

THE AVAILABILITY AND ACCESSIBILITY OF GREEN URBAN AREAS IN TORUŃ, POLAND. TOWARDS A BIOPHILIC CITY

Krzysztof Rogatka¹  • Mateusz Kowalski² 

¹ Department of Urban Studies and Sustainable Development,
Faculty of Earth Sciences and Spatial Management, Nicolaus Copernicus University in Toruń
Lwowska 1, 87-100 Toruń: Poland
e-mail: krogatka@umk.pl

² Doctoral School of Social Sciences
Nicolaus Copernicus University in Toruń
Bojarskiego 1, 87-100 Toruń: Poland
e-mail: mkowalski@doktorant.umk.pl (corresponding author)

Abstract

Cities worldwide are confronting numerous problems and challenges that affect the human-nature relationship in urban spaces. The biophilic city concept, proposed by T. Beatley, is a response to improving the quality of life in cities and creating a lasting connection between people and nature. A biophilic city is a place immersed in nature, where residents do not visit nature but live within it. It is therefore a city with good availability and accessibility to green urban areas (GUAs). The aim of the study is to identify the availability (area share) and accessibility of GUAs in Toruń (Poland). We carried out (1) geospatial analyses through which we examined the availability (% area share) of GUAs in the area of city and its 20 urban planning units – UPUs (the threshold value of the indicator was set at 30%); (2) network geospatial analyses; through which we analysed the accessibility of GUAs in Toruń – the share of the 300-metre zone in the area of the city and individual UPUs (the threshold value of the indicator was 50% after excluding the green areas themselves from the area of the city and UPUs). The analyses conducted indicate that a high level of availability does not always translate into the same level of accessibility. The research also shows that, on a citywide scale, Toruń meets the assumptions set out in the article, i.e., records indicators above the established thresholds. However, the city should take action at the individual UPU level to reduce disparities across different parts of the city. The actions should take into account local and even micro-local conditions.

Keywords

biophilic city • urban greenery • availability • accessibility • GIS • Toruń • Poland

Introduction and aim of the study

Currently, more than half of the planet's population lives in cities. According to the scenarios by UN-Habitat (2022), this share will increase to 68.4% in 2050. Today's cities are landscapes that have been heavily transformed by man, and can be described as: cultural, when they maintain the right balance between natural and anthropogenic components; degraded, where a clear disruption of the aforementioned nature-human relationship is evident; or devastated, where nature has been destroyed completely or to a significant extent (Mazurski, 2012). Much of the damage to the urban environment was done in the 19th century through rapid industrialisation. As rightly pointed out by Davies (2015), progress was accompanied by urban growth, which was characterised by such high levels of mortality, squalor, and poverty that they threatened the very survival of these centres. Another revolution for cities was undoubtedly the development of motoring in the 20th century, which changed the face of cities forever. This was clearly visible in American cities, where wide thoroughfares and extensive motorway overpasses were planned at the expense of green spaces and even downtown development. This also initiated a new process in cities: suburbanization. The availability of quick access to the city center led to the sprawl of development into the valuable, open spaces of the suburbs on an unprecedented scale. (Hall, 2014, p. 329). These negative changes that took place in cities over the centuries have had a common denominator – the transformation of the environment leading to its degradation. The degradation of nature occurred both qualitatively and quantitatively. Among other things, there was a decline in biodiversity caused by pollution and the fragmentation of urban natural systems. All of this translated into a decline in people's quality of life and health, both physical and mental, as well as in interpersonal relationships, because green areas are places of rest and

respite from the hustle and bustle of the city, but also important meeting places (Rogatka et al., 2025; Kowalski, 2026). In response to the many errors and resulting problems, people started demanding a return to contact with 'true nature', which integrates humans, animals, and plants as mutually necessary worlds (Karwinska, 2008). Over the past centuries, new visions of urban development have emerged in an attempt to reverse the negative effects of anthropogenisation (Barucka, 2014). One such example is Ebenezer Howard's ground-breaking 'garden cities' of 1902 (Pastor et al., 2023). As stated by Czapiewska (2017), the concept has inspired transformations in architecture and urban planning for more than 100 years, encouraging health-oriented space planning. Nowadays, too, there are numerous references to the 'garden city', indicating the enormous role of nature, and thus of greenery, in the urban environment. There is a green turn – a turn to nature, a turn to biophilia.

Biophilia (Gr. 'bio' – life; 'philia' – love) means love of life. The first one to write about biophilia was Erich Fromm (1973), who defined it as a passionate love of life and everything that lives. The concept of biophilia was effectively propagated by sociobiologist Edward Osborne Wilson, to whom the term is ultimately attributed (Krčmářová, 2009; Beatley, 2016; Kowalski, 2026). Wilson (1986) described it as an innate tendency to focus on life and life-like processes. These reactions follow human evolution (Ulrich, 1983; Zhong et al., 2022). In this context, the concept of biophilia is often mentioned together with the savannah hypothesis, which relates to residential choice and landscape preference. This hypothesis is based on numerous evolutionary accounts that claim that humans have lived in the savannah of East Africa for more than 2 million years. According to Orians & Heerwagen (1992) humans have a general preference for savannah-like environments – large, open spaces offering the opportunity to enjoy a wide horizon along with the presence of scattered trees that may once have served prehistoric humans

