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THE IMPACT OF INSTITUTIONAL ASPECTS ON THE AVAILABILITY, ACCESSIBILITY, AND ATTRACTIVENESS OF GREEN SPACES IN LODZ

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supervision of
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Summary in Polish

Tytuł: Wpływ aspektów instytucjonalnych na istnienie, dostępność i atrakcyjność terenów zieleni w Łodzi

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Tereny zieleni wpływają na jakość życia i zdrowie mieszkańców miast, świadcząc na ich rzecz szereg usług ekosystemów. Jednak ograniczenie podaży terenów zieleni (a co za tym idzie – usług ekosystemów) ma zdecydowanie negatywny wpływ na kondycję psychofizyczną ludzi. Jednak samo istnienie terenów zieleni (zarówno tych formalnych, np. parki i lasy, jak i nieformalnych, np. nieużytki) nie wystarczy. Z punktu widzenia wielu potencjalnych korzyści, a w konsekwencji dostosowanego do potrzeb społecznych planowania przestrzennego, istotny jest również fizyczny dostęp do terenów zieleni oraz ich atrakcyjność. Z kolei korzyści te mogą znacznie ograniczać różnorodne bariery. Tymczasem w literaturze naukowej brakuje jednomyślności w definiowaniu różnych pojęć związanych z podażą terenów zieleni. Część naukowców używa wymiennie terminów: istnienie (availability) i dostępność (accessibility), pisząc o szeroko pojętej bliskości zieleni (proximity). Z kolei nierzadko atrakcyjność terenów zieleni jest utożsamiana z ich dostępnością i zbiorczo nazywana jakością. Właśnie do tego problemu badawczego odnoszę się w mojej rozprawie.

W odpowiedzi na powyższe wyzwania i niejasności został określony główny cel mojej rozprawy: klasyfikacja barier instytucjonalnych wpływających na podaż terenów zieleni, a także rozróżnieniu poziomów wpływających na tę podaż. Postawiłam sobie za cel również operacjonalizację zaproponowanej klasyfikacji barier poprzez stworzenie zestawu wskaźników, które mogłyby być wykorzystane w innych badaniach związanych z tworzeniem i zarządzaniem terenami zieleni, a także w praktyce planistycznej. Główny cel mojej pracy doktorskiej powstał z potrzeby lepszego uporządkowania zagadnień związanych z istnieniem, dostępnością i atrakcyjnością miejskich terenów zieleni, które w literaturze są opisywane w nieusystematyzowany sposób.

Praca składa się ze wstępu, czterech połączonych ze sobą artykułów naukowych opublikowanych w międzynarodowych czasopismach oraz zakończenia. Całość została przygotowana w języku angielskim. Studium przypadku, którym posługuję się we wszystkich artykułach, jest Łódź. Wybrałam to miasto ze względu na liczne badania związane z terenami zieleni (głównie parkami), które zostały do tej pory przeprowadzone. Dotyczyły one m.in. wyceny wartości terenów zieleni, przywiązania do miejsca, funkcji społecznych parków oraz percepcji nieformalnych terenów zieleni. Istotną luką w tychże badaniach pozostawały kwestie związane z usystematyzowaniem zagadnień związanych z podażą terenów zieleni w mieście, czym zajęłam się w mojej rozprawie.

Pierwszy z artykułów stanowi podstawę moich dalszych analiz. Sformułowałam w nim ramy analityczne związane z podażą terenów zieleni, opisałam instytucjonalne bariery, które mają wpływ na tę podaż, sklasyfikowałam tereny zieleni, a także wyróżniłam kluczowych aktorów, którzy mają wpływ na ich tworzenie i kształtowanie. W tym artykule zostały sformułowane następujące hipotezy:

1. Na istnienie, dostępność i atrakcyjność miejskich terenów zieleni wpływają wyraźnie identyfikowalne bariery instytucjonalne;
2. Instytucje formalne mają większy wpływ na istnienie barier niż instytucje nieformalne.

Drugi artykuł przedstawia analizę tego, w jaki sposób różne bariery instytucjonalne, które ograniczają podaż terenów zieleni, wpływają na dostarczanie usług ekosystemów. Badanie dotyczyło trzech różnych studiów przypadku. Pierwsze studium, związane z liberalizacją ustawy Prawo ochrony środowiska, dotyczyło całej Polski, z kolei pozostałe dwa przykłady były zlokalizowane w Łodzi. W tym artykule sformułowałam następujące hipotezy:

1. Podaż terenów zieleni na każdym z trzech poziomów (istnienia, dostępności i atrakcyjności) inaczej wpływa na usługi ekosystemów;
2. Fizyczny dostęp do terenów zieleni nie zawsze jest tożsamy z dostępem do usług ekosystemów.

Trzecie badanie wiązało się ze stworzeniem zestawu wskaźników i ich obliczeniem (dla parków w Łodzi) w oparciu o trzy poziomy podaży terenów zieleni i bariery wpływające na podaż tychże terenów, które zostały opisane w pierwszym artykule. Na tym etapie uwzględniłam również wnioski z artykułu drugiego dotyczącego usług ekosystemów. W tym artykule

weryfikowałam hipotezę, że każdy park w mieście jest narażony na występowanie barier, choć obciążają one podaż tych terenów zieleni w różnym stopniu.

Ostatni artykuł z cyklu ponownie opierał się na wprowadzonych w pierwszym artykule ramach analitycznych i pokazywał, wokół jakich parków (ocenionych pod kątem występowania barier) mieszkają najbardziej i najmniej wrażliwe grupy mieszkańców (ocenionych pod względem statusu społeczno-ekonomicznego). W ostatnim artykule bezpośrednio odniosłam się do klasyfikacji parków opartej na obliczonym wcześniej zestawie wskaźników. W tym artykule weryfikowałam hipotezę, jakoby najbardziej wrażliwe grupy mieszkańców skupiały się wokół parków ocenionych najgorzej pod względem występowania barier, z kolei grupy najmniej wrażliwe miałyby czerpać korzyści z parków, które w najmniejszym stopniu są obciążone różnorodnymi barierami.

Moje badania wykazały, że aspekty instytucjonalne mają bardzo duży wpływ na podaż terenów zieleni w mieście, a także na dostarczanie usług ekosystemów, co również przekłada się na ograniczenia w dostępie do terenów zieleni i związanych z nimi korzyści dla najbardziej wrażliwych grup mieszkańców. Identyfikacja barier, analiza wskaźników i osadzenie tych aspektów w kontekście sprawiedliwości środowiskowej może pomóc decydentom i planistom w podejmowaniu najlepszych możliwych decyzji dotyczących tworzenia nowych terenów zieleni oraz właściwego zarządzania tymi, które już istnieją. Warto podkreślić, że ramy analityczne, które opracowałam i wykorzystałam w moich artykułach były wykorzystywane przez innych badaczy.

Summary in English

Title: The impact of institutional aspects on the availability, accessibility, and attractiveness of green spaces in Lodz

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Urban green spaces (UGS) influence the quality of life and health of city residents by providing them with a number of ecosystem services. Limiting UGS provision (and thus – ecosystem services) has a negative impact on the psychophysical condition of people. However, the mere existence of UGS (both formal, such as parks and forests, and informal, such as brownfields) is not enough. From the point of view of many potential benefits, and, consequently, spatial planning adapted to social needs, physical access to UGS and their attractiveness are also important. In turn, these benefits can significantly reduce a variety of barriers. Meanwhile, the scientific literature lacks unanimity in defining various concepts related to UGS provision. Some scientists use the different terms interchangeably, e.g., 'availability' and 'accessibility', are often used in the broad sense of 'proximity'. In turn, the attractiveness of UGS is often equated with their availability and collectively referred to as quality. This is the research problem that I address in my dissertation.

In response to the above challenges and uncertainties, the main goal of my dissertation was to classify institutional barriers affecting UGS provision, and to differentiate the levels of this provision. At the same time, I intended to operationalize the proposed classification of barriers by creating a set of indicators that could be used in other research related to the creation and management of UGS, as well as in planning practice. The main goal of my doctoral dissertation arose from the need to better organize the issues related to the availability, accessibility, and attractiveness of UGS, which are described in the literature in an incongruent way.

This thesis consists of an introduction, four interconnected scientific articles published in international journals, and discussion and conclusions wrapping up the whole series of articles. Everything has been prepared in English. The case study that I use in all articles is Lodz. I chose this city because of the numerous studies related to UGS (mainly parks) that have been carried out so far. They concerned, inter alia, valuation of UGS, attachment to the place, social functions of parks and the perception of informal green spaces. The issues related

to the systematization of aspects related to UGS provision in the city remained a significant gap in these studies, which I dealt with in my dissertation.

The first article constitutes the basis for further analysis. In it, I formulated the analytical framework related to UGS provision, described the institutional barriers that affect this provision, classified UGS, and distinguished key actors who have an impact on the creation and management of UGS. This article addresses the following hypotheses:

1. UGS availability, accessibility, and attractiveness are affected by respective, clearly identifiable institutional barriers;
2. Formal institutions have a greater influence on the existence of barriers than informal institutions.

The second article analyzes how various institutional barriers that limit UGS provision affect the delivery of ecosystem services. The study looked at three different case studies. The first study, related to the liberalization of the Environmental Protection Law, covered the entire territory of Poland, while the other two examples were located in Lodz. In this article, I addressed the following hypotheses:

1. UGS provision at each of the three levels (availability, accessibility, and attractiveness) affects ecosystem services differently;
2. Physical access to UGS is not always the same as access to ecosystem services.

The third article involved the creation of a set of indicators and their calculation (for parks in Lodz) based on the three levels of UGS provision and barriers affecting the provision of these spaces, which were described in the first article. At this stage, I also took into account the conclusions of the second article on ecosystem services. In this third article, I addressed the hypothesis that each park in the city is exposed to barriers, although these barriers affect UGS provision to different extents.

The last article in the series was again based on the analytical framework introduced in the first article and investigated socio-economic composition of people living around parks assessed in terms of the presence of barriers. In the last article, I directly referred to the classification of parks based on the previously calculated set of indicators. In this article, I tested the hypothesis that the most vulnerable groups of inhabitants concentrate around parks whose provision is affected by the largest number of barriers at each of the three levels of UGS provision, while the least vulnerable benefit from the proximity of parks that are the least affected.

My research has shown that institutional aspects have a very large impact on UGS provision in the city, as well as on the provision of ecosystem services, which also translates into limitations in access to UGS and the related benefits for the most vulnerable groups of residents. Identifying barriers, analysing indicators, and embedding these aspects in the context of environmental justice can help policymakers and planners to make the best possible decisions about creating new UGS and managing those that already exist. It is worth emphasizing that the analytical framework that I developed and used in my articles was also successfully used by other researchers.

Introduction

Quality of life and urban green space provision targets

Urban green spaces (UGS) are extremely important for modern cities and their inhabitants. UGS provide a number of ecosystem services (ES) that affect the quality of human life by regulating the microclimate, reducing the urban heat island effect, oxygen production, noise reduction, as well as offering place for building social bonds, relaxation and recreation (Andersson et al., 2015; Camps-Calvet et al., 2016; Haines-Young and Potschin, 2018). Importantly, UGS influence the resilience of cities to climate change (Bäckstrand and Lövbrand, 2006; Kabisch, Frantzeskaki, et al., 2016) and other disturbances (Tidball and Krasny, 2014). Moreover, UGS have a positive effect on the psychophysical condition of people, improve their overall well-being and help reduce stress (Andersson et al., 2019; Enssle and Kabisch, 2020). In turn, limited UGS provision has a negative impact on the psycho-physical condition of the inhabitants (Coutts and Hahn, 2015; Enssle and Kabisch, 2020; Finlay et al., 2015) and that leads to an increase in health care spending (Wolf and Robbins, 2015), as well as problems with continuity of employment and payment of welfare benefits (Rolls and Sunderland, 2014; Werna, 2013). In turn, this may leads to a decrease in city revenues and investment opportunities in the long term, hence all of these issues have important economic consequences.

One of the specific targets to be attained within the Sustainable Development Goals promoted by the United Nations is to "provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities" (UN General Assembly, 2015, target 11.7). This is part of the broader goal of making cities inclusive, safe, resilient and sustainable. Indeed, cities are of specific focus here because of very high population density, high levels of air pollution and limited provision of the natural environment. According to the World Health Organization (WHO, 2010), a city should ensure at least 9 m^2 of UGS per capita. Different researchers showed that this amount may have a meaningful impact only when a given UGS is accessible (residents can freely enter it), safe (residents are not afraid to use it), and also useful (this space meets residents' expectations, they want to be there due to its recreational amenities and facilities) (Corley et al., 2018; Kaczynski et al., 2016). However, the most important aspect is the distance from home to UGS, which links to whether UGS are evenly distributed in a city (Kabisch, Strohbach,

et al., 2016; Wüstemann et al., 2017). According to the European Environment Agency (which provides information and guidance on the environment), every urban resident should have access to UGS at a distance from the place of residence of no more than 900–1000 m, which is covered on average (on foot) in about 15 minutes (Schipperijn et al., 2010; Stanners and Bourdeau, 1995).

In addition to international documents related to the provision of UGS (which are developed and used all over the world), numerous local programs and strategies feature UGS provision standards and targets. For example, according to the Environmental Protection Program for the City of Lodz for 2018–2021 (City of Lodz Office, 2018): "actions in the field of improving the quality of UGS and their provision are primarily related to the process of revitalizing the downtown space and involve the creation of new UGS, planting individual trees and shrubs along streets and enriching the revitalized squares." In turn, the Integrated Development Strategy for Lodz 2030+ (City Office of Lodz, 2020) underlines the need for the "introduction of standards regarding the protection and shaping of UGS, that would shape the environment from the perspective of adaptation to climate change, and planning UGS and recreational areas as valuable places for rest with park infrastructure encouraging to spend time actively." Finally, the Study of Conditions of Spatial Development of the City of Lodz (the Masterplan for Lodz) (Municipal Planning Office, 2018) put forward specific UGS provision standards for different types of residential areas – the maximum Euclidean distance to green spaces of certain size (Table 1). Besides, for new investments, it also specified the minimum share of biologically active area in the total area at the level of 25%.

Table 1. UGS provision standards set by the Masterplan for Lodz

Functional units in the city	**Green space in ha**	**Euclidean distance to a green space in meters**
Core urban area, city centre	≥3	800
	[1;3)	400
	[0,2;1)	200
Large housing estates (blocks of flats), outside of the core urban area, high population density	≥3	500
	[1;3)	400
	[0,2;1)	200
Outskirts of the city, low density of population	≥3	1000

Research problem: availability, accessibility, and attractiveness – different understanding of UGS provision

Researchers measure the provision of UGS with the use of a variety of approaches and indicators (e.g., Euclidean distance, buffer, service area, walking distance, two-step floating catchment area or variable-width floating catchment area) (Biernacka, 2020; Wolff, 2021). Moreover, the different concepts of UGS provision are used interchangeably and tend to be ambiguous. For example, both availability and accessibility typically refer to proximity, while attractiveness tends to be confounded with accessibility (Table 2). In response to these ambiguities, I proposed a clear distinction of three levels of UGS provision, each of which refers to different aspects of UGS provision. I associate availability with the existence of UGS, and as a foundation for the two other aspects. Only once UGS are available can we consider higher accessibility and attractiveness needs (Figure 1). In short, the proposed three levels of UGS provision can be defined as follows:

1. **Availability** – a UGS is available, when it exists (especially when considered within a suitable distance from where one lives).
2. **Accessibility** – a UGS is accessible, when one feels that he or she is welcome there, and can freely reach and enter this UGS and safely use it for recreational purposes at any time, without any restrictions.
3. **Attractiveness** – a UGS is attractive, when one willingly wants to use it and spend his or her time there, and when this UGS corresponds with one's individual needs, expectations and preferences.

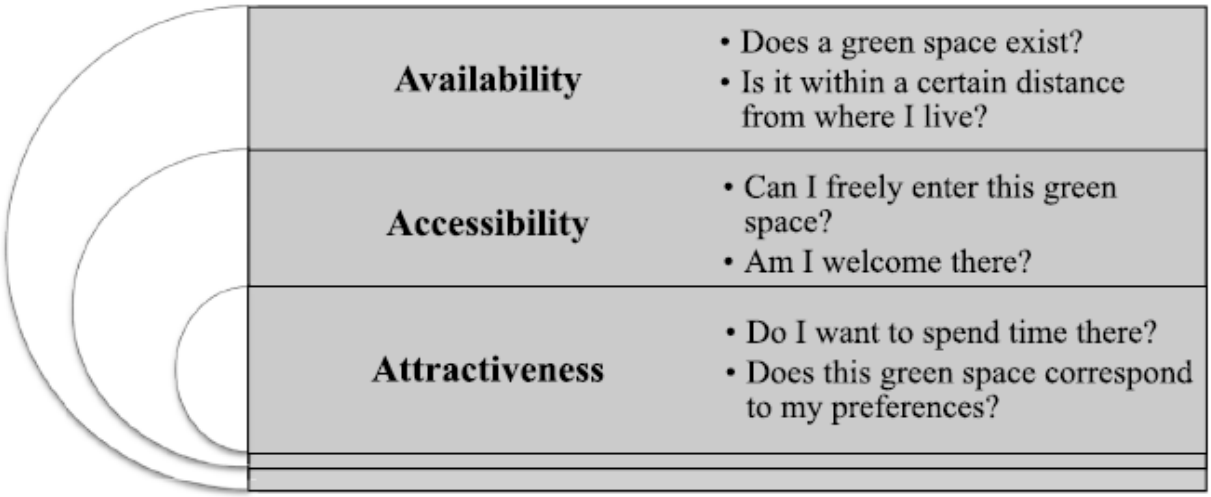

Figure 1. Three levels of UGS provision: availability, accessibility, and attractiveness.

Table 2. Selected definitions of availability, accessibility, and attractiveness measures used in the literature, with sample references – showing the scope of ambiguity and the need for a more clear cut definitions

Name used in the literature	Measures	References
Availability	"One of the best-known measures is 900–1000 m to the nearest UGS, which is meant to represent a 15-minute walking distance".	(Stanners and Bourdeau, 1995)
	"A distance of 300–400 m is often mentioned as threshold after which use starts to decline more rapidly".	(Giles-Corti et al., 2005)
	"The park's service area is most often measured from the park's entrances, following all sidewalks and paths to calculate walking distances that people would have to cover to reach this park (e.g., 500-m service area)".	(Sister et al., 2010)
	"A particularly advanced service area variant is the floating catchment area or two-step floating catchment area (2SFCA). To calculate the serviceability of UGS, the green area should be divided by the total population (supply to demand ratio)".	(Wu et al., 2016)
	"Amount of green area in a certain defined distance to where urban residents live". Measure: share of population living within a 500-m and a 300-m distance to green and forest areas of a minimum size of 2 ha.	(Kabisch, Strohbach, et al., 2016)
Accessibility	Six different scenarios – Euclidean and Network distance: • Euclidean distance to the nearest centroid of any green space; • Euclidean distance to the nearest boundary point of any green space; • Euclidean distance to the nearest access point of any green space; • Network distance to the nearest centroid of any green space ('network path only' and 'full network path'); • Network distance to the nearest boundary point of any green space; • Network distance to the nearest access point of any green space.	(Higgs et al., 2012)
	"The distance to the nearest urban green space measured as the Euclidean distance between the place of residence and the border of the nearest urban green site. The amount of urban green space in hectares/square meters within a walking distance to the place of residence (defined as buffer area of 500 m around centroid of the grid cell/household)".	(Wüstemann et al., 2017)
	"Park proximity is one of the most relevant domains of access".	(Powers et al., 2019)
	"Accessibility can have a broad meaning, but in this paper, reference is made to the physical accessibility determined by walking or by driving distance between the access points in parks and the residential areas".	(Vîlcea and Șoșea, 2020)
	"We defined access as whether or not a postal code is located within 300 m of a public greenspace equal to or greater than one hectare".	(Jarvis et al., 2020)

	Three different methods (distance – 500 meters): • Buffer analysis (Euclidean); • Network analysis (Network); • Distance-decay analysis (Network).	(Wolff, 2021)
Attractiveness	Five groups of indicators: • Space (users can move freely); • Nature (biodiversity); • Culture and history (social and cultural activities); • Quietness (soundscape); • Facilities (e.g., footpaths, playgrounds).	(Van Herzele and Wiedemann, 2003)
	Four main factors: • Location; • Leisure and sports facilities; • Quality of environment; • Diversity of vegetation.	(Colesca and Alpopi, 2011)
	Indicators – six complex variables: • Attributes associated with reaching the park; • Elements constituting the park's equipment; • Three key park facilities; • Attributes related to the appearance of the park; • Factors deteriorating the quality of the park; • Elements contributing to the poor quality of the parks' surroundings.	(Kaczynski et al., 2016)
Attractiveness and accessibility	• Access: congestion; accessibility for people with disabilities, availability of information; • Amenities (e.g., restrooms, benches, lighting, playgrounds); • Safety: high-quality lighting and fencing, less litter, fewer criminal activities (e.g., vandalism and drug dealing); • Social and inclusion: provide a familiar and comfortable social context for social interaction and gathering; • Visual and aesthetic: connected pathways, absence of incivilities, such as graffiti and litter; • Ecological (e.g., number of trees, leaf area index, biodiversity).	(Corley et al., 2018)
	The tool includes 90 items divided into eleven thematic dimensions: surrounding, access, facilities, amenities, aesthetics and attractions, incivilities, safety, potential usage, land covers, animal biodiversity, and bird biodiversity.	(Knobel et al., 2021)

Three levels of UGS provision and environmental justice

In spite of the United Nations' goal to ensure universal access to safe and inclusive UGS, not all urban residents are able to benefit from equal access to such spaces. In particular, various socio-economically disadvantaged groups (because of race, level of income, etc.) are also disadvantaged when it comes to the provision of UGS, which is a manifestation of environmental injustice (Anguelovski and Connolly, 2021). Although this is most often considered in the context of distributive justice, i.e., whether environmental benefits (e.g., access to UGS) and environmental threats are evenly distributed in the society (Low, 2013), it is also important to consider other justice dimensions in this context. For example, when it comes to recognition justice, it is important to account for the different preferences of residents regarding the functions and equipment of UGS. Seniors, children and teenagers, and people with disabilities have different needs and expectations, and it is important that their demand for UGS (i.e., various needs) is satisfied (Corazon et al., 2019; Schipperijn et al., 2010; Shu et al., 2022; Wen et al., 2018). Moreover, taking into account the level of attractiveness, the less affluent ethnic minorities typically use only small UGS, which lack equipment and park infrastructure, and which are quite crowded and often neglected (Kimpton, 2017; Rigolon, 2016).

Research related to the availability of UGS and environmental justice shows that funds for UGS are allocated in wealthier districts (Tan and Samsudin, 2017), and places where minorities live are underfunded (Stodolska et al., 2011). In addition, people with a lower socio-economic status may be forced to move out from a given neighbourhood by wealthier groups following UGS improvements, a phenomenon called eco- or green gentrification (Anguelovski et al., 2018). At the accessibility level, issues related to environmental injustice refer to aspects of insecurity and lack of information, which mainly affect women and ethnic minorities (Byrne, 2012; Maruthaveeran and van den Bosh, 2015; Powers et al., 2019). Moreover, more vulnerable groups – the less wealthy families with children (Łaszkiewicz and Sikorska, 2020) and seniors (Li et al., 2006) – have a significantly limited possibility of reaching UGS due to financial and physical limitations. Such groups may have a problem with reaching remote UGS (e.g., they have to cross the entire city to use the forest) or with entering UGS where a fee is charged (e.g., in the case of the Botanical Garden in Lodz, specially designed gardens).

Case study city – Lodz

The case study city that I analyzed in my thesis is Lodz (Łódź), a city located in central Poland, which has a population of approx. 672 200 and covers an area of 293 km^2 (Główny Urząd Statystyczny, 2021). Lodz is an interesting case study due to historical conditions, and the fact that UGS in this city have already been studied extensively in terms of their functions (Łaszkiewicz et al., 2020), social perception and preferences (Łaszkiewicz et al., 2019; Pietrzyk-Kaszyńska et al., 2017; Włodarczyk-Marciniak et al., 2020), and data availability (Feltynowski et al., 2018). However, to the best of my knowledge, so far no study has systematically addressed UGS provision in Lodz.

Although in my thesis I refer to different types of UGS, I focus most attention on parks, due to the fact that parks are the most frequented and well-managed UGS. Indeed, it is common that authors who study UGS management and importance to society focus on parks (Kaczynski et al., 2016; Kothencz and Blaschke, 2017; Pietrzyk-Kaszyńska et al., 2017; Zwierzchowska and Mizgajski, 2019). The distribution of parks in Lodz is not even, which makes it an interesting case from the point of view of environmental justice. Most parks are located in the inner part of the city (mostly small squares) and in the western part of the city (large parks), and they are missing in the north (with one exception) and east.

The uneven distribution of parks in Lodz results (among others) from chaotic spatial development and the spontaneous growth of the manufacturing industry in the 19th century (Jakóbczyk-Gryszkiewicz, 2011). However, the monoculture textile industry suddenly collapsed in the 1990s, which had an impact on the socio-economic situation of many of the city's inhabitants. Same as other cities in Poland and in other postsocialist cities, Lodz struggles with a spatial crisis (Blinnikov et al., 2006; Kronenberg et al., 2020; Niedziałkowski and Beunen, 2019), which results in a lack of local zoning plans (coverage by plans is 25.5%, as of 2021), many brownfields in the city center, the unknown status of numerous plots, constant development pressure on open spaces, and the primacy of the market forces, such as developers and their interests, which affects the quantity and quality of UGS (in particular, informal UGS), and also their accessibility (e.g., gated communities). Despite that, studies carried out so far in Lodz do not indicate large inequalities among the extreme socio-economic groups of inhabitants (Łaszkiewicz et al., 2021; Marcińczak and Sagan, 2011), in contrast to, for example, American cities (Reichl, 2016; Wen et al., 2013; Wolch et al., 2005; Xiao et al., 2018).

Goals, hypotheses, the institutional context, and an overview of the four articles

My dissertation takes the form of a series of four interconnected articles (Figure 2). The main goal of my dissertation is to classify institutional barriers that affect UGS provision, specifically distinguishing between the three levels of availability, accessibility, and attractiveness. In addition, I intended to operationalize this classification system into a series of indicators that could be used in the practice of UGS management and research. In this way, the dissertation responds to the broader need to better organize the issues related to the provision of UGS, in particular with regard to the interchangeably and often inconsistently used terms of availability, accessibility, and attractiveness. I carried out my analyses in Lodz, but I made sure that similar analyses could be replicated in other contexts, pending adjustments to specific local conditions of other cities. Table 3 briefly describes the goals and hypotheses of the four articles.

UGS provision is affected by various barriers. I define barriers as all factors that affect UGS provision, i.e., their existence and the possibility of entering and using them (for recreational purposes) (Kronenberg, 2015; Schipperijn et al., 2010). I take into account those barriers that can be directly introduced or removed by various actors, in specific institutional contexts. Conversely, I do not refer to issues related, e.g., to topography. When referring to actors, I mean all the stakeholders who have influence on UGS provision. I distinguish between informal actors (e.g., groups of residents) and formal actors (e.g., planners and decision-makers). Based on their competences, actors can create barriers that affect UGS provision. At the same time, institutional conditions and social rules indicate the competences of individual actors, shaping their mandates and influences. By institutional conditions I understand formal and informal rules and principles prevailing that shape human habits, behavior, and interactions (Ostrom, 2009; Vatn, 2005, 2007). Additionally, institutions enable a better understanding of historical and cultural conditions and their influence on economic and political decisions, shaping social relations and preferences (Sokołowicz, 2015). Moreover, institutional aspects translate into the development and use of various types of infrastructure, including green infrastructure, and into the distribution of benefits from these infrastructures (Andersson et al., 2019).

Table 3. Goals and hypotheses of the articles included in this dissertation

Article	Goals	Hypotheses
First article: Classification of institutional barriers affecting the availability, accessibility, and attractiveness of UGS	To identify and classify various institutional barriers preventing UGS provision	UGS availability, accessibility, and attractiveness are affected by respective, clearly identifiable institutional barriers
	To identify the actors responsible for institutional barriers and their mandates	Formal institutions have a greater influence on the existence of barriers than informal institutions
Second article: Urban green space availability, accessibility and attractiveness and the delivery of ecosystem services	To determine how different institutional barriers that limit UGS provision affect the delivery of ES	UGS provision at each of the three levels (availability, accessibility, and attractiveness) affects ecosystem services differently
		Physical access to UGS is not always the same as access to ecosystem services
Third article: An integrated system of monitoring the availability, accessibility, and attractiveness of urban parks and green squares	To propose a set of indicators that represent barriers which prevent park provision	Each park in the city is exposed to barriers, although these barriers affect UGS provision to different extents
Fourth article: Park availability, accessibility, and attractiveness in relation to the least and most vulnerable inhabitants	To identify which groups of inhabitants (the most or the least vulnerable) live around parks depending on how their availability, accessibility, and attractiveness are compromised by the respective barriers	The most vulnerable groups of inhabitants concentrate around parks whose provision is affected by the largest number of barriers at each of the three levels of UGS provision, while the least vulnerable benefit from the proximity of parks that are the least affected

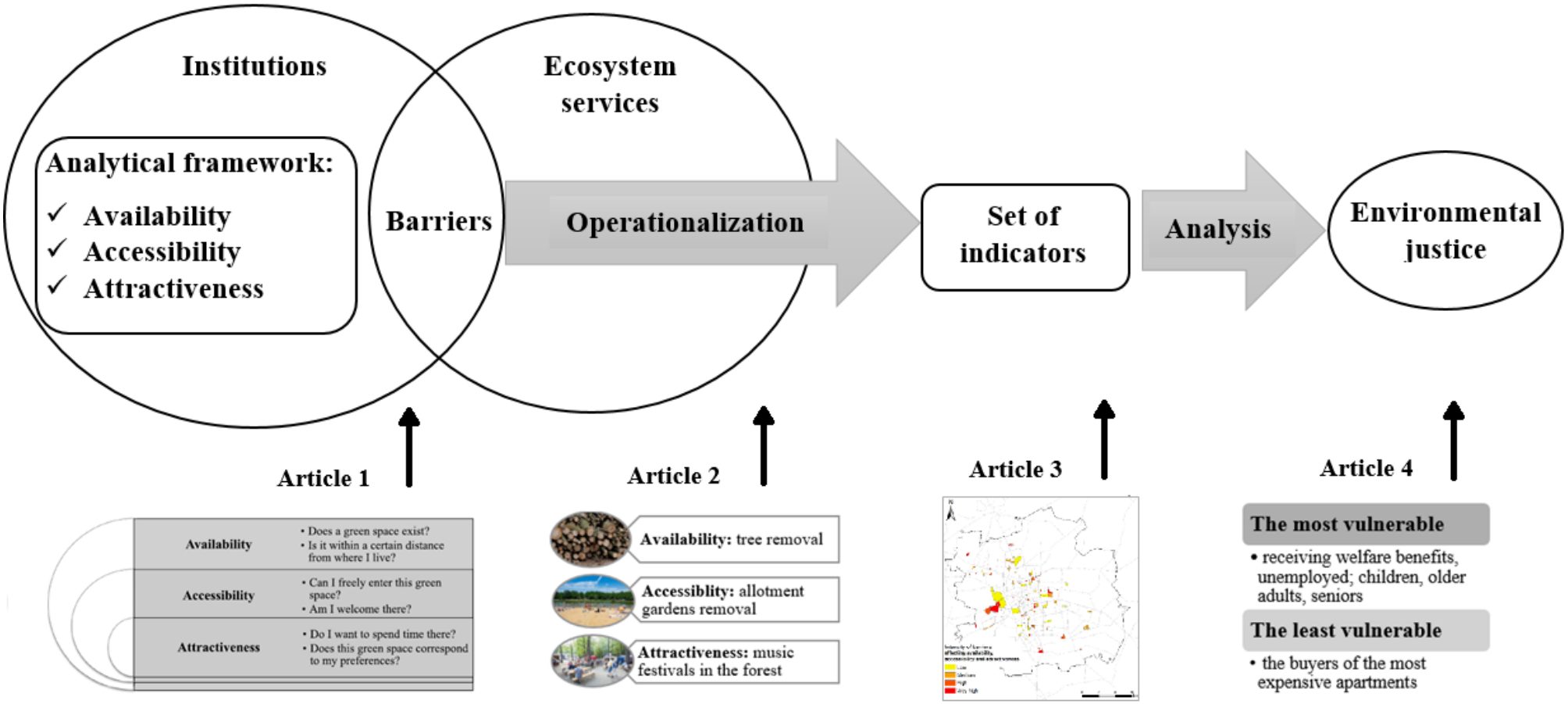

Figure 2. The relationship between the four articles that make up a doctoral dissertation.

The first article set the theoretical foundation and analytical framework regarding the three levels of UGS provision: availability, accessibility, and attractiveness, and the barriers that affect each of these levels, as well as the actors who have an impact on the creation or elimination of these barriers (Biernacka and Kronenberg, 2018). Subsequent articles were based on the classification of institutional barriers presented in the first one. The barriers can be divided into five main groups: economic (e.g., lack of financial resources for the creation of new UGS or their maintenance), related to spatial planning (e.g., new development investments or the lack of local zoning plans), legal (e.g., legal acts affecting the existence of UGS), related to the inhabitants' attitudes and involvement (e.g., lack of social participation and ecological awareness), and connected with UGS management (e.g., lack of safety, lack of park infrastructure or leisure equipment) (Table 4).

