major role in local green infrastructure and providing cultural ecosystem services has Elbe River, both in the city and outside the city. The infrastructure along the river enables the inhabitants a comfortable way to move in the landscape.

Fig. 4: Green infrastructure in Litoměřice



The core elements of GI also correspond with the areas that are included in the calculation of the green space availability indicator.

Fig. 5 shows the differences in the qualitative assessment of the core elements of GI between Benešov and Litoměřice, with Litoměřice showing a higher representation of 1 (best quality) ratings for most categories, especially for "stability" and "suitability of the plant selection". Benešov, on the other hand, dominates in medium quality (2), especially in the categories "quality of maintenance" and "stability".

Availability of public green areas

Areas of publicly accessible residential green space (larger than 0.5 ha) cover an area of 18.67 ha in Benešov, which is equal to less than 4 % of the total built-up area of the town. In Litoměřice, this share is much greater—9 % (67.69 ha). Similar proportions are then logical within the individual polygons of serviceability. The ring of 300 m around the areas of residential green space, which can be understood as an aerial distance from the edge of the areas and can be taken as a basic indicator of accessibility, occupies an area of 173.19 ha (33.35 % of the total area of the built-up area) in Benešov and 509.07 ha (69.54 %) in Litoměřice. If we take into account the road network and once again set the maximum walking distance of 300 m, the area of accessibility in Benešov is 144.57 ha (27.84 % of the total area of the built-up area), and that in Litoměřice is 443.71 ha (60.61 %). However, the connection of these polygons with the number of inhabitants is much more interesting. While the polygon representing an aerial distance of 300 m from the green area occupies 1/3 of the territory in Benešov, the population in this area is equal to 77.8 % of the total population. In

Litoměřice, it even accounts for more than 96 % of the total population. Slightly fewer inhabitants fall within the service polygon, which was calculated on the basis of the road network: 70.2 % of the population in Benešov and 94.77 % in Litoměřice. The accessibility maps of Benešov (Fig. 6) and Litoměřice (Fig. 7) are shown below.

Fig. 5: Overall qualitative assessment of the core elements of green infrastructure