as a place to hide (Ulrich, 1983; Joye & De Block, 2011). Kellert & Wilson (1995) emphasise man's innate connection and belonging to the natural world, manifested through preserved primal instincts. According to these researchers, one example is the shape of trees – those that can be climbed and have a wide canopy that looks like an umbrella are found more attractive than others. People also tend to perceive natural environmental components: water, green vegetation or flowers, as better than artificial elements, such as structures made of glass or concrete. The phenomenon of biophilia is multidimensional and can be considered from many perspectives: psychological, biological, cultural, symbolic, or aesthetic (Kellert & Wilson, 1995). Research on the relationship between humans and nature, or the impact of nature on human senses, has been conducted by many researchers (Andrusaityte et al., 2016; Berg & Custers, 2011; McEachan et al., 2016; Shanahan et al., 2016). One of the best-known experiments was the one carried out by Roger Ulrich (1984) who studied the length of hospital stay of patients after gallbladder surgery depending on the view they had from the windows of the hospital rooms. The study found that recovery was faster for patients who could see the natural landscape from their windows. This was one of the first studies to confirm the regenerative power of nature. Modern scientists also attempt to identify its impact on humans. Research by Capaldi et al. (2014) suggests that contact with nature can lead to improvements in mood, cognitive function, and health. A meta-analysis conducted by Capaldi's team on 30 research samples ($N = 8523$) indicates that contact with nature and feelings of happiness are strongly linked. Another study, implemented by Grahn & Stigsdotter (2003), found that increasing the availability of green space fosters more regenerative, stress-reducing environments.

Biophilia is a focus on life and nature, the innate human bond with nature. Therefore, the following questions should be asked: Is the city, as the basic environment of human

life, able to provide this bond? Will we find nature in this highly transformed environment? As pointed out by Beatley (2011), biophilic cities are immersed in nature, and people are surrounded by it. In these cities one does not visit nature but lives in it. For this to happen, however, our cities need good availability and accessibility of biologically active areas. Mostly, these comprise green areas – city parks, squares, and greens (Loures et al., 2007; Yokohari & Amati, 2005). Their numerous advantages are cited by Klein et al., 2024; Kukulska-Kozieł et al., 2024, and Rogatka et al., 2015, who not only focus on their impact on protecting the environment and creating a favourable microclimate, but also place man as the main beneficiary in terms of health and well-being (happiness levels). The hygienic, biological, and regenerative value of greenery is also described by Chmielewski (2016), who points out that it increases in proportion to the volume of biomass concentrated in one place and, at the same time, is an indispensable element of any human residence. The functions of green spaces have been described holistically by Kasińska & Sieniawska-Kuras (2009), who listed five main ones: (1) biological and health; (2) aesthetic and artistic; (3) leisure; (4) educational and social; and (5) economic.

In the spatial context, the 3-30-300 rule, developed by Konijnendijk (2021), closely aligns with the concept of a biophilic city. It stated that every resident should be able to see at least 3 trees from their flat window; the neighborhood in which they live should have 30% vegetation cover; and the distance from their place of residence to the nearest green space should be no more than 300 meters. This principle can therefore serve as a benchmark for assessing the spatial biophilic potential of a city. A city that is immersed in nature, thus providing residents with easy, daily contact with nature (Beatley, 2011). The positive impact of this contact is described above.

The aim of the study is to identify the availability (area share) and accessibility of green

urban areas (GUAs) in Toruń (Poland). These two elements (30 and 300 principles) are essential for determining the city's spatial biophilic potential. The following research questions were constructed:

1. Whether and to what extent does the city of Toruń meet the availability criterion (minimum share of GUA) in the total city area and in individual urban planning units (UPUs)?
2. What spatial inequalities occur in the availability of GUAs between individual urban planning units, and which UPUs show deficits?
3. Whether and to what extent does the city of Toruń meet the accessibility criterion in the total city area and in individual urban planning units (UPUs)?
4. What spatial inequalities occur in the accessibility of GUAs between individual urban planning units, and which UPUs show deficits?

Methods

Research area

The main research area is Toruń, a city in Poland located in the Kuyavian-Pomeranian Voivodeship, one of the two capitals of the region, alongside Bydgoszcz. According to the Local Data Bank of Statistics Poland (GUS, 2024), the city had a population of 193,717 in 2024. According to data from the Head Office of Geodesy and Cartography, the city covers approximately 116 km² (GUGiK, 2024). The spatial arrangement of green spaces in Toruń is determined by natural and historical factors. The city is situated in the Toruń-Eberswald Proglacial Stream Valley, shaped by the retreating glacier, which constitutes a significant physiographic barrier to urban development. Especially in the central part of the valley, transformed by the flowing waters of the Vistula River, which formed numerous terraces. Currently, these areas are largely

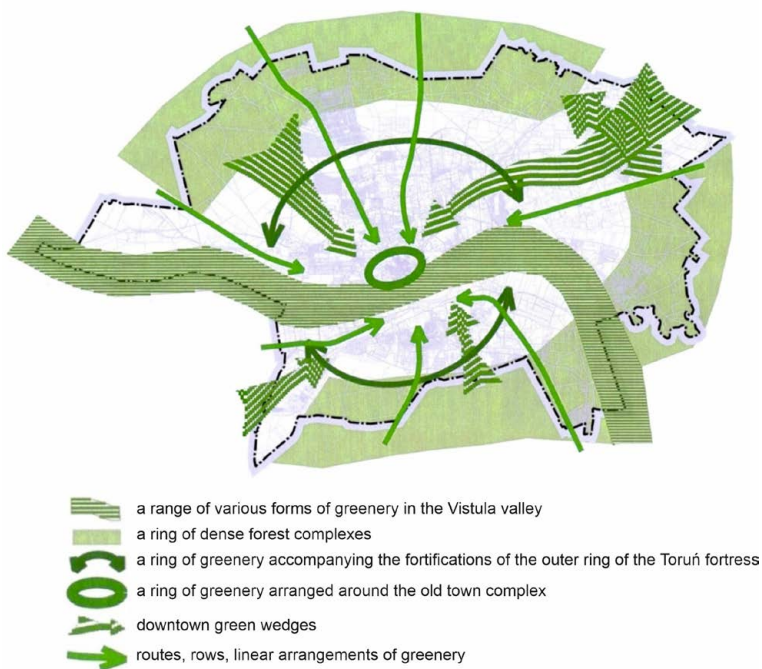


Figure 1. The ring-wedge system of green urban areas in Toruń

Source: Taken and modified from The Concept of development of green areas in Toruń (Municipal Urban Planning Office of Toruń, 2018)