The second article aimed at analyzing how different barriers which restrict UGS provision affect the delivery of ES (Biernacka and Kronenberg, 2019). This study shows the broader context of the three levels of UGS provision on the basis of three case studies. It extended the previous analysis to include issues related to ES, different ways of using UGS, and the different underlying conflicts and trade-offs. The first case study focused on the liberalization of the Polish Nature Conservation Act in 2017 that led to massive removal of trees in Poland. The second case concerned replacement of an allotment garden colony with a public beach and park in the center of Lodz. The third case study featured conflict between the different uses of the Lagiewniki Forest connected with loud music and beer festivals during spring and summer. Thanks to three specific case studies that involved different categories of UGS (one related to the whole country, and the two others focused specifically on Lodz), I was able to show how the different barriers affect the provision of ES, and to indicate the actors who play a key role in each case study.

Table 4. Specific examples that represent the five main groups of institutional barriers hindering the availability, accessibility, and attractiveness of UGS

Type of institutional barrier on all three levels	Availability	Accessibility	Attractiveness
Economic	Lack of funds	Entrance fees, opening hours	Lack of funds
Spatial planning	Spatial planning failures	Physical barriers	Congestion – too many users of an UGS
	New investments		
Legal rules	Legal and government failures	Lack of standards in documents related to the UGS provision	-
Inhabitants' attitudes and involvement	Insufficient social support for the existence of certain UGS	Unwritten social norms	Lack of involvement in social initiatives related to the development of UGS, lack of social participation
Management of UGS	-	Dangerous events in UGS – lack of city monitoring	Poorly managed, devastated UGS or an exaggeratedly manicured UGS
			Poor existence of park furniture or leisure equipment
			Loud outdoor events which discourage some users, e.g., festivals

The third article focused on indicators representing barriers that prevent UGS provision on three levels – availability, accessibility, and attractiveness (Biernacka et al., 2020). This analysis followed the classification of barriers from the first article, with additional input from the analysis of how the different aspects of UGS provision are connected with the delivery of ES

from the second article, and operationalized barriers in a set of 20 indicators. I used these indicators to assess 115 parks and green squares located in Lodz. I presented the procedure of data processing and creating indicators by using QGIS 2.18 software. My analysis showed that very small parks in the city center are mostly fenced, lack park infrastructure and leisure facilities, as well as blue infrastructure, and their users are exposed to different nuisances (noise, air pollution). In turn, parks with the least number of barriers are typically large and outside of the city center. Importantly, in each of the parks, the existence of barriers was noted at least on one of the levels. My article features an integrated system for monitoring the three levels of UGS provision, which can also be used in other cities and in planning practice to identify UGS (formal and informal) that are particularly endangered, inaccessible, or where there is a lack of appropriate infrastructure and equipment, and which do not fulfill their basic functions.

The fourth article showed differences in the provision of parks at the three levels from the perspective of environmental justice (Biernacka et al., 2022). This builds on the three previous articles and it is a direct continuation of the third article. I used the classification of parks from the third article and investigated which groups of inhabitants live around parks depending on how their availability, accessibility, and attractiveness are compromised by the respective barriers. The most vulnerable in my study were residents with lower socio-economic status (receiving welfare benefits, unemployed), children and youth, older adults and seniors, and the least vulnerable were buyers of the most expensive apartments in 2011–2018. The results showed that some less privileged groups live around parks rated lower in terms of the presence of barriers, but these inequalities are relatively small. However, these differences may increase due to new development investments which are recently taking place in the vicinity of large parks and UGS in Lodz.

The following four chapters include the original articles published in the relevant journals in 2018, 2019, 2020, and 2022. Each is preceded by brief information on my contribution and on the parameters of the journal. They are summed up in the discussion part at the end of this dissertation. The four articles constitute a coherent series, because each of them is based on the analytical framework proposed in the first one, and they continuously build on each other. The analytical framework is extended with information on ES, then operationalized in a set of indicators, and finally used in an analysis of population distribution from the point of view of park provision (environmental justice).

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Article 1

Article 1: Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces

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Jakub Kronenberg 25%

My contribution:

Conducting a detailed literature review, preparing the concept of the article, developing an analytical framework – three levels of UGS provision with their graphic presentation, conducting all analyses, preparing the manuscript, visualization of results. I estimate my contribution to this article at 75%.

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Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces

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ABSTRACT

The main goal of this article is to identify and classify institutional barriers which prevent the use of urban green spaces (UGS) at three levels: availability (whether a UGS exists), accessibility (whether it is physically and psychologically accessible, e.g., not fenced off), and attractiveness (whether it is attractive enough for potential users to visit). We reviewed the impacts on UGS provision exerted by different actors (individuals, formal and informal groups, community councils, city authorities, national governmental and non-governmental organizations), along with the relevant institutional foundations of those impacts. As a result, we identified and classified the different barriers for which these actors are responsible in the case of fifteen UGS types in our case study city, Lodz (Łódź) in Poland. The main barriers at different levels concern conflicting interests, physical barriers (private green spaces), and the lack of funds, together with legal and governmental failures (public green spaces). These barriers result from the different actors' mandates or lack thereof. Our analysis has implications for the operationalization of UGS availability, accessibility and attractiveness, and, in particular, for mapping UGS and setting the relevant indicators and thresholds for UGS availability, accessibility and attractiveness.

1. Introduction

1.1. Ensuring universal access to green spaces

As stipulated in the UN's Sustainable Development Goals (Goal 11.7, UN General Assembly, 2015), one of the globally important sustainability challenges is to ensure "universal access to safe, inclusive and accessible, green and public spaces." A similar commitment has been reiterated in several other international documents and declarations (WHO, 2012; European Commission, 2013, 2015; United Nations, 2017). This is particularly important in the face of ongoing urbanization (Seto et al., 2016), and considering the multiple health benefits and ecosystem services offered to urban inhabitants by green spaces (Ekkel and de Vries, 2017; Gómez-Baggethun et al., 2013; van den Berg et al., 2015).

Various indicators have been developed to measure access to public spaces, and urban green spaces (UGS) in particular, both for urban planning and research purposes (Kabisch et al., 2016). Although some authors explicitly distinguish between the presence (availability) of UGS and their accessibility (Kabisch et al., 2016), these terms continue to be used ambiguously (Gupta et al., 2016; Morar et al., 2014; Oh and Jeong, 2007; Pafi et al., 2016; Poelman, 2016; Schipperijn et al., 2017; Wüstemann et al., 2017). Researchers have measured what they called UGS availability and accessibility in multiple ways, taking into account such features as size (Gupta et al., 2016), safety, and the presence of park furniture (Niță et al., 2018; Schipperijn et al., 2010) – investigating where such UGS are located compared to where people live. Accessibility is most often calculated with the use of road network distances, but such studies relatively rarely consider additional factors which would make green spaces difficult to access, at least for certain groups of prospective users (Wright Wendel et al., 2012). The newest wave of studies combine many different measures of UGS provision, including issues of physical and psychological access, and the appearance and attractiveness of UGS, such as the size and shape of the UGS, recreational equipment, biodiversity, and the number of users (Kaczynski et al., 2016; Kimpton, 2017; Park, 2017).

In general, although many different indicators of access to UGS have already been proposed and applied, a more systematic approach to the various aspects of UGS provision is necessary. In particular, it is essential to clearly differentiate between the different aspects of UGS provision and to consider factors which prevent UGS provision (along with how to remove these factors). A more complex analysis of barriers would provide support for UGS management and governance which favour inclusive and accessible UGS. The same is true for blue

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infrastructure (e.g., ponds, lakes, rivers), which is inextricably linked with the existence of UGS.

1.2. Availability vs. accessibility vs. attractiveness

In response to the abovementioned challenges, we propose that three aspects of UGS provision be distinguished to make the common claim of "access to UGS" more specific: availability, accessibility and attractiveness (it should be noted that we only focus on those benefits which require physical presence in a UGS, such as recreational use, or enjoying nature and silence, and we do not consider ecosystem services such as microclimate regulation, hydrological cycle regulation, noise mitigation or ventilation):

1 **Availability** – a UGS is available, when it exists (especially when considered within a suitable distance from where one lives).
2 **Accessibility** – a UGS is accessible, when one feels that he or she is welcome there, and can freely reach and enter this UGS and safely use it for recreational purposes at any time, without any restrictions.
3 **Attractiveness** – a UGS is attractive, when one willingly wants to use it and spend his or her time there, and when this UGS corresponds with one's individual needs, expectations and preferences.

We refer to these three aspects as levels to indicate that a UGS first has to be available to then consider its accessibility, and it has to be available and accessible for prospective users to consider its attractiveness. As a result, we present these three aspects in a hierarchical order, as in Fig. 1. One can also connect these three levels with the proximity to where prospective users live. Availability would then refer to the existence of any UGS within a certain distance from where a person lives. It could be narrowed down to the availability of UGS of certain characteristics, such as only the accessible or attractive ones. Hence, again, for a UGS to be attractive, it must first be accessible, and for a UGS to be accessible, it must first be available.

The above issues are relevant to UGS planning and research. It is particularly important to add the second and third level to the more frequently analysed UGS availability. There are multiple factors which affect the availability, accessibility and attractiveness of UGS, which are crucial from the point of view of urban planning and, in particular, in terms of operationalizing the "universal access" commitments mentioned in the opening paragraph of this article. In light of the above, the main goal of this article is to identify and classify barriers to UGS availability, accessibility and attractiveness. Our primary focus is on the institutional context within which these barriers emerge and operate.

1.3. Institutional context associated with barriers preventing UGS provision

In terms of barriers preventing UGS provision, we considered all factors that limit the existence of, as well as the opportunity to enter and use a UGS (Kaczynski et al., 2016; Kronenberg, 2015; Park, 2017; Schipperijn et al., 2017). We specifically focus on those barriers which are mediated by human agency – or which emerge within certain institutional contexts – and leave out those which result from urban morphology. This is because only the former can be relatively easily removed, although they may require legal changes or changing various social norms. Hence, we consider it particularly important to study how these barriers emerge within a given institutional context.

The institutional context refers to the formal and informal rules of a governance system that shapes human choices, behaviours and interactions (Ostrom, 2009; Vatn, 2005). As the determinants of the roles and responsibilities in a system, institutions are also key to understanding the present governance of UGS (Mincey et al., 2013) and they play an important role in the development, use and discourse surrounding all kinds of infrastructures, including green infrastructure. Broadly speaking, institutions define what is and is not allowed in a society, including the opportunities of various actors to introduce barriers preventing UGS provision.

Through actors, we understand all stakeholders that can influence the three levels of UGS provision, both informally (e.g., individual users, a community of residents) and formally (e.g., city authorities or national organizations). On the one hand, actors establish barriers preventing UGS provision based on their mandates (institutional empowerment), and on the other hand, their ability to do this arises from the broader institutional context, indicating what particular actors are allowed to do. These two aspects influence each other, resulting in potential of the different UGS to exist, and to be accessible and attractive to prospective users (Fig. 2). In short, institutions act as filters, mediating the availability, accessibility and attractiveness of UGS (Andersson et al., 2015).

So far, institutional analysis has mostly focused on the first level of UGS provision – looking into which institutions are responsible for UGS availability (Mincey et al., 2013; Young and McPherson, 2013) and investigating institutional failures responsible for inadequate UGS availability (Battaglia et al., 2014; Kronenberg, 2015). Increasing attention has been paid to the involvement of different stakeholders in UGS governance (Ernstson et al., 2008, 2010; Krasny et al., 2015; Colding and Barthel, 2013; Ambrose-Oji et al., 2017), hence also to how they can contribute to UGS availability, accessibility and attractiveness. We complement such analyses with a systematic framework on what prevents UGS availability, accessibility and attractiveness, on the roles

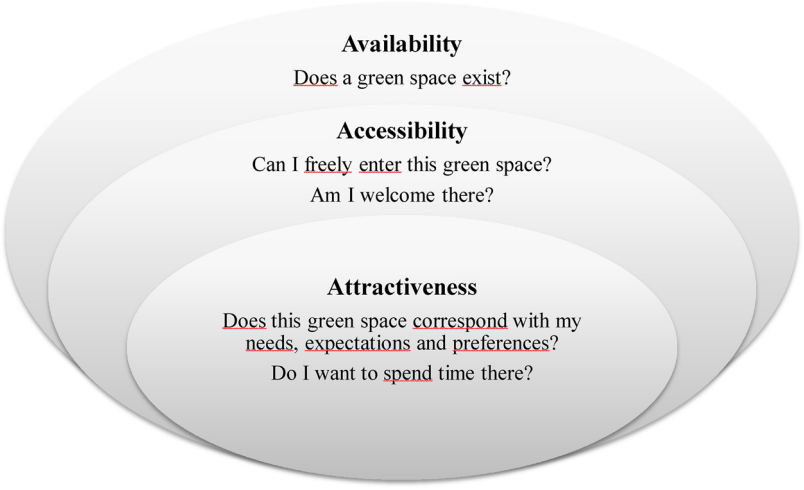

Fig. 1. Three levels of urban green space provision illustrated with personal questions relevant to prospective users.

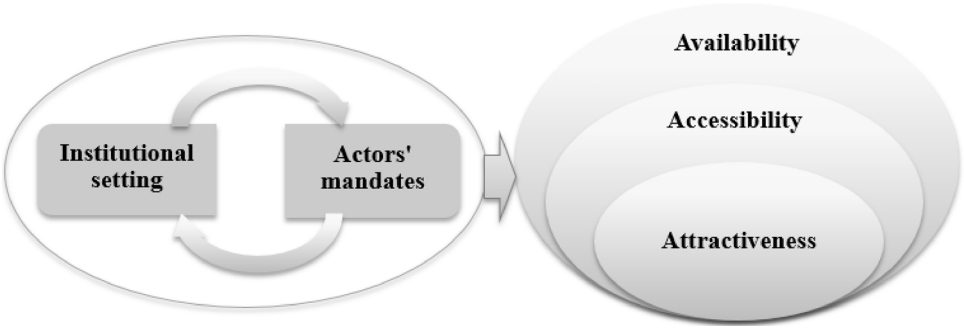

Fig. 2. The feedback loop between the actors' mandates and the more general institutional setting influencing the potential availability, accessibility and attractiveness of urban green spaces.

played in this context by different actors, and on the institutional context within which these actors set the respective barriers.

1.4. Overview of the present article

In the following section, we present our proposed three-step approach to determine UGS types, actors and barriers, and to classify and characterize these barriers. We test this approach in Lodz (Łódź), the third largest city in Poland. As the first step in that direction, we identify UGS types and different actors managing or using different kinds of UGS. As part of the analysis of the actors, we specify whose decisions influence UGS availability/accessibility/attractiveness as well as based on which institutional mandates these decisions are made. Next, we identify barriers preventing UGS provision, separately investigating the three levels. Eventually, this leads us to the classification of the different barriers with regard to who is behind each of them, along with examples of such barriers. Then, we propose specific solutions for Lodz, showing how to partly shift responsibility for UGS provision from formal to informal actors to overcome some of the identified barriers. We next show how to improve UGS provision in general and, finally, we discuss how to further operationalize the understanding of institutional barriers in the context of "universal access" commitments.

2. Methods

We propose three steps to identify the actors and barriers that affect UGS provision which can be followed in any urban context (see Fig. 3 and the three subsections below for more detail). In the case of each step, we suggest what needs to be analysed. We begin by determining the actors responsible for the existence and management of UGS. It is necessary to indicate which actors have an impact on UGS and what these actors' responsibilities are. The second step is to identify barriers. We give examples of documents which should be analysed for this purpose and suggest what to look for in those documents. In the end, the actors and barriers need to be connected at the three levels of availability, accessibility and attractiveness.

We illustrate the above procedure using the example of Lodz, which represents cities in Central and Eastern Europe. Much research on UGS management and governance has already been carried out in this city (Giergiczny and Kronenberg, 2014; Krauze et al., 2010; Kronenberg et al., 2017, 2016; Ratajczyk et al., 2017, 2010), which makes it a good starting point for our extended analysis. Interestingly, the availability of UGS in Lodz is quite high by European standards – according to the Urban Atlas data, 76% of the population lives within 500 m of a UGS of at least 2 ha, and 53% within 300 m (Kabisch et al., 2016), even though UGS have been shrinking since the beginning of the 1990s (Feltynowski et al., 2018; Kabisch and Haase, 2013). Still, there are many barriers to UGS provision.

We used the UGS typology developed within the EU FP7 project GREEN SURGE (Cvejić et al., 2015) and reviewed the websites of the actors responsible for UGS management to identify and describe UGS types located within the administrative borders of Lodz. To find out who uses UGS and what their local characteristics are, we used our expert knowledge, conducted field research and analysed websites, regulations, as well as legal acts. We focused on 15 major UGS types present in Lodz. We describe both formal UGS, which are well developed and maintained (e.g., parks, green squares, allotment gardens, the botanical garden or the zoological garden), as well as informal UGS lying fallow and uncontrolled (e.g., brownfields or grasslands).

2.1. Identification of UGS types and actors

To determine the relevant UGS types in Lodz, we used spatially explicit databases available from the Centre of Geodesy in Lodz and the Municipal Planning Office. The versions we analysed originate from the beginning of 2017. Moreover, based on previous analyses carried out in Lodz (especially Kronenberg et al., 2016), an analysis of the legal documents, statutes and websites of the city office etc., and a literature review (Wycichowska, 2010, 2015), we identified different actors involved in UGS management and governance in Lodz. More specifically, we investigated who influences the UGS' existence, size, type, way of use, equipment and design. Additional pieces of information were obtained during meetings with the different actors, the purpose of which was to determine their competences and responsibilities. A similar analysis could also be narrowed down to selected UGS types only, for example, parks or green squares.

2.2. Identification of barriers preventing the provision of UGS

To identify and classify the specific institutional barriers to UGS availability, accessibility and attractiveness, we studied legal documents (content analysis): statutes, regulations, acts, local zoning plans for Lodz, and the duties and powers of the different stakeholders. We analysed the maps and statutes of formal institutions responsible for the management of certain types of UGS, and the relevant social norms. We also checked the duties and powers of the city authorities and other stakeholders responsible for UGS management and related activities on the websites of pre-identified actors. Finally, we derived additional information on institutional barriers from the existing literature on governmental and social failures in UGS governance (e.g., Kronenberg, 2015) and on what people seek in UGS (e.g., Pietrzyk-Kaszyńska et al., 2017), as well as from websites and observing UGS management and planning in the city (data sources and information extracted are reported in Table 1). We checked the content of the different presented documents for any mention of UGS management/governance and identified the most relevant information, most specifically regarding the actors' competences, management procedures, impacts on UGS, guidelines related to the protection of UGS, inhabitants' attitudes, presence of – recreational and sports facilities, park furniture, entry

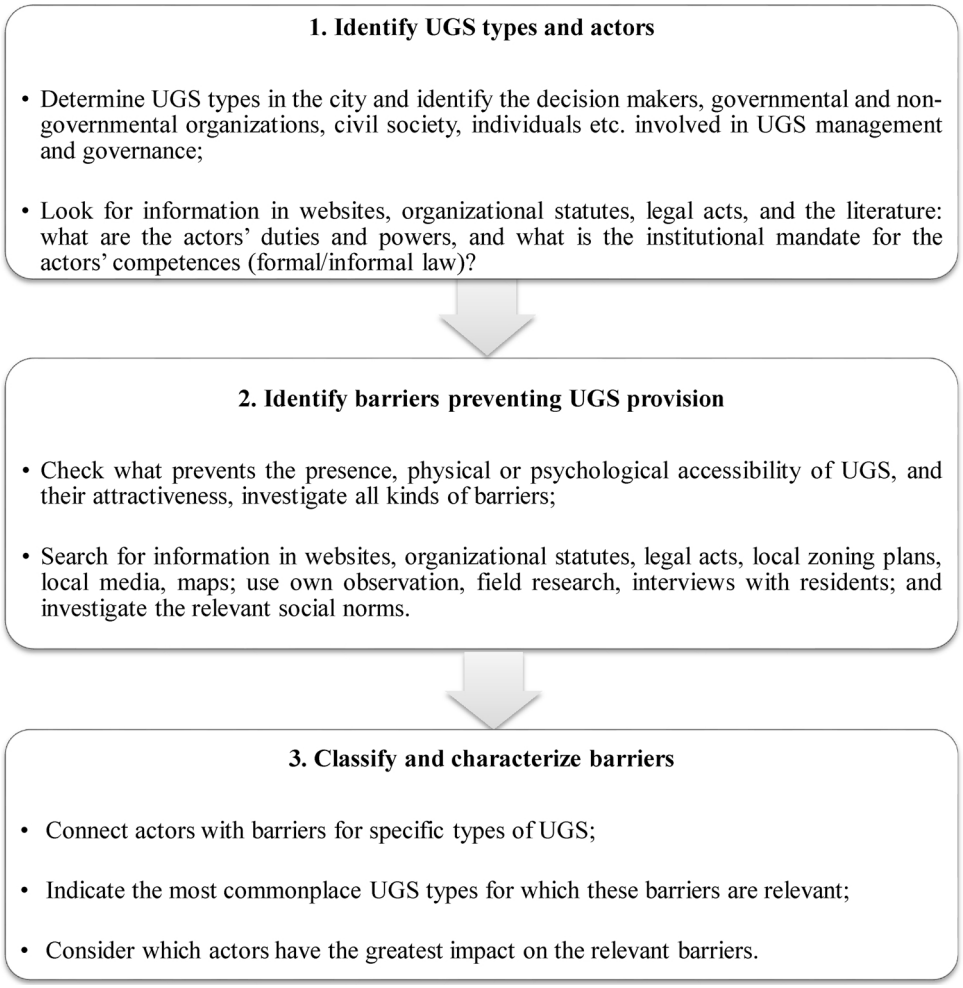

Fig. 3. Procedure for identifying and classifying institutional barriers preventing the provision of UGS.

fees, opening hours and outdoor events.

2.3. Classification and characterization of barriers

Having identified the actors who have or may have an impact on the provision of UGS, as well as the duties and powers of these actors, we investigated specifically which actors influence the three levels of provisioning of the different types of UGS. In the case of our analysis, the three levels of UGS provision correspond with the following questions:

1 **Availability** – does the actor have any impact on the existence of a UGS?
2 **Accessibility** – does the actor have an impact on restricting UGS access, for example by putting up a fence, setting opening hours, collecting entrance fees, and behaving in an inhospitable way?
3 **Attractiveness** – can the actor affect UGS management and maintenance, and decide – for example – on the presence of street (UGS)

Table 1
Obtaining data connected with barriers preventing the provision of UGS.

Data sources	Key examples of documents	Examples of information sought
Legal documents, regulations, acts	The Nature Conservation Act, the Forest Act, the Rail Transport Act, the Family Allotment Gardens Act, Building Law, Water Law	What the specific competencies of given actors are, what actions they can take, what they decide about
Organizational statutes	The Statutes of the Polish Association of Allotment Gardeners, the Statutes of the National Forests Holding	Management procedures, who is responsible, potential impacts on UGS existence, fences, and other opportunities to use UGS
Publicly available maps, local zoning plans	Database of topographic objects (BDOT), local zoning plans – from Municipal Planning Office, nuisance factors and objects	The presence of recreational and sports facilities, park furniture, lighting in UGS; to what extent local zoning plans cover UGS, whether there are guidelines related to the protection of UGS or other specific management regimes, whether noise or air pollution levels are exceeded, or if there are nuisances, such as airports, landfill, or sewage treatment plants near a UGS
Websites	Websites of the Urban Greenery Board, the Municipal Sports and Recreation Centre, the Zoo, the Botanical Garden	Entry fees, opening hours and loud events or festivals organized in a UGS
Observation of UGS management, planning and governance	City initiatives related to UGS, new investments, voting in participatory budget and public consultations	To what extent the preservation of UGS is promoted, what attitudes inhabitants have towards the UGS, are UGS well managed, are there abandoned or ruined spaces

furniture or leisure and recreational equipment?

We assigned barriers to the three levels of UGS provision and matched each of them with the actors who have the most significant impact on a given barrier. Finally, we divided the effects of the different actors into three categories. Their impact may result directly from legal mandates, as stipulated in the relevant legal documents, or other descriptions of the actors' duties and powers (e.g., City Office, Community Council, Municipal Planning Office, Ministry of Environment, Polish Association of Allotment Gardeners). Alternatively, the actors' mandate may be based on common law, unwritten social norms or other secondary endorsements, such as bottom-up social initiatives or the ability to take part in public consultations or other participatory processes, e.g., participatory budgeting (e.g., individual users and owners, a community of residents). We also distinguished situations when a given actor does not have an impact, either because of lack of a relevant mandate or because the connection was judged insignificant or absent.

3. Results

3.1. Identification of UGS types and actors

In Lodz we distinguished 15 main types of UGS: street greenery; private garden; neighbourhood green space; educational garden; Botanical Garden and Zoological Garden; green spaces along railway tracks; green square; allotment garden; cemetery; park; public forest; private forest; arable land, grassland; orchard; brownfield, greenfield. We also distinguished six main groups of actors associated with the provision of UGS:

1 Individuals (e.g., owner, company, individual user, parish);
2 Informal groups of people (e.g., community of residents);
3 Formalized groups of people (e.g., housing association, cooperative, association of allotment gardeners);
4 Community council (the lowest level of public administration in the city; Lodz is divided into 36 communities);
5 City authorities responsible for UGS management and the related administrative activities (e.g., City Office, City Council, Urban Greenery Board, Municipal Planning Office, Department of Municipal Services of the City Office, Department of Architecture and Urbanization of the City Office, Department of Environmental Protection and Agriculture of the City Office, City Forestry Office, Municipal Sports and Recreation Centre);
6 National governmental and non-governmental organizations (e.g., Ministry of the Environment, Ministry of Infrastructure and Construction, Ministry of Development, National Fund for Environmental Protection and Water Management, Regional Fund for Environmental Protection and Water Management, Polish Association of Allotment Gardeners, National Forests Holding, Foundation for Sustainable Development, the Sendzimir Foundation).

Here we present the main actors – managers and users of green spaces – in connection with the different UGS types and their characteristics (Table 2).

In short, formal UGS and street (or UGS) furniture in Lodz are managed by the Urban Greenery Board, while ponds and recreational facilities are managed by the Municipal Sports and Recreation Centre, the Department of Municipal Services and (to a smaller extent) community councils. The Urban Planning Office prepares strategic documents which guide the City Council's decisions on spatial planning. Small, informal and dispersed UGS are managed by private owners and formalized groups of people, e.g., housing associations, although some are not managed at all (Pietrzyk-Kaszyńska et al., 2017). The existence and maintenance of green and blue infrastructure (mainly trees and ponds) are also supported by NGOs (e.g., the Sendzimir Foundation (Giergiczny and Kronenberg, 2014)), academic institutions (e.g., the European Regional Centre for Ecohydrology and the University of Lodz (Ratajczyk et al., 2017)) as well as additional, specific programs financed by the city (e.g., "The Green Backyards" program) and other funding agencies (e.g., educational gardens financed by the Regional Fund for Environmental Protection and Water Management in Lodz).

3.2. Identification of barriers preventing the provision of UGS

We identified barriers which can prevent the provision of UGS (availability, accessibility and attractiveness), and which are related to the activity and mandate of the abovementioned actors. We introduce barriers representing each of the three levels before moving to a detailed classification in the next subsection.

In the case of availability, barriers are most often related to conflicting interests of different stakeholders, which are further reinforced by specific legal, governmental or spatial planning settings within which the existence of UGS cannot be secured. All of the above may be further complicated by insufficient social support for the existence of certain UGS. All of these factors reinforce each other, as exemplified by new investments, especially in informal UGS, which are favoured in light of legal regulations which downplay the importance of UGS, especially when local zoning plans are not created and when there are no actors who would oppose the elimination of UGS.

In the case of accessibility, restrictions may result from both physical and psychological barriers. Physical barriers are most often related to property rights (resulting in fences, entrance fees etc.) and spatial planning failures (as exemplified by busy roads or railroads separating residents from UGS). Psychological barriers are connected with discouraging surroundings or company (e.g., a UGS may be occupied by a specific group of people which other users may prefer to avoid). Alternatively, prospective users may not feel comfortable in a given area due to social norms which "tell them" that they cannot enter somewhere (again this may be related to a sense of not belonging to particular place or to its specific user group).

In the case of attractiveness, barriers may be related to specific equipment or management rules, as well as to noise and other nuisances in the surroundings of a UGS. All of these may result from decisions made by the relevant actors or spatial planning failures. However, these barriers may be differently perceived by different users. For example, some users may prefer more, while others less park furniture and leisure equipment; some may feel better in a UGS with overgrown paths, while others may prefer manicured lawns.

Many aspects connected with barriers preventing the provision of UGS, e.g., scarcity of park furniture and leisure equipment, result from a lack of funds. At the same time, a lack of funds represents other barriers, especially from the first level, such as a lack of funds to purchase new plots of land to create new UGS. This is often connected with insufficient social support for certain UGS, especially given other priorities. In addition, access to UGS and their attractiveness may be limited by barriers only for specific groups of people, for example the disabled – a lack of paths or wheelchair ramps, the homeless – pressure from other user groups or young people – a lack of sports fields or meeting places.

Clearly, some barriers preventing the provision of UGS are only partly related to institutions and partly to some other factors, such as geography and urban morphology. For example, physical barriers may result from urban morphology: rivers and other water bodies cutting through the urban tissue or steep heights making certain UGS difficult to access for certain user groups. Similarly, the attractiveness of a UGS may be affected by atmospheric and soil conditions – air pollution, e.g.: from road, rail, industry, domestic heating stoves, car engines, odours, e.g.: from landfill, sewage treatment plants, car engines, windy places and humid soils. Although these barriers are not directly related to institutions, they are to some extent regulated by them, e.g., allowing some of the abovementioned nuisances to be located close to UGS, and

Table 2
Actors involved in UGS management and governance in Lodz, along with the basic characteristics of the relevant UGS.

UGS type	Managers	Users	Characteristics
Street greenery	Urban Greenery Board	All inhabitants	Trees, shrubs and lawns located along roads
Private garden	Property owners	Owners and tenants	Private property with trees, flowers or shrubs, sometimes also a small pond and garden architecture (swings, gazebos, barbecue, etc.); including gardens around detached or semi-detached houses, terraced houses, tenement buildings, gated communities; most often fenced
Neighbourhood green space	Housing association, housing cooperative and tenants' association	Residents of the settlements, but also – to some extent – other inhabitants of the city	Green spaces in multi-family residential areas (blocks of flats), which often consist of lawns, trees, shrubs, benches, and sometimes playgrounds, sandpits and small gardens; increasingly often fenced (following the gated communities pattern)
Educational garden	School directors and teachers	School children, students	Educational gardens created near schools and kindergartens; most often fenced
Botanical Garden, Zoological Garden	Urban Greenery Board	All inhabitants	Collections of plants and animals of special interest, large UGS with ponds; fenced and subject to entrance fees, highly managed
Green spaces along railway tracks	Polish Railway Lines, the state-owned company which operates the public rail network	Railway maintenance services	Green spaces along railway tracks and close to railway stations; often marked with "no access" signs
Green square	Urban Greenery Board and, in some cases, a community council	All inhabitants	Small but well-kept areas, with trees, shrubs and flowers, sometimes small benches and playgrounds
Allotment garden	Allotment garden council (garden complex); Polish Association of Allotment Gardeners (nationally); city office (often leases land)	Registered allotment garden users and their guests	In fenced allotment garden complexes, gardeners lease small plots with gazebos, flowerbeds, fruit trees, also small ponds, greenhouses and garden swings; access restricted to registered users and their guests
Cemetery	Municipal cemeteries in Lodz managed by the Urban Greenery Board and other cemeteries managed by the relevant religious or business organizations	All inhabitants; cemeteries sometimes serve recreational purposes, provided people comply with specific rules and behave properly	Tombstones, monuments and chapels, but also trees, shrubs and wild animals; fenced and closed at night
Park	Urban Greenery Board, Department of Municipal Services of the City Office	All inhabitants	Well-kept areas with trees, shrubs, flowerbeds, benches, playgrounds, fountains and outdoor gyms (sometimes), ponds (often)
Urban forest (public)	Urban Greenery Board, City Forestry Office, Municipal Sports and Recreation Centre	All inhabitants	Places of leisure and recreation for all residents, and oases for biodiversity, ponds (sometimes) (e.g., in the largest Lagiewniki Forest there are pedestrian paths, educational paths, ponds and bonfire and picnic places)
Urban forest (private)	Private owners	All inhabitants	Much less used, hence also frequented by wildlife; ponds (sometimes); typically not managed for recreation
Arable land, grassland (private)	Private owners	Private owners	Private owners determine whether these areas are fenced and make decisions regarding planting, grazing or leaving them fallow; mostly located on the outskirts of the city
Orchard (private)	Private owners	Private owners	Private owners decide whether they are fenced (most often they are) and make decisions related to their use; mostly located on the outskirts of the city
Brownfield, greenfield (vacant lot)	Highly diverse (from individuals to the state), but often with unresolved legal status	Few users who go their own way	Undeveloped or post-industrial areas, often covered with lush vegetation, but when they are purchased by investors who introduce new functions to these places, most of the existing greenery is lost; poorly managed, often closed and unsafe

thus influencing their accessibility and attractiveness.