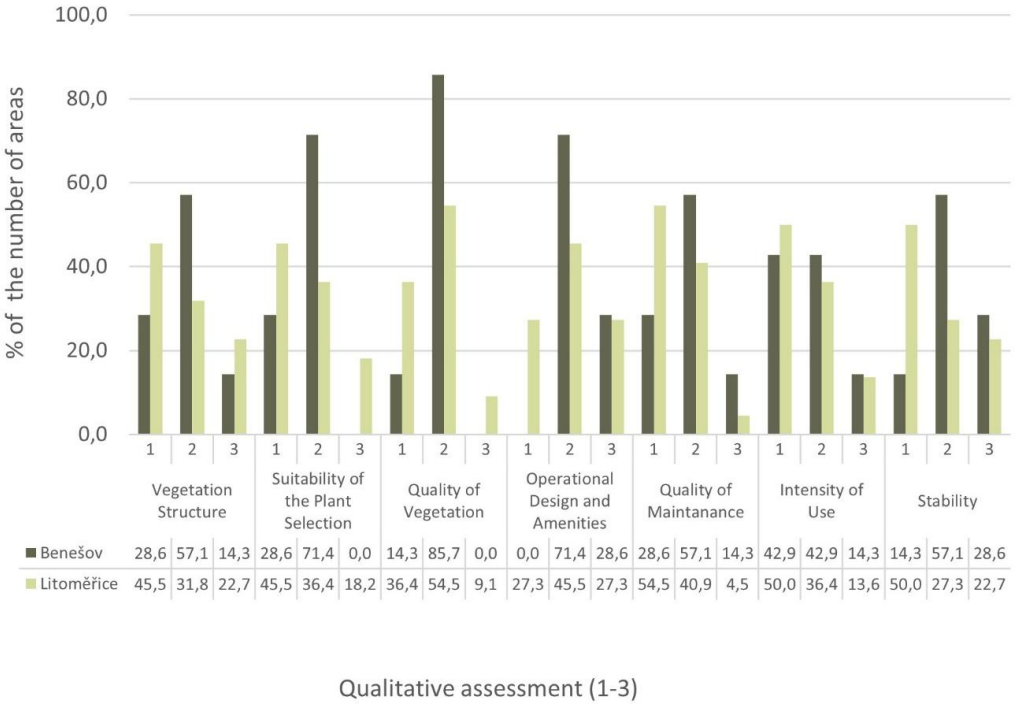


Fig. 6: Accessibility map of Benešov

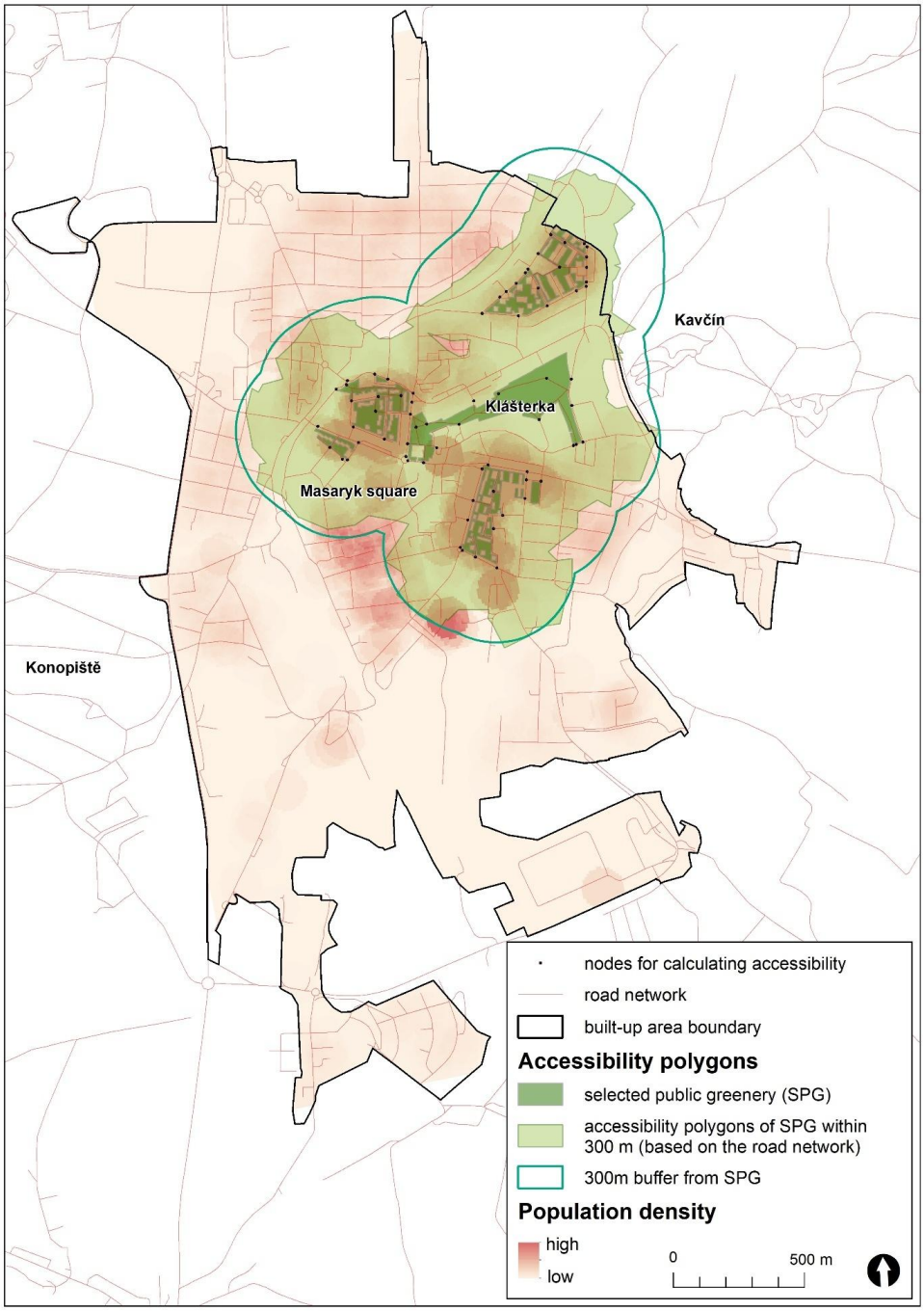
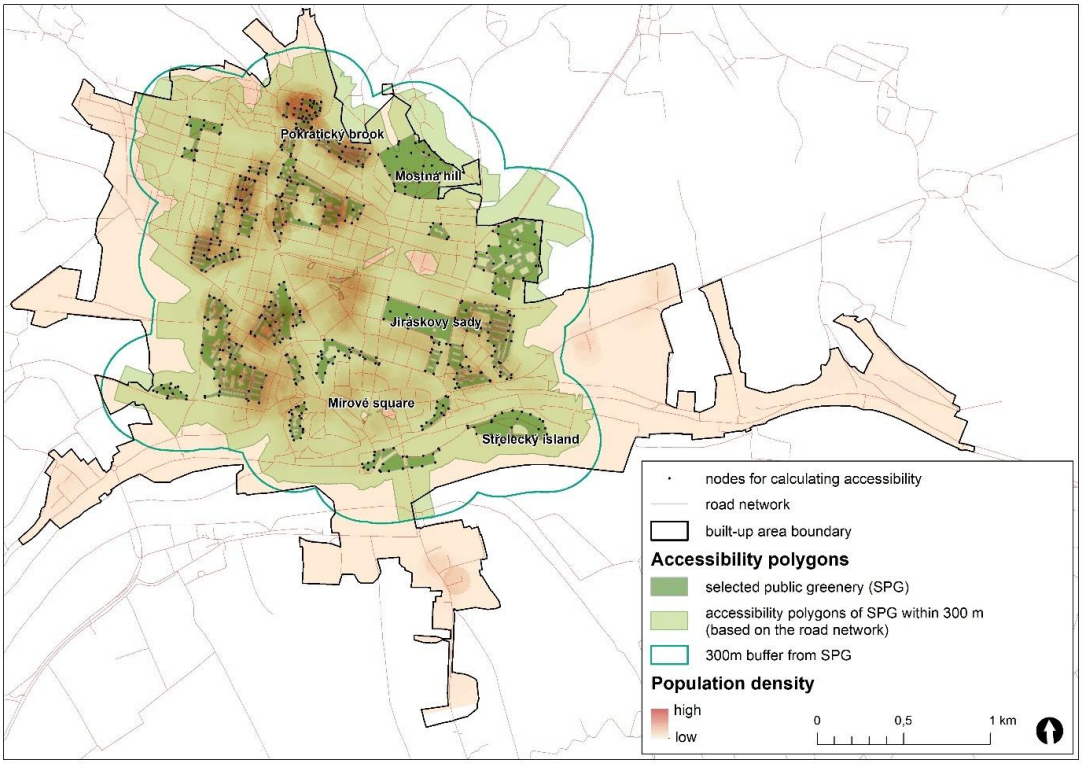