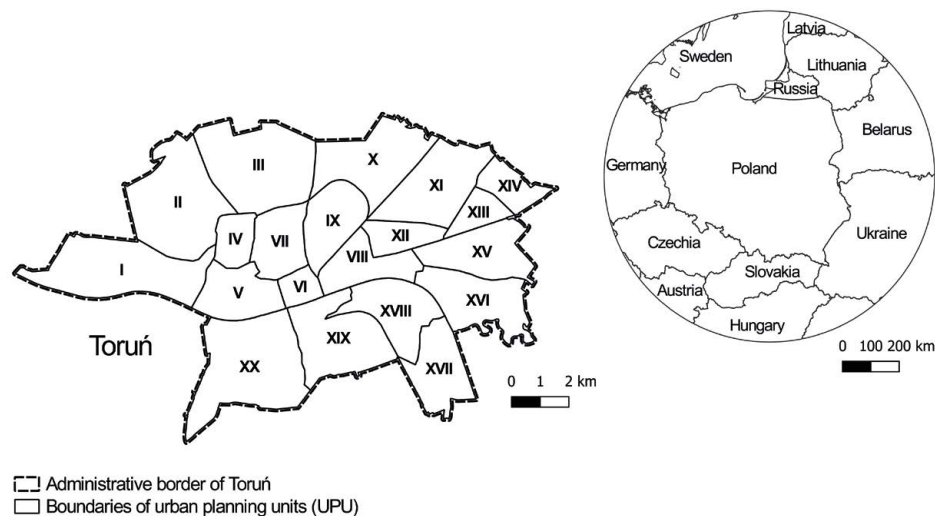
green patches. The second factor stems from the historical role of the city as a fortress. Two rings of fortifications remain visible in the spatial layout of the city to this day: an inner ring, in the form of the so-called *planty* around the Old Town, and an outer ring. After changes in military technology and the loss of functionality of fortifications, artificially dense pine forest complexes were introduced on the former viewing areas of the outer ring. The green space system of Toruń is complemented by wedges of downtown greenery and linear greenery along traffic arteries, giving it a ring-and-wedge character (Fig. 1).

The study area is divided into twenty urban planning units (UPUs), the boundaries of which were obtained from the Municipal Urban Planning Office in Toruń (Fig. 2). Each unit differs in terms of, among other things, physiography, function, land cover, and the character of development. The most important characteristics of each UPU are included in Appendix 1.

Data

For the study, data from 2018-2024 were used. The authors used the most up-to-date databases available (as of March 2024). Although the comparative analysis of spatial databases falls outside the main purpose of this article, it was decided to use diverse sources to minimize the risk of obtaining results burdened by data-specific errors.

The first database that was used to assess the availability of green spaces in Toruń is the Urban Atlas (UA), specifically the original 2018 edition. This package is being implemented by European Environmental Agency as a targeted tool for Functional Urban Areas (FUAs). UA based on Very High Resolution (VHR) imagery with the resolution 2-4 m, achieving a horizontal positional accuracy of less than 5 m. It maintains a Minimum Mapping Unit ranging from 0.25 ha for urban classes, e.g., for those used in analyses like – 14100: Green urban areas; 14200: Sports and leisure facilities, to 1 ha for



Urban planning units (UPUs) in Toruń:

I Starotoruńskie Przedmieście; II Barbarka; III Wrzosey; IV Bielany; V Bydgoskie Przedmieście; VI Old Town; VII Chełmińskie Przedmieście; VIII Jakubskie Przedmieście; IX Mokre Przedmieście; X Katarzynka; XI Grębocin Przy Lesie; XII Rubinkowo; XIII Bielawy; XIV Grębocin Nad Strugą; XV Na Skarpie; XVI Kaszczorek; XVII Czerniewice; XVIII Rudak; XIX Stawki; XX Podgórz

Figure 2. Spatial scope of research

Source: Own elaboration based on data from Head Office of Geodesy and Cartography (Poland), Eurostat and the Municipal Urban Planning Office of Toruń

classes outside the main urban fabric, used in analyses – 23000: Pastures; 31000: Forests; 32000: Herbaceous vegetation associations (European Environmental Agency, 2021).

Also, the physical object database that forms the basis of the Open Street Map (OSM) was used in the work. It is an editable map of the world created by volunteers, made available under a license that allows almost unlimited use. The database collection also includes a land use category that contains vector data in the form of polygons. In this case, the following land use classes found in OSM were treated as greenery: allotments, cemetery, forest, grass, meadow, orchard, and parks. Compared to the database derived from the Copernicus program datasets, OSM is characterised by an even greater degree of accuracy and data fragmentation – although it lacks formal spatial resolution, it allows for the capture of small areas that are often imperceptible, including through UA. This is because users often rely on high-resolution orthophotomaps and accurate GPS tools (OpenStreetMap Wiki, 2026).

One of the most accurate datasets containing land cover information in its thematic scope is the Polish Database of Topographic Objects (DTO). It includes the location of topographic objects in vector form, together with their basic descriptive characteristics. It is important to emphasise the detail of the database, which is the equivalent of a traditional topographic map at a scale of 1:10,000. The dataset is not limited by the Minimum Mapping Unit, so it can cover micro-scale structures down to 0.1 ha. The horizontal accuracy ranges from 1.5 m to 5.0 m. The following vector layers representing greenery were extracted from the database: forest or wooded land (OT_PTLZ_A), permanent crops (allotments, plantations, orchards, nurseries) (OT_PTUT_A), grass vegetation and agricultural crops (OT_PTTR_A). In addition, a land use complex – a church complex and a cemetery (OT_KUSC_A) – was used but restricted to cemetery green area (GUGiK, 2021).