3.3. Classification and characterization of barriers

Finally, we move to the detailed classification and characterization of institutional barriers and actors with the greatest impact on them. We indicate which actors create and maintain different barriers to the provision of UGS, based on which mandate, along with examples of UGS affected by these barriers. The institutional barriers presented in Table 3 are interrelated and, at each level, the City Office with its different agencies, notably the Urban Greenery Board, along with individual owners, have the most important influence and the strongest mandate.

The barriers at the first level (availability) are mainly associated with the decisions of the City Office and its agencies regarding new investments, the creation of local zoning plans, and the allocation of financial resources that can support the existence of UGS or lead to their reduction. The barriers at the second level (accessibility) and third level (attractiveness) are mostly related to the decisions made by the relevant managers, i.e., again, mostly the City Office and its agencies, as well as individual owners.

3.4. Synthesis

In Table 4, we synthesize the influence of different actors on the availability, accessibility and attractiveness of different UGS types. The impacts of different actors are distinguished based on formal mandates (legal standards, laws, codes, acts, statutes, regulations, duties and powers of the relevant institutions) and informal mandates (common law, unwritten social norms, through social initiatives, social participation and participatory budgeting). There are also situations when a given actor does not have an impact or it is not relevant to consider this actor's impact.

For example, the availability, accessibility and attractiveness of

Table 3
Institutional barriers hindering the availability, accessibility and attractiveness of urban green spaces.

Three levels of UGS provision	Groups of barriers	Key examples of barriers in each group	Actors with the greatest impact	The actors' mandate	The most typical UGS affected
Availability	New investments – elimination of UGS	New shopping centres, warehouses, office buildings, new housing developments	City Office, individual (investors)	Duties and powers of these governing bodies, Building law, local zoning plans	Allotment garden, brownfield, street greenery
		New roads	City Office	Duties and powers of these governing bodies, local zoning plans	Street greenery, allotment garden, brownfield
	Legal and governmental failures	Unclear legal status of a UGS	City Office	Duties and powers of these governing bodies – management of funds in the city, issuing decisions related to land use	Urban forest, arable land, grassland, brownfield
		Lack of funds to maintain or redeem a UGS			Street greenery, neighbourhood green space, green square
		Regulations which downplay the importance of a UGS or poor enforcement	Ministry of Infrastructure and Construction, Ministry of Development, City Office		Street greenery, allotment garden, green spaces along railway tracks
	Spatial planning failures	Lack of local zoning plans, insufficient inclusion of UGS in plans	City Council, Municipal Planning Office, Department of Architecture and Urbanization, Department of Environmental Protection and Agriculture	Duties and powers of these governing bodies, Building law, local zoning plans	Urban forest (public), arable land, grassland, brownfield
	Insufficient social support for the existence of certain UGS		Individual owners	Informal rules, lack of: public awareness, active civil society and knowledge of the environment and ecosystem services	Private garden, arable land, grassland, urban forest (private)
Accessibility	Physical barriers – there are physical obstacles to reach a UGS	Fences	Individual owners	Building law, national regulations	Private garden, educational garden, allotment garden
		Busy roads, railways	City Office	Duties and powers of these governing bodies, local zoning plans	Allotment garden, cemetery, park, urban forest
		Densely built-up areas, especially with industry or gated communities next to a UGS	City Office, Municipal Planning Office, individual (investors)	Duties and powers of these governing bodies, Building law, local zoning plans	Urban forest, brownfield, park, green square
		Entrance fee (fenced space)	City Office	Duties and powers of Urban Greenery Board, the Nature Conservation Act	Botanical Garden, Zoological Garden, some parks
		Opening hours (fenced space)	City Office, individual owners and managers	Duties and powers of parishes, school administrators	Botanical Garden, Zoological Garden, cemetery
	Psychological barriers – perception of the place is based on unwritten social norms, the prospective users' negative feelings	Inhospitable area (may result from property rights)	City Office, Municipal Planning Office, individual owners, managers of allotment gardens	Duties and powers of these governing bodies, property rights, local zoning plans, unwritten rules concerning allotment gardens or private properties	Green spaces along railway tracks, allotment garden, urban forest (private), arable land
		Discouraging surroundings or company (e.g., a UGS occupied by a specific group of people, e.g., drunk people, cultural inappropriateness)	City Office, Police, Municipal Police, civil society as a mediator	Duties and powers of the City Office, governing bodies, bottom-up social initiatives	Neighbourhood green space, park, urban forest (public)
			Police, Municipal Police	Duties and powers of these governing bodies	Neighbourhood green space, green spaces along railway tracks, park
Attractiveness	Insufficient equipment in a UGS	Scarcity of park furniture (e.g., benches, footpaths, trash cans) and leisure equipment (e.g., playgrounds, outdoor gyms, playing fields)	Urban Greenery Board, Community council, informal groups of people, City Office, Department of Municipal Services, Municipal Sports and Recreation Centre	Duties and powers of these governing bodies, participatory budgeting, social participation	Neighbourhood green space, green square, park
		Lack of lighting	Urban Greenery Board, Community council, Department of Municipal Services	Duties and powers of these governing bodies, the Nature Conservation Act, the Rail Transport Act	Neighbourhood green space, green square, park
	A poorly managed, dilapidated or exaggeratedly well-groomed UGS	A lot of rubbish (including unauthorized landfill sites), people not cleaning up after their dogs	Community council, Department of Municipal Services, individual users	Duties and powers of these governing bodies, lack of public awareness, civil society and knowledge	Neighbourhood green space, green spaces along railway tracks, urban forest (public and private)

(*continued on next page*)

Table 3 (*continued*)

Three levels of UGS provision	Groups of barriers	Key examples of barriers in each group	Actors with the greatest impact	The actors' mandate	The most typical UGS affected
		Overgrown paths	Urban Greenery Board, Community council	Duties and powers of these governing bodies	Neighbourhood green space, urban forest, brownfield
		Excessively manicured UGS			Park, green square, street greenery
	Too many users of a UGS	Congestion	City Office, Urban Greenery Board, Community council	Duties and powers of these governing bodies	Botanical Garden, Zoological Garden, park, urban forest (public)
	Noise and other nuisances	Road, rail, industrial noise	City Office, Municipal Planning Office, Road and Transport Board, individual investor	Duties and powers of these governing bodies	Street greenery, green square, allotment gardens
		Outdoor events which discourage some users (e.g., loud festivals, concerts, picnics connected with loud music and smoke from barbecues)	City Office, Department of Municipal Services, Municipal Sports and Recreation Centre, individual companies which lease recreational facilities from the City Office	Duties and powers of these governing bodies	Botanical Garden, urban forest (public), park, Zoological Garden
		Other nuisances, e.g., odours from a sewage treatment plant, exhaust gases	City Office, Municipal Planning Office, individual investor, individual users	Duties and powers of these governing bodies, lack of public awareness and knowledge of their negative impact on the environment and air quality	Street greenery, urban forest, brownfield

street greenery depends primarily on the administrative bodies, such as the City Office and, in particular, its Urban Greenery Board, which has the largest power in this area. On a local scale, community councils may decide about planting new trees and removing old ones and pruning tree branches, although they have to collaborate in this area with the Urban Greenery Board. Informal and formalized groups of people may oppose the felling of trees while proposing the planting of new trees (e.g., by submitting projects to be considered in participatory budgeting). National governmental and non-governmental organizations can set and lobby for additional standards regarding the availability of street greenery. Conversely, in the case of brownfields, their owners or temporary managers have the most significant impact on all three levels – and brownfields can be owned privately or by the city and the state, and often they have unresolved legal status, which makes their management even more difficult.

Barring the availability (existence) of UGS is relatively easy (e.g., the relevant actors can remove trees or liquidate allotment gardens), especially when compared with the opposite situation, i.e., creating or expanding UGS is difficult. Furthermore, only a few actors have an impact on the existence of UGS, and those with direct influence must respect the principles imposed by the law. Regarding the second level of accessibility, more actors have relevant rights and opportunities, and can propose better UGS accessibility or restrict access. The second level is dominated by legal standards and regulations, but it also involves unwritten social norms and contracts. Changing accessibility is easier to enforce than changing availability, but it is less frequently considered in practice. The third level also involves many actors, and their duties and powers result both from formal and informal rules.

Among all the groups of actors, individual owners and bodies appointed by the City Office have the greatest impact on the provision of UGS at all three levels, which confirms the centralized character of UGS management in Lodz. The rights, duties and powers of these actors arise from statutory laws, a variety of regulations and legal acts that apply to property rights, as well as spatial planning regulations. Informal groups of people, community councils and national governmental and non-governmental organizations have the smallest possibility to influence UGS accessibility. Community councils have certain duties and powers delegated by the city, but their activities are limited to managing neighbourhood open green spaces. Informal groups of people and NGOs do not have any formal mandate to change the provision of UGS at any level, except through bottom-up activities to open some UGS to the public or to improve their attractiveness. However, they may oppose the felling of trees, propose planting new trees and contribute to changes in the provision of UGS through participation in participatory budgeting and public consultations organized by the City Office.

4. Discussion

Our analysis highlights institutional shortcomings related to the provision of UGS, i.e., why certain UGS are not created, are not publicly accessible or are not attractive enough, even if they could be so, at least in theory. In the following paragraphs, we propose specific solutions for Lodz to eliminate (or at least reduce) barriers preventing the provision of UGS (Subsection 4.1). Then we show more generally how to improve the provision of UGS in line with the notion of ensuring "universal access" (Subsection 4.2). Finally, we discuss how to further operationalize the understanding of institutional barriers and the actors behind them, indicating the importance of our classification of barriers (Subsection 4.3).

4.1. Specific recommendations regarding the provision of UGS in Lodz

In Lodz, as well as in other post-socialist cities, decision-making and policies (including those related to environmental protection and green infrastructure management) are often imposed in a top-down manner (Krajter Ostoić et al., 2017; Niță et al., 2018; Scrieciu and Stringer,

Table 4
The impact of different actors on the three levels of UGS provision. The three symbols in each cell represent, respectively, whether a given actor influences the availability, accessibility or attractiveness of a given UGS type. A formal mandate based on legal regulations, and the actors' duties and powers is marked with "+", an informal mandate based on common law or unwritten social norms is marked with "~", and a situation when an actor does not have an impact is marked with ".".

UGS type	Individual	Informal group of people	Formalized group of people	Community council	City office	National governmental and non-governmental organizations
Street greenery	...	~..	~..	+..	+++	~..
Private garden	+++	...	~++	...	+..	...
Neighbourhood green space	..~	..~	+++	..+	+++	...
Educational garden	~++	~.~	~~~	...	+.+	...
Botanical Garden, Zoological Garden	...	...	...	...	+++	...
Green spaces along railway tracks	+++	...	...	...	...	...
Green square	...	..~	...	..+	+++	...
Allotment garden	.~~	.~.	+++	...	+++	.++
Cemetery	.++	...	..~	...	+++	..~
Park	...	..~	..~	...	+++	..~
Urban forest (public)	...	...	...	...	+++	...
Urban forest (private)	+++	...	.++	...	+~~	.~~
Arable land, grassland (private)	+++	...	...	...	+..	...
Orchard	+++	...	...	...	+..	...
Brownfield, greenfield	+++	.~~	...	...	+++	...

2008). Moreover, decision-makers in Polish cities often do not co-operate with each other and they know very little about projects or the main issues dealt with by other officials (Kronenberg et al., 2016; Ratajczyk et al., 2017). This is combined with the low participation of inhabitants and potentially interested other actors (NGOs, researchers) and quite often insufficient funding for UGS (Kronenberg, 2015). Still, both NGOs and researchers have successfully lobbied that more attention should be paid to the provision of UGS in various strategic and planning documents of the city (Giergiczny and Kronenberg, 2014; Ratajczyk et al., 2017).

A legitimate solution might be to delegate the wide power, currently belonging to the City Office, to other actors (formal and informal groups of people, NGOs) which are directly interested in shaping green and recreational spaces, their attractiveness and their greater accessibility, at least on a temporary basis (Colding and Barthel, 2013). Had the former imposed specific guidelines and standards on UGS management, the role of informal actors would have become more important, which would likely have resulted in improved UGS availability, accessibility and attractiveness in the city. Such standards could refer in particular to public participation or consultation procedures or to other rules for including different actors in creating or designing UGS. The broader involvement of informal groups would reflect social mobilization for urban green space governance, which is currently largely lacking. The inclusion of other actors (not only the authorities and owners) in decisions regarding the provision of UGS (through public consultation or participatory budgeting) would be an expression of procedural justice (Low, 2013) and would give them a greater sense of agency and the impact they have on what happens in the city.

Besides, the City Office has the opportunity to enable people to cooperate and manage a given UGS together (e.g., brownfields may be converted into community gardens). The common goal (community gardening, planting trees) and cooperation are very important for the integration of different social groups in the city (Krasny et al., 2014). This is of key importance from the point of view of creating so-called urban commons which may be owned by many owners, such as the state, local government, private actors or collectively, but in which case, the user groups may be endowed with a set of rights, including the right to create their own governance rules, including the right of others to use a given area (Bendt et al., 2013; Colding and Barthel, 2013).

Finally, non-governmental organizations may better educate officials, decision makers, planners and inhabitants about the importance of UGS. Indeed, even enhanced cooperation between city authorities, NGOs and scientific institutions can provide a lot of useful information and valuable solutions related to the protection of UGS and influence the relevant policies and documents (Kronenberg et al., 2016; Mincey et al., 2013; Ratajczyk et al., 2017).

4.2. How can the provision of UGS be improved more generally?

To ensure "universal access to safe, inclusive and accessible, green and public spaces," the city authorities should carefully control new investments and prevent the ongoing degradation and enclosure of UGS. It is necessary to determine which UGS are private, which belong to the city and which have unresolved legal status, because this also influences the degree of difficulty related to keeping or making them available, accessible and attractive. Indeed, limited access is often related to informal UGS, such as a brownfield, grassland and green spaces along railway tracks (Rupprecht and Byrne, 2014). The city authorities should focus much more attention on these spaces, and strive to safeguard their existence and to make them accessible and more attractive, especially in areas with the largest discrepancy between supply and demand for UGS.

UGS accessibility can also be enhanced with the proper incentives, such as subsidies and other support programs for allotment gardeners and owners of private gardens who grant other users access to their gardens (Colding and Barthel, 2013). It is worth noting that, in our case study city, residents do not have access to allotment gardens (apart from allotment owners and their guests). Similarly, to improve access to UGS, the City Office may grant free entrance to the Zoological and Botanical Gardens to the less affluent or the unemployed and other inhabitants excluded because of their socio-economic status (a similar program already exists in Lodz, with discounts for large families and the elderly).

At the level of attractiveness, the proper management of UGS, making them clean, safe (well lit) and adapted to the needs and preferences of the inhabitants, involves trade-offs between the needs of different groups of prospective users. The level of attractiveness is the easiest to change, although it still requires additional funds, which are often difficult to raise due to the low priority of UGS maintenance and management in the case of public actors (the local authorities). Of course, meeting the expectations of all social groups in the city is hardly possible; while well-kept, monitored and well-equipped spaces are preferred by many social groups, others will prefer "wilder" and overgrown UGS. When the zoning of areas for different uses (to account for the needs of different user groups) is not possible, the main priority should be given to satisfying the needs of the most vulnerable

inhabitants (children and elderly) (Poklembová et al., 2012; Raymond et al., 2016).

4.3. Operationalization of the concept of institutional barriers preventing the provision of UGS

At the local level, performing an analysis of institutional barriers preventing UGS availability, accessibility and attractiveness should be part of any urban planning initiative (such as the creation of local zoning plans or decisions regarding new investments). However, it should be noted that in different situations, different specific aspects need to be considered. It is not always possible to analyse all three levels of UGS provision; and, especially in the case of general plans and strategies, the first level (availability) is most crucial. Our list of barriers may need to be extended to reflect local circumstances in other cities, but it provides guidance on which issues, actors and mandates require attention. Finally, we need analytical approaches more than ready-made answers if we are to handle different local contexts.

Availability is typically represented in most maps presenting UGS, although attention needs to be paid to different UGS types, some of which are only rarely considered as green spaces (Feltynowski et al., 2018). However, as argued in this article, such information is not complete in terms of representing UGS provision. To verify whether specific UGS are accessible, one needs to investigate local zoning plans and collate detailed maps of UGS (e.g., using orthophotomaps or local land surveying resources) with data and maps related to property rights, new investments (a UGS may be closed, at least temporarily, due to construction), schools and kindergartens (educational garden), tree felling and road traffic, etc. UGS attractiveness can be investigated with the use of participatory GIS or questionnaires to reflect the perceptions of urban inhabitants (Kothencz and Blaschke, 2017; Krajter Ostoić et al., 2017; Pietrzyk-Kaszyńska et al., 2017). Additionally, the second and third level can best be investigated through field research to check which UGS are fenced, abandoned or in poor condition, who uses which UGS (e.g., using participant observations, time-use surveys), or where there is not enough park furniture and leisure equipment. Having identified the key barriers in a given city, policy makers or other interested stakeholders can create a comprehensive inventory of UGS and visualize UGS availability, accessibility and attractiveness on a map. Eventually, they can use this information to improve the current situation.

As indicated in the introduction, several attempts have already been made to depict various aspects improving and barriers preventing the provision of UGS for research or planning purposes (however, often they were not explicitly called barriers) (Annerstedt van den Bosch et al., 2016; Ekkel and de Vries, 2017; Kronenberg, 2015). Our approach adds to these in terms of a broader look at all groups of barriers, including particular barriers which affect the availability, accessibility and attractiveness of different types of UGS. At the availability level, we analysed, in particular, legal and spatial issues related to urban planning and decisions taken by municipal officials. At the level of accessibility, we focused not only on physical barriers, such as main roads, railways and navigable waterways (Van Herzele and Wiedemann, 2003), but also on the psychological aspect, which results from the inhabitants' perception of UGS (Krajter Ostoić et al., 2017; Park, 2017; Wright Wendel et al., 2012). The aspect of UGS attractiveness has been analysed in the literature, often referred to as UGS quality (Dillen et al., 2012; Giles-Corti et al., 2005; Stigsdotter, 2012; Zhou and Rana, 2012), but in our classification we included these issues in the broader overview of what affects the use of UGS. The relevant UGS characteristics include equipment, appearance and the number of users, but also less obvious and common aspects, such as outdoor events, noise and other nuisances. A more comprehensive analysis will translate into better planning and implementation of activities related to the elimination of the main barriers and the more equal provision of UGS in the city.

Such activities are beginning to be implemented in the practice of setting the relevant UGS availability standards which take into account certain aspects of accessibility or attractiveness. For example, in a document related to the development and management of UGS in Krakow (Kowalewska, 2017), UGS availability has been connected with ownership status, existing facilities and recreation equipment, while a separate analysis focused on the identification of UGS threatened by investment pressure.

Even though some aspects can be generalized, institutional barriers are specific to local contexts. Different cities (especially in different countries) have their own land-use planning standards (e.g., type of residential development or building density), environmental and social problems, and a variety of institutions responsible for managing UGS, their duties and powers (including whether they result from formal regulations or unwritten social norms). All of these aspects must be taken into account when performing a similar analysis in a different local context. It should be noted that for planning purposes, barriers need to be studied separately for different groups of prospective users, including marginalized groups, such as the disabled and the homeless. Here we present only some general sources of data, possibilities and indications for analysing different types of barriers. However, our research can still be deepened by investigating physical access to UGS with the use of public transport.

5. Conclusions

In this article, we identified and systematized various institutional barriers preventing the three levels of UGS provision: availability (existence), accessibility (physical and psychological access), and attractiveness (design and management), as well as the actors responsible for these barriers and those actors' mandates. These barriers are related to legal rules, spatial planning, economic issues, the management of UGS, and inhabitants' attitudes and involvement. Our study shows the diversity of barriers, many of which were previously identified by other researchers and city authorities, but which have not been properly classified or related to specific UGS or actors' mandates. Thanks to the extensive and more detailed analysis of these barriers, decision makers, planners and researchers can find key barriers in their city, introduce appropriate solutions and thus provide "universal" UGS provision, as required by international commitments. Finally, it is advisable to visualize individual barriers on maps, which would improve the understanding of the current situation in different cities and provide grounds for making better decisions regarding UGS availability, accessibility and attractiveness.

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Appendix A

Translations of Polish names of departments, offices and funds used in the article:

- Centre of Geodesy in Lodz – Łódzki Ośrodek Geodezji
- City Council – Rada Miasta
- City Forestry Office – Leśnictwo Miejskie
- City Office – Urząd Miasta
- Community Council – Rada Osiedla
- Department of Architecture and Urbanization of the City Office – Wydział Architektury i Rozwoju Urzędu Miasta
- Department of Environmental Protection and Agriculture of the City

Office – Wydział Ochrony Środowiska i Rolnictwa Urzędu Miasta
- Department of Municipal Services of the City Office – Wydział Gospodarki Komunalnej Urzędu Miasta
- Housing association – Spółdzielnia mieszkaniowa
- Municipal Sports and Recreation Centre – Miejski Ośrodek Sportu i Rekreacji
- National Forests Holding – Lasy Państwowe
- National Fund for Environmental Protection and Water Management – Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej
- Polish Association of Allotment Gardeners – Polski Związek Działkowców
- Regional Fund for Environmental Protection and Water Management in Lodz – Wojewódzki Fundusz Ochrony Środowiska i Gospodarki Wodnej w Łodzi
- Urban Greenery Board – Zarząd Zieleni Miejskiej
- Municipal Planning Office – Miejska Pracownia Urbanistyczna

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Article 2

Article 2: Urban green space availability, accessibility and attractiveness, and the delivery of ecosystem services

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Urban Green Space Availability, Accessibility and Attractiveness, and the Delivery of Ecosystem Services

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Urban Green Space Availability, Accessibility and Attractiveness, and the Delivery of Ecosystem Services

The main goal of this article is to analyze how different barriers which restrict urban green space (UGS) provision – notably their availability, accessibility and attractiveness – affect the delivery of ecosystem services (ESs). Our analysis involves three case studies in Lodz, Poland: the removal of trees in private properties following the liberalization of the Nature Conservation Act (availability); the replacement of allotment gardens with a city beach (accessibility); and the organization of entertainment events in the forest (attractiveness). The analyzed barriers include governmental failures, insufficient social support for the existence of certain UGSs, changes in spatial planning and activities discouraging other users. Our analysis shows that physical access to UGSs is not always equal to access to ESs, and that different ESs are affected differently at the three levels of UGS provision. Also, those who suffer from the loss of access to ESs are often not involved in making the relevant UGS provision decisions. All of these issues add new aspects to the current debates related to political ecology, environmental justice and ES trade-offs.

Keywords

Barriers; urban ecosystem services; institutions; residents' preferences; urban green space provision

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INTRODUCTION

Recent political, practical and academic discussions on urban green space (UGS) availability, accessibility and attractiveness (Comber et al. 2008; Kabisch et al. 2016; La Rosa 2014), need to be further extended to cover the context of ecosystem services (ES). This is because access to UGSs is not always equal to access to ESs, and – vice versa – the lack of physical access to UGSs does not have to mean exclusion from the delivery of (certain) ESs.

We refer to UGSs as all green spaces in urban areas, including forests, parks, private gardens, allotment gardens, cemeteries, brownfields, arable land, meadows and greenery along railway tracks, regardless of whether they are formally managed by the city, by their private owners or through any other arrangement. This broad definition allows us to capture all kinds of benefits associated with urban ecosystems and their services, without narrowing them to any specific management regime. Also, it allows us to perceive a broad spectrum of UGS availability, accessibility and attractiveness (collectively referred to as UGS provision), which we associate with the different levels of the possibility of inhabitants using UGSs. Note that a green space first has to be available to then consider its accessibility, and it has to be available and accessible for prospective users to consider its attractiveness (Biernacka and Kronenberg 2018) (Figure 1).

All three levels of UGS provision distinguished here – availability, accessibility and attractiveness – are related to institutions, and may be restricted by the different barriers connected with economic issues, spatial planning, legal rules, social norms, the inhabitants' preferences and the management of UGSs (Biernacka and Kronenberg 2018). Barriers preventing UGS provision may be very diverse, both in general and between the different levels, as indicated by the following examples. UGSs may not be *available* due to governmental and social failures, such as faulty decisions taken by officials or the lack of social support for UGS preservation. What is more, existing and nearby UGSs may still not be *accessible* because of numerous physical and psychological barriers, e.g., busy streets, railways (Van Herzele and Wiedemann 2003), fences, densely built-up areas, as well as social norms, entrance restrictions (La Rosa 2014; Park 2017) and discouraging surroundings (Biernacka and Kronenberg 2018). Eventually, even when they are available and accessible, the UGS may not be *attractive* enough for urban inhabitants because of problems such as a lack of equipment and park furniture, poor maintenance, congestion, noise and other nuisances (Dillen et al. 2012; Schipperijn et al. 2010; Grahn and Stigsdotter 2010) or at least they may be perceived as unattractive (Krajter Ostoić et al. 2017).

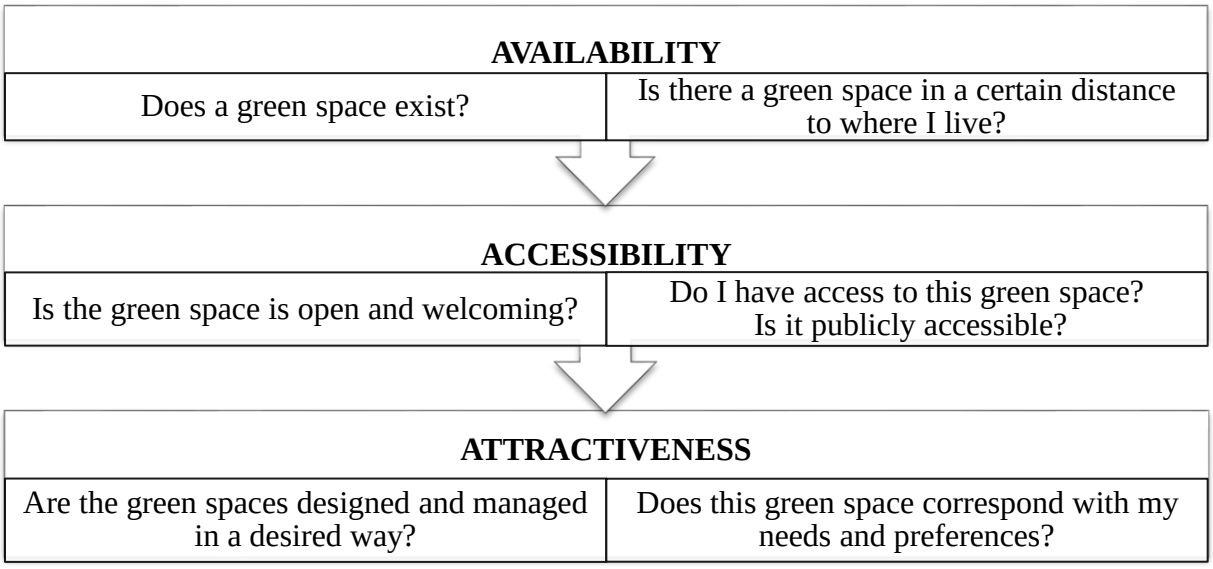

Figure 1. Three levels of urban green space provision (Biernacka and Kronenberg, 2018).

Following Haines-Young and Potschin (2018, page 3), we define ecosystem services as "as the contributions that ecosystems make to human well-being, and distinct from the goods and benefits that people subsequently derive from them." The realization of ES benefits is strongly influenced by contextual factors, such as institutions or available technology, i.e., system components that do not provide ES themselves but which help realize and mediate benefits (Andersson et al. 2015). In line with this argument, we put emphasis on institutions, defined as formal and informal rules of the "social game" (Vatn 2005), and on the different actors who influence UGS provision based on their institutional mandates, such as individual users, formal and informal groups and city authorities.

All of these situations have important implications for the delivery of ESs. For the delivery of some ESs it is enough that a given UGS exists, while the delivery of other ESs may require that a given UGS is characterized by some level of physical or psychological accessibility, and in other cases, the delivery of ESs may be related to the perceived level of attractiveness of a relevant UGS. For example, urban inhabitants may not have access to fenced, private gardens and some of the related ESs (e.g. physical, intellectual and spiritual interactions with the natural environment), but still benefit from many other services which do not require physical access (e.g. the mediation of nuisances of anthropogenic origin, the regulation of temperature and humidity, pollination and seed dispersal) (Andersson et al. 2015; Camps-Calvet et al. 2016).

The main goal of this article is to analyze how different barriers restricting UGS provision affect the delivery of ESs. We focus on three levels of UGS provision: availability, accessibility and attractiveness, represented respectively by three case studies in Lodz (Łódź), Poland. Note that barriers preventing UGS provision, and ultimately also ES delivery, reflect the different, often conflicting interests of different stakeholders. As indicated above, our analysis is intended to broaden the discussion on UGS provision with additional consideration of its relationships with the delivery of ESs. Previous analyses of UGS provision can be associated with selected cultural

ESs only (recreational), but we argue that the broader context should be taken into account when planning urban green infrastructure (cf. Kabisch 2019).

All of the above links to differences in the various stakeholders' interests, preferences, expectations and opportunities to act regarding UGS management and use (Ernstson 2013; Goodness et al. 2016; Kimpton 2017; Rigolon 2017), which often results in misunderstandings and conflict situations (Castro et al. 2014; Zérah 2007). They are related to trade-offs in land use and the delivery of ESs. Indeed, UGS provision is not equal for all inhabitants, and some social groups (e.g., due to their income, race or ethnic variations) are less privileged than others (Rigolon et al. 2018a; Rigolon et al., 2018b; Walker 2012). Similar problems have also been observed in other geographical scales (Laterra et al. 2019). Moreover, some inhabitants may be less privileged because they live in relatively poor cities (Joassart-Marcelli 2010; Joassart-Marcelli et al. 2011) or they have good access, but only to small, fragmented and unattractive UGSs (dangerous neighborhood, lack of park infrastructure and leisure equipment) (Dahmann et al. 2010; Gobster 2002; Kabisch 2019; Perez-Verdin et al. 2004). Furthermore, the fact that the less privileged groups cannot benefit from many ESs provided by UGSs further weakens their general well-being and physical and mental health (Łaszkiewicz et al. 2018; Wolch et al. 2014). As a result, it is important to analyze the different stakeholders' stakes and roles, as well as the relevant institutional contexts.

This article is organized as follows. In the following section, we present our three case studies connected with UGS provision and ES delivery. We characterize our case studies by presenting the context and the involved groups of stakeholders. Then, we move to research methods, which are connected mostly with the analysis of secondary data (public discussions in the media, public consultations) and interviews. With the use of these methods, we determined which ESs have been limited for which groups of residents (and which have not) as a result of changes in UGS provision, along with the relevant institutional contexts. Finally, we synthesize our findings by highlighting that limiting UGS provision does not mean limiting the delivery of all ESs, and we point out that similar conflict situations are often not caused by people who are directly involved in them; rather, ES users tend to be confounded by top-down decisions and legal changes.

MATERIALS AND METHODS

Introduction to the case studies

We analyzed three case studies in Lodz (the third largest city in Poland with almost 700,000 inhabitants). The first case study reflects a problem relevant to all cities in the country, while the second and third ones concern specific locations in Lodz. However, all three case studies have universal implications. One can easily find parallels between the described situations and similar conflict situations regarding reduced UGS provision in other geographical contexts. Our focus on Lodz was motivated by the fact that UGS governance and management have already been well-studied in this city (Feltynowski et al. 2018; Kronenberg et al. 2017; Ratajczyk et al. 2017), which provided a good starting point for our analysis.

The first case study refers to the liberalization of the Polish Nature Conservation Act in 2017 (Articles 83, 85, 86 and 89), as a result of which landowners no longer needed to seek official permission from the municipality's office to cut trees on their property. This resulted in the massive removal of trees throughout the country. In previous years, records of tree felling were kept (tree removal had to be reported to the City Office), but since 2017, such a comparison is not possible based on official registers because the reporting obligation was also repealed, so the scale of the problem remains to be investigated. Polish cities lack specific data related to tree felling; there are practically no inventories of trees, neither on private or public properties (Feltynowski et al. 2018), which makes it even more difficult to trace the real effect of the massive tree removal of 2017. The 2017 removal of trees provides an extreme example of downplaying the importance of urban green spaces and urban trees, in particular, and illustrates the barriers (in particular governmental failures) to preserving urban ESs (Kronenberg 2015). In this case, the conflict of interest concerns the removal of trees (the stakes of its supporters and opponents), which is related to the liberalization of the law (in combination with property rights), as well as limiting the delivery of certain ESs.

The second case study features trade-offs related to the potential replacement of allotment gardens (over 100 plots in an area of 4.5 ha) with a public beach and park around a reservoir on the Jasien (Jasień) river in the center of Lodz (Figure 2). Allotment gardens are complexes of small plots (usually up to 500 square meters) allotted to individual leasees for the cultivation of plants or other recreational purposes (Bell et al. 2016; Drilling et al. 2016; Speak et al. 2015). For this area, the Municipal Planning Office is currently developing a local zoning plan (City Office of Lodz, 2017). This case study reflects broader controversies surrounding the existence of allotment gardens in Polish cities, in particular, in central areas, which are partly related to the fact that allotment gardens are only accessible to a restricted group of registered users (Drilling et al. 2016; Kosmala 2013). This case illustrates the broader disregard for allotment gardens in Poland, and the desire to replace them with other land uses, only some of which involve the preservation of the green character of these spaces (Haase et al. 2019). Indeed, challenges to the preservation of urban allotment gardens are common to many countries (Drilling et al. 2016; Spilková and Vágner 2016). In this case, the conflict of interest concerns the desire to use the allotment gardens' area in a different way (limiting access to ESs for allotment owners, but improving access to certain ESs for a wider group of residents) and the formal decisions which led to a public vote.