Fig. 7: Accessibility map of Litoměřice



Potential Areas for Accessibility Improvement

Only green spaces such as greenery of recreation buildings, agricultural greenery, greenery of commercial areas, special purpose greenery, neglected greenery, others and close-to-nature greenery that are accessible and larger than 0.5 ha were identified as potential areas for improving accessibility to green spaces in the city. After a thorough field survey, only those areas that actually offer potential for improving the accessibility of public green spaces were selected.

The so-called potential areas, which cover areas of 13.41 ha in Benešov and 8.08 ha in Litoměřice, were selected to improve the accessibility of public greenery. The area of accessibility would thus increase by almost 21 % in Benešov and by 5 % in Litoměřice, considering the road network. These percentages correspond to an increase in the service polygon of 106.49 ha in Benešov and 36.24 ha in Litoměřice. These figures suggest that there is much more room for potential improvement in cultural ecosystem services in Benešov, whereas in Litoměřice, this potential is almost exhausted, and most residents already have comfortably accessible parkland areas larger than 0.5 ha. If the remaining potential (the aforementioned approx. 8 ha of land) could be fulfilled in Litoměřice, more than 96 % of the population would have convenient access to these green infrastructure areas, an increase of 1.53 percentage points compared with the current situation. In the case of Benešov, this would constitute 74.42 % of the population of this town, an increase of 4.18 percentage points. Notably, however, the potential green areas in Benešov are not located in the most

needed parts of the city, i.e., where there is a higher concentration of inhabitants. These data are also well documented in the resulting maps.