The paper also draws on information contained in the document *The Concept of Development of Green Areas in Toruń* (CDGA), and

more specifically in the graphic annex 'Diagnosis of the state of green areas in Toruń' at scale 1:20000 (Municipal Office in Toruń, 2018). This type of data is highly reliable, as it required site visits during the collection phase, among other methods. The map in the form of a .pdf file was imported into QGIS, where it was georeferenced and projected to the PL-1992 (EPSG:2180) coordinate system, and individual patches of greenery were vectorized in order to facilitate the analysis. For the purposes of the work, the categories of greenery and their nomenclature were modified, and the following were separated: forests, parks, squares and greens, allotments, cemeteries, fortress greenery, and greenery of ecological importance. The data obtained was updated on the basis of the 2022 orthophotomap, the main changes were made within the Old Town (treated holistically in the document as the 'Old Town Greenery' category). The update also applied to the allotments category.

Proposed indicators and methods of calculation

The diagram of the use of the previously described databases is presented in Figure 3. These data were processed in QGIS software. We carried out: (1) geospatial analyses through which we examined the availability (% area share) of GUAs in the city's area and its 20 UPUs (the threshold value of the indicator was set at 30%); (2) network geospatial analyses through which we analysed the accessibility of GUAs in Toruń – the share of the 300-metre zone in the area of the city and individual UPUs (the threshold value of the indicator is 50% after excluding the GUAs themselves from the area of the city and UPUs). For this aim, we used the results of the analysis of the surface share of GUAs (The Concept of Development of Green Areas in Toruń) and the network of pedestrian routes from the OpenStreetMap as input data updated on the basis of an orthophotomap (total, 2010.34 km of pedestrian routes in Toruń and a kilometer buffer around the city were

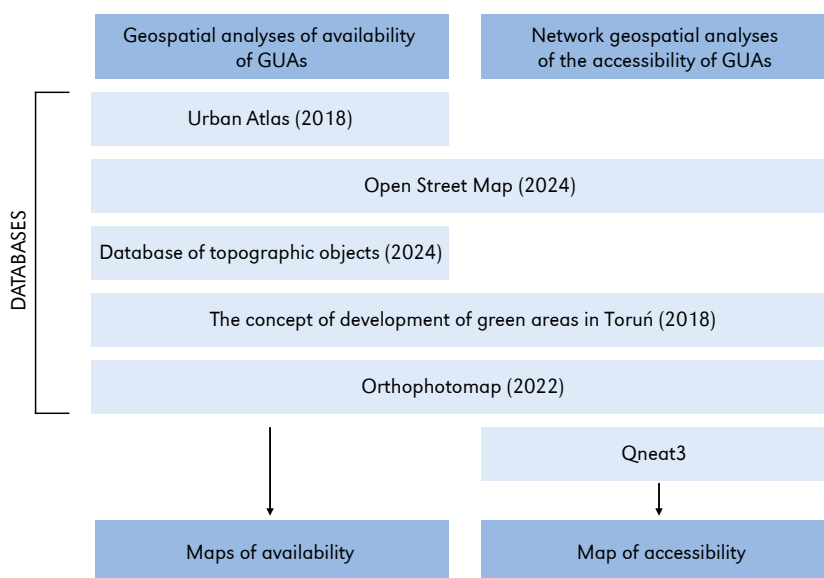


Figure 3. Research methods and databases

drawn manually). The tool used for the network analysis was the QNEAT3 plug-in. The 300-meter zone was adopted under the 3-30-300 rule, with a 50% threshold serving as the critical mass indicator. Excluding GUAs from the reference area allowed the assessment of urban fabric coverage solely by the accessibility zone, thus avoiding a logical fallacy.

Results

Availability of GUAs

Analyzing the overall city area, the results obtained from all databases exceed 30%, with the average share of GUAs in Toruń at 48.05%. The highest result was obtained for the DTO database at 64.22%, followed by UA at 46.39%, OSM at 45.35%, and CDGA at 36.24%. Despite the lack of a minimum mapping unit, the OSM database showed slightly lower values than the UA database across the entire city, which may be due to a combination of the selectivity (Voluntary Geographic Information) of the former and the complete systematicity of the latter. In the case of availability, the DTO database is the most accurate, accounting for the

widest range of GUAs, including microforms. However, to accurately depict the actual state of GUAs available to residents, individual patches of vegetation, such as roadside lawns, are often excluded from the analysis. Using a threshold of 0.5 ha, for example, avoids inflating the results by including areas whose size does not allow for recreation and relaxation for residents. This is confirmed by the result calculated based on the city's document (CDGA).

At the urban planning unit level, taking average values into account, 14 out of 20 UPUs exceeded the designated threshold. The highest values were achieved by units located in the ring of forest complexes surrounding the city: II Barbarka (DTO: 96.67%; OSM: 89.74%; CDGA: 76.53%; UA: 75.95%); XV Na Skarpie (DTO: 76.96%; OSM: 72.22%; UA: 71.60%; CDGA: 70.85%); and X Katarzynka (DTO: 85.13%; OSM: 74.09%; UA: 62.28%; CDGA: 60.59%). A large share in the case of two bases was also recorded by unit XVII Czerniewice, also located in the belt of external forest complexes (DTO: 74.78%; UA: 68.96%). At the other extreme, there were three districts that were on average covered with GUA by less

than 20%: VII Chełmińskie Przedmieście (DTO: 28.63%; UA: 13.51%; OSM: 12.08%; CDGA: 7.08%); VI Old Town (DTO: 25.22%; UA: 18.35%; OSM: 17.93%; CDGA: 12.83%); and XIII Bielawy (DTO: 35.71%; OSM: 20.30%; UA: 19.92%; CDGA: 1.51%). In the case of the first two units, the low share of greenery may be due to the high building density. In the case of VI Old Town, these are medieval tenement houses, and vegetation in this unit occurs mainly in the site of the former inner ring of fortifications. In the case of unit VII Chełmińskie Przedmieście, the preserved historical buildings have been densified by contemporary development; only small plots of vegetation remain, as well as green belts along traffic arteries. The situation is somewhat different in unit XIII Bielawy, which can be