The third example represents a conflict between the different uses of the Lagiewniki (Łagiewniki) Forest in the north of Lodz (Figure 2). For most inhabitants of Lodz, the 1200-hectare Lagiewniki Forest is primarily an easily accessible place for recreation and relaxation, just a few kilometers from the city center (Jaskulski and Szmidt 2015). Since 2015, new types of entertainment activities have been organized in Arturowek (Arturówek), a leisure facility located in the southern part of the forest, with a public beach, ponds, playgrounds, a health path and mini outdoor gym. These activities have included loud music, beer and picnic festivals that attract large numbers of participants and disturb other users looking for peace and relaxation in the forest. In this case, the conflict of interest concerns the desire to use other cultural ESs and the different interests and preferences of different groups of forest users.

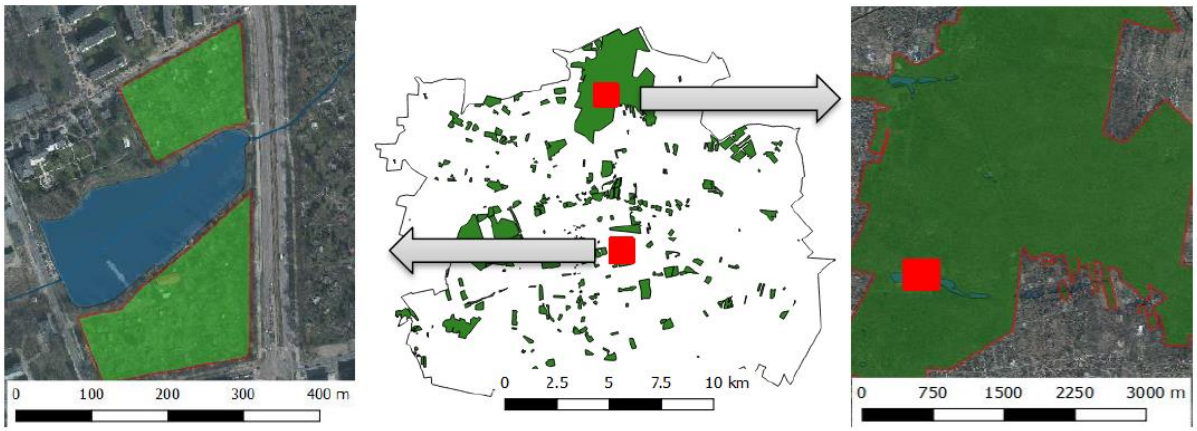

Figure 2. A map of Lodz with its main green spaces shows the location of allotment gardens near the reservoir on the Jasien river (left picture) and Lagiewniki Forest (right picture) with Arturowek (red square)

Research methods

To analyze the case study of tree felling in Lodz, we followed the heated public debate in Poland with opinions expressed in newspaper articles, on websites and in blogs, featuring official statements of various organizations and the personal statements of experts and interviewed members of the broader society. We selected and carefully read those newspaper articles, institutional statements and blog posts which directly referred to the benefits provided by trees to the broader society. Some of them acknowledged and others negated the importance of these benefits, and they prioritized the different interests differently. Of the several hundred articles and press notes which focused on tree felling, only some specifically addressed the above issues. We tried to capture the key arguments mentioned in the debate with regard to who benefitted and who lost out as a result of the removal of trees. Indeed, although there were numerous opponents of the revised law and especially of tree felling, there was also a comparable number of supporters and satisfied landowners. Both groups widely discussed the sense and relevance of protecting urban trees (vs. protecting the private interests of property owners). This material represents what emerged in the discussion as important standpoints regarding what society considers to be important results of the reduced availability of urban trees. Moreover, we analyzed the old and new versions of the Nature Conservation Act to capture specific changes in the law.

The potential replacement of allotment gardens by the Jasien river with a public beach and park was subject to broad discussion in Lodz, and it was voted through the municipal platform used by the City Office as a forum for public consultations – Vox Populi (City Office of Lodz, 2017). In this case, public consultations were organized following the strong opposition of allotment gardeners which emerged when the City Office announced its plan to liquidate allotment gardens and create a public beach and a park in their place. Apart from online voting, citizens could use hard copies of voting cards which they obtained from the City Office. Apart from the results and the special form of this vote, we analyzed Internet fora and media articles regarding the liquidation of allotment gardens by the Jasien river, official city plans related to the management of this area and additional materials from the Municipal Planning Office.

Our analysis of the conflicting uses of Lagiewniki Forest was based on interviews with forest users, supported by our own participant observation. To investigate opinions regarding the new entertainment events and how they affected the attractiveness of the forest, we interviewed 418 people from May to September 2017. The interviews were carried out in three places – in Arturowek (next to the site where the events took place), 1.5 km north of it (in the middle of the forest), and 2.3 km north of it (close to another major access point to the forest). The respondents were asked in a short survey (13 questions) whether they had participated in the music, beer and picnic festivals, and what they thought about them. The group of respondents was very diverse, reflecting the typical diversity of forest users, including different age groups, families with children, single people, as well as groups of friends; walkers along with those practicing sports (joggers, cyclists); they were also diversified in terms of socio-economic status. The interviews took place during the music, beer and picnic festivals throughout the whole season and each interview session lasted around two hours in each of the above three spots simultaneously. As soon as one interview was over, we approached the next passer-by. The results of our survey provide a general overview of the situation and indicate the different preferences and opinions of the residents.

Our approach to studying the barriers preventing the delivery of different types of ESs provided by UGSs follows the classification of barriers previously used in the context of UGS provision (Biernacka and Kronenberg 2018) and the most recent Common International Classification of Ecosystem Services (CICES) version 5.1 (Haines-Young and Potschin 2018). CICES was endorsed by the European Environment Agency and created in response to the need for a standardized, systematic classification of ecosystem services. This classification consists of sections, divisions, groups, classes and types of classes, with the three main sections divided into provisioning, regulation and maintenance, and cultural. CICES 'Version 5' was based on a review of the scientific literature, survey results and workshops, and it is commonly followed in Europe.

Each of the case studies concerns a different scale, types of green space, groups of stakeholders, as well as barriers that caused the occurrence of a given conflict situation. Due to this diversity, research methods and their results are not directly comparable. However, as already indicated earlier, the case studies are used to highlight the different problems and mechanisms, and not to serve as in-depth presentations of what happened in each of the described situations.

RESULTS

In the following subsections, we refer to our three case studies, indicating the key stakeholders involved in each case, along with their stakes, the institutional background, including the roles of the different stakeholders, and finally, the barriers which affect UGS provision and their impacts on the different ESs in each case study. We synthesize these results in Table 1 and finally provide a more general overview of how preventing UGS provision influences the delivery of ES.

Table 1. Synthesis of our case studies

Case study	Level of UGS provision	Types of barriers preventing UGS provision	Key stakeholders with conflicting interests, preferences and attitudes	Key ecosystem service groups restricted with reduced UGS provision
Removing trees on private properties	Availability	Liberalization of law, insufficient social support for the existence of certain UGS	Some property owners vs. Nearby residents, activists	Bio-remediation Filtration Hydrological cycle and water flow reduction Intellectual and representative interactions with the natural environment Pollination Seed dispersal Sequestration Smell and noise reduction Symbolic Visual screening
Elimination of allotment gardens by the Jasien river and the creation of a public beach and park	Accessibility	Changes in spatial planning, insufficient social support for the existence of certain UGS	Local authorities, potentially many inhabitants vs. Allotment gardeners	Bequest value Cultivated terrestrial plants Pollination Seed dispersal Physical and experiential interactions with the natural environment* Smell and noise reduction* Visual screening*
Organizing entertainment events in Lagiewniki Forest	Attractiveness	Loud and crowded outdoor events which discourage some users	People who enjoy popular entertainment vs. People who enjoy nature	Intellectual, representative, spiritual and symbolic interactions with the natural environment

* These services will remain available even when allotment gardens are replaced with a public beach and park, although some of them will be available to a different group of beneficiaries.

Preventing the availability of urban trees and the related ecosystem services

The massive removal of trees on private properties led to numerous objections and protests. These were motivated by the awareness of the positive external effects generated by trees in housing estates and private gardens. Indeed, while the benefits provided by trees represent public goods, the trees themselves are located on private land; hence, they are considered private property. Conversely, private property owners welcomed this change of law as a sanction of their right to manage their properties according to their own needs and preferences.

The change of law was related to the populist government's convictions, advocated most fiercely by the former minister of the environment, Jan Szyszko, reflecting his belief in sacrosanct private property. As a result, trees were often removed without a clear need, to seize the opportunity just in case the rules might change again (which indeed happened after six months).

When trees are removed, the nearby residents suffer the most; hence, those who cut trees also lost multiple benefits provided by the trees.

Legal failures, property rights and insufficient social support for the existence of urban trees represent the main barriers affecting the availability of urban trees, and consequently also the related ESs. When trees are removed from a city, services which are limited the most belong to the regulation and maintenance section (e.g., bio-remediation, filtration, carbon sequestration, smell and noise reduction, visual screening, hydrological cycle and water flow reduction, pollination, and seed dispersal) but also to the cultural section (e.g., aesthetic, symbolic, heritage).

Changes in the delivery of ecosystem services following the planned replacement of allotment gardens (restricted access) with a public city beach and park

In the online vote concerning the existence of allotment gardens by the Jasien River (N=8096), about 66% of respondents voted in favor of liquidating the allotment gardens, while about 26% voted to keep the gardens as they were (the remaining 8% voted for an intermediate solution, i.e., the partial liquidation of the allotment gardens) (City Office of Lodz, 2017). Meanwhile, in the paper vote in the City Office (N=447), most people opted to keep the allotment gardens – about 91%. It is worth noting that using the paper version requires a higher level of determination, and is usually used by those who have limited access to the internet, which might suggest that these were mostly allotment gardeners (elderly people).

The city of Lodz is the owner of the land where the allotment gardens are located, and it can execute its property rights by making the relevant land use decisions. Meanwhile, allotment gardeners are only land tenants, and the only way in which they can express their negative opinion is to protest or participate in a vote. If allotment gardens are replaced with a city beach and park, the UGS will remain available (will continue to exist), but its character will change, along with its accessibility for different user groups. This case study represents two different aspects of UGS accessibility: physical and psychological. Currently, the allotment gardens are fenced and only accessible to a restricted group of users, to whom a city beach and a park will most probably not only be unattractive but even psychologically inaccessible. This is because the character of this place will change and it will be taken over by a completely different group of users – the city plans to make it a fashionable place, the type of which usually attracts younger people who like to spend time in popular places where other similar people spend time.

The institutional context here reflects the insufficient social support for the existence of allotment gardens and the official decisions of the City Office favoring certain forms of UGS (and consequently the interests of the relevant social groups). Moreover, spatial planning failures and property rights (from the point of view of gardeners) are also barriers here, because due to the new local zoning plan, gardeners will lose the possibility of using leased plots. The City Office perceives a beach and a park as more appropriate for a modern city, compared to the allegedly outdated allotment gardens. This is partly related to the fact that allotment gardens deliver regulation and maintenance ESs similar to many other types of UGS, but their delivery of ESs representing the other two sections is restricted to registered users. This is mostly because of physical barriers (fences). A public beach and park could potentially offer a narrower range of regulation and maintenance ESs, with a restricted capacity to deliver services such as those related to lifecycle maintenance (reduced biodiversity, more people, and more infrastructure). Also, they

would not offer any provisioning services. Meanwhile, a public beach and park would open the opportunity to use ESs from the cultural section to a broader group of inhabitants.

Restricting the attractiveness of a municipal forest

Only slightly more than half of our respondents – forest users/visitors – had heard of the new entertainment events organized in the forest (227 out of 418 people) and this share was more or less equal in all three sites. Of those who knew these events and chose not to participate in them (157 people), 127 expressed negative opinions. In response to an optional request for additional comments, 50 people provided openly negative remarks – 9 people from Arturowek (4% of those interviewed in this site), 31 people from middle of the forest (23% of those interviewed in this site) and 10 people from the farthest place from the festivals (17% of those interviewed in this site); 18 had positive comments (10 of whom were interviewed in Arturowek). The former claimed that the forest should be an oasis of peace (especially those people interviewed in the middle of the forest, who care about silence and contact with nature; usually they were cyclists and runners), while the latter suggested that entertainment events constituted good fun for people in the open air.

The festivals are organized in the forest at the City Office's approval by the lessee. The City is the owner and manager of the land, and this particular site has been traditionally used for recreational purposes, with different activities coordinated by the Municipal Sports and Recreation Centre. Any opponents to activities taking place in the forest can either complain about them to the City Office, which requires additional effort, or avoid the area where the festivals are held (according to our survey results, about 41% of respondents who expressed negative opinions about these events changed the routes and locations visited in the forest to avoid nuisances). In practice, this means that, from the legal point of view, dissatisfied regular forest users are barely able to influence these events.

While the forest is still available and accessible, it becomes less attractive for regular users. The loud music, beer and picnic festivals involve many barriers associated with the third level of UGS provision – attractiveness – such as crowds, drunk people, noise, smoke from the barbecues, rubbish and improper behavior. In other words, the regular users' opportunity to benefit from cultural ES (e.g., scientific, educational, cultural, aesthetic and symbolic) is restricted by alternative uses of the forest as a site of entertainment events. In addition, we can assume that such festivals have a negative impact on the wild animals living in the forest.

Connecting barriers preventing the provision of urban green spaces with access to ecosystem services

In an attempt to generalize our findings, we considered a matrix of different ESs, the delivery of which is restricted by the different barriers preventing UGS provision at three levels (availability, accessibility and attractiveness) (Table 2). This matrix clearly indicates that not all barriers from a given level of UGS provision affect the delivery of different ESs to the same extent, and that cultural services are the most vulnerable to restricted UGS provision, while regulation and maintenance services are the least affected.

Table 2. Examples of the limitation of delivering different ecosystem services in the context of barriers preventing three levels of urban green space provision – availability, accessibility and attractiveness (for a broader overview of the barriers, along with their classification, see Biernacka and Kronenberg (2018))

Sections of ESs	Levels of UGS provision and types of barriers		
	Availability	Accessibility	Attractiveness
Provisioning	Barriers affecting this level (e.g., legal errors, new investments that cause the removal of trees) are directly related to the existence of UGS, and lack of UGS translates into the lack of any ES	Barriers affecting this level (e.g., fences, dangerous surroundings) affect physical access to UGS, which is essential to obtain physical products from ecosystems (e.g., through plant cultivation or animal husbandry)	Attractiveness is not typically associated with the provisioning ESs
Regulation and maintenance	Barriers affecting this level (e.g. legal errors, new investments that cause the removal of trees) are directly related to the existence of UGS, and the lack of UGS translates into the lack of any ES	Accessibility is not typically associated with the regulation and maintenance ESs	Attractiveness is barely associated with the regulation and maintenance ESs
Cultural	Barriers affecting this level (e.g. legal errors, new investments that cause the removal of trees) are directly related to the existence of UGS, and lack of UGS translates into the lack of any ES	Barriers from this level have an impact on those ESs from this section which require physical access, i.e., most of them (with exceptions such as intellectual and representative interactions with the natural environment – aesthetic experience, heritage)	Barriers affecting this level have an impact on the delivery of ESs from this section, because issues such as the visual aspects of UGS, the existence of park furniture, and the number of users or their behavior, directly translate into the willingness and frequency of using UGS and interactions with the environment

Barriers preventing UGS availability (e.g., new investments, legal, government and spatial failures, insufficient social support for the existence of certain UGSs) have the most important and clear implications for the delivery of ESs from all three sections: provisioning, regulation and maintenance, and culture. Clearly, without UGSs there are no ESs. At the second level of physical and psychological accessibility, restricted access to UGSs mainly affects the delivery of provisioning services (e.g., cultivated plants, reared animals) and, to a lesser extent, cultural services (those interactions with natural environment which require physical access). Barriers restricting UGS attractiveness affect only the cultural section of ESs as they translate into the users' willingness to visit the respective UGS.

DISCUSSION AND CONCLUSIONS

The aim of this study was to analyze how different barriers preventing UGS provision restrict access to ESs. We focused on three levels of UGS provision: availability, accessibility and attractiveness, and three situations where UGS provision was restricted. Our analysis shows that ES provision is not equal with UGS provision, at least not at all levels of UGS provision. This is a relevant extension of previous discussions on UGS provision. Only the most basic level of UGS availability is the most closely related with the delivery of the relevant ES, while at the level of UGS accessibility, the differences between ES delivery and UGS provision are the most significant.

Our case studies do confirm that ES delivery is closely related to the relevant institutional settings and failures. Our analysis shows that institutions act as filters or mediating factors (Andersson et al. 2015). The most relevant barriers in the light of our case studies are property rights, legal and spatial planning failures, insufficient social support for the existence or preservation of UGS, and loud entertainment events (especially because of noise and improper behavior). Property rights, in particular, are linked to trade-offs between the ESs offered by private land as externalities, and benefits from other land uses which could potentially be monetized by the owners. Our results indicate once again that ESs are co-produced by ecosystems and people – or, perhaps, rather the institutional settings within which they are delivered (Spangenberg et al. 2014). This is particularly evident in the case of accessibility and attractiveness, as even when they change, UGSs continue to exist, albeit in a different form and offering a different set of ES (Felipe-Lucia et al. 2015).

In each of the three case studies, decisions related to the existence and functions of particular areas affected the delivery of ESs to certain groups of city residents. At the first level of UGS provision – availability – the removal of trees results in the loss of all ESs. In the case of allotment gardens near the reservoir on the Jasien river and the second level of UGS provision – accessibility – some ESs are lost (especially from the point of view of allotment gardeners), other ESs appear (at least for a larger group of city inhabitants), and some ESs remain unchanged (of course, this depends on how this space will change, e.g., how many trees will remain, what share of impermeable surface and buildings will be achieved). As for the last level of UGS provision – attractiveness and the example of the municipal forest in Lodz – due to the organization of entertainment events, access to ESs is gained by those who otherwise would not use them (many of whom would probably not go to the forest had it not been for the entertainment events). Conversely, regular users lose access to some ESs (they change their routes because of loud festivals or refrain from going to this forest at all).

It is often assumed that stakeholder choices of ecosystem use are central in ES trade-off analysis (Turkelboom et al. 2018). However, as shown by our case studies, stakeholders who make decisions are not necessarily those who benefit from ESs or who are ultimately responsible for ES delivery and UGS provision (Ernstson 2013). Our case studies highlight the role of surprise and novelty (Faber, Manstetten and Proops 1992a; Faber, Manstetten anad Proops 1992b) – often the inhabitants do not expect that something will happen, but when it happens, some of them gain and others lose (especially in the context of ES delivery). For example, in our first case study, we referred to a specific legal change which can represent broader, unexpected changes, which can dramatically affect the existence (availability) of UGSs. The change was so surprising and unpredictable that it could be classified as "political fiction" – before it was introduced, no one

thought that something like that could happen in real life. This may have dramatic and irreparable consequences as in the case of the removal of trees: property owners "benefited" from the liberalization of the law, while local residents lost many ESs provided by the trees, although none of these groups had expected such legal changes nor lobbied for them beforehand. However, due to loud protests and people's objections, the government decided to toughen the law related to the removal of trees from private properties, which is an obvious manifestation that the liberalization indeed represented a governmental failure (Bojar-Fiałkowski 2017). The consideration of the different barriers to UGS provision should be part of every local planning process, not only with regard to UGS planning in general but also with regard to the distribution of specific benefits related to UGS availability, accessibility and attractiveness.

Our three case studies in one city in Poland illustrate some general phenomena and mechanisms responsible for limiting the delivery of ESs by imposing barriers limiting UGS provision. We indicated that access to UGSs is not always equal to the delivery of ESs. Moreover, institutional context and barriers (e.g., property rights, legal failures or insufficient social support for the existence of UGSs) are crucial in terms of delivering ESs. Our findings should be considered in future studies related to political ecology and environmental justice, especially with regard to conflicts surrounding access to UGSs and the relevant ESs. Further research should focus on a deeper analysis of delivering different ESs in connection with many other types of barriers limiting UGS provision. Such studies would benefit from the direct involvement of the different stakeholders and from their specific perception of what prevents access to the different UGSs and ESs.

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Article 3

Article 3: An integrated system of monitoring the availability, accessibility and attractiveness of urban parks and green squares

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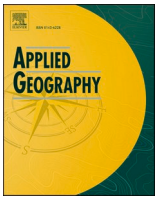

An integrated system of monitoring the availability, accessibility and attractiveness of urban parks and green squares

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ABSTRACT

The main goal of this article is to propose a set of 20 indicators that represent barriers which prevent urban green space (UGS) provision on three levels – availability, accessibility, and attractiveness. These barriers include new investments, such as residential areas and roads; a lack of local zoning plans; fences and entrance fees; a lack of amenities, facilities and entrances; noise; particulates. To test our set of indicators, we investigated 115 parks and green squares in Lodz (Łódź), the third-largest city in Poland. We focused on parks as key examples of UGS, as they are the best explored and most recognizable spaces in most cities. We derived data for our analysis from thematic, publicly available maps and databases, and additional data were provided by managers of UGS. Moreover, we present the procedure of data processing and creating indicators by using the QGIS 2.18 software. Our analysis shows that very small parks in the city center are mostly fenced, lack park infrastructure, leisure facilities, and blue infrastructure, and people are exposed to different nuisances (noise, air pollution). In turn, parks with the lowest number of barriers are typically large and not in the city center. If compared with the spatial distribution of different groups of inhabitants and their socio-economic status, our results would show the actual availability, accessibility, and attractiveness. Our set of indicators is meant to facilitate further discussions with the different stakeholders, planners in particular, in order to remove barriers (at least partly) and increase the overall availability, accessibility, and attractiveness of UGS. Other indicators (based on those used in our article) can be constructed for the needs of other cities, but researchers should take into account data availability, the local context, institutional conditions, and UGS specificities. Besides, each case requires proper interpretation and individual consideration.

1. Introduction

Urban green spaces (UGS) provide numerous ecosystem services (Andersson, Kronenberg, Cvejić, & Adams, 2015; Gómez-Baggethun & Barton, 2013), which are essential for the quality of life of urban inhabitants (Cooper, Brady, Steen, & Bryce, 2016). However, the ability of UGS to provide benefits to urban inhabitants depends on mediating factors or filters, which involve the relevant infrastructure, institutions, and inhabitants' preferences (Andersson et al., 2019; Biernacka & Kronenberg, 2019). Therefore, providing publicly available, accessible, and attractive UGS should be a priority task for city authorities and planners. However, this requires a proper monitoring system. The relevant indicators need to provide easy to interpret information on whether specific UGS are indeed available, accessible, and attractive to the inhabitants. Thanks to this, decision-makers can better understand and improve the situation related to the provision of UGS and the related benefits in their cities.

There have been many previous studies regarding the availability and accessibility of UGS (especially parks) (Kabisch, Strohbach, Haase, & Kronenberg, 2016; La Rosa, 2014; Morar, Radoslav, Spiridon, & Păcurar, 2014; Ngom, Gosselin, & Blais, 2016; Oh & Jeong, 2007; Park, 2017; Zhang, Lu, & Holt, 2011; Žlender & Ward Thompson, 2017), as well as their attractiveness (Park, 2017; Van Herzele & Wiedemann, 2003). In general, UGS availability can be directly related to the existence of UGS (Kabisch et al., 2016; Kronenberg, 2015). Accessibility applies to the physical and psychological possibilities of using UGS (Park, 2017; Wright Wendel, Zarger, & Mihelcic, 2012), while attractiveness is related to the preferences and expectations of residents regarding the appearance and equipment of UGS. The latter studies focus on equipping UGS with park infrastructure and recreational

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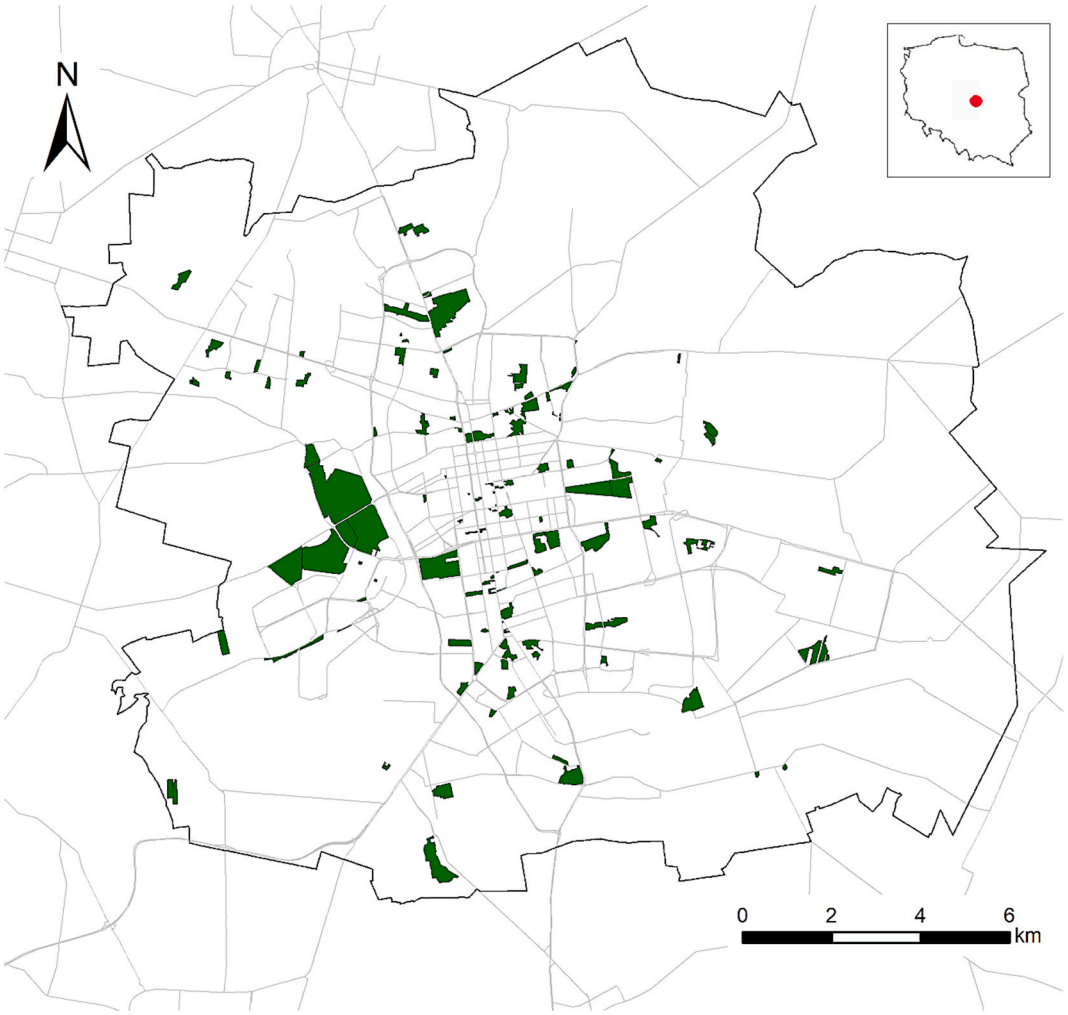

Fig. 1. Map of Lodz (in Poland) with the analyzed 115 public parks and green squares. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

equipment (Kaczynski et al., 2016, 2016; Niță et al., 2018). They also consider the number of users, the visual aspects, biodiversity (Van Herzele & Wiedemann, 2003), the shape and size of UGS (Ngom et al., 2016), and also safety (Bogar & Beyer, 2016; Maas et al., 2009). At each level of UGS provision, one can identify different barriers that prevent, respectively, the availability, accessibility, and attractiveness of specific UGS (Biernacka & Kronenberg, 2018). Barriers may translate into eliminating a given UGS (thus affecting its availability); they may restrict the possibilities of reaching or entering a given UGS (affecting accessibility); and they may affect the potential users' willingness to use a given UGS when this UGS does not meet their expectations and preferences (affecting its attractiveness).

Availability is typically measured as the walking distance (Giles-Corti et al., 2005; Morar et al., 2014; Oh & Jeong, 2007) or Euclidean distance to the nearest UGS (Higgs, Fry, & Langford, 2012) and also UGS coverage in a buffer (Wüstemann, Kalisch, & Kolbe, 2017). Accessibility can be measured by checking the existence of fences and dense buildings around a UGS and other physical obstacles (e.g., busy roads, rivers, hills) (Van Herzele & Wiedemann, 2003), but one can also examine the psychological accessibility of UGS (e.g., the level of safety or the

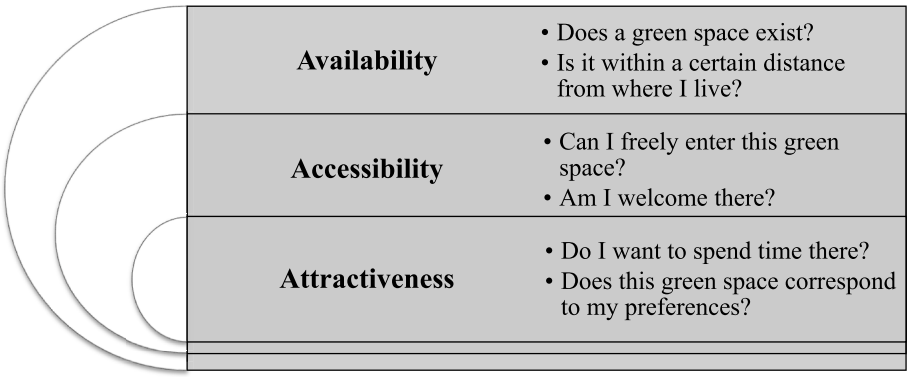

Fig. 2. Three levels of urban green space provision for city inhabitants (Biernacka & Kronenberg, 2018).

Barriers preventing UGS availability, accessibility, and attractiveness		Maps and other databases	Additional data about UGS	Field research (on-site)	Individual users' feedback
		Automated collection of data and mapping	Manual collection of data and mapping	High additional workload related to field visits	Very high additional workload related to surveying a representative sample
		Increasing cost (time and effort) related to acquiring data →			
AVAILABILITY	A lack of local zoning plans/protection of UGS/historic preservation in existing local zoning plans for UGS	■			
	New investments, e.g., buildings, roads	■	■	■	
	Insufficient social support for the existence of certain UGS			■	■
ACCESSIBILITY	Repetitive crime in the vicinity of UGS	■	■		
	Limited accessibility of part of a UGS/restricted entrance opportunities due to fences and dense buildings	■	■	■	
	Entrance fee/opening hours		■	■	
	Discouraging company, e.g., drunk people, inappropriate behavior			■	■
ATTRACTIVENESS	The share of area inside UGS covered with concrete	■		■	
	Lack of blue infrastructure	■		■	■
	Transportation and industrial noise/air pollution	■		■	■
	Poor existence of park infrastructure, leisure equipment	■	■	■	■
	Repetitive, loud, and crowded outdoor events in UGS		■	■	■

Fig. 3. Examples of barriers preventing UGS availability, accessibility and attractiveness along with the most representative relevant data sources. Only considering all selected data sources (gray rectangles) gives the most comprehensive picture about a particular barrier.

appropriation of a UGS by other users) (Biernacka & Kronenberg, 2018). Attractiveness is often measured with composite indicators. For example, ParkIndex measures factors ranging from how to get to a park, its equipment, and appearance, to factors that negatively affect the perception of a given UGS and its surroundings (Kaczynski et al., 2016). Sociotope involves expert and user assessments of open public spaces (including UGS) (Ståhle, 2006) while participatory GIS or SoftGIS aim to capture individual residents' opinions and perceptions of a given UGS with the use of a geo-questionnaire (Pietrzyk-Kaszyńska, Czepkiewicz, & Kronenberg, 2017). Still, the aforementioned approaches do not address UGS provision in a sufficiently integrated way.

The analysis and monitoring of barriers preventing UGS provision further support cross-sectional studies of the potential of UGS to provide benefits to urban inhabitants. For example, considering recreational purposes, city residents may have a large park that potentially corresponds to their expectations (available and attractive) on the other side of a busy street, but to reach it, they may need to use the nearest pedestrian crossing which may happen to be 1 km from where they live, hence making this park barely accessible. Furthermore, UGS may be well maintained, but there may be noisy and annoying groups of people consuming alcohol nearby, or people may be exposed to car fumes, which could discourage potential users (again indicating the reduced accessibility and attractiveness of an available and partly attractive UGS). Such an analysis is particularly relevant from the point of view of

Fig. 4. Map showing the intensity of barriers affecting the availability of parks in Lodz.

environmental justice, indicating whether UGS are, in general, available to different groups of residents, or, more specifically, whether different groups of residents have sufficient access to UGS, and whether the UGS that are potentially available and accessible to different groups of residents are more or less attractive.