DISCUSSION

The quality of life in settlements is usually documented by the area of green space per capita or a more concise indicator, i.e., the availability of green space. Comparing these data with existing knowledge is problematic because the methodologies (in particular, which green space is counted) differ. The World Health Organization (WHO) recommends 50 m^2/inhabitant as the ideal range of urban green space, while setting 9 m^2/inhabitant as the bare minimum necessary to ensure quality of life for residents (WHO, 2010; Salaš *et al*., 2022). Another example is the Spatial Analytical Documents of Prague (IPR Praha, 2021), which reports values ranging from 14–50 m^2 per inhabitant in the city centre to 1001–1482 m^2 per inhabitant at the outskirts. Litoměřice is very close to the ideal standard of 50 m^2 per inhabitant, with both cities meeting the WHO minimum requirement. According to the European Environment Agency (EEA, 2020), the availability of green space varies considerably between European cities. For example, the city of Karlovy Vary has more than 200 m^2 per inhabitant, whereas Barcelona and Geneva have less than 5 m^2 per inhabitant. In the analysis of 15 Czech cities, the median value is 23.2 m^2 per inhabitant, with Litoměřice and Benešov being above this average.

Litoměřice is larger than Benešov. The built-up area of Litoměřice is 732 ha, whereas that of Benešov is only 519 ha. Nonetheless, it would be possible to use potential elements of green infrastructure in Benešov, i.e., close-to-nature green areas, green areas of abandoned sites and other green areas, to expand green areas. In particular, it would be useful to add new parks and landscaped spaces that would better serve the recreational needs of residents and are under-represented in Benešov.

In the case of the accessibility of green spaces, one of the European Common Indicators for the assessment of sustainable development at the local level can be used: the indicator of the accessibility of public spaces and services. This has been defined as the proportion of the population living within 300 m of public open spaces larger than 0.5 ha, which include parks, gardens and other open spaces free of charge to the public, including uncovered sports grounds. In 2003, the Final Report was published, according to which 69 % of the inhabitants of 22 European cities had accessible public spaces within 300 m (Ambiente Italia Research Institute, 2003). In the Czech Republic, these indicators were monitored until about 2010; for example, in Svitavy (2004), 92 % of the population was within reach of such spaces; in Vsetín (2010), 100 %; and in Krnov (2009), 54 %. Today, the indicator of the accessibility of green spaces in the Czech Republic appears in sustainable development audits according to the Aalborg Commitments. Chrudim (2022) and Kopřivnice (2023) reported the availability of green spaces for 75 % and 33 % of the population, respectively (CENIA, 2024). European comparisons show that in Scandinavia and Western Europe, more than 2/3 of the population has access to green spaces, whereas in Southern and Eastern Europe, the availability is less than 40 % (Kabisch *et al*., 2016).

The Institute of Planning and Development of Prague (IPR Praha, 2014) states indicator 65: the share of the population with access to green space within 5 minutes in 2014 was 90.35 %. Our results demonstrate the availability of public green space greater than 0.5 ha within 300 m for 70.2 % (air distance) and 70.24 % (by road) of the total population in Benešov and 97 % (air distance) 94.77 % (by road) in Litoměřice.

Therefore, both cities have very good accessibility to green spaces and are above average in the European context. In Benešov, however, work is needed to compensate for the

difference between good accessibility and the lower number of green spaces that could face higher visitor numbers. The higher use of small parks and green spaces in residential developments shows that they are under more pressure. This overcrowding can lead to feelings of stress and reduced quality of recreational functions, as research has shown (Stokols, 1972), and it may also increase maintenance costs. Expanding green infrastructure in Benešov would not only improve the quality of life of residents but also promote the long-term sustainability of public spaces.

CONCLUSION

In this paper, we focused on the indicator of accessibility, emphasizing the key need to distinguish between areas that actually provide their cultural functions and those that only formally fulfil it. In most current studies, all public green spaces are included in the accessibility indicator, without examining whether these spaces are capable of fulfilling the cultural functions. To analyse urban green infrastructure effectively, it was necessary to apply a comprehensive approach that combines analysis in a GIS environment with field surveys. The reason is that the green spaces on the map do not always correspond to the actual situation, and their real functions cannot be objectively assessed without direct examination. Although this research has covered only a limited number of cities thus far, we hope that our findings will provide a useful basis for further studies and lead to the development of a holistic approach to assess the availability and quality of urban green spaces at a broader scale.