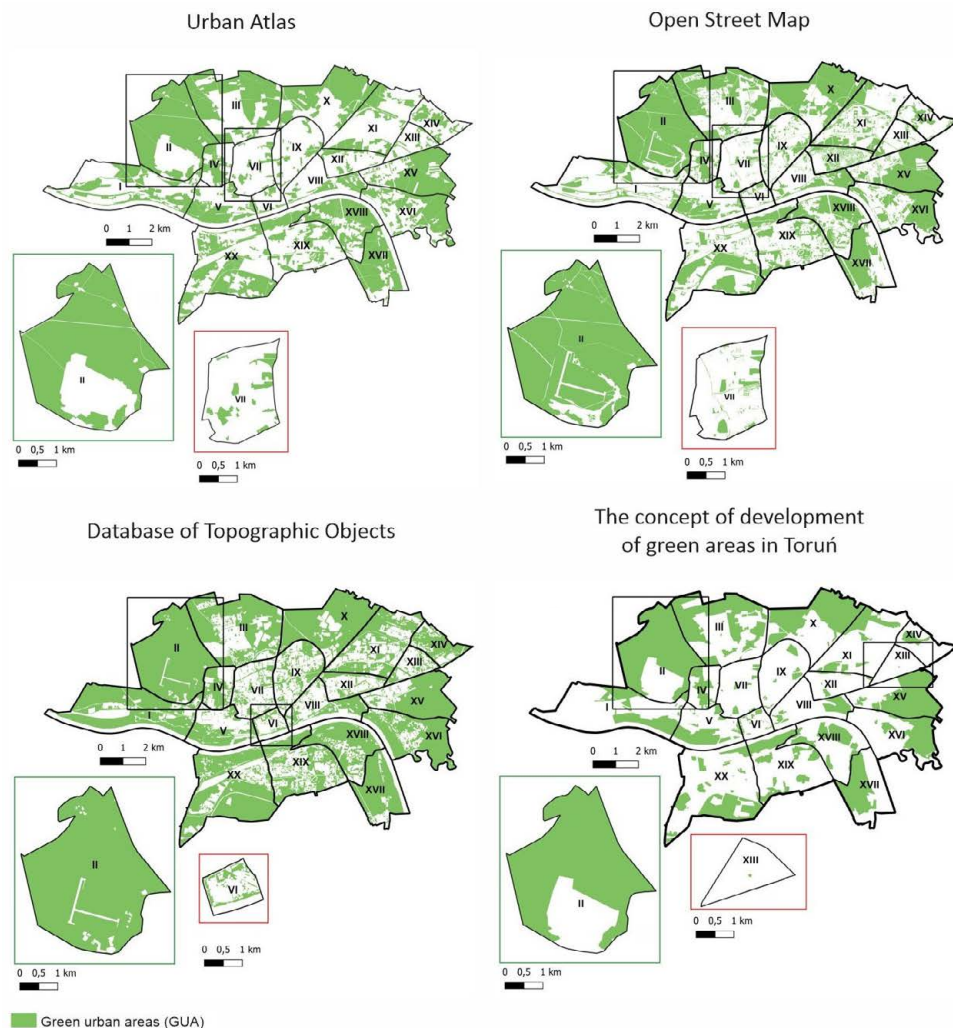
described as a suburb of single-family houses located within the city limits. The character of the buildings is well reflected in the obtained results; the DTO database can include, for example, gardens located on private properties, whereas the CDGA results omit this type of vegetation. Units bordering the river record values exceeding the minimum threshold of 30% (with the exception of unit VI Old Town and VIII Jakubskie Przedmieście). These shares are the highest in the DTO, UA, and OSM databases, indicating the dominance of natural vegetation forms located in the river valley over the formal types designated in the CDGA database (Fig. 4).

The Table 1. provides a summary of the availability indicator values, and it includes the results from all the databases analysed.

Table 1. Summary of availability in urban area and urban planning units

No.	Urban planning unit name	UA	OSM	DTO	CDGA	Average
		%				
TORUŃ		46.39	45.35	64.22	36.24	48.05
I	Starotoruńskie Przedmieście	34.57	22.23	67.95	23.81	37.14
II	Barbarka	75.95	89.74	96.67	76.53	84.72
III	Wrzosey	58.93	52.87	65.09	50.80	56.92
IV	Bielany	47.27	47.12	56.83	38.35	47.39
V	Bydgoskie Przedmieście	42.18	38.62	44.32	34.75	39.97
VI	Old Town	18.35	17.93	25.22	12.83	18.58
VII	Chełmińskie Przedmieście	13.51	12.08	28.63	7.08	15.32
VIII	Jakubskie Przedmieście	25.95	31.85	38.24	19.11	28.79
IX	Mokre Przedmieście	14.13	20.68	38.35	7.38	20.13
X	Katarzynka	62.28	74.09	85.13	60.59	70.52
XI	Grębocin Przy Lesie	28.82	30.91	55.32	21.30	34.09
XII	Rubinkowo	24.62	40.05	35.56	7.74	26.99
XIII	Bielawy	19.92	20.30	35.71	1.51	19.36
XIV	Grębocin Nad Strugą	35.71	24.29	71.19	14.22	36.35
XV	Na Skarpie	71.60	72.22	76.96	70.85	72.91
XVI	Kaszczonek	54.20	48.84	74.85	35.21	53.28
XVII	Czerniewice	68.96	53.43	74.78	48.20	61.34
XVIII	Rudak	58.79	50.59	67.37	29.72	51.62
XIX	Stawki	35.34	36.61	53.06	27.80	38.20
XX	Podgórz	44.49	37.34	70.38	27.95	45.04

Source: Own elaboration based on geospatial analyses



Urban planning units (UPUs) in Toruń:

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Figure 4. Green urban areas (GUAs) in the best and worst UPUs in terms of availability

Source: Own elaboration based on UA, OSM, DTO and CDGA

Accessibility of GUAs

Following geospatial analyses of the area share of green urban areas, a network analysis of their accessibility was also conducted. Materials prepared on the basis of The Concept of Development of Green Areas in Toruń were selected as input data because of the

reliability of such studies and the individualised approach to a specific area of analysis (Toruń).