The main goal of our article is to propose a set of indicators that represent the barriers that prevent UGS provision on three levels (availability, accessibility, and attractiveness). For the different barriers that affect the provision of UGS, we propose relevant data sources and set up a procedure to calculate an indicator and present it on a map. We test our set of indicators in the case of parks located in Lodz (Łódź), the third-largest city in Poland. We suggest that the proposed indicators would facilitate further discussions with the different stakeholders, and eventually help to remove barriers and increase the overall availability, accessibility, and attractiveness of UGS.

The article is structured as follows: first, we present the scope of our analysis and types of different data sources, and provide a brief description of our case study city – Lodz. Next, we present the data processing, indicating the relevant sources of data, software, and tools, before moving to the calculation methods for the various indicators. Eventually, this leads us to obtain specific indicators for each of the barriers. Then, we discuss the results and indicate why our approach is relevant and useful, what the potential limitations are, and we also state for whom such a system of indicators should be of interest.

2. Materials and methods

2.1. Parks in Lodz

Parks are the most frequented, recognizable, and well-managed UGS in the vast majority of cities, including Lodz (Pietrzyk-Kaszyńska et al., 2017). Indeed, various analyses related to the management, use, and importance of UGS for society focus on parks (Bedimo-Rung, Mowen, & Cohen, 2005; Chiesura, 2004; Kaczynski et al., 2016; Kothencz & Blaschke, 2017; Larson, Jennings, & Cloutier, 2016; Zhang et al., 2011; Zupan & Büdenbender, 2019). Following this tradition, we test our approach related to creating indicators and mapping barriers on parks, especially given that the relevant data are relatively more easily available for parks, compared to other types of UGS.

In Lodz, there are 115 parks and green squares (Fig. 1), the area of which constitutes only about 3% of the city area. According to official UGS statistics in Poland, 'green squares' constitute a special category of the smallest parks; hence, we refer to both categories as parks. In Lodz, several small parks and squares have been created in recent years to

Table 1
Data sources used for mapping barriers preventing UGS provision in Lodz. Classification of barriers derived from Biernacka and Kronenberg (2018).

Lev.	Barriers	Data sources and year	Description of data, comments, year for data
AVAILABILITY	1. New investments – buildings New construction projects may threaten the existence of parks because, during the construction of a new housing estate or a supermarket, trees within and partly around a given plot are often cut down	- Department of Architecture and Urbanization of the City Office (new investments) - Center of Geodesy in Lodz (plots) - 2017–2018	We selected the following large, new investments which may potentially affect parks: - a car showroom, car wash, and gas station - a complex of garages and residential buildings - an office building, production building, and warehouse - a school playground and tennis court - a supermarket, restaurant, and shopping complex - terraced houses, student accommodation, and a nursing home - a telecommunications tower with a base station; a mobile telephony base station - a helicopter landing pad - We considered the future impact of urban planning decisions related to (major) new investments - We used a 10 m buffer because new investments often affect the trees located outside of the relevant plots (at least in Poland) - The area around a construction site is often occupied by special temporary structures for construction workers, which may involve the removal of additional shrubs and trees - As an example, we used issued permits for new buildings and register of land and buildings
	2. New investments – roads New road investments may threaten the existence of parks because, during the construction of a new road, trees within and around this road are often cut down, e.g., due to the creation of additional infrastructure	- Municipal Planning Office (planned road investments, parks) - Masterplan (The Study of Conditions of Spatial Development of the City of Lodz) (Municipal Planning Office) - 2018	- We used a 25 m buffer because road or railway investments in Lodz are not very extensive; a 25 m buffer is sufficient to cover possible tree removal; however, in the case of large highways and multi-lane roads, which may occur in cities, the buffer should be correspondingly larger - The area around a construction site is often occupied by special temporary structures for construction workers, which may involve additional removal of trees and shrubbery - We did not take into account new railway investments because they are not planned for the coming years in Lodz
	3. Lack of local zoning plans for parks Local zoning plans indicate what can be found in a given area and how much biologically active space should be preserved; without such plans, UGS are less formally protected	- Municipal Planning Office (local zoning plans, parks) - 2017	- We used local zoning plans that were already accepted by the Municipal Planning Office as of March 2017 (covering around 22% of the area of Lodz)
	4. Lack of protection of trees/UGS in existing local zoning plans for parks Local zoning plans may contain special provisions related to the protection of UGS, which gives them additional protection	- Municipal Planning Office (local zoning plans, parks) - 2017	- We used local zoning plans and analyzed them in terms of specific records related to: - tree protection (a ban on tree removal in the described area) - new plantings (obligation to replenish plantings in the described area) - compensation for necessary tree removal in the described area - formation of biologically active areas (an indication of the share of biologically active areas, e.g., grass in the described area)
	5. Lack of historic preservation in existing local zoning plans for parks Local zoning plans may contain records related to historic preservation, which gives additional protection	- Municipal Planning Office (local zoning plans, parks) - As of end 2017	- The historic preservation of a park provides additional protection for parks, or specific parts of the park, in local zoning plans
ACCESSIBILITY	6. Park entrances not connected with pedestrian crossings Busy roads can significantly hinder or prevent access to the park, especially when there are no pedestrian crossings or the distance between the nearest pedestrian crossings is significant	- OpenStreetMap (roads, pedestrian crossings) - 2018	- From all types of roads we have chosen only the largest, most heavily used: motorways (at least 2-lane roadways, collision-free intersections with other roads), trunk roads (two- or single-lane, multi-level intersections with other roads), and primary (communication between big cities) and secondary roads (connections between voivodships, completing primary roads in Poland) - We assume that people will use official entrances to get to the park and would cross the street using official pedestrian crossings
	7. Uneven distribution of park entrances Uneven distribution of entrances to parks may make it difficult to enter the park, especially for the disabled or elderly	- Urban Greenery Board - Orthophotomap - 2017	- We assume that people will use official entrances to enter parks
	8. Entrance fees Entrance fees can be a significant barrier for people with very low incomes or for large families	- Information from websites related to UGS management - 2018	- In the case of the parks in Lodz, fees are collected only at the Zoo and the Botanical Garden

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Table 1 (*continued*)

Lev.	Barriers	Data sources and year	Description of data, comments, year for data
	9. Opening hours, temporarily closed Closing the park in the evenings may make it difficult to use it, especially for dog owners or runners	- Information from websites related to UGS management - Urban Greenery Board - 2018	- In the case of the parks in Lodz, opening hours are in operation at the Zoo, the Botanical Garden, Źródliska I Park, Źródliska II Park, Matejko Park, and Sienkiewicz Park
	10. Limited accessibility of part of a park Buildings located in the park limit its area and may also constitute a physical barrier	- Orthophotomap - 2017	- Buildings to which access is restricted in Lodz's parks: private buildings, garages, restaurants, a swimming pool, a greenhouse, sports centers
	11. Restricted entrance opportunities due to fences and buildings around a park Fences and dense buildings around parks constitute physical obstacles in reaching these parks	- Database of Topographic Objects (fences) – 2015 - Orthophotomap – 2017	- We took into consideration every fence (even small ones), hedge, and building on the border of a park
	12. Repetitive crime in the immediate vicinity of a park Due to crimes in the neighborhood of a park, it is perceived as dangerous, and people are afraid to use it, especially after dark	- Data on crimes committed between 2000 and 2015 from the Municipal Police in Lodz	- We focused on repetitive crime, so we took into account crime that occurred at least four times in the same place - We assume that if within six years a crime was reported at least four times in a given place, it means that the immediate vicinity of this park is dangerous
ATTRACTIVENESS	13. Poor existence of park infrastructure: - footpaths - lighting - toilets Lack of basic park infrastructure reduces park attractiveness	- Database of Topographic Objects (footpaths) −2015 - Geodetic Records of the Terrain Armaments Network (lighting) – 2018 - Urban Greenery Board and Department of Municipal Services of the City Office (toilets) −2018	- We used data related to footpaths, lighting, and toilets as the basic and most needed leisure equipment, but one could also add layers with benches or trash cans, i.e., data generally related to other park infrastructure
	14. Poor existence of leisure equipment in a park: - playgrounds - sports facilities - outdoor gyms Lack of basic equipment in the park reduces its attractiveness	- Urban Greenery Board - Database of Topographic Objects – 2015	- We used data related to playgrounds, sports facilities, and outdoor gyms, as the basic and most needed leisure equipment, but one could also add layers with other leisure facilities, e.g., picnic places, skateparks, fountains
	15. Poor existence of water in a park: - ponds - lakes - rivers - canals Lack of blue infrastructure limits the attractiveness of a park	- Database of Topographic Objects - 2015	- In Lodz, we have only small rivers or canals in the parks; therefore, for the purposes of our indicators we only considered those with a minimum width of 1 m - In the case of ponds or lakes, we calculate the water surface
	16. Repetitive loud and crowded outdoor events in a park: festivals, popular music concerts, large-scale picnics Loud events may reduce the attractiveness of a park	- Information from websites related to UGS management - Urban Greenery Board - 2018	- We mean repetitive events during spring and summer period which are connected with loud music, smoke, and the smell from barbecues, rubbish, and congestion, which may discourage users who are looking for silence and contact with nature
	17. Road, rail, or tram noise in a park Noise may reduce the attractiveness of a park	- Acoustic map from the Department of Environmental Protection and Agriculture of the City Office - 2013 – the most recent one available	- We consider all three sources of transportation noise together - Data related to noise generated by industry are not relevant in the case of parks in Lodz, but could potentially be included in a similar analysis elsewhere - The attractiveness of parks could also be limited by airports, sewage treatment plants, or garbage dumps. In Lodz, these places are quite small and are located at a significant distance from parks (on the outskirts of the city), so we do not take them into account
	18. Particulates (PM 10, PM 2.5) in a park Air pollution may discourage the use of a park	- Municipal Planning Office - 2017	- We choose only the particulates most relevant in the case of Lodz, but one can also choose other air pollutants, e.g., sulfur dioxide, nitric oxide, carbon monoxide, lead, ozone - We considered exceeded legally allowed levels of PM 10 and PM 2.5 for the whole city
	19. Share of area inside of a park covered with concrete The lack of a biologically active space may reduce the attractiveness of a park	- Orthophotomap - 2017	- We chose any impermeable surface in the park, e.g., concrete squares, paved sports fields, outdoor gyms and playgrounds, concrete fountains, and monuments (excluding paths)
	20. Area of a park Park size is crucial, especially when it comes to its multifunctionality	- Municipal Planning Office - 2019	- The size of a park significantly affects its attractiveness; in general, larger parks are perceived as more attractive

Table 2
The procedure of data processing and creating indicators for different barriers which prevent the provision of parks in Lodz.

Lev.	Barriers	Adding and processing data in GIS software	Indicators
AVAILABILITY	1. New investments – buildings	1. Add geocoded addresses of new investments to the map 2. Add layers with parks and plot 3. Create a new layer with addresses, which are assigned to the appropriate plot 4. Add a buffer around the plots – 10 m (geoprocessing tools → buffer) 5. Indicate parks located in the buffer around the plot (geoprocessing tools → intersection) 6. Calculate the area of parks potentially affected by new investments (field calculator → geometry → function: area)	$New\ buildings_i = \frac{Invest_i}{Area_i} \times 100\%$, where: $Area_i$ is the area of the i-th UGS, $Invest_i$ is the common part of the i-th UGS and a new investment in a 10 m buffer.
	2. New investments – roads	1. Add layers with parks as well as planned road and railway investments to the map 2. Add a buffer around roads/railroad tracks – 25 m (geoprocessing tools → buffer) 3. Indicate parks located in the buffer around the planned roads/railroad tracks (geoprocessing tools → intersection) 4. Calculate the area of parks potentially affected by new investments (field calculator → geometry → function: area)	$New\ roads_i = \frac{Road_i}{Area_i} \times 100\%$, where: $Road_i$ is the common part of the i-th UGS and a new investment in a 25 m buffer.
	3. Lack of local zoning plans for parks	1. Add layers with parks and local zoning plans to the map 2. Select parks which are included in local zoning plans (geoprocessing tools → intersection) 3. Indicate parks which are not included in the plans (from the layer with all parks subtract the layer with the parks that are covered by local zoning plans → geoprocessing tools → difference) 4. Calculate the area of parks which are not covered by the local zoning plans (field calculator → geometry → function: area)	$Lack\ of\ local\ zoning\ plans_i = \left(1 - \frac{Plan_i}{Area_i}\right) \times 100\%$, where: $Plan_i$ is part of the i-th UGS which is covered by the local zoning plan.
	4. Lack of protection of trees/UGS in existing local zoning plans for parks	1. Add layers with parks and local zoning plans to the map 2. Select parks which are covered by local zoning plans (geoprocessing tools → intersection) 3. Add layers with local zoning plans in which there are specific provisions regarding the protection of trees/UGS (select these plans from all in the attribute table) 4. Select parks which are not included in local zoning plans with specific provisions regarding the protection of trees/UGS (geoprocessing tools → difference) 5. Calculate the area of parks which are not included in the local zoning plans with specific provisions regarding the protection of trees/UGS (field calculator → geometry → function: area)	$Lack\ of\ protection\ in\ local\ zoning\ plans_i = \left(1 - \frac{PlanP_i}{Area_i}\right) \times 100\%$, where: $PlanP_i$ is part of the i-th UGS which is covered by the local zoning plan in which there are specific provisions regarding the protection of the i-th UGS.
	5. Lack of historic preservation in existing local zoning plans for parks	1. Add layers with parks and local zoning plans with areas protected within specific conservation measures to the map 2. Select parks which are protected within specific conservation measures (geoprocessing tools → intersection) 3. Indicate these parks which are not protected within specific conservation measures (geoprocessing tools → difference) 4. Calculate the area of the parks which are not protected within specific conservation measures (field calculator → geometry → function: area)	$Lack\ of\ historic\ preservation\ in\ local\ zoning\ plans_i = \left(1 - \frac{Protect_i}{Area_i}\right) \times 100\%$, where: $Protect_i$ is part of the i-th UGS which is covered by historic preservation.
ACCESSIBILITY	6. Park entrances not connected with pedestrian crossings	1. Add layers with parks, roads, pedestrian crossings, and entrances to parks 2. Add buffers around parks – 100 m (geoprocessing tools → buffer) 3. Select pedestrian crossings in the buffer (100 m) around parks (geoprocessing tools → intersection) 4. Prepare road network for calculations (vector → PST plugin → Split polylines) 5. Calculate the shortest network distance between each entrance to a given park and the nearest pedestrian crossing (vector → PST plugin → Attraction Reach)	$Entrances\ not\ connected\ with\ pedestrian\ crossings_i = \frac{EntrH_i}{Entr_i} \times 100\%$, where: $EntrH_i$ is number of entrances to the i-th UGS which are more than 100 m from the nearest pedestrian crossing near the i-th UGS, $Entr_i$ is the number of entrances to the i-th UGS.

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Table 2 (*continued*)

Lev.	Barriers	Adding and processing data in GIS software	Indicators
		6. For each park, set the number of entrances which have the nearest pedestrian crossing more than 100 m away	
	7. Uneven distribution of park entrances	1. Add layers with parks and entrances to parks 2. Extract the perimeter of the parks from polygons (vector → geometry → convert polygons to lines) 3. Calculate the circumference for all parks (field calculator → geometry → function: length) 4. Divide the circumference lines into sections according to park entrances: (geoprocessing tools → split lines at points) 5. Calculate the length of segments between pairs of entrances to the parks: add a field with the calculated line length from the function: length	$Distribution\ of\ park\ entrances_i = \frac{Acc_i}{Cir_i}$, where: Cir_i is the circumference of the i-th UGS, Acc_i is the longest distance between two entrances to the i-th UGS.
	8. Entrance fee in a park	1. Add a layer with parks 2. Create a new layer with parks in which fees apply	$Entrance\ fee_i = \begin{cases} 1 & \text{if there is a fee in the } i\text{th UGS} \\ 0 & \text{if there is no fee in the } i\text{th UGS} \end{cases}$
	9. Opening hours in a park, temporarily closed	1. Add a layer with parks 2. Create a new layer with parks in which opening hours apply	$Opening\ Hours_i = \begin{cases} 1 \text{ if there are opening hours in the } i\text{th UGS} \\ 0 \text{ if there are no opening hours in the } i\text{th UGS} \end{cases}$
	10. Limited accessibility of part of a park	1. Add layers with parks and an orthophotomap 2. Select buildings in parks – manually drawn 3. Calculate area covered by buildings (field calculator → geometry → function: area)	$Limited\ accessibility\ of\ part\ of\ a\ park_i = \frac{Built_i}{Area_i} \times 100\%$, where: $Built_i$ is the area covered by buildings inside of the i-th UGS.
	11. Restricted entrance opportunities due to fences and buildings around a park	1. Add layers with parks, fences, and an orthophotomap 2. Select buildings and fences located around the park – manual selection 3. Calculate the length of built-up area and fences (field calculator → geometry → function: length)	$Fences\ and\ buildings\ around\ a\ park_i = \frac{FencBuilt_i}{Cir_i} \times 100\%$, where: $FencBuilt_i$ is the length of buildings and fences located around the i-th UGS.
	12. Repetitive crime in the immediate neighborhood of a park	1. Add layers with parks and crime 2. Add buffers around the parks – 100 m (geoprocessing tools → buffer) 3. Select crime in the buffer (100 m) around the parks (geoprocessing tools → intersection) 4. Calculate the sum of the points (crimes) in the 100-m buffer around each park	$Crime\ in\ neighborhood\ of\ a\ park_i = \frac{NumbC_i}{Area_i}$, where: $NumbC_i$ is the number of recorded criminal acts in the buffer around the i-th UGS,
ATTRACTIVENESS	13. Poor existence of small infrastructure in a park: • footpaths • toilet • lighting	1. Add layers with parks, footpaths, toilets, and lighting to the map 2. Select footpaths, toilets, and lighting located in parks (geoprocessing tools → intersection) 3. Calculate the length of footpaths (field calculator → geometry → function: length)	$Poor\ existence\ of\ footpaths_i = \max_i\left\{\frac{Length_i}{Area_i}\right\} - \frac{Length_i}{Area_i}$, where: $Length_i$ is the length of footpaths in the i-th UGS.
			$Poor\ existence\ of\ toilets_i = \begin{cases} 1 \text{ if there are no toilets in the } i\text{th UGS} \\ 0 \text{ if there are toilets in the } i\text{th UGS} \end{cases}$
			$Poor\ existence\ of\ lighting_i = \begin{cases} 1 \text{ if there is no lighting in the } i\text{th UGS} \\ 0 \text{ if there is lighting in the } i\text{th UGS} \end{cases}$
	14. Poor existence of leisure equipment in a park: • playgrounds • sports facilities • outdoor gyms	1. Add layers with parks, playgrounds, sports facilities outdoor gyms and toilets to the map 2. Select playgrounds, sports facilities outdoor gyms and toilets parks (geoprocessing tools → intersection)	$Poor\ existence\ of\ playgrounds_i = \begin{cases} 1 \text{ if there are no playgrounds in the } i\text{th UGS} \\ 0 \text{ if there are playgrounds in the } i\text{th UGS} \end{cases}$
			$Poor\ existence\ of\ sport\ facilities_i =$ $\begin{cases} 1 \text{ if there are no sports fields in the } i\text{th UGS} \\ 0 \text{ if there are sports fields in the } i\text{th UGS} \end{cases}$
			$Poor\ existence\ of\ outdoor\ gyms_i =$ $\begin{cases} 1 \text{ if there are no outdoor gyms in the } i\text{th UGS} \\ 0 \text{ if there are outdoor gyms in the } i\text{th UGS} \end{cases}$
	15. Poor existence of water in a park: • ponds • lakes • rivers • canals	1. Add layers with parks, ponds, lakes, rivers, and canals 2. Select ponds, lakes, rivers, and canals in parks (geoprocessing tools → intersection) 3. Calculate the surface of the ponds, lakes, rivers, and canals in the park (field calculator → geometry → function: area)	$Poor\ existence\ of\ water_i = \left(1 - \frac{AreaPR_i}{Area_i}\right) \times 100\%$, where: $AreaPR_i$ is the surface of ponds and lakes, as well as rivers and canals in the i-th UGS.

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Table 2 (*continued*)

Lev.	Barriers	Adding and processing data in GIS software	Indicators
	16. Repetitive loud and crowded outdoor events in a park: festivals, popular music concerts, large-scale picnics	1. Add a layer with parks 2. Create a new layer with points which represent loud events in parks	$Loud\ outdoor\ events_i = \begin{cases} 1 \text{ if there is a loud outdoor event in the } i\text{th UGS} \\ 0 \text{ if there is no loud outdoor event in the } i\text{th UGS} \end{cases}$
	17. Road, rail, or tram noise in a park	1. Add layers with parks and areas where legally acceptable noise level caused by road, railway and tram traffic are exceeded 2. Select parks which are exposed to noise excesses (geoprocessing tools → intersection) 3. Calculate the area of parks which are exposed to noise levels that exceed the legal limits (field calculator → geometry → function: area)	$Transport\ noise_i = \frac{Noise_i}{Area_i} \times 100\%$, where: $Noise_i$ is part of the i-th UGS area exposed to exceeded noise levels.
	18. Particulates in a park (PM 10, PM 2.5)	1. Add layers with parks and areas where legally allowed levels of PM 10 and PM 2.5 are exceeded 2. Select parks which are exposed to excessive amounts of particulates (geoprocessing tools → intersection) 4. Calculate the area of parks which are exposed to exceeded legal levels of PM10 and PM 2.5 (field calculator → geometry → function: area)	$Particulates\ in\ a\ park_i = \frac{Partic_i}{Area_i} \times 100\%$, where: $Partic_i$ is part of the i-th UGS area exposed to exceeded legal levels of PM 10 and PM 2.5.
	19. Share of area inside of a park covered with concrete	1. Add layers with parks and an orthophotomap 2. Select areas in parks which are covered with impermeable surfaces – manually drawn 3. Calculate the surface of the impermeable areas (field calculator → geometry → function: area)	$Lack\ of\ biologically\ active\ space_i = \frac{Con_i}{Area_i} \times 100\%$, where: Con_i is the area inside of the park covered with concrete, lack of biologically active space inside of the i-th UGS.
	20. Area of a park	1. Add layers with parks 2. Calculate the area of parks (field calculator → geometry → function: area)	$Area_i = \max_i\{Area_i\} - Area_i$, where: $Area_i$ is the area of the i-th UGS.

serve residents and increase neighborhood attractiveness. The largest and most popular parks are Pilsudski Park (with diverse playgrounds, sports facilities, outdoor gyms, paths for runners, and lakes), 3rd May Park (with different sports facilities and playgrounds), Poniatowski Park (with a lake, tennis courts, and a bicycle track), and Mickiewicz Park (with different sports facilities and several lakes).

2.2. *Potential sources of data on barriers preventing UGS provision*

Following previous research (Biernacka & Kronenberg, 2018), we distinguish three levels of UGS provision and consider the different barriers which limit UGS provision at all three levels (Fig. 2). For example, UGS availability is affected by a lack of local zoning plans or developing green spaces into residential areas and new roads. Accessibility depends on, e.g., busy roads, fences, entrance fees, or discouraging, dangerous surroundings. In turn, attractiveness is affected by a lack of amenities and facilities, but also noise or other discouraging uses. Barriers preventing UGS availability, accessibility, and attractiveness can be represented with different data sources, which can also be arranged hierarchically.

Data sources related to barriers affecting the provision of UGS can be divided into four main groups (which differ in the ease of obtaining data and the amount of work and time involved in data analysis): thematic maps and other databases; additional data provided by managers of UGS; case-specific field research; and surveys (individual user feedback, social media analysis) (Fig. 3). Publicly available maps are quite a good source provided by municipalities, open internet sources, and other spatially explicit databases (e.g., CORINE Land Cover time series and Urban Atlas, both provided by EEA, the freely accessible Landsat archives by NASA, or crowdsourced data such as OpenStreetMap). In this group, the process of acquiring data is the simplest, and to a large extent it can be automated with the use of GIS software. Barriers based on such data can be relatively easily identified, and the different degrees of UGS accessibility and attractiveness can be marked on the relevant maps. The second group of potential data sources comprises additional data about UGS, available from the relevant bodies responsible for the management of those spaces. The third group, based on research carried out in the field, requires additional time and effort and involves UGS observation and the identification of occurring barriers. Only during field visits can we recognize the actual condition of UGS and the real character of public events (concerts, festivals, open markets, sports events, etc.) organized in a UGS, and determine whether they might act as an attraction or a deterrent factor for prospective users. In the case of the fourth group, one can obtain additional data about UGS directly from its users (social surveys and self-reporting). Thanks to interviews carried out in the field or online (participatory GIS, mental maps or mobile apps and potentially even analyzing secondary data from social media), we can obtain information on whether people are willing to use UGS and why (or why not, e.g., what makes it difficult to use, which facilities are missing in a given place) (Hamstead et al., 2018; Schuppe, Qureshi, Lautenbach, & Kabisch, 2016).

In our study, we use the first two groups of data sources (maps and databases, and additional information from UGS managers). In our case, these data sources could be relatively easily obtained, although, in some instances, this involved additional effort and processing of the obtained information (e.g., the acquisition of park boundaries, the geocoding of new investments and information related to crimes committed around the parks, drawing some objects manually). Field visits, surveys, and observations could potentially be used to validate information based on the publically available data (e.g., to check whether the fences indicated on some maps are not broken, or whether UGS are maintained to an expected standard), but using them requires more time and additional effort. Furthermore, we focus only on whether the existence of a given park may be threatened by particular barriers, and respectively, whether it is accessible and attractive, without analyzing these issues in the context of the spatial distribution of residents, which we leave for

further research.

2.3. Specific data sources for barriers in Lodz

In our study, we focus on barriers that can be investigated and mapped through the use of thematic maps and other databases, additional data provided by managers of UGS, and publicly available maps, which we will present below in more detail. We distinguish groups of barriers, such as new investments; a lack of local zoning plans; physical barriers (fences, busy roads, entrance fees); safety; the poor existence of small infrastructure; leisure equipment and water; and noise and air pollution. Data connected with barriers limiting UGS provision may be very dispersed and require many different sources and contact with the relevant institutions. We used the data available for our case study city, mostly for 2017–2018, but in the case of three sources, we had to reach back to 2013 and 2015 (Table 1).

Data on park location and borders were acquired from the Municipal Planning Office (and partly from the Center of Geodesy in Lodz). However, the boundaries of parks from different sources did not overlap, or they overlapped with private buildings, streets, garages, or parking lots. Therefore, it was necessary to verify these borders in consultation with the Municipal Planning Office and using the most recent orthophotomap at the time (2017, available online at http://mapa.lodz.pl). The inconsistencies regarding official information on the boundaries of parks – the most apparent type of UGS – indicate challenges in UGS management in the context of poor data availability (Feltynowski et al., 2018).

To create our indicators, we used databases such as BDOT – the Database of Topographic Objects, local zoning plans, OpenStreetMap, orthophotomap, acoustic maps, and other spatially explicit databases, e.g., registers of land and buildings. Obtaining data from various sources was also associated with certain problems, and additional comments for some barriers are necessary. For example, data on new investments (e.g., a complex of residential buildings, office buildings, and commercial centers) are not homogeneously recorded by the City Office (Table 1). Some of the data in the database have only addresses, some have plot numbers, some have addresses as well as parcel numbers, while some of the data have redundant plot numbers. Therefore, we had to unify these data and select only those addresses that could be geocoded.

We obtained additional data about UGS from the literature, the websites and resources of organizations responsible for UGS management (the Urban Greenery Board, the Municipal Sports and Recreation Center, the Municipal Police Station in Lodz, the Center of Geodesy in Lodz, the Zoo, and the Botanical Garden) and from various documents provided by the Municipal Planning Office (e.g., the Study on the Conditions and Directions of Spatial Development – i.e., the masterplan (Municipal Planning Office, 2018)). Again, obtaining these data proved challenging. Some institutions in the city dealing with UGS do not use geographic information systems; sometimes, they do not even store the relevant information in any electronic format. Therefore, obtaining information on park infrastructure from the Urban Greenery Board, or information on toilets from the Department of Municipal Services of the City Office, was connected with additional work and the digitalization and geocoding of all the information we obtained.

2.4. Data processing and indicators

In Table 2, we present the procedure of data processing and creating indicators. We indicate what we added to the map and what kinds of layers (e.g., parks, roads, local zoning plans, fences, crime, facilities, noise, etc.) and tools (e.g., buffer, product, difference, intersection, area, length) we used. In the first column, we indicated one of the three levels of UGS provision. Then we have the name of the barrier and a detailed description of how we mapped a given barrier (which layers we created and added, which steps we took, which tools we used). In the last column, there is a formula for the indicator. Some of our barriers can be defined only as dummy variables, e.g., entrance fees, opening hours, loud and crowded outdoor events, the existence of park infrastructure, or leisure equipment. All indicators were presented in such a way that the higher their value, the more intense the barrier.

As already mentioned, each indicator represents one barrier that refers to the availability, accessibility, or attractiveness of parks. To express the general intensity of the barriers for these levels of UGS provision, we have to calculate, separately for each level, aggregated indicators. We calculate aggregated indicators of availability, accessibility, and attractiveness as an arithmetic mean of the indicators that refer to a given level. Because each raw indicator of a barrier was expressed in different units, we had to standardize the raw indicators before computing the average value. The raw indicators were standardized as follows:

$$s_i = \frac{(x_i - x_{min})}{(x_{max} - x_{min})}, s_i \in [0; 1]$$

where: s_i is the standardized indicator of the i-th UGS, x_i is a partial indicator of the i-th UGS, and $x_{\min}$ and $x_{\max}$ refer to the minimum and maximum values of a given indicator for all UGS.

In addition to the aggregated indicators of barriers for the availability, accessibility, or attractiveness of parks, we calculated one general indicator, which represented the availability, accessibility, and attractiveness levels altogether. Similar to the above, we calculated this indicator as an arithmetic mean of the three standardized aggregated indicators for availability, accessibility, and attractiveness. Additional standardization allowed us to equalize the importance of each level of UGS provision in an aggregated indicator.

In our analysis, we used mainly the QGIS 2.18 software and calculated indicators for each park located in Lodz.

3. Results

In this section, we present three maps showing the aggregate results for the averaged values of indicators on three levels: availability, accessibility, and attractiveness (Figs. 4–6, respectively), and one map showing the combined average for all barriers on the three levels altogether (Fig. 7). To ensure readability, we present only the enlarged central parts of the city. The entire maps showing the intensity of barriers affecting the availability, accessibility, and attractiveness of all parks are available as Electronic Supplementary Material (ESM) (Maps 1, 2, 3, and 4). In each map, the parks are divided into four quantiles, each one representing, respectively, from the lowest to the highest intensity of barriers affecting a given park. A table with calculated partial indicators for 115 parks and each of the 20 barriers is available as ESM (Indicators for parks), also featuring a dictionary with English and Polish names of parks. Moreover, the ESM features three maps with examples of specific barriers that affect availability and attractiveness (Maps 5, 6, and 7).

Although parks seem to be the most secure UGS, as they are legally sanctioned and deeply ingrained in the public consciousness, their existence should not be taken for granted (Fig. 4). This is especially true when parks are not included in local zoning plans or when they are not covered by special prescriptions regarding the protection of green spaces. Only four parks in Lodz are exposed to new building investment, and this problem affects an area equal to 0.18% of all parks. Thirty-one parks are exposed to new road investments, and the affected area represents 3.04% of the total park area in the city. Eighty-one parks are not covered by local zoning plans, which constitutes 81.21% of the total park area in the city. Ninety-eight parks are not protected by additional provisions regarding the protection of trees/UGS in existing local zoning plans, which constitutes an area equal to 86.98% of the total park area in the city. Ninety-two parks are not protected with the provisions regarding historic preservation in the local zoning plans, constituting an area equal to 51.82% of the total park area in the city. Parks in the city

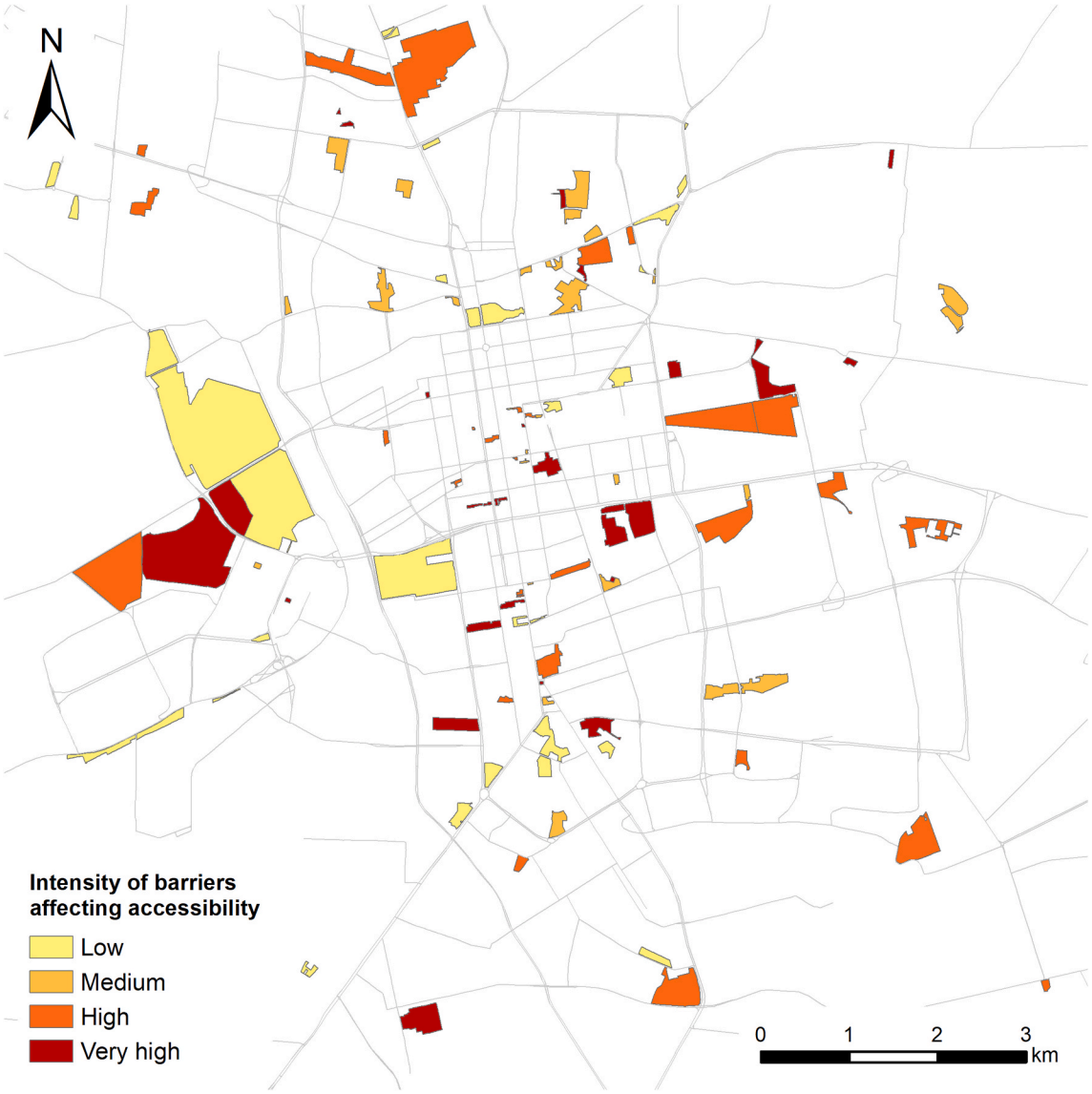

Fig. 5. Map showing the intensity of barriers affecting the accessibility of parks in Lodz.

center are characterized by greater availability and a lower intensity of barriers than parks located on the outskirts of the city; meanwhile, there are almost no parks available in the north and east of Lodz.