The model cities were Benešov in Central Bohemia and Litoměřice in the Ústí nad Labem region. The starting points for the elaboration of the indicator of public green space availability were the analysis of the areas of public urban green space and the development of the GI concept. The definition of core and supporting GI elements is based on a typology of green space types and a quantitative assessment. The core elements are also the areas that are counted in the indicator of the availability of green spaces for inhabitants. The following characteristics document the status of urban green space elements in terms of cultural ecosystem services. Greenery in Benešov accounts for 20 % of the city's area (105.6 ha), and GI with CESs accounts for 54 % of the city's green areas. Within the city of Benešov, the core elements of green infrastructure account for 18.67 ha, which represents 3.59 % of the total built-up area, which is 519.32 ha, and 17.7 % of green areas. The supporting elements of green infrastructure occupy 39.17 ha, which is 7.54 % of the total built-up area and 37.1 % of the green space. Potential green infrastructure elements cover 47.72 ha, which is 9.19 % of the total built-up area. Among these potential sites, 13.41 ha (2.58 % of the total built-up area) were selected for accessibility improvements, representing 12.7 % of all green space in the city.

In Litoměřice, the green area accounts for 17 % of the city area (126.17 ha), and GI with CESs accounts for 47.2 % of the green area. The core elements of green infrastructure cover 67.69 ha, which represents 9.25 % of the total built-up area and 732.07 ha and 53.65 % of green areas. The supporting green infrastructure elements cover 41.95 ha of land, which is 5.73 % of the total built-up area and 33.25 % of green space. Potential green infrastructure features cover 16.54 ha of land, accounting for 2.26 % of the total built-up area. Among these potential sites, 6 sites—8.08 ha (1.1 % of the total built-up area)—were selected to improve accessibility, representing 6.4 % of all green space in the town.

The difference in these indicators is due to the urban structure, which includes green areas, and the overall smaller area of green areas in Benešov (105.6 ha compared with 126.17 ha in Litoměřice).

The contribution of this study also lies in the fact that it tests several variants of creating an indicator of green space accessibility. First, a 300 m ring around the green spaces of the settlement is used. Second, a 300 m walking distance along the road network is used to connect these data with the distribution of the population. The results show that 70.2 % of the population in Benešov and 97 % in Litoměřice have public green spaces accessible along the road network within 300 m. Improving accessibility is possible by using potential green areas that are currently unable to fulfil the ECS of culture; in Benešov, this is 12.7 % of green areas (13.41 ha), and in Litoměřice, it is 6.40 % of green areas (8.08 ha). Utilizing potential green spaces and improving the quality of existing spaces is a way to improve the quality of life of inhabitants, not only in our model cities.

The qualitative analysis reveals opportunities to improve the quality of existing areas and enhance recreational ECSs. The lowest rated characteristic in both towns is operational design and amenities (2.29 Benešov, 2.00 Litoměřice), followed by the vegetation structure (1.86 Benešov, 1.77 Litoměřice). The best (1.71 Benešov, 1.64 Litoměřice) in both cities is interest in these areas, i.e., intensity of use. There were more stable areas in Litoměřice (grade 1.73), where 50 % were stable in terms of function. The situation was worse in Benešov, which had a grade of 2.14, where 14.3 % of the areas were stable in terms of function. Subsequent measures with a change of concept and a total reconstruction project were required in 28.6% of the areas in Benešov and 22.7 % in Litoměřice, whereas other measures without a change of concept were needed to improve the condition of the area.

The findings show that high-quality urban greenery, not only in terms of area but also in terms of its ability to provide cultural ecosystem services, is essential for sustainable urban development. Improving the availability of green space for 74 % of the population of Benešov and 96 % of the population of Litoměřice can be achieved through targeted revitalization measures and thoughtful improvement of existing urban green spaces. These data can be generated for any city to create objective strategic plans, while other indicators, such as the impact of green spaces on the microclimate of cities or on the psychological health of inhabitants, should also be monitored.

ACKNOWLEDGMENT

This research was supported by the research project TAČR PPZ SS02030018 DivLand (Centre for Landscape and Biodiversity).

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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