In light of the calculations, the VI Old Town has the best accessibility to green spaces, with 95.07% of its area within the 300-metre zone (after excluding green spaces). V Bydgoskie

Przedmieście came second (85.61%) and IV Bielany came third (84.11%). These are historic districts. In VI Old Town, despite the low GUAs coverage rates, the ring-shaped vegetation arrangement around the UPU makes access easy and evenly distributed. In the case of V Bydgoskie Przedmieście, the decisive factor is the good access to the City Park, which is also partially located in the river valley. Unit IV Bielany, on the other hand, lies within the northwestern green wedge. At the other extreme, there were: XIII Bielawy, which recorded the lowest rate (24.25%), I Starotoruńskie Przedmieście (29.40%) and XVII Czerniewice (29.61%). Unit XIII Bielawy, which scored low for GUAs' availability, also had poor accessibility due to spatial barriers, such as the exit road towards Warsaw effectively cuts these areas off from the green area of unit XV Na Skarpie. In the case of the next two UPUs, despite their location near a river valley, these areas are difficult to access due to numerous obstacles, including terrain. The indicator for the city as a whole is at 52.72%, thus slightly exceeding the target value of 50.00%. In more detail, 12 of the 20 UPUs exceeded this threshold (Fig. 5., Fig. 6).

Discussion

Availability of GUAs

The research was based on the 3-30-300 concept mentioned above (Konijnendijk, 2021). Considering the city as a whole, Toruń meets the established requirements. This is also confirmed by other studies of this type, including those by Starczewski et al. (2023), who reported that in Poland, the share of green areas in the largest cities is increasing, currently averaging 29%, which is close to the assumptions of the 3-30-300 rule. The value of this indicator suggests that the situation in Toruń is very good compared with other Polish centres. Also, with medium-sized cities, where the surface share of green space fluctuates around 19%, as stated by Senetra et al. (2018). Furthermore, Toruń compares favorably with other European cities. According to Fuller & Gaston (2009), when Polish cities record average values, in Europe as a whole, the average proportion of GUAs is barely 19%. Problems in Toruń occur locally within individual UPUs. As Gupta et al. (2016) point out, this stems, among other things, from the type of development, which impacts the ability to develop the space between buildings

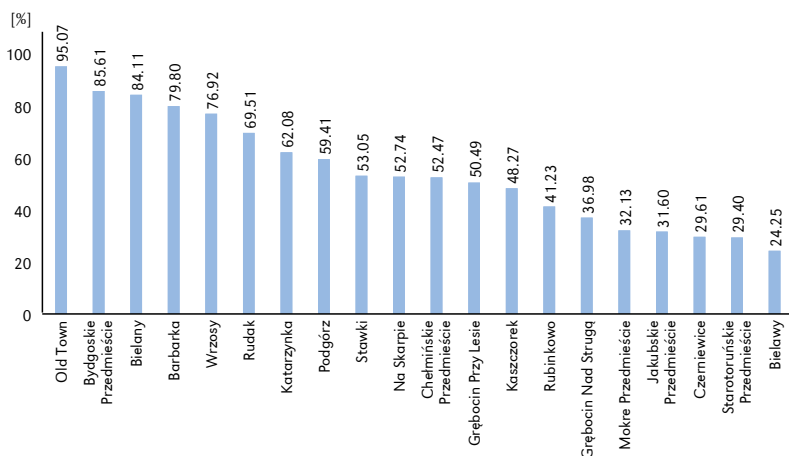
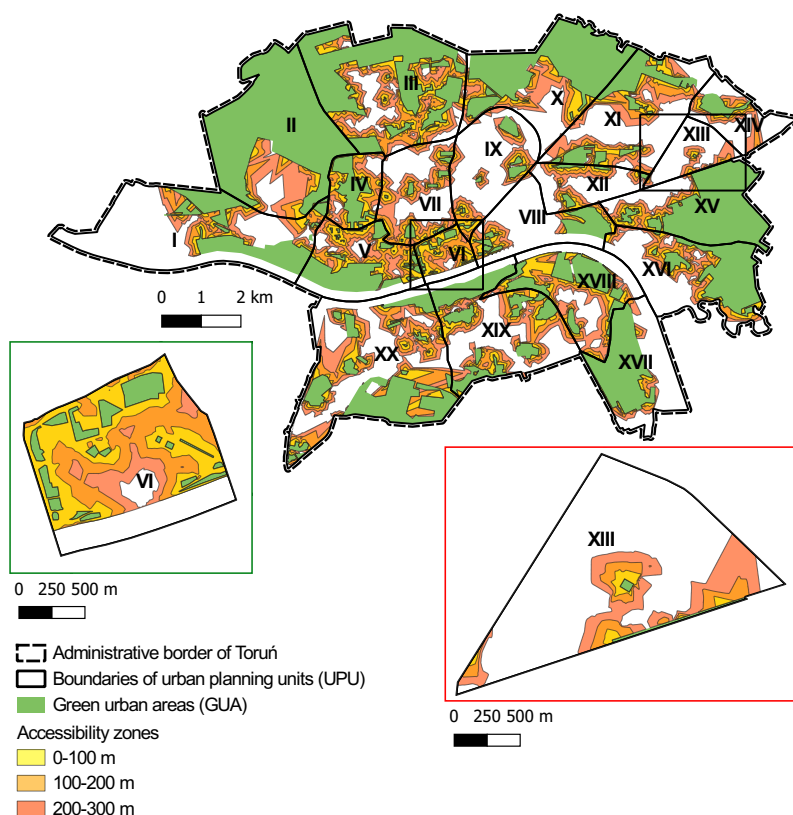