The accessibility of parks in Lodz is very diverse (Fig. 5). We identified parks that do not have any barriers associated with physical or psychological accessibility, but there are also parks that are characterized by a significant number of such barriers, especially the Botanical Garden and the Zoological Garden. In the case of 81 parks, entrances are not connected with pedestrian crossings. Excessive distance between individual entrances affects the Botanical Garden and a few small parks. Entrance fees apply only in two parks in Lodz – the Botanical Garden and the Zoological Garden – while limited opening hours restrict access to six parks. Limited accessibility of part of the park (because of buildings, e.g., private buildings, garages, or restaurants) affects 29 parks representing 0.99% of the total area of parks in the city. The length of fences and buildings around the parks in relation to the total circumference of parks is 46.95%. Parks characterized by a high percentage of repetitive crime are mostly small green squares in the city center, but only in the case of 18 parks was no repetitive crime recorded, and these parks are located on the outskirts of the city.

The attractiveness of parks in Lodz is less affected by the selected barriers than their availability and accessibility (Fig. 6). The least attractive are very small parks located mainly in the city center and a few medium-sized parks located on the outskirts of Lodz. The most attractive are: Mickiewicz Park, Widzewska Gorka Park, Gray Ranks Park and Park on the Jasien River. The least attractive ones are small green squares in the city center. In seven parks, there are no paths, in 81 – there are no toilets, and in 20 – there is no lighting. In terms of park equipment, few parks have sports fields (only 23), then outdoor gyms (33), while most parks have playgrounds (51). Lodz's parks lack blue infrastructure as lakes, ponds or rivers are only present in 27 parks and cover 4.29% of the total area of the parks. Only three parks are exposed to loud events, although 96 parks are exposed to transportation noise. More than half of the parks are, in some part, exposed to excessive concentrations of particulates, while 41 are exposed entirely to such pollution. Moreover, 82 parks in the city have impermeable parts of their surface. The parks with the most concrete include the green square at the corner of Sienkiewicz and Narutowicz Streets (76% impermeable) and the green square at the corner of Wolczanska and 6th August Streets (67% impermeable). Both of these squares in the city center resemble parking lots rather than green squares. In terms of size, the largest parks include Pilsudski Park (190 ha), the Botanical Garden (67 ha) and Mickiewicz Park (50 ha), while the smallest include the green square at the corner of Palka and Pankiewicz Streets (0.08 ha), the green square at

Fig. 6. Map showing the intensity of barriers affecting the attractiveness of parks in Lodz.

the corner of Narutowicz Street (0.09 ha), and park on Wolczanska and 6th August Streets (0.09 ha).

Strzeminski Park, Olszynka Grochowska Square, and the park on Palki Street are the most severely affected by the presence of barriers on all three levels (Fig. 7). Such parks are very small, mostly fenced, and with a lack of park infrastructure (e.g., toilets), leisure facilities (e.g., playgrounds or outdoor gyms) and blue infrastructure, and the people who visit are exposed to significant concentrations of air pollution. In turn, the parks affected by the lowest number of barriers are typically large and not in the city center. Most of them have numerous amenities, good park infrastructure, blue infrastructure, the immediate vicinity of these parks is safe, and visitors are not exposed to noise or air pollution. The best examples include Pilsudski Park, Mickiewicz Park, 3rd May Park, Staromiejski (Old Town) Park, and Poniatowski Park. Still, the two centrally located parks – Staromiejski and 3rd May – are affected by noise and air pollution, and Staromiejski by crime.

4. Discussion

4.1. The availability, accessibility, and attractiveness of parks in Lodz

In each park in Lodz, we found barriers that influenced their existence, physical and psychological accessibility, and attractiveness. The parks were rated quite well in terms of their provision on all three levels, and we forced differentiation with the use of quantiles to be able to recognize the parks that functioned better and those that performed less well. The highest intensity of barriers was noted in the center and on the outskirts of the city. The availability of parks in the city center is usually not endangered, but their surroundings are not safe, and most often, they are not attractive enough, mainly due to their small size (the space for various amenities is very limited). Large and medium parks are usually characterized by a small number of barriers associated with attractiveness, but they may suffer from limited accessibility (e.g., associated with a small number of entrances).

Other researchers also pointed to similar barriers related to UGS accessibility and attractiveness as we did in this study, e.g., physical barriers (e.g., roads) (Van Herzele & Wiedemann, 2003), dangerous neighborhoods or lack of safety in UGS (e.g., thieves, drug addicts) (Bogar & Beyer, 2016; Boulton, Dedekorkut-Howes, & Byrne, 2018; Sreetheran & van den Bosch, 2014), a lack of facilities (e.g., sports facilities, playgrounds) (Boulton et al., 2018; Park, 2017), bad park quality (e.g., lack of equipment, poorly managed) (Park, 2017) or lack of open space and density of buildings around UGS (Tian, Jim, & Wang, 2014). Kaczynski et al. (2016), in their ParkIndex, included several of the

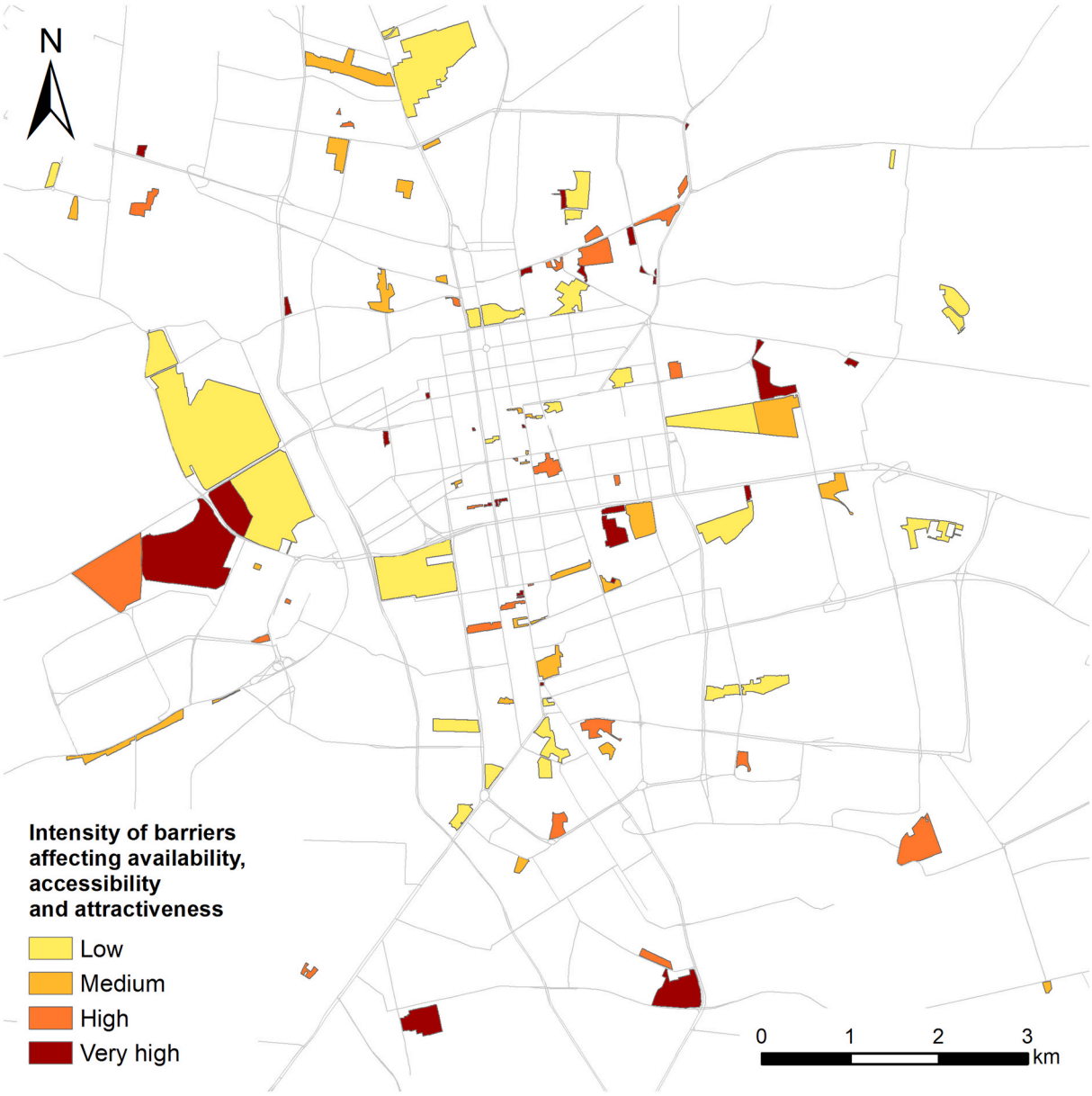

Fig. 7. Map showing the intensity of barriers affecting the availability, accessibility and attractiveness of parks in Lodz.

barriers considered here, such as a lack of equipment and paths, excessive noise, poor lighting, and high volumes of traffic around the park. Specifically, with regard to the parks in Lodz, another study found that those located in the very center are perceived by the inhabitants as neglected or poorly managed, i.e., unattractive (e.g., Moniuszko Park, Rynkowska Passage, Abramowski Passage, and Rubinstein Passage) (Feltynowski, 2016). Similarly, in our study, these parks are affected by many barriers related to attractiveness. Other studies carried out in Lodz – using hedonic pricing – indicated that the size of a park strongly influences its attractiveness; small parks typically did not influence apartment prices, in contrast to large ones (Czembrowski & Kronenberg, 2016; Łaszkiewicz, Czembrowski, & Kronenberg, 2019).

Different parks have different functions, and there is no possibility or need to build a football pitch in every park, but it is important to maximize their usability and differentiate parks in terms of the functions provided. It is also important to ensure basic standards regarding park provision, including attractiveness, throughout a city. Ultimately, each UGS case requires proper interpretation and individual consideration as there may be multiple additional factors affecting their availability, accessibility, and attractiveness, including proximity to other UGS and the characteristics of the general neighborhood.

We can distinguish several parks where the high intensity of barriers can be explained by their specific conditions or character. In particular, the Botanical Garden and the Zoological Garden (in the west of the city) have many amenities and are well-equipped, but they are characterized by low accessibility due to entrance fees and opening hours. In turn, Źródliska I Park is characterized by low accessibility and attractiveness because it lacks equipment and park infrastructure, it is fenced, and there are opening hours, even though it is a well-known and highly visited, historical park in Lodz. A similar example is the 1st May Park (in the south of the city), which has no basic park infrastructure or facilities (e.g., toilets, playgrounds), but has a large pond (with leisure facilities, such as boat rental and a skating rink), which attracts many city residents during summer and winter. Another example that highlights individual park specificity is the Survivors Park, which has a historical function with a museum and a monument commemorating people who went through the Ghetto Litzmannstadt, which was part of the plan to exterminate Jews by the Third Reich during World War II – in that case, outdoor gyms or sports facilities might be seen out of place.

We started our analysis with the barriers preventing UGS

availability, accessibility, and attractiveness (Biernacka & Kronenberg, 2018), and not with what might encourage (attract) the use of UGS (as is the case in sociotope mapping (Ståhle, 2006)). However, paradoxically, some of our barriers may be seen by some users as incentives to use certain parks. For example, fenced parks that are closed at night may be desirable because of the sense of safety, proper care, and even a perceived elitism, while loud festivals (in some cases) can attract residents who are interested in popular entertainment. Therefore, in further studies, it would be possible to test other indicators and approaches to the three levels of UGS provision, especially to their attractiveness. In particular, one could consider natural and landscape features and nature monuments, which provide diversification of ecosystems and scenic or cultural benefits (Pietrzyk-Kaszyńska et al., 2017). In addition, nature reserves can be seen as highlights, but in the case of Lodz, this is of marginal importance because there is only one nature reserve in a park (Polesie Konstantynowskie in Pilsudski Park). Biodiversity can be considered another factor that conditions the attractiveness of a given park (Colesca & Alpopi, 2011; Giles-Corti et al., 2005). In addition, one could consider completely different attractors, such as the park's location in a city and the neighborhood (Tian et al., 2014). Examples of such potential attractors in Lodz include historic heritage (e.g., Ksiezy Mlyn, a renovated group of textile factories, workers' buildings, and rich industrialists' palaces from the 19th century, which represents particularly high biocultural value (Czembrowski, Łaszkiewicz, & Kronenberg, 2016)) or other tourist attractions (e.g., Manufaktura, a shopping and entertainment center, again located in a historic factory complex).

We consider our approach particularly useful when investigating UGS provision from the perspective of environmental justice, i.e., which socioeconomic groups are more exposed to which barriers. So far, for spatial planning purposes in Lodz, only the Euclidean distance from the place of living to the nearest UGS (including its minimum area) has been taken into account in the local masterplan, omitting other factors that may affect UGS provision. Our indicators could be used to refine spatial planning in the city. Still, the presented indicators and our analysis show only the distribution and intensity of individual barriers and the classification of parks in Lodz. In order to show the actual availability, accessibility, and attractiveness, it would be necessary to compare our results with the spatial distribution of inhabitants, including their characteristics and socio-economic status, which is also worth considering in further research.

4.2. Broader usefulness of the presented indicators

The proposed set of indicators makes it possible to capture to what extent a given park is affected by the different barriers that prevent – or potentially prevent – its availability, accessibility, and attractiveness. These indicators can be calculated for all urban green spaces, regardless of size, type, and how they are used. One can use our system as a protocol for similar analyses in other cities. In Lodz, because of the general problem of limited availability of data on UGS (Feltynowski et al., 2018), part of the challenge was to collect baseline information for this study. Indeed, even the different departments of the City Office use different boundaries of parks, and there are different actors responsible for managing parks, and separately the infrastructure and facilities located therein. Hence, the different data that were available from different actors were also in different formats, and often not spatially explicit. Hopefully, in other cities (countries), the availability of such data would be much better, allowing for the automation of the analysis.

When extending our system of indicators to other contexts (other cities or other types of UGS), one needs to consider that some UGS remain private property, or they may be managed by actors other than city authorities. In such cases, UGS owners or managers set the rules regarding attractiveness and accessibility, and even availability. For example, part of one of the parks in Lodz (Staszic Park) was returned to a private owner, who fenced the place off – the problem of the restitution of land nationalized during the socialist period affected the availability of many UGS in postsocialist countries (Kronenberg et al., 2020). Similarly, the inhabitants of Lodz were concerned about potential access restrictions related to the fact that one of the urban public parks has recently been transferred from the city authorities to the Technical University of Lodz. Some UGS may change their status or character. In Lodz, due to the ongoing revitalization process in the city center and the upcoming Expo Horticultural 2024, some of the parks are currently closed and being renovated (Moniuszko, Sienkiewicz and 3rd May Parks). That arouses anxiety among some residents and activists because such activities currently restrict physical access to parks and may result in the character of the parks changing.

Different barriers and indicators are not equal and do not hinder UGS provision in the same way; therefore, for a better and more complete picture, it is possible to combine individual indicators. For example, indicators connected with the distribution of entrances to parks and the distance between them could be considered together, including pedestrian crossings and their distances to entrances to parks. Moreover, one could consider adding different features connected with transportation modes, such as bicycle and car parking, or public transport stops. In other studies, it would also be possible to apply weights to particular indicators (knowing which ones are more relevant in a given context) or to divide UGS due to their character or area, e.g., smaller and larger parks could be considered separately. Furthermore, one could conduct a similar analysis using other sources of data (e.g., case-specific field research and surveys). However, the advantage of those that we have taken into account is that they are typically easily and readily available.

Mapping the barriers that prevent UGS provision is relatively easy in the case of formal and public green spaces, as it is relatively easy to obtain data and identify the borders and various aspects of their status. If we took into account UGS other than parks, for example, informal green spaces such as brownfields, greenfields, or the green spaces beside railway tracks, the results would be quite different. Most of these areas would probably be assessed as endangered and unattractive in Lodz. If we were to analyze and calculate the indicators for all UGS in Lodz (including informal ones) and consider the spatial distribution of residents, then it would be possible to assess UGS provision on three levels (availability, accessibility, and attractiveness) from the perspective of environmental justice for the whole city. We would get a picture of who has access to what UGS, and in which parts of the city UGS are less available, accessible, and attractive.

Our analysis included only parks in one city, and it can serve as an example of how to use the proposed indicators. A similar analysis carried out in a different city might need to take into account local institutional conditions, UGS specificities, and the distribution of residents, as well as their needs and specific expectations (which may differ from city to city). Further research should also take into account the character of individual parks and their geometry (not only size) (cf. Ngom et al., 2016). Finally, we only used maps and databases, with additional information from UGS managers, but one can also obtain information from field visits, surveys, and additional observations, especially to examine UGS in greater detail.

5. Conclusions

Our set of indicators shows that every park in Lodz is affected by barriers limiting its availability, accessibility, or attractiveness. Very small parks (especially green squares) are characterized by a higher intensity of barriers than the larger ones. The highest intensity of barriers was noted in the center and on the outskirts of the city. However, only by comparing our results for the calculated indicators (preferably for all UGS – including informal ones) with the spatial distribution of city residents would it be possible to obtain a real view of UGS provision – determining which groups of residents are exposed to environmental injustice. By calculating these indicators, decision-makers and city planners can obtain information such as which UGS can be threatened by new investments, which are the least accessible due to various

obstacles, or which lack basic park infrastructure and equipment. The utility of the proposed system of indicators depends on the availability of the underlying data. Hopefully, the system would be easier to implement in cities where different local authorities systematically use GIS software and closely collaborate on UGS management.

CRediT authorship contribution statement

Magdalena Biernacka: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Jakub Kronenberg:** Conceptualization, Writing - original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Edyta Łaszkiewicz:** Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Visualization, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apgeog.2020.102152.

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Article 4

Article 4: Park availability, accessibility, and attractiveness in relation to the least and most vulnerable inhabitants

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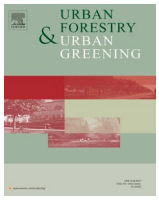

Park availability, accessibility, and attractiveness in relation to the least and most vulnerable inhabitants

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ABSTRACT

With this paper, we enrich the environmental justice debate by investigating differences in the provision of parks in Lodz, Poland, at three levels: availability, accessibility, and attractiveness. A park is 'available' when it exists within a suitable distance from where we live; it is 'accessible' when we feel that we are welcome there, and we can freely reach and safely use this park; it is 'attractive' when we willingly want to use it and spend time there. Our research hypothesis is that the most vulnerable groups of inhabitants concentrate around parks whose provision is affected by the largest number of barriers at each of the three levels, while the least vulnerable benefit from the vicinity of parks that are the least affected. Apart from the statistical analysis – the correlation between the indicators that represent the three levels of park provision and those that represent the most and least economically vulnerable using Pearson's coefficient – we scrutinize three case study parks. The results confirm that there are inequalities at the level of attractiveness for the most vulnerable groups; meanwhile, no statistically significant results were recorded for the least vulnerable groups. The differences would probably be more explicit had socioeconomic segregation been higher in Lodz. The results may also be influenced by the unique postsocialist and postindustrial legacy of our city. The ongoing revitalization of the city center and the increased activity of developers may exclude the most vulnerable inhabitants and deepen segregation.

1. Introduction

The provision of urban green spaces (UGS) translates into the good psychophysical condition of residents (Bertram and Rehdanz, 2015; Ekkel and de Vries, 2017; Larson et al., 2016) and improves their overall quality of life and health (Andersson et al., 2019; Elmqvist et al., 2015; Łaszkiewicz et al., 2018). This has clear economic consequences: investing in UGS brings measurable benefits, such as reduced healthcare expenses, environmental cost savings, market sales, employment, and new investments (Andersson et al., 2015; Brengman et al., 2012; Carter et al., 2015; Elmqvist et al., 2015). For all of the above reasons, many local and international documents have called for the equitable provision of UGS to all urban inhabitants (European Commission, 2015; UN General Assembly, 2015; United Nations, 2017; WHO, 2012).

However, as exemplified by a great number of studies, the distribution of UGS in different cities is far from equitable (Mears et al., 2019; Rigolon, 2016; Wolch et al., 2014), which is also partly due to economic reasons. Those who can afford it are likely to pay more to live close to UGS (Brander and Koetse, 2011; Heckert and Mennis, 2012; Łaszkiewicz et al., 2019). Greener areas tend to be inhabited by socioeconomically less vulnerable groups (those with a higher socioeconomic status) (Wolch et al., 2014). Most typically, inequalities in UGS provision follow broader socioeconomic segregation (Łaszkiewicz et al., 2021; Qiu and Zhao, 2019; van Vuuren et al., 2019). Existing inequalities may contribute to further environmental injustice among city residents, with ongoing gentrification and displacement (Anguelovski, 2016; Kabisch and Haase, 2014; Sister et al., 2010). Apart from the general economic consequences of a lack of UGS provision for urban development, inequalities and segregation lead to additional tension in local societies.

It is not only the availability (existence) of UGS that counts in this context, but also their quality, and especially the quality as perceived by their users, city residents (Park, 2017; Stessens et al., 2020). Indeed, economic valuation shows that attractive UGS have a significant impact on the prices of nearby houses, especially when the distance from the real estate to the nearby UGS is short (up to 250 m) (Daams et al., 2019). Other studies indicate that mainly large, well-maintained , and

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attractive parks, positively assessed in terms of their various social functions and, in particular, multifunctionality, increase the prices of nearby real estate (Czembrowski et al., 2019; Panduro and Veie, 2013), suggesting that some UGS more than others can be associated with luxury (Łaszkiewicz et al., 2019).

Following Biernacka and Kronenberg (2018), UGS provision should be considered at three distinct levels: availability, accessibility, and attractiveness. Availability is the most basic level, and refers to whether a UGS is near to the place of residence. Accessibility can be divided into physical, psychological, and informational, and it refers to whether a given UGS can be easily reached and entered, whether or not people are afraid to be there or feel "unwelcome", or whether there is enough information on a given UGS for potential users to know about it and reach it. Attractiveness indicates whether potential users want to use a particular UGS and spend time there.

UGS provision may be affected by a number of barriers, and – at each level – different UGS may be affected by the respective barriers to different extents. These differences concern different types of UGS (e.g., formal vs. informal), but they also occur between UGS of the same type, translating into a large diversity even within the best known and most prominent UGS category – parks. Some parks are secure and protected (hence steadily available), while others are potentially vulnerable to encroachment by new investments and other land uses. Some parks may be easily accessible, while others may be fenced, surrounded by busy streets, railway tracks, or other physical barriers, and they may be affected by crime or occupied by a particular group of users. Some parks may be highly attractive in terms of their park infrastructure, leisure equipment, cleanliness, the presence of water, or the lack of noise and air pollution, while others may suffer from deficits in each of these categories. Indeed, comprehensive studies on UGS provision should address all three levels to show the widest picture of UGS provision (Biernacka et al., 2020; Boulton et al., 2018; Rigolon, 2016). In this study, we adopt such a comprehensive approach to study differences in UGS provision at all three levels.

The main goal of this article is to investigate which groups of inhabitants (the most or the least vulnerable) live around parks depending on how their availability, accessibility, and attractiveness are compromised by the above barriers. The novelty of our approach to studying environmental justice resides in explicitly distinguishing between the above three levels of UGS provision. After all, parks may be available to urban residents (they may live close to parks), but for various reasons, these parks may not be accessible to them, or the parks that are available may not be attractive enough to meet the nearby inhabitants' needs. Our case study city is Lodz (Łódź) in Poland, where parks have already been assessed through the lens of barriers that affect their availability, accessibility, and attractiveness, and where all 107 parks suffer from barriers affecting at least one of these three levels.

Following a large body of environmental justice literature, our research hypothesis is that the most vulnerable groups of inhabitants, typically with lower socioeconomic status, children and youth, seniors and the elderly, concentrate around parks (if they live nearby at all) whose provision is affected by the largest number of barriers at each of the three levels. That is, the most vulnerable inhabitants live around parks endangered at the first level (availability); their accessibility to parks is relatively worse, e.g., they live in less safe neighborhoods of parks; and they also live close to the less attractive parks in terms of park size, infrastructure, leisure equipment, and water reservoirs, but also due to noise and air pollution. Meanwhile, the least vulnerable, i.e., those with higher socioeconomic status, benefit from parks rated better on all three levels.

To support the above hypothesis, in the next section, we provide an overview of the literature on UGS provision at the three levels from the environmental justice perspective. Next, we describe Lodz's inhabitants and parks. Then, we present our analytical framework, focusing on how we distinguished between the different groups of residents, indicators representing barriers affecting UGS provision, and our operationalization of the parks' service area. From that, we describe our data sources and data analysis. Next, we present the results regarding who lives close to parks with different statuses – whether the different socioeconomic groups are indeed differently affected by barriers preventing park availability, accessibility, and attractiveness, both in general, in the city, and around the three case study parks. In the discussion, we present our results in the context of environmental justice, and recommend further research directions. Finally, we move to the conclusions.

2. Environmental justice in the context of availability, accessibility, and attractiveness of UGS

In the context of UGS provision, environmental justice might be investigated through the lens of demand and supply, indicating – from both perspectives – whether cities are efficiently using the resources at their disposal to satisfy the inhabitants' needs. Demand for UGS could be associated with the inhabitants' preferences (whether different socioeconomic groups demand the same UGS properties) and opinions on whether these preferences are satisfied (Anguelovski et al., 2018a; Iojă et al., 2011). Supply could be investigated by analyzing the type of UGS (type, number, size, shape) located close to where the selected socioeconomic groups reside, with a particular focus on their ethnic backgrounds (Boone et al., 2009; Kabisch and Haase, 2014; Sister et al., 2010). We have adopted the supply-side perspective, benefitting from the indicators of UGS provision proposed by Biernacka et al. (2020). The three levels of UGS provision offer a useful way to organize a literature overview on UGS provision in environmental justice studies (cf. Kronenberg et al., 2020). To disambiguate the different concepts pertaining to UGS provision (Wolff et al., 2022), in the following paragraphs, we explain the environmental justice context of the three aspects we covered.

Studies on the availability of UGS and environmental justice indicate that state funds tend to be allocated to creating parks where higher and middle-income people live (Joassart-Marcelli, 2010; Tan and Samsudin, 2017). Suburbs inhabited by low-income ethnic minorities (e.g., Latinos and African Americans in the USA) are often underfunded (Stodolska et al., 2011). Similarly, better off residents typically benefit from new or revitalized UGS, while less affluent residents tend to be displaced because they cannot afford to live in the revitalized "green" district (Ali et al., 2020; Anguelovski et al., 2018b; Pearsall and Eller, 2020).

Studies on the accessibility of parks mainly concern safety issues and physical and psychological exclusion. It has been shown that ethnic minorities often live close to parks associated with lower security compared to parks in wealthier neighborhoods (Cutts et al., 2009; Rigolon, 2016; Stodolska et al., 2011; Wolch et al., 2014). In addition, ethnic minorities (e.g., Latin Americans in Los Angeles) felt "out of place" in some parks and had the feeling that they were excluded because most park users were white people who lived in the vicinity of the parks. Moreover, Latin Americans felt unwanted there because of a lack of information in Spanish (Byrne, 2012). Some parks charge entrance fees (e.g., botanical gardens, zoological gardens, specially designed gardens), which may exclude less affluent residents (Biernacka and Kronenberg, 2018). Meanwhile, new UGS created in gentrified districts tend to be less accessible (for former residents) than those created in wealthier districts due to the privatization of these UGS (fences and psychological exclusion) (Pearsall and Eller, 2020). Studies in postsocialist cities show that residents of wealthier districts have better access to UGS compared to less prestigious housing estates with social housing (Csomós et al., 2020).

Families with infants and young children (Łaszkiewicz and Sikorska, 2020; Sikorska et al., 2020; Xing et al., 2020) tend to have difficulties reaching remote UGS because of (obvious) mobility restrictions and safety reasons. The elderly are characterized by much lower physical mobility (Balfour and Kaplan, 2002; Li et al., 2006), as well as health problems, which significantly hinders getting to UGS located even several hundred meters from where they live. These UGS may also be inaccessible to them due to their lower socioeconomic status (Guo et al.,

2019). Women tend to feel less comfortable in certain UGS, which limits their accessibility to larger (unlit or overgrown) UGS and some of the benefits they offer (Madge, 1997; Maruthaveeran and van den Bosh, 2015; Sreetheran and van den Bosch, 2014). Finally, the least privileged groups, such as people experiencing homelessness, may be formally banned from parks and other public green spaces, with their needs related to the use of UGS completely ignored (Evangelista, 2019; Koprowska et al., 2020a).

With regard to the environmental injustice context of UGS attractiveness, studies from Australia and the USA show that the poorer ethnic minorities (in particular, African Americans) typically only have access to smaller, inferior UGS with significant congestion (Boone et al., 2009; Kimpton, 2017; Sister et al., 2010). Meanwhile, Rigolon's (2016) review of the literature related to access to parks by various groups of residents in different cities indicated that low-income minorities live close to less attractive parks with inferior equipment and lower security, compared to parks located in wealthier neighborhoods, if they live close to them at all. Similar results were obtained when examining residents in Sheffield (UK), where inhabitants with lower socioeconomic status had access to poor-quality parks (Mears et al., 2019). Finally, parks in different parts of the world are not necessarily adapted to the needs of the elderly – one of the key groups of their users – lacking the necessary and preferred equipment (e.g., benches, toilets, picnic places) (Kabisch and Haase, 2014). Meanwhile, a review of the literature on the use of UGS by the elderly and their preferences, based on publications from Europe, the Americas, Asia, and Australia, shows that they prefer UGS near their place of residence to which they have easy access, which are safe, and which meet their esthetic and equipment needs (e.g., toilets, picnic areas, outdoor gyms) (Wen et al., 2018).

In summary, in light of the literature on environmental justice and UGS provision, the most vulnerable and the least privileged groups include residents with a lower socioeconomic status (e.g., ethnic minorities), as well as the elderly and families with young children.

3. Materials and methods

3.1. Case study city – Lodz

3.1.1. Socioeconomic characteristics of the inhabitants of Poland and Lodz

Compared to other developed countries in the European Union (EU) and the OECD, Poland ranks relatively poorly. In Poland, GDP per capita is quite low, even in purchasing power standards (73% of the EU average in 2019), even in comparison with several other postsocialist countries (https://ec.europa.eu/eurostat). With approx. 6000 euro per person (annual net earnings in 2018), Poland takes one of the lowest positions in the EU, similar to Croatia (https://ec.europa.eu/eurostat). The distribution of income in Polish society is relatively even as measured by the Gini coefficient – with a value of 27.8 (in 2018), compared to the mean value for all EU countries (30.4). However, using other measures (e.g., data on households, national accounts, and data from tax offices), Poland has the highest level of income inequality in the EU, i.e., 10% of the highest-earning Poles account for 40% of national income (Blanchet et al., 2019).

Lodz has approx. 680,000 inhabitants and suffers from high depopulation (Dzieciuchowicz, 2014; Szukalski, 2012) and relatively low earnings, compared to other large cities in Poland (https://bdl.stat.gov.pl/BDL). Moreover, Lodz is a particularly difficult case due to the spontaneous growth of the manufacturing industry and chaotic spatial development (which resulted in – among other things – the uneven distribution of parks) in the 19th century, and the sudden collapse of the dominant textile industry in the 1990s (Jakóbczyk-Gryszkiewicz, 2011). In Lodz, there are also emerging processes related to gentrification (Jakóbczyk-Gryszkiewicz et al., 2014; Zasina et al., 2020) and spatial segregation of residents, with a predominance of people with a higher socioeconomic status on the outskirts of the city (Koprowska et al., 2020b; Łaszkiewicz et al., 2021). However, currently, segregation is quite low, mainly present on a microscale. The large number of elderly people in Lodz is an important issue, as it has one of the highest percentages of elderly residents among the large Polish cities (Janiszewska and Dmochowska-Dudek, 2017).

3.1.2. Characteristics of parks in Lodz

Parks are the most recognizable and well-managed UGS in different cities, including Lodz (Pietrzyk-Kaszyńska et al., 2017), although they cover only about 3% of the city area (Feltynowski et al., 2018). The distribution of parks in Lodz is not even. Most are located in the inner part of the city (mostly small squares, two large parks) and to the west of the city (larger parks), while they are missing in the north and east (Fig. 1).

Based on official data (Municipal Planning Office, 2018) and connecting the boundaries of some adjacent parks, we obtained: six very large parks (which stand out in terms of park infrastructure and leisure equipment); 42 large parks (with park infrastructure and leisure equipment); 25 medium parks (typically equipped better than the smallest green squares); and 34 small green squares (characterized by the limited availability of park infrastructure and leisure equipment) (Fig. 1, Table 1). The median size for all parks in Lodz is 2.2 ha (for details, see Supplementary Material A).

A systematic assessment of the availability, accessibility, and attractiveness of parks in Lodz was conducted by Biernacka et al. (2020), while a comprehensive assessment of the parks' attractiveness and social functions was convened by Łaszkiewicz et al. (2020). Biernacka et al. (2020) showed that parks located in the outskirts are characterized by a higher intensity of barriers that affect availability than parks located in the city center. In terms of accessibility, there is a high diversity throughout the city. The most dangerous parks are those with a small area, which are located in the city center; like several medium-sized parks on the outskirts of Lodz, they are also the least attractive. Large parks are affected by the fewest barriers, and they are well equipped with park infrastructure (e.g., paths), blue infrastructure (e.g., ponds), and numerous amenities (e.g., playgrounds, sports fields). The immediate vicinity of these parks is typically safe, and visitors are not exposed to additional nuisances (e.g., noise, air pollution). Other research related to the availability of parks in Lodz showed that the largest concentration of potential park users was noted in the city center, and that the parks located there are characterized by the best availability (time needed to reach a park from the place of living on foot, but also using public transport, bicycle, or car), even though they are mostly small (Borowska-Stefańska and Wiśniewski, 2017). In turn, reaching parks located on the outskirts takes more time (Borowska-Stefańska and Wiśniewski, 2017), which is largely due to lower population density (Koprowska et al., 2020b). Although parks in Lodz seem to be well-studied, their provision has not yet been considered from the perspective of environmental justice.

3.2. Analytical framework

3.2.1. The most and the least vulnerable groups distinguished in this study

In our study, the most economically vulnerable are represented by people receiving welfare benefits and the unemployed (including the long-term unemployed). These two groups reflect broader social problems, such as a low level of education, poor health, addiction to psychoactive substances, and housing problems (Warzywoda-Kruszyńska and Jankowski, 2013; Warzywoda-Kruszyńska and Kruszyński, 2011). In terms of the different age groups, we consider children and youths (0–20, 21% of the city population), seniors (61–80, 30% of the city population), and the elderly (81 +, 7% of city population) to be the most vulnerable (Sikorska et al., 2020). Retirees and pensioners were the most numerous group who use the assistance of the Municipal Social Assistance Center in Lodz, with large families as the other dominant group of beneficiaries. The problems of the inhabitants in these age groups (seniors and the elderly, and children and youths) result from numerous

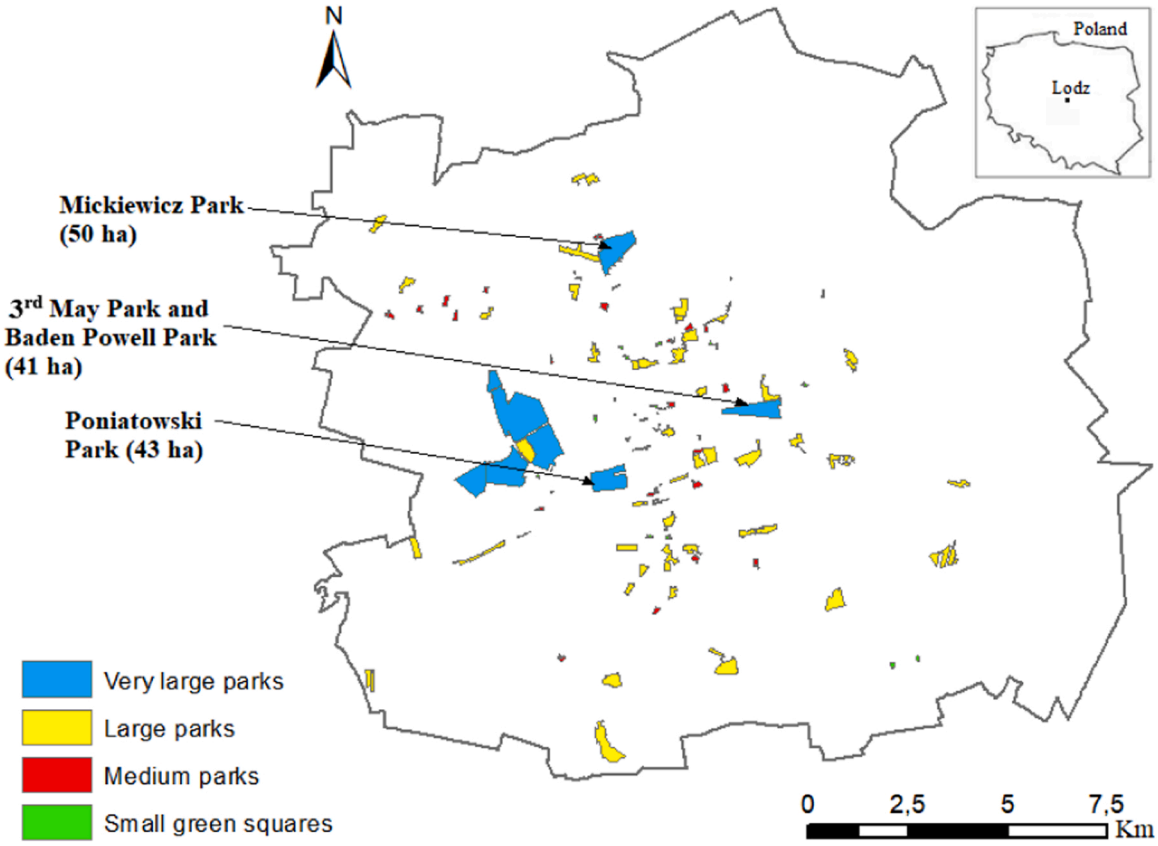

Fig. 1. Location of 107 public parks and green squares, and three case study parks – Mickiewicz Park, the 3rd May park and Baden Powell Park complex, and Poniatowski Park in Lodz (Poland).

Table 1
Categories of parks, their numbers differentiated by their area, and their assessment in terms of barriers preventing parks' availability, accessibility, and attractiveness – good, medium, and insufficient – categorization based on Biernacka et al. (2020).

Park categories/ main information	Very large parks	Large parks	Medium parks	Small green squares
Park area (ha)	[30–190]	[3–30]	[1–3]	[0.1–1]
Average area of parks (ha)	71.6	8.9	1.8	0.5
Number of parks	6	42	25	34
Availability	Good	Medium	Insufficient	Medium
Accessibility	Medium	Medium	Good	Medium
Attractiveness	Good	Good	Medium	Insufficient

dysfunctions in the family (e.g., unemployment, disability, chronic disease, or alcoholism) (Municipal Social Assistance Center, 2018).

The least vulnerable are represented by the buyers of the most expensive apartments in 2011–2018. Wealthier inhabitants prefer new housing investments (Marcińczak and Sagan, 2011) (e.g., apartments, lofts), and this translates into grouping high-quality, luxurious investments in more attractive places, sometimes near UGS (e.g., parks, forests), water, open space, and other amenities. Apart from distinguishing the most expensive apartments in the sample, we also recognized differences between the primary and secondary real estate markets. According to the National Bank of Poland, in 2018, the average price per square meter on the primary market was approx. 19% higher compared to the prices in the secondary market. Additionally, for the least vulnerable groups, real estate is often a form of fixed asset and long-term investment, typically intended for rent.

3.2.2. Availability, accessibility, and attractiveness of parks in Lodz

As a point of departure, we use 20 indicators proposed by Biernacka et al. (2020) to present factors that affect park availability (e.g., new road or construction projects that encroach into the park area, protecting parks through local zoning plans and how they are prescribed, or lack thereof), accessibility (e.g., the number of entrances, entry fees and opening hours, fences, or crime in the vicinity of a park), and attractiveness (e.g., lack of park infrastructure, leisure equipment, and water; noise and air pollution, and the area of a park) (Fig. 2).

We assume that a given park primarily serves its closest residents. Although residents can move around and use other green spaces, the most vulnerable groups have limited possibilities to move, especially for financial reasons or other limitations (e.g., mobility). Indeed, other studies show that, in their everyday life, people most often use the nearest green spaces (Schipperijn et al., 2010a, 2010b; Wen et al., 2018).

3.2.3. Parks' service area

To capture the impact of a given park on the nearby residents, a service area (SA) is more relevant compared to a circular buffer or Euclidean distance because it does not overestimate the area that can be reached by pedestrians (Gutiérrez and García-Palomares, 2008). Indeed, an SA is the most commonly used and preferred approach in this type of analysis (Higgs et al., 2012; Sikorska et al., 2020). To calculate the SA for parks in Lodz, we used a road network map based on data from the OpenStreetMap (2017), which was adjusted for disconnected islands and supplemented with additional connections using the Database of Topographic Objects for Poland (2015) and Google's satellite view. When calculating distances, we eliminated main roads that are not used by pedestrians (e.g., motorways or primary and secondary roads).

We combined our division of parks with the recommendations from the Masterplan for Lodz (Municipal Planning Office, 2018) and the literature (Gupta et al., 2016; Van Herzele and Wiedemann, 2003) to set

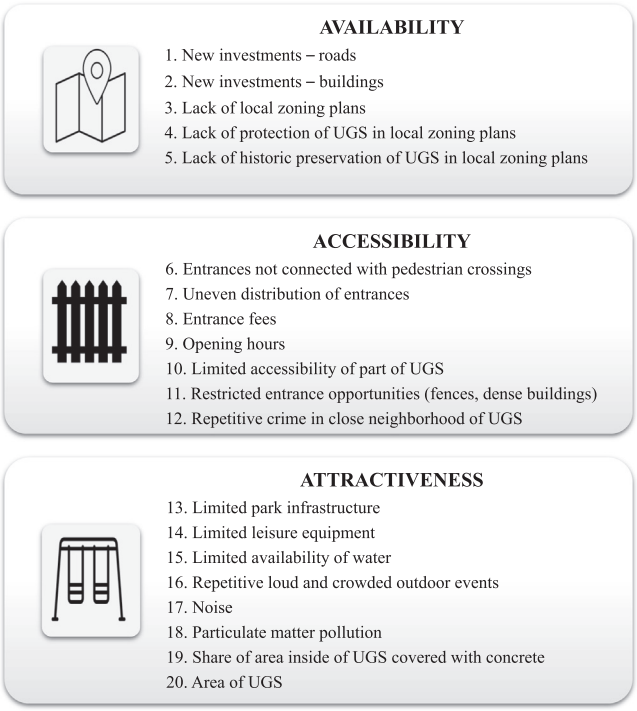

Fig. 2. Indicators representing barriers affecting urban green space (UGS) provision used in the study (for details, see Supplementary Material B).

four different SA variants for the different categories of parks (cf. Table 1). For small green squares, medium parks, large parks, and very large parks, we used, respectively, 200, 400, 800, and 1200 SA in meters. Alternatively, the size of SA could be delimited based on the distance decay functions representing the distance within which parks affect the socio-spatial distribution of inhabitants (Łaszkiewicz et al., 2022).

3.3. Data sources

3.3.1. Welfare-related features of inhabitants and age groups

We obtained data on the unemployed (registered as of 2018) from the Labor Office in Lodz. These data consist of addresses and information regarding whether a given person has remained unemployed for a long time. Meanwhile, data on residents who receive different welfare benefits originated from the Municipal Social Assistance Center in Lodz (also as of 2018).

Regarding the different age groups, we used registration data for 2018, which consists of address, age of registered residents (in ten-year intervals), and the number of people residing at a given address (data at building level). We used spatially explicit data at the level of individual residential buildings, which we obtained from the Citizen Affairs Department of the City Office (Table 2). All addresses were manually geolocated, with a small percentage (approx. 1%) rejected due to incomplete address/missing building number.

When it comes to the real estate data, we associated the highest socioeconomic status residents with the three highest quantiles (percentiles) of apartment sales transactions for each year: 85, 90, and 95, to capture the most luxurious apartments. In Lodz, the primary market represents the upper segment of the real estate market (primary market transactions yielded prices 13% higher than secondary market transactions in our database). Hence we also studied the share of primary market transactions in the different SA variants. We used data for 2011–2018 obtained from the Center of Geodesy in Lodz (Table 2).

Table 2
Type of data, sources, and the respective years.

Type of data	Source of data	Year of data
Registered unemployed	District Labor Office in Lodz	2018
Residents receiving welfare benefits	Municipal Social Assistance Center in Lodz	2018
Registration data	Citizens' Affairs Department of the City Office	2018
Real estate transactions	Center of Geodesy in Lodz	2011–2018

3.3.2. Indicators representing UGS provision

Data on park location and borders were acquired from the Municipal Planning Office and also from the Center of Geodesy in Lodz. The boundaries of parks from different sources did not overlap; therefore, it was necessary to verify these borders in consultation with the Municipal Planning Office and using the most recent orthophotomap at the time (2017) (Biernacka et al., 2020). Biernacka et al. (2020) distinguished 115 parks; however, for our analysis, 16 parks were merged with adjacent green squares or other parks to form larger complexes, better reflecting the social perception of these areas. Eventually, we considered 107 parks and green squares in the city.

We used UGS provision indicators proposed by Biernacka et al. (2020), but recalculated them for the newly divided parks and green squares. Various sources of data were needed to calculate these indicators, e.g., BDOT (the Database of Topographic Objects), OpenStreetMap, acoustic maps, orthophotomap, local zoning plans, and other spatially explicit databases (e.g., registers of land and buildings). We used additional data about parks from the websites of the relevant entities in the city, e.g., the Urban Green Space Authority, the Municipal Police Station in Lodz, the Center of Geodesy in Lodz, the Municipal Sports and Recreation Center, the Zoo, the Botanical Garden, and from documents provided by the Municipal Planning Office. For details on the classification of barriers and indicators, see Supplementary Material B.

3.4. Data analysis

3.4.1. Statistical analysis

We studied the correlation between the indicators of three levels of UGS provision and the indicators representing the most economically vulnerable, the least economically vulnerable, and age groups of residents using Pearson's coefficient. The correlations were calculated for all parks and all SA variants, respectively: SA 200 m for small green squares; SA 400 m for medium parks; SA 800 m for large parks, and SA 1200 m for very large parks. We calculated the statistical significance for the correlation coefficient (significant at the level of 0.05 and 0.01). We also analyzed the sensitivity of the results by performing additional correlation analyses for different variants of park size and SA ranges, as well as for additional percentiles of apartment sales transactions (for details, see Supplementary Material C).

3.4.2. Additional case study analysis

Apart from the statistical analysis covering all parks and the whole city area, we analyzed three case studies – examples of parks over 20 ha. We selected Mickiewicz Park, Poniatowski Park, and the combined complex of the 3rd May and Baden Powell Parks (Fig. 1) because of their size, location, heritage status, and overall attractiveness. There is also an interesting distribution of the unemployed and those receiving welfare benefits in relation to the less vulnerable groups, and also a relatively high number of transactions with the highest apartment prices (percentile 95). Previous research involving hedonic pricing, sociotope assessment, and mapping the barriers that prevent UGS provision showed that large parks in Lodz are treated as amenities and offer various social and recreational functions (Biernacka et al., 2020; Łaszkiewicz et al., 2020, 2019), hence we decided to investigate these three examples in detail.

4. Results

4.1. Barriers preventing park provision that affect different socioeconomic groups

The unemployed, people who receive targeted benefits, children who receive social assistance benefits for meals, and also children and youths enjoy good park availability. Meanwhile, seniors and the elderly live close to the parks whose availability is threatened. In turn, only children and youth have poorer park accessibility. The unemployed, long-term unemployed, and inhabitants who receive different welfare benefits have a worse provision of more attractive parks. For indicators related to the real estate market representing the least economically vulnerable group, there are no statistically significant correlations on any of the three levels of UGS provision (Table 3).

As confirmed by the additional sensitivity analysis, the results are stable for different tested options (for details, see Supplementary Material C).

4.2. Case study parks

Fig. 3 compares data for the most vulnerable groups for these three parks with data for all parks (107) and the very large parks (six), while Fig. 4 compares data for the least vulnerable group for the same three groups of parks.

4.2.1. Mickiewicz Park

Mickiewicz Park (50 ha) is located in the northern part of Lodz, surrounded by a historic villa neighborhood – Julianow. As revealed by the analysis of barriers that prevent UGS provision, the existence of Mickiewicz Park is not threatened; it is physically and psychologically accessible, and it has many amenities, which confirms its attractiveness (Biernacka et al., 2020). Around Mickiewicz Park, there were fewer unemployed and long-term unemployed, as well as fewer inhabitants receiving welfare benefits compared to the SA of all parks (107) and the two other case study parks (Fig. 3). Regarding the real estate market of the least vulnerable group, there were fewer transactions around the park, both from the primary and secondary markets, in relation to the SA of all parks and the two other case study parks (Fig. 4). The median price is higher (over 24%) than the median price for all parks (2011–2018), which may confirm the attractiveness and luxuriousness of this neighborhood.

Table 3
Correlation of the three levels of UGS provision (availability, accessibility, and attractiveness) with the indicators representing the most economically vulnerable, the vulnerable age groups, and least economically vulnerable groups of inhabitants for all parks (SA 200, 400, 800, and 1200). Note: The higher is correlation coefficient, the more UGS provision is affected by the respective barriers.

	Availability	*Accessibility*	*Attractiveness*
The most economically vulnerable			
Unemployed/total	-0.25*	-0.02	0.34**
Long-term unemployed/total	-0.19	-0.03	0.31**
Total number of welfare benefits/total	-0.12	-0.09	0.34**
Targeted benefit/total	-0.22*	-0.07	0.36**
Periodic benefit/total	0.21*	-0.17	0.18
Permanent benefit/total	-0.13	0.06	0.33**
Allowance for meals for children/total children (0–10)	-0.37**	-0.01	0.31**
The vulnerable age groups			
Children and youth 0–20/total	-0.42**	0.20*	-0.09
Seniors 61–80/total	0.48**	-0.17	-0.17
The elderly 81 + /total	0.27**	-0.17	0.10
The least economically vulnerable			
95th percentile/number of transactions	-0.10	0.12	0.01
Median – real estate prices per square meter	-0.08	0.01	-0.08
Primary transactions/all transactions	-0.16	0.08	-0.02

Significance level: 0.01'**', 0.05'*'.

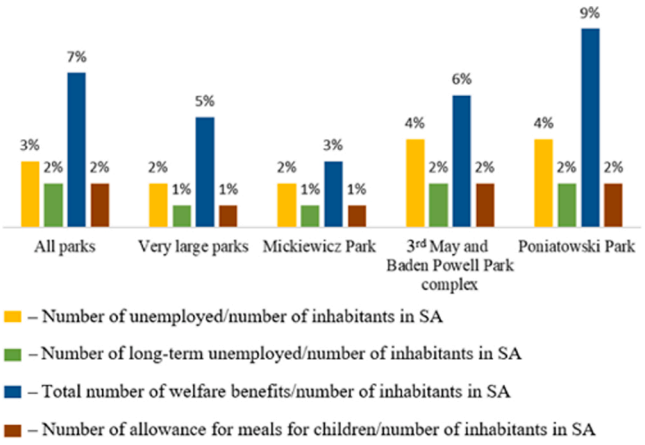

Fig. 3. Data for the most vulnerable groups for all parks (107), very large parks (6), and the three case study parks (Mickiewicz Park, 3rd May and Baden Powell Park complex and Poniatowski Park).

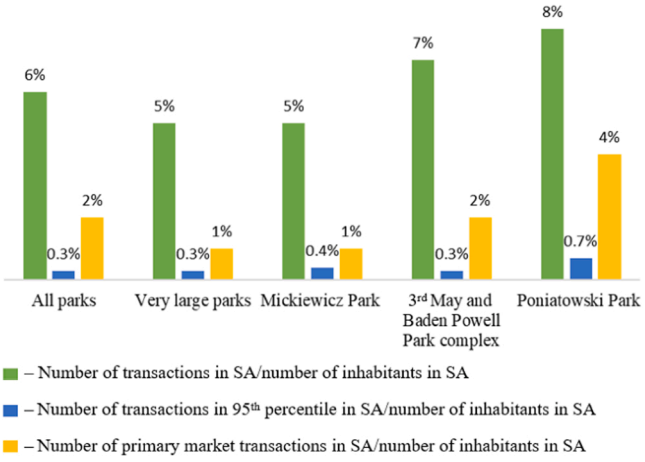

Fig. 4. Data from the real estate market for the least vulnerable groups for all parks (107), very large parks (6), and the three case study parks (Mickiewicz Park, 3rd May and Baden Powell Park complex and Poniatowski Park).

4.2.2. The 3rd May Park and Baden Powell Park complex

The 3rd May Park and Baden Powell Park (together covering 41 ha) form a large park complex located in the center of Lodz, with the 3rd May Park considered a remnant of the historical Lodz Forest. These parks are very well rated in terms of the absence of barriers preventing their availability and attractiveness, with slightly worse accessibility (Biernacka et al., 2020). There are plans to host the International Horticultural Exhibition in these two parks, together with a neighboring green square, in 2029. Data analysis shows that the number of unemployed, long-term unemployed, and people receiving welfare benefits in relation to the SA is similar around the 3rd May Park and Baden Powell Park complex and around all parks (Fig. 3). Regarding the real estate market, there was a similar number of transactions around the park complex, both from the primary and secondary market, compared to the SA of all parks and the two other case study parks (Fig. 4). The median price is slightly higher than the median for all parks (2011–2018).

Although people with a lower socioeconomic status (the most vulnerable) dominate in the center of Lodz, the area around the 3rd May Park and the Baden Powell Park is inhabited by people with a higher socioeconomic status. They are located to the north of the parks in the

old villa district – Radiostacja (Łaszkiewicz et al., 2021; Municipal Planning Office, 2018). Moreover, new investments are planned to the south of this park complex, including housing estates and parking lots. The area of the planned new developments is currently a postindustrial brownfield, partly an informal green space. Such new investments are expected to attract people with a higher socioeconomic status.

4.2.3. Poniatowski Park

Poniatowski Park (43 ha) is located in the city center near the campus of the Lodz University of Technology and one of the two main railway stations (Lodz Kaliska). In terms of the presence of barriers, this park is assessed very well on all three levels – it has good availability, is easily accessible, and has ample park infrastructure and sports and leisure equipment (Biernacka et al., 2020). Around the park, there is a similar number of unemployed and long-term unemployed people in comparison to the SA of all parks; in turn, the number of welfare benefits is higher (Fig. 3). When it comes to the real estate market of the least vulnerable group, there were more transactions in the primary and secondary real estate market in the vicinity of this park than in the SA of all parks. There was also a much higher percentage of transactions in the 95th percentile (the highest apartment prices) (Fig. 4) and higher prices (over 27%) in relation to all transactions in the SA of all parks (in relation to the number of inhabitants in these SAs). Such increased developer activity and high prices result from the fact that this area is extremely attractive due to the mere presence of large and well-managed park, but also the very convenient location – the city center, with good transport connections. Additionally, there was a relatively large share of vacant, postindustrial land in the SA of this park which is gradually being converted into new residential developments.

5. Discussion

5.1. Results in the context of environmental justice

While multiple environmental justice studies have addressed different issues related to UGS provision separately, as revealed by our overview of the literature, we addressed them comprehensively and checked whether the availability, accessibility, and attractiveness of parks differ for the most and the least socioeconomically vulnerable groups. We explicitly focused on barriers that prevent park provision at these three levels, and checked who lives in the SA of parks affected by the different barriers to different extents.

In Lodz, even the most vulnerable groups are quite well represented around parks and enjoy good park availability. However, the availability of parks for seniors and the elderly is limited, and these results are consistent with what we can find in the literature on environmental justice (Guo et al., 2019; Wen et al., 2018). Still, in Lodz, the most vulnerable groups have access to parks with a large number of barriers affecting their attractiveness (small, crowded, poorly maintained, without proper equipment), which is also the case in many other cities (Mears et al., 2019; Rigolon, 2016). Meanwhile, for the least vulnerable groups, there are no significant correlations with the three levels of park provision. This contradicts many studies that identified such correlations, especially given that cities typically invest in UGS in wealthier, more representative districts (Pearsall and Eller, 2020; Tan and Samsudin, 2017).

Our results for the three case study parks do not indicate disparities in the distribution of the least and most vulnerable socioeconomic groups. In particular, around Poniatowski Park, there are relatively many inhabitants who received welfare benefits, compared to the SA for all parks, and many new housing transactions, including the most expensive ones. For the time being, we can say that the most and the least vulnerable are mixed with each other (although they are located on opposite sides of the park). However, this may change due to the great interest of developers in this area – located near this big and attractive park in the city center. Each park should be approached as a separate case study because the particular social structure depends on the character of a given park, the historical conditions (e.g., old villa neighborhood), and current investment and planning decisions. It also depends on additional factors that influence the attractiveness of the neighborhood (e.g., noise and safety).

Parks in Lodz are characterized as amenities, i.e., they have a positive impact on real estate prices, especially the largest parks in the city center (including our three case study parks) (Łaszkiewicz et al., 2019). Another hedonic pricing study in Lodz confirmed that large parks affect real estate prices, and these prices are additionally affected by factors such as the parks' attractiveness and multifunctionality (Czembrowski and Kronenberg, 2016). Therefore, in the longer run, the most economically vulnerable groups may be pushed out of these attractive areas. Without intervention, we can expect gentrification in these areas. This is likely to reduce the parks' availability for the most vulnerable groups, as well as their broader accessibility (new, fenced housing estates may make it increasingly difficult to reach a park). In addition, the surroundings of some large parks (e.g., Mickiewicz Park or part of the 3rd May Park) are already inhabited by groups with a higher socioeconomic status and the possibility of buying a house or apartment in these areas is limited. Indeed, the present inhabitants are attached to these attractive places and are reluctant to move (Łaszkiewicz et al., 2018). The ongoing revival of the city center and the planned organization of the International Horticultural Exhibition in 2029 may increase the attractiveness of park surroundings and attract developers, which in turn may increase segregation and deepen the divisions between the most and least vulnerable inhabitants.

Socioeconomic segregation is only starting in Lodz, and so far, it has only been observed on a microscale (e.g., in the vicinity of the 3rd May Park and Baden Powell Park complex) (Łaszkiewicz et al., 2021), and only going down to the microscale can we check whether segregation occurs and where. Therefore, with a low level of segregation, there is no chance of large inequalities across the city, unlike what happens in many cities in the USA or Australia (Kimpton, 2017; Sister et al., 2010; Stodolska et al., 2011). Our analysis of the distribution of various socioeconomic groups around parks shows that there are only a few significant differences in the provision of parks assessed for the presence of barriers at three levels. However, these differences have not yet indicated large inequalities. This may be explained by the postsocialist and postindustrial legacy of our case study city (Jakóbczyk-Gryszkiewicz, 2011; Kronenberg et al., 2020), with a relatively large share of unused and neglected areas, which are still to be developed, even in the city center. Moreover, with a relatively low share of the city area covered by local zoning plans, there is spatial chaos, which again links to the historical legacy of spontaneous industrial growth in the 19th century, and the postindustrial and postsocialist continuum.

In order to counteract further segregation and inequalities, appropriate policies should be planned and implemented at three levels of UGS provision (Baycan-Levent and Nijkamp, 2009). When it comes to availability, local zoning plans should be created with adequate provisions regarding UGS per capita and per residential type; they should include all types of vegetated areas but also include their ecological quality (Biernacka and Kronenberg, 2018). In particular, new UGS should be created where they are lacking (e.g., in the form of pocket parks, small green squares, or rain gardens) (Peschardt et al., 2012). With regard to accessibility, fencing off private housing estates should be limited, and decision-makers in the city must ensure that new investments are not planned for the park area (Vesselinov et al., 2007). Moreover, social housing should be created or made accessible around attractive UGS, so that more vulnerable groups have access to such spaces. This is particularly relevant when buildings are renovated (e.g., as part of revitalization), in which case former inhabitants should have the right and the financial possibility to return (Audycka, 2021). Regarding attractiveness, city planners should better manage parks that are neglected or particularly frequently visited and are the closest UGS for lower-income people (e.g., in the city center in Lodz).

Decision-makers should consider different preferences of various social groups and involve inhabitants in the participatory process (Kabisch and Haase, 2014).

5.2. Further research and limitations

In Lodz, socioeconomic segregation is relatively low (Łaszkiewicz et al., 2021), and it is primarily associated with economic background. Hence a similar analysis could provide very different results in a case study city where segregation is larger, with groups strongly marginalized based on ethnicity, religion, etc. (e.g., in the USA).

In our study, the starting point was the assessment of parks in terms of the presence of barriers on the three levels of UGS provision in the selected SA ranges. However, this logic could be reversed, and the distance to parks (or other types of UGS) could be examined for selected groups of residents (diversified in terms of their socioeconomic status) while still keeping the lens of the three levels of UGS provision.

The fact that there is no access to a park in the vicinity of a place of residence (or it ranks high in terms of the number of barriers) does not mean that there is no access to UGS at all (Biernacka and Kronenberg, 2018; Feltynowski et al., 2018). Residents can use many other types of UGS, including informal ones, e.g., grasslands, private gardens, neighborhood green spaces, or allotment gardens. Therefore, more detailed and broader studies are advisable, taking into account all categories of UGS in cities, assessed in terms of the presence of barriers at the three levels (Biernacka et al., 2020). Only by examining a smaller part of a city (districts), and even the distribution of residents around individual parks/UGS (going down from macro- to microscale), can we check which groups of inhabitants have access to better or worse UGS assessed in terms of the presence of barriers at all three levels. In addition, considering that inequalities can be microscale, further research may use local statistics, such as LISA (local indicator of spatial association).

We did not have access to data on income groups; therefore, we used real estate market data (the most expensive transactions, transactions from the primary market) and data on welfare benefits and unemployment to identify the least and most vulnerable groups in the city. Using income groups would be the most reliable option in future research. Moreover, due to the limited availability of data, we only analyzed extreme socioeconomic groups – the most and the least economically vulnerable – leaving the middle of the range, which is still very heterogeneous, out of the scope of our analysis. That group also deserves further research.

Finally, the quantification of social inequalities in our study may suffer from uncontrolled spatial autocorrelation. Indeed, spatial autocorrelation is commonly observed in quantification of social inequalities regarding UGS (Łaszkiewicz et al., 2021). The existence of spatial autocorrelation can be explained by the First Law of Geography (Tobler, 1970, p. 236), according to which "everything is related to everything else, but near things are more related than distant things." Therefore, the necessary direction of future analysis is to explore an association between UGS proximity and spatial distribution of socioeconomic groups with the use of global and local spatial autocorrelation coefficients, such as Moran's I statistics (Anselin, 1988), and to apply spatial regression models (Chakraborty, 2011). As demonstrated by Chen et al. (2020) and Nesbitt et al. (2019), spatial regression models make it possible to control for spatial autocorrelation and may enrich the understanding of complexity of social-ecological processes.

6. Conclusions

Analyzing environmental justice through the prism of the three levels of parks supply (availability, accessibility, and attractiveness) and the barriers associated with them helps to capture many different issues related to the unequal provision of parks. Thanks to this, we were able to determine whether the most and least vulnerable groups actually live around parks that differ in terms of barriers affecting their provision. Such an analysis provides a more nuanced view on environmental justice and, most importantly, it makes it possible to distinguish between these three aspects, which vary in importance for different users. For multiple reasons, it is vital to have UGS nearby (availability). Only once green spaces are available can we consider higher accessibility and attractiveness needs.

We found some inequalities for the most vulnerable groups (the unemployed and those receiving welfare benefits) and for seniors and the elderly, which is in line with the reviewed literature on environmental justice analyzed through the lens of UGS availability, accessibility, and attractiveness. However, no statistically significant results were recorded for the least vulnerable group. The analysis of the three case study parks showed that there is no strong dividing line between the most and the least vulnerable groups, but this may change in the near future (due to ongoing urban revival, new developments, and the planned International Horticultural Exhibition).