Figure 5. Share of the 300-metre zone to the nearest green areas in the area of UPUs after exclusion of green areas

Source: Own elaboration based on The Concept of Development of Green Areas in Toruń (2018), Orthophotomap (2022) and Open Street Map data



Urban planning units (UPUs) in Toruń:

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Figure 6. Accessibility to green urban areas in the best and worst UPUs

Source: Own elaboration based on The Concept of Development of Green Areas in Toruń (2018), Orthophotomap (2022) and Open Street Map data

into green urban areas. These authors cite terraced housing along long, narrow streets as an example. A similar problem is faced by unit VII Chełmińskie Przedmieście, where dense development, further crisscrossed by thoroughfares, makes it impossible to introduce greenery. For these types of areas, the only solution seems to be micro-scale elements, as suggested by the biophilic city concept – green roofs, walls, and street trees and shrubs. Kronenberg et al. (2020) add that many GUAs in post-socialist cities (including

Toruń) were lost due to so-called construction terrorism, i.e., aggressive land development based on the exploitation of the neoliberal economic system, weak legal protection, and, consequently, the abuse of legal loopholes. This mechanism is also visible in the case of post-industrial areas, which could be successfully adapted for recreation and leisure purposes in districts with high development density. However, these brownfields are being transformed into intensive multi-family housing developments. This type of situation

can be observed in unit VIII Jakubskie Przedmieście, which, despite bordering the river, recorded availability index values below the established threshold, due to intense development. In this discussion, there are legitimate arguments that it is crucial to find a way to make a city both compact, i.e., not sprawling into adjacent areas, and green at the same time (Rogatka & Ribeiro, 2015; Warchalska-Troll & Pistelok, 2023). On the one hand, increasing the density of buildings limits the process of urban sprawl, but on the other hand such activities should be carried out taking into account the reserve of land for publicly available GUAs. This balance is particularly vital because urban sprawl affects cities worldwide, and protecting the natural areas surrounding cities is essential. Fuller & Gaston (2009) argue that as cities grow, interactions between people and nature increasingly depend on the quality of the landscape beyond formal networks of green spaces. This is confirmed by the high availability index in the peripheral UPUs of Toruń, where dense forest complexes are the dominant form of GUAs. In turn, in central units, such as VI Old Town and VII Chełmińskie Przedmieście, access to nature should be sought in the few formal green areas, i.e., parks and squares. Similar conclusions were drawn in Poland by Kabisch et al. (2016) in Łódź, and by Gorzelany et al. (2023) in Kraków.

Accessibility of GUAs

Also in the context of the accessibility indicator, Toruń exceeded the established threshold of 50%, albeit by a small margin. For comparison, a very similar result was obtained by Zwierzchowska & Lupa (2021), who used spatial analyses to examine the accessibility of GUAs for kindergartens in Poznań. Analyses showed that 50.50% of establishments have access to green areas within 300 meters. However, as with availability, problems in Toruń occur locally at individual UPUs. An interesting conclusion from the analyses is that a high level of availability (area share of GUAs) does not necessarily

translate into the same level in terms of accessibility. This is clearly evident when comparing forest complexes located on the outskirts of the city with centrally located parks. The situation in Toruń is, in many cases, the opposite of the availability results. Unit VI Old Town, located in the city center, is characterized by the highest accessibility index value, while units located in the outer belt of compact forest complexes, such as XVII Czerniewice, have much lower values. Similar results were reported by Gorzelany et al. (2023) in Kraków, where the central Old Town district exhibits very good accessibility. In contrast, the outlying districts had accessibility scores below the city average. This is explained by the research of Woźniak et al. (2025), who attribute it to differences in road network density and varying terrain slope. This is the case in Toruń's river valley units, where pedestrian paths and trails are often lacking (I Starotoruńskie Przedmieście). The negative impact of spatial barriers on the accessibility of GUAs is described by Oh & Jeong (2007) using the example of Seoul, where major highways prevent residents from accessing the river. In Toruń, a similar situation occurs in unit XIII Bielawy, which is separated from the forest complexes located in the neighboring unit XV Na Skarpie by a wide thoroughfare.

Towards a biophilic city

As mentioned by Kronenberg et al. (2020), the availability and accessibility of green spaces in our cities determine the degree of environmental justice. It means that everyone living in a city should have easy access to nature. This is one of the key assumptions of the biophilic city concept: a city that, as mentioned in the introduction, is immersed in nature, with nature surrounding people. In such a city, one does not visit nature, but lives in it (Beatley, 2011). The article partially applies the 3-30-300 principle (Konijnendijk, 2021), which directly implements the assumptions of the biophilic city concept from the micro scale – the view from the window, through

the meso scale – the neighborhood/district, to the macro scale – the entire city.

In the context of the biophilic city concept, it is also necessary to examine the databases used in this article. As Przewoźna et al. (2024) point out, the WHO guidelines recommend that availability and accessibility analyses include areas of 0.5 hectares or more. However, after conducting their own research, these authors recommend expanding these criteria to include smaller green spaces. They emphasize that it is crucial to recognize the value of pocket parks and other GUAs, which residents rate highly for their proximity and the ecosystem services they provide. This approach also guided the authors of this article. Considering the smallest patches of GUAs is a biophilic approach because, as Beatley (2016) points out, in our cities, we should care for nature at each of the previously mentioned scales, from the micro to the macro. From the smallest patch of urban lawn to the regional greenery system in which the city is located. In the case of Toruń, this is the Toruń-Eberswald Proglacial Stream Valley system with the Vistula River in its central part and forest complexes surrounding the city.

Summary

A biophilic city is a city immersed in nature and, therefore, characterized by good availability and accessibility of green urban areas. Analyses indicate that a good level of availability does not always translate into a corresponding level of accessibility. Biophilicity can therefore be improved in existing urban fabric in two ways, taking into account the specific characteristics of a given urban unit or district. On the outskirts of the city, spatial barriers that limit residents' access to large forest complexes should be eliminated. Simultaneously, care should be taken not to excessively interfere with the natural character of these areas. On the other hand, in city centers, particularly in densely built-up districts where land for new parks and squares is scarce, other biophilic solutions should be implemented on a smaller scale – from pocket

parks to green roofs and walls, as well as planting vegetation along streets and major thoroughfares. Our research shows that, on a citywide scale, Toruń meets the assumptions set out in the article, i.e., records indicators above the established thresholds. However, the city should take action at the level of individual urban planning units to reduce the disparities in the availability and accessibility of green urban areas. Such actions would be consistent with the broader trend of combating environmental injustice. Our research provides a basis for creating an urban management policy for GUAs in Toruń. However, this does not mean that the information contained in the article is only local. It can be successfully used for comparative purposes and scaled up for other urban centres, which is precisely what the authors plan to do.

Authors' contribution

KR: Conceptualization, Methodology, Resources, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision.

MK: Conceptualization, Methodology, Resources, Data curation, Formal analysis, Investigation, Software, Visualization, Writing – original draft.

Editors' note:

Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

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Appendix 1

Table 1. Urban Planning Unit's characteristics

No.	UPU characteristics
I	It encompasses the river's floodplains, with agricultural fields and woodlots, as well as degraded areas of defunct chemical plants. The development consists primarily of halls and warehouses, but also includes a stadium, a racetrack, a municipal sewage treatment plant, and, in the western part, a religious building with associated buildings.
II	The area is mainly forested; there is also a sports airfield here, the surface of which, apart from the runways, is grassy.
III	The unit consists of three main parts: the western part is composed of extensive single-family housing, and the eastern part is composed of a newly constructed estate of low-rise multi-family buildings. Both estates are surrounded by forest.
IV	There is a university campus here, as well as forest areas, a housing estate of single-family houses and a smaller estate of low-rise multi-family buildings.
V	The unit borders the river to the south, where the historic City Park is located. The development is largely dense, with tenement buildings. The northern section features a mix of semi-detached and detached houses, as well as prefabricated housing estates, including both low-rise and high-rise buildings.
VI	The area of the historic medieval old town, surrounded by greenery, was created on the site of the former inner ring of fortifications with an encroaching cultural function.
VII	An area characterized by dense, diverse development. The historic layout has been transformed by transportation infrastructure and further densified by new development. The northern part features a mix of single-family housing and multi-family prefabricated buildings from the 1990s, as well as a former railway area.
VIII	To the south, the unit borders the river, with green areas extending along the slopes and wetlands lower in the valley. Where development is possible, there is a conflict of functions. In the northern part, post-industrial areas are being transformed into intensive, high-rise residential development.
IX	In the southern part, the residential function is dominated by multi-family buildings (tall apartment blocks). In the northern part, production and warehousing predominate.
X	An area with a large share of pine forests. A municipal cemetery is located in the western part, and a municipal landfill and storage areas are located in the southeast.
XI	The unit is dominated by a former textile factory, now an area of service, warehousing, and industrial use. In the southern part, there are allotment gardens along a small watercourse.
XII	A housing estate made of so-called large-panel system buildings, one of the two largest in the city.
XIII	A unit dominated by single-family housing on the outskirts of the city.
XIV	A highly diversified unit, including single-family housing, warehouse areas, and wasteland.
XV	The second of the large housing estates was built using the so-called large-panel system. In the eastern part, forests surround the city.
XVI	To the west, the unit borders a river and its floodplain. The southern boundary of the unit, and thus the city, is defined by a second river. Forests dominate the eastern part, while the central part is dominated by single-family homes (with development encroaching on the forest).
XVII	Forested and floodplain areas. Lightly developed in the southern part.
XVIII	In the river's floodplain, there are allotment gardens. In the central part of the unit is a residential development. In the southern part, warehouse buildings. Also, a reservoir was created here after a clay pit flooded.
XIX	A unit with a diverse range of functions and developments. It borders the river to the north. A nature reserve encompasses the riverside riparian forests. In the center lies the historic, fortified railway station, with the fortifications' slopes revitalized as a park. Furthermore, in the center of the unit, there are residential areas, and in the southern part, military areas.

No.	UPU characteristics
XX	The unit is crisscrossed by linear and surface spatial barriers, including railway lines, a highway, and military areas. Furthermore, to the north lies the river's floodplain. In the western part, new development consists primarily of low-rise multi-family buildings. In the eastern part, the historic center of the former separate urban center consists of tenement houses with the encroaching new development of low-rise multi-family buildings.

Urban planning units (UPUs) in Toruń: I Starotoruńskie Przedmieście; II Barbarka; III Wrzasy; IV Bielany; V Bydgoskie Przedmieście; VI Old Town; VII Chełmińskie Przedmieście; VIII Jakubskie Przedmieście; IX Mokre Przedmieście; X Katarzynka; XI Grębocin Przy Lesie; XII Rubinkowo; XIII Bielawy; XIV Grębocin Nad Strugą; XV Na Skarpie; XVI Kaszczorek; XVII Czerniewice; XVIII Rudak; XIX Stawki; XX Podgórz