The results do not indicate large inequalities among the extreme socioeconomic groups of inhabitants in our case study city, which seems to be due to the uniqueness of the postsocialist and postindustrial legacy of Lodz, with chaotic spatial planning, unequal distribution of parks, and no clear socioeconomic segregation. To provide more straightforward results, our research approach should be tested in more explicit city contexts that are typically studied through the lens of urban environmental justice (with higher segregation and stable and developed planning contexts).

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2022.127585.

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Discussion and conclusions

The main goal of my dissertation was to classify institutional barriers that affect UGS provision, specifically distinguishing between the three levels of availability, accessibility, and attractiveness. I classified the three levels of UGS provision and the different barriers that affect it: economic, legal, and connected with spatial planning, the inhabitants' attitudes and UGS management. Based on this analytical framework, I put forward a set of 20 indicators and used them to assess the availability, accessibility, and attractiveness of parks in Lodz. In this way, in my series of closely connected articles, I proposed a solution to the problem of how to systematically approach various issues related to UGS provision. This original solution can be used to support urban planning and various comparative analyses of urban green spaces. Indeed, it has already been followed by other researchers, and it has been used as a starting point for other, yet more complex frameworks.

Three of the four articles constituting this thesis built on the basic analytical framework proposed in the first one. Each of them complemented the framework with additional detail. The main conclusions from my articles are summarized in Table 1. They are discussed in the following paragraphs, along with a more general discussion on the usefulness of the whole framework.

Table 1. Goals and main conclusions from the four articles

Article	Goals	Conclusions
First article: Classification of institutional barriers affecting the availability, accessibility, and attractiveness of UGS	To identify and classify various institutional barriers preventing UGS provision	Institutional barriers are mostly related to legal rules, spatial planning, economic issues, the management of UGS, and the inhabitants' attitudes
	To identify the actors responsible for institutional barriers and their mandates	Thanks to the extensive and detailed analysis of barriers, decision makers, planners and researchers can find key barriers in their city, introduce appropriate solutions and, based on this, work on ensuring 'universal' UGS provision

Second article: Urban green space availability, accessibility and attractiveness and the delivery of ecosystem services	To determine how different institutional barriers that limit UGS provision affect the delivery of ES	Institutional context and barriers, such as property rights, legal failures, insufficient social support for the existence of UGS, are crucial in terms of delivering ES
Third article: An integrated system of monitoring the availability, accessibility, and attractiveness of urban parks and green squares	To propose a set of indicators that represent barriers which prevent park provision	By calculating indicators, decision makers and city planners can obtain information useful for planning UGS in the city that would correspond with the demand for such spaces, for example considering which UGS can be threatened by new investments, which are the least available due to various obstacles or which lack basic park infrastructure and equipment
Fourth article: Park availability, accessibility, and attractiveness in relation to the least and most vulnerable inhabitants	To identify which groups of inhabitants (the most or the least vulnerable) live around parks depending on how their availability, accessibility, and attractiveness are compromised by the respective barriers	Some inequalities exist in the case of the most vulnerable groups
		The results do not indicate large inequalities among the extreme socio-economic groups of inhabitants in case study city, which seems to be due to the specificity of the postsocialist and postindustrial legacy of Lodz

The results from the first article support the hypothesis that formal institutions have a greater influence on the existence of barriers than informal institutions. Moreover, institutional conditions have a large impact on UGS and the related barriers, which is also confirmed by other researchers (Battaglia et al., 2014; Boulton et al., 2018; Kronenberg, 2015). This is especially important, because decision makers and planners should strive to ensure that all

residents have equal access to attractive, safe, and well managed UGS within a reasonable distance from their home (Natural England, 2010; WHO, 2010).

The results from the second article showed that barriers preventing UGS availability (e.g., new investments, legal and spatial failures) have the most important and clear implications for the delivery of ES from all three sections: provisioning, regulation and maintenance, and cultural. This supports my hypothesis that UGS provision at each of the three levels (availability, accessibility, and attractiveness) affects ES delivery differently. I built my reasoning on the classification of barriers affecting UGS provision at the three separate levels put forward in the first article. Moreover, the conclusions of my second article can be related to the three filters that mediate the flow of benefits from UGS: interactions among green, blue, and built infrastructure; the regulatory power and governance of institutions; and people's individual perceptions and values (Andersson et al., 2019). I indicated that those who make decisions, such as government institutions, are usually not those who lose access to UGS and ES (Ernstson, 2013). Unfortunately, such legal (e.g., liberalization of the law related to cutting down trees) and spatial changes (e.g., allotment gardens removal) are often undertaken without an in-depth analysis, to pursue the different actors' own political goals (especially in postsocialist cities) (Csomós et al., 2020; Niedziałkowski and Beunen, 2019) and may negatively affect the three levels of UGS provision, and thus access to benefits.

The purpose of my third article was to propose a set of indicators that would represent barriers which affect park provision, and its main research hypothesis was that each park in the city is exposed to barriers, but to a different extent. The results of this article showed that small parks in the city center and medium-sized parks on the outskirts are most endangered in terms of the presence of barriers on all three levels, while large parks are the least endangered. Moreover, the presence of barriers is not evenly distributed among parks, but each park suffers from some barrier, at least on one of the three levels. The underlying analytical framework and the indicators derived from it to assess parks in Lodz were further used to study park provision in Lodz to various socio-economic status groups in the fourth article.

The fourth article featured in this dissertation contributes to the ongoing discussion on environmental justice and UGS provision, and supports the hypothesis that the most vulnerable groups of inhabitants concentrate around parks whose provision is affected by the largest number of barriers at each of the three levels of UGS provision, while the least vulnerable benefit from the proximity of parks that are the least affected. Various studies confirm that the needs of all residents are not satisfied on a similar level (Łaszkiewicz et al., 2018; Ngom et al.,

2016). In particular, the needs of the most disadvantaged (vulnerable) groups (e.g., ethnic minorities, the homeless, the unemployed, seniors, and families with children) are also underserved when it comes to the provision of UGS (Evangelista, 2019; Guo et al., 2019; Rigolon, 2016; Sikorska et al., 2020), which is also supported by the results of my last article. However, my results do not indicate large inequalities among the extreme socio-economic groups of inhabitants in Lodz , which seems to be due to the specificity of the postsocialist and postindustrial legacy of this case study city.

Although I tested the set of the proposed indicators on the example of parks (in the third and fourth article), my analytical framework can be easily applied to other types of UGS – both formal and informal (e.g., forests, allotment gardens, neighbourhood green spaces, meadows or brownfields), regardless of their ownership status and possibilities of use. According to the theory of property rights, access to common-pool resources and public goods should be the same for everyone (Chiodelli and Moroni, 2014; Poklembová et al., 2012), but in reality even in the case of UGS belonging to the most basic category of parks, access tends not to be equal. In the context of institutional barriers preventing access to UGS, it is relevant to refer to the theory of property rights (Figure 1). Indeed, property rights refer to specific UGS provision indicators. Therefore, UGS provision depends not only on institutional conditions, but also on property rights, which are often imprecise, especially in the case of informal UGS (e.g., brownfields, grasslands). Often, such spaces are treated by city authorities as reserve areas for development and new investments (Biernacka and Kronenberg, 2018; Feltynowski et al., 2018), even though they provide many ES (Rupprecht, 2017; Rupprecht et al., 2015; Sikorska et al., 2020).

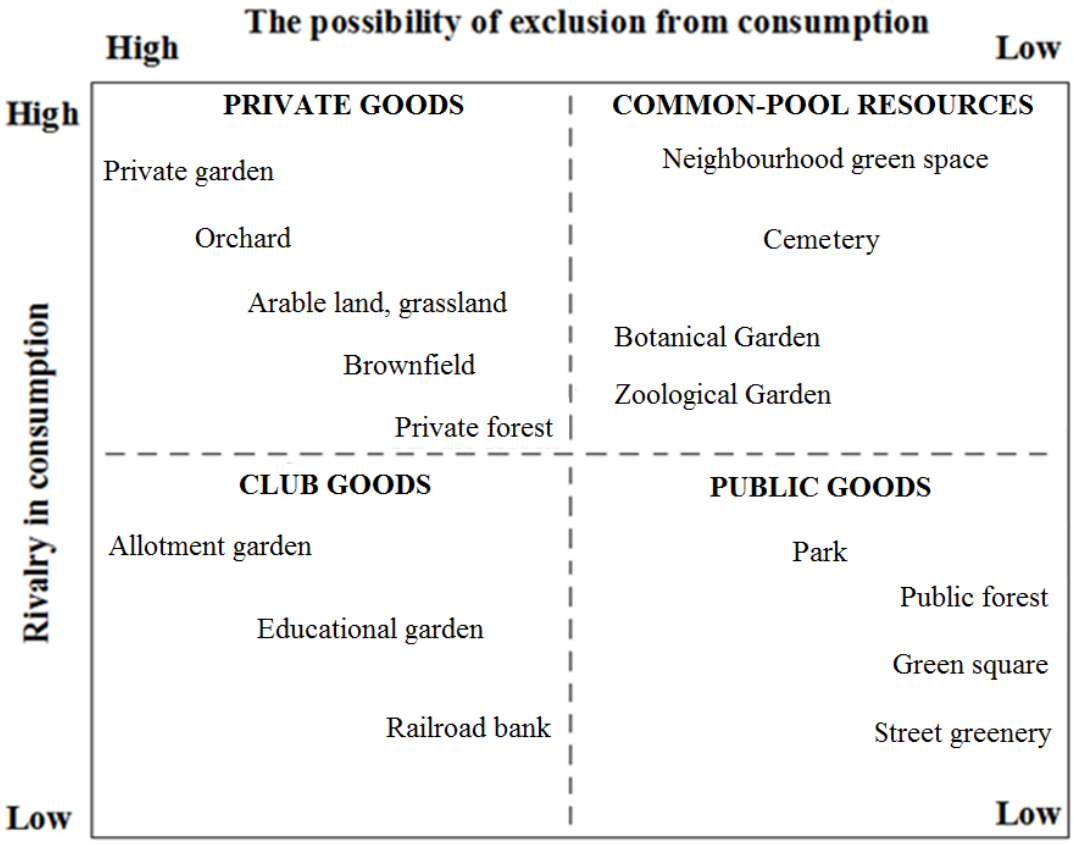

Figure 1. Different types of UGS in terms of rivalry in consumption and exclusion from consumption.

I developed my analytical framework in response to the complex aspects related to UGS provision and the need to prioritize them. The system of three levels of UGS provision proposed in this thesis (availability, accessibility, and attractiveness) and the related indicators can help to organize knowledge about all UGS, which is necessary to plan a city which is friendly to residents and resistant to climate change (Carter et al., 2015; Rice et al., 2020). Identifying barriers, analyzing indicators and embedding these aspects in the context of environmental justice can help policy makers and planners make the best possible decisions about creating new UGS, and how best to manage those which already exist. Indicators referring to these three levels should form the basis of the standards of providing UGS to residents.

I used my theoretical framework from this dissertation in further research related to formal and informal UGS for a selected part of the city of Lodz (Jasień and Karolewka river valleys). I pointed out that a detailed analysis of land cover based on an orthophotomap, in combination with geodetic and planning documents, allows for a detailed classification of UGS. Moreover, it is also important to investigate the demand side related to the use of UGS, which is another strand of my current research, regarding the perceived accessibility and attractiveness of UGS

in the Jasień river valley, based on a representative survey of inhabitants that responded to a geo-questionnaire. The results of the survey will serve as an important supplement to the expert assessments of UGS accessibility and attractiveness that I have carried out so far.

Finally, the analytical framework that I developed and used in my articles has been followed by other researchers. Among other purposes, my framework was used as a basis to create UGS quality indicators and to analyse environmental justice in the context of UGS provision (Kraemer and Kabisch, 2021; Kronenberg et al., 2020; Li et al., 2019; Noël et al., 2021; Pérez-delHoyo et al., 2021). My analytical framework is obviously not definitive and final, it needs to be developed further, but it is a milestone that is used to build new and even more complete classifications of barriers affecting UGS provision (cf. Wolff et al., 2022). And it is already being used in other contexts, as in the case of Barber et al. (2021) who derived the indicators they used from "the excellent original papers by our project colleagues," i.e., those papers that constitute the present dissertation. Ultimately, the three levels of UGS provision (availability, accessibility, and attractiveness) along with the specific indicators that I proposed may be used in research and planning in many other cities, and with regard to different types of UGS.

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Appendix 1 – Supplementary Material to Article 3

Statistics

Indicator	Average	Minimum	Maximum
1. New buildings	0.00	0.00	0.29
2. New roads	0.05	0.00	0.71
3. Lack of local zoning plans	0.95	0.29	1.00
4. Lack of protection in local zoning plans	0.88	0.00	1.00
5. Lack of historic preservation in local zoning plans	0.57	0.00	1.00
6. Entrances not connected with pedestrian crossings	0.46	0.00	1.00
7. Distribution of park entrances	0.38	0.08	0.91
8. Entrance fee	0.02	0.00	1.00
9. Opening hours	0.05	0.00	1.00
10. Limited accessibility of part of a park	0.01	0.00	0.11
11. Fences and buildings around a park	0.50	0.00	1.00
12. Crime in neighborhood of a park	0.00	0.00	0.01
13a. Poor existence of footpaths	0.10	0.00	0.14
13b. Poor existence of toilets	0.70	0.00	1.00
13c. Poor existence of lighting	0.17	0.00	1.00
14a. Poor existence of playgrounds	0.56	0.00	1.00
14b. Poor existence of sport facilities	0.80	0.00	1.00
14c. Poor existence of outdoor gyms	0.71	0.00	1.00
15. Poor existence of water	0.98	0.38	1.00
16. Loud outdoor events	0.03	0.00	1.00
17. Transport noise	0.32	0.00	1.00
18. Particulates in a park	0.49	0.00	1.00
19. Lack of biologically active space	0.06	0.00	0.76
20. Area of a park	1827859.51	0.00	1901992.05

Indicators

Name of park/Green square	1. New buildings	2. New roads	3. Lack of local zoning plans	4. Lack of protection in local zoning plans	5. Lack of historic preservation in local zoning plans	6. Entrances not connected with pedestrian crossings	7. Distribution of park entrances	8. Entrance fee	9. Opening hours	10. Limited accessibility of part of a park	11. Fences and buildings around a park	12. Crime in neighborhood of a park	13a. Poor existence of footpaths	13b. Poor existence of toilets	13c. Poor existence of lighting	14a. Poor existence of playgrounds	14b. Poor existence of sport facilities	14c. Poor existence of outdoor gyms	15. Poor existence of water	16. Loud outdoor events	17. Transport noise	18. Particulates in a park	19. Lack of biologically active space	20. Area of a park
Botanical Garden	0%	2%	98%	4%	100%	50%	71%	1	1	1%	89%	0.0000	0.11	0	0	0	1	1	98%	1	3%	0%	1%	1237374
Zoological Garden	0%	15%	85%	100%	0%	0%	45%	1	1	0%	99%	0.0000	0.10	0	1	0	1	1	99%	0	13%	0%	2%	1737388
Grabienski Forest Park	0%	0%	100%	100%	100%	100%	41%	0	0	0%	44%	0.0000	0.13	0	0	1	1	0	100%	0	0%	0%	0%	1880712
1st May Park	0%	0%	100%	100%	100%	83%	44%	0	0	0%	41%	0.0000	0.12	1	0	1	1	1	58%	0	0%	0%	0%	1613765
3rd May Park	0%	18%	82%	0%	0%	50%	41%	0	0	4%	41%	0.0000	0.12	0	0	0	0	1	99%	0	4%	100%	16%	1674611
Baden Powell Park	0%	11%	89%	81%	94%	75%	27%	0	0	2%	57%	0.0000	0.10	0	0	0	0	0	100%	0	2%	63%	3%	1716295
Helenow Park	0%	0%	100%	100%	0%	36%	24%	0	0	0%	78%	0.0001	0.09	0	0	0	0	1	90%	0	16%	100%	1%	1812721
Park in Lososiowa Street	0%	0%	100%	100%	100%	36%	22%	0	0	0%	56%	0.0003	0.13	1	0	1	1	0	100%	1	2%	0%	0%	1851756
Mickiewicz Park	0%	0%	100%	100%	0%	69%	26%	0	0	0%	70%	0.0000	0.11	0	0	0	0	0	94%	0	4%	0%	1%	1405282
Strug Park	0%	0%	100%	100%	100%	60%	20%	0	0	2%	29%	0.0004	0.10	0	0	0	1	0	100%	0	0%	0%	1%	1874509
Army of Lodz Park	0%	0%	100%	100%	100%	100%	56%	0	0	0%	75%	0.0000	0.13	1	0	0	1	1	100%	0	0%	0%	0%	1826794
Sienkiewicz Park	0%	0%	100%	100%	0%	14%	40%	0	1	1%	96%	0.0007	0.09	0	0	0	1	1	100%	0	10%	100%	3%	1857427
Dabrowski Park	0%	0%	100%	100%	100%	100%	30%	0	0	0%	52%	0.0001	0.10	1	0	1	0	0	100%	0	8%	100%	1%	1847702
Kilinski Park	0%	0%	100%	100%	0%	25%	31%	0	0	0%	62%	0.0001	0.12	1	0	1	1	0	100%	0	49%	100%	0%	1880359
Matejko Park	0%	0%	100%	100%	0%	67%	41%	0	1	0%	98%	0.0003	0.07	0	0	0	1	1	100%	0	17%	100%	2%	1878854
Pilsudski Park	0%	0%	100%	100%	6%	24%	8%	0	0	2%	25%	0.0000	0.12	0	0	0	0	0	98%	1	4%	0%	1%	0
Poniatowski Park	0%	0%	100%	100%	0%	21%	21%	0	0	3%	34%	0.0000	0.10	0	0	0	1	0	99%	0	39%	33%	1%	1475367
Slowacki Park	0%	0%	100%	100%	0%	25%	36%	0	0	0%	10%	0.0002	0.10	0	0	0	0	1	100%	0	92%	100%	1%	1868357
Klepacz Park	0%	4%	96%	100%	0%	45%	39%	0	0	6%	52%	0.0002	0.10	1	0	1	1	1	100%	0	22%	33%	5%	1870700
Zaruski Park	0%	0%	100%	0%	100%	73%	14%	0	0	0%	26%	0.0000	0.11	0	0	0	1	0	100%	0	0%	100%	0%	1814398
Zeromski Park	0%	0%	100%	100%	100%	0%	15%	0	0	0%	3%	0.0005	0.09	0	0	0	1	0	100%	0	3%	0%	8%	1878082
Moniuszko Park	0%	0%	100%	0%	0%	0%	27%	0	0	0%	21%	0.0007	0.08	1	0	1	1	1	100%	0	11%	100%	0%	1885049
Staszic Park	0%	0%	100%	100%	0%	10%	25%	0	0	0%	65%	0.0004	0.09	0	0	0	1	1	100%	0	20%	100%	1%	1861334
Grey Ranks Park	0%	14%	86%	100%	100%	56%	17%	0	0	0%	62%	0.0001	0.10	0	0	0	0	0	100%	0	0%	0%	2%	1798405
Rejtan Park	0%	0%	100%	100%	0%	100%	34%	0	0	0%	98%	0.0004	0.10	1	0	0	0	0	100%	0	10%	0%	0%	1832162
Anders Park	0%	0%	100%	100%	100%	76%	12%	0	0	0%	59%	0.0005	0.09	1	0	1	1	1	100%	0	0%	0%	4%	1860754
Reymont Park	0%	0%	100%	100%	0%	73%	30%	0	0	0%	73%	0.0003	0.10	0	0	0	1	1	85%	0	9%	100%	1%	1842439
Kielecki Park	0%	0%	100%	100%	100%	50%	25%	0	0	1%	0%	0.0004	0.10	1	0	0	1	1	100%	0	2%	0%	12%	1882697
Legions Park	0%	0%	100%	31%	0%	21%	15%	0	0	1%	55%	0.0002	0.09	1	0	0	1	1	100%	0	14%	100%	3%	1802201
Janow Park	0%	0%	100%	100%	100%	29%	32%	0	0	0%	50%	0.0001	0.11	1	0	0	1	1	100%	0	0%	0%	0%	1849835
Mlynek Park	0%	0%	100%	100%	100%	100%	29%	0	0	0%	19%	0.0000	0.12	1	0	1	1	1	81%	0	0%	0%	2%	1741650
Smulsko Park	0%	0%	100%	100%	100%	100%	45%	0	0	0%	84%	0.0000	0.12	1	0	0	1	1	100%	0	0%	0%	0%	1816916
Park on Jasien River	0%	6%	94%	100%	97%	86%	25%	0	0	0%	48%	0.0001	0.12	0	0	0	0	0	94%	0	3%	2%	0%	1755048
Survivors Park	0%	0%	100%	100%	100%	50%	35%	0	0	0%	59%	0.0000	0.08	0	0	1	1	1	98%	0	16%	20%	9%	1818854
Park on Ner River	0%	0%	100%	100%	100%	100%	26%	0	0	0%	7%	0.0000	0.13	0	0	0	0	0	100%	0	2%	0%	1%	1807276
Piastowski Park	0%	0%	100%	100%	100%	85%	23%	0	0	0%	50%	0.0002	0.11	1	0	0	1	0	100%	0	0%	0%	2%	1842477
Podolski Park	0%	0%	100%	100%	100%	69%	12%	0	0	0%	42%	0.0004	0.09	0	0	0	0	0	100%	0	20%	0%	1%	1786332
Park in Lecznicza Street	0%	0%	100%	100%	100%	0%	26%	0	0	0%	24%	0.0008	0.09	0	0	0	1	1	100%	0	0%	100%	1%	1884312
Park in Skrzywana Street	0%	5%	95%	100%	0%	50%	43%	0	0	0%	78%	0.0007	0.11	0	0	1	1	1	99%	0	12%	0%	0%	1893982
Sielanka Park	0%	0%	100%	100%	0%	36%	20%	0	0	0%	18%	0.0003	0.07	1	0	0	0	1	89%	0	92%	0%	1%	1864833
Staromiejski (Old Town) Park	0%	0%	100%	100%	0%	17%	11%	0	0	0%	17%	0.0004	0.09	0	0	0	1	0	98%	0	38%	100%	2%	1802961
Jan's Ponds Park	0%	0%	100%	100%	97%	45%	24%	0	0	4%	42%	0.0001	0.10	1	0	1	1	1	75%	0	77%	0%	1%	1738904
Widzewska Gorka Park	0%	0%	100%	100%	100%	44%	19%	0	0	4%	49%	0.0004	0.08	0	0	0	0	0	100%	0	0%	0%	6%	1820480
Widzew Park	0%	0%	100%	100%	100%	71%	26%	0	0	1%	60%	0.0001	0.10	0	0	0	1	0	86%	0	22%	0%	0%	1841149
Wiejski Brojecka Park	0%	0%	100%	100%	100%	67%	39%	0	0	0%	34%	0.0000	0.11	1	0	0	1	0	100%	0	38%	0%	0%	1893437
Zrodliska I Park	0%	0%	100%	100%	0%	33%	39%	0	1	2%	98%	0.0000	0.10	0	0	0	0	1	98%	0	26%	100%	3%	1797778
Zrodliska II Park	0%	1%	99%	100%	0%	100%	47%	0	1	0%	99%	0.0002	0.11	1	0	1	1	1	100%	0	0%	100%	0%	1838973
Olechowka Springs Park	0%	0%	100%	100%	100%	62%	39%	0	0	0%	0%	0.0000	0.11	1	0	0	1	0	100%	0	1%	0%	2%	1725699
Abramowski green square	0%	7%	93%	100%	0%	0%	51%	0	0	0%	89%	0.0009	0.08	1	0	0	1	1	100%	0	6%	100%	6%	1871989
Rynkowska green square	0%	0%	100%	100%	0%	100%	49%	0	0	0%	79%	0.0000	0.07	1	0	1	1	1	100%	0	53%	100%	12%	1900559
Jozewski green square	0%	0%	100%	100%	0%	75%	63%	0	0	0%	63%	0.0034	0.03	1	0	1	1	1	100%	0	37%	100%	42%	1897200
Rubinstein green square	0%	0%	100%	0%	0%	0%	43%	0	0	0%	81%	0.0048	0.05	1	0	0	1	1	100%	0	18%	100%	16%	1895719
Haller green square	0%	0%	100%	100%	100%	0%	53%	0	0	5%	42%	0.0013	0.09	1	0	0	1	1	100%	0	74%	100%	5%	1894214
John Paul II green square	0%	0%	100%	100%	0%	50%	37%	0	0	0%	0%	0.0006	0.14	1	0	1	1	1	100%	0	7%	100%	4%	1892914
Reymont green square	0%	0%	100%	100%	0%	0%	91%	0	0	0%	96%	0.0056	0.08	1	0	1	1	1	100%	0	100%	100%	0%	1901402
Rudzka Gora Park	0%	0%	100%	100%	100%	100%	32%	0	0	1%	75%	0.0000	0.12	1	0	1	1	1	100%	0	2%	100%	2%	1789652
Gdansk green square	0%	0%	100%	100%	100%	33%	32%	0	0	0%	55%	0.0006	0.08	1	0	1	0	1	100%	0	15%	0%	0%	1882846
Gdynia scymen green square	0%	0%	100%	100%	100%	67%	20%	0	0	0%	7%	0.0002	0.12	1	0	1	1	1	100%	0	12%	0%	8%	1872937
Dubaniewicz green square	0%	0%	100%	100%	100%	40%	22%	0	0	0%	54%	0.0003	0.08	1	0	1	0	0	100%	0	51%	100%	10%	1863247
Szustrowa green square	0%	8%	92%	100%	100%	0%	76%	0	0	0%	54%	0.0002	0.13	1	1	1	1	1	99%	0	54%	12%	0%	1888973
Linke green square	0%	0%	100%	100%	0%	0%	77%	0	0	0%	100%	0.0084	0.10	1	0	1	1	1	100%	0	97%	100%	17%	1900580
Hungarian Revolution of 1956 green square	0%	0%	100%	100%	0%	0%	67%	0	0	0%	40%	0.0069	0.06	1	0	1	1	1	100%	0	88%	100%	21%	1901677
Kolbe green square	0%	0%	100%	100%	100%	86%	23%	0	0	0%	60%	0.0007	0.11	1	0	0	1	1	100%	0	52%	0%	2%	1881419
Strzeminski green square	0%	0%	100%	100%	100%	100%	60%	0	0	0%	100%	0.0000	0.13	1	1	1	1	1	100%	0	0%	100%	0%	1900497
Strzelec green square	0%	7%	93%	2%	0%	50%	39%	0	0	0%	33%	0.0005	0.11	1	0	1	1	1	100%	0	0%	100%	10%	1900749
Forest green square near Odrzanska Street	0%	0%	100%	100%	100%	40%	36%	0	0	0%	0%	0.0004	0.14	1	0	1	1	1	100%	0	1%	0%	0%	1888897
Niemczyk green square	0%	5%	95%	100%	0%	100%	41%	0	0	0%	63%	0.0003	0.13	1	0	1	1	1	100%	0	91%	100%	0%	1885553

Name of park/Green square	1. New buildings	2. New roads	3. Lack of local zoning plans	4. Lack of protection in local zoning plans	5. Lack of historic preservation in local zoning plans	6. Entrances not connected with pedestrian crossings	7. Distribution of park entrances	8. Entrance fee	9. Opening hours	10. Limited accessibility of part of a park	11. Fences and buildings around a park	12. Crime in neighborhood of a park	13a. Poor existence of footpaths	13b. Poor existence of toilets	13c. Poor existence of lighting	14a. Poor existence of playgrounds	14b. Poor existence of sport facilities	14c. Poor existence of outdoor gyms	15. Poor existence of water	16. Loud outdoor events	17. Transport noise	18. Particulates in a park	19. Lack of biologically active space	20. Area of a park
Olszynka Grochowska green square	29%	0%	100%	100%	100%	80%	24%	0	0	0%	72%	0.0010	0.11	1	0	1	1	1	100%	0	0%	0%	4%	1886795
Primate of the Millennium green square	0%	0%	100%	100%	100%	17%	39%	0	0	0%	0%	0.0009	0.10	1	0	1	1	1	100%	0	100%	0%	8%	1891973
Wiskitno pond green square	0%	0%	100%	100%	100%	0%	67%	0	0	0%	97%	0.0000	0.10	1	0	1	1	0	38%	0	11%	0%	0%	1893509
Green square near Palka and Pankiewicz Streets	0%	0%	100%	100%	100%	0%	51%	0	0	0%	16%	0.0012	0.14	1	1	1	1	1	100%	0	100%	100%	0%	1901992
Green square near Palka Street	0%	9%	91%	100%	100%	0%	71%	0	0	0%	40%	0.0000	0.11	1	1	1	1	1	100%	0	100%	100%	0%	1900627
Aleja PCK green square	0%	3%	97%	100%	0%	50%	28%	0	0	2%	82%	0.0013	0.10	1	0	1	1	1	100%	0	7%	100%	46%	1889034
Lodzkie Blonia green square	0%	10%	90%	38%	0%	63%	34%	0	0	0%	42%	0.0021	0.09	1	0	1	1	1	100%	0	11%	100%	8%	1899549
Hotel Centrum green square	0%	0%	100%	100%	100%	100%	25%	0	0	0%	28%	0.0000	0.12	1	0	1	1	1	100%	0	6%	0%	0%	1514219
Paris Commune green square	0%	0%	100%	100%	0%	0%	26%	0	0	0%	41%	0.0057	0.06	1	0	1	1	1	100%	0	5%	100%	8%	1900565
Independence green square	0%	0%	100%	0%	0%	43%	30%	0	0	0%	33%	0.0025	0.08	1	0	1	1	1	100%	0	78%	100%	9%	1895729
Piastowski green square	0%	26%	74%	100%	100%	0%	21%	0	0	0%	0%	0.0024	0.09	1	0	0	0	0	100%	0	51%	100%	17%	1894418
Green square near Grey Ranks Park	0%	8%	92%	100%	100%	100%	48%	0	0	0%	53%	0.0002	0.08	1	1	1	1	1	100%	0	0%	0%	0%	1889623
Green square near Survivors Park	0%	0%	100%	100%	100%	100%	77%	0	0	0%	70%	0.0004	0.12	0	0	1	1	1	100%	0	6%	98%	8%	1894418
Green square near Switezianki Street	0%	0%	100%	100%	100%	80%	31%	0	0	0%	78%	0.0002	0.13	1	0	1	1	1	100%	0	23%	0%	1%	1859237
Green square near Hipoteczna Street	0%	0%	100%	100%	100%	40%	37%	0	0	0%	32%	0.0002	0.11	0	0	0	1	1	100%	0	29%	0%	1%	1841356
Green square near Aleksandrowska Street	0%	0%	100%	100%	100%	100%	32%	0	0	0%	40%	0.0005	0.11	1	1	1	1	1	100%	0	54%	0%	0%	1891904
Green square near Brzezna Street	0%	0%	100%	100%	0%	0%	72%	0	0	0%	11%	0.0057	0.00	1	1	1	1	1	100%	0	100%	100%	15%	1901604
Green square near Drewnowska and Wlokniarzy Streets	0%	54%	46%	100%	100%	25%	42%	0	0	0%	38%	0.0000	0.11	1	1	1	1	1	100%	0	100%	0%	0%	1891694
Green square near Gdanska and Konernik Streets	0%	0%	100%	100%	0%	33%	38%	0	0	0%	89%	0.0021	0.08	1	1	0	1	0	100%	0	8%	100%	26%	1899046
Green square near Gdanska and Wolczanska Streets	0%	0%	100%	100%	0%	100%	49%	0	0	0%	83%	0.0026	0.09	1	1	0	0	0	100%	0	22%	100%	8%	1898660
Green square near Junacka Street	0%	0%	100%	0%	100%	100%	49%	0	0	0%	98%	0.0000	0.11	0	0	0	0	0	100%	0	0%	0%	1%	1892800
Green square near Kalinowa Street	0%	0%	100%	100%	22%	100%	34%	0	0	0%	68%	0.0000	0.13	1	0	1	1	1	100%	0	19%	0%	0%	1894934
Green square near Konstytucyjna and Malachowski Streets	1%	13%	87%	100%	100%	100%	53%	0	0	0%	56%	0.0001	0.13	1	0	1	1	1	100%	0	2%	100%	0%	1802214
Green square near Lisciasta Street	0%	0%	100%	100%	100%	95%	29%	0	0	0%	57%	0.0001	0.11	1	0	0	0	0	86%	0	12%	0%	1%	1751646
Green square near Lutomierska and Dewnowska Streets	0%	51%	49%	100%	100%	27%	28%	0	0	0%	54%	0.0001	0.09	1	0	0	1	1	100%	0	16%	0%	1%	1838888
Green square near Maratonska Street	10%	62%	38%	100%	100%	44%	19%	0	0	0%	21%	0.0001	0.12	1	0	0	1	0	100%	0	66%	0%	9%	1807153
Green square near Mazowiecka and Lawinowa Streets	0%	44%	56%	100%	100%	100%	54%	0	0	0%	28%	0.0000	0.14	1	0	1	1	1	100%	0	0%	100%	0%	1894048
Green square near Narutowicz Street	0%	0%	100%	0%	0%	0%	27%	0	0	0%	0%	0.0047	0.10	1	1	1	1	1	100%	0	54%	100%	26%	1901974
Green square near Paris Street	0%	71%	29%	100%	99%	50%	53%	0	0	0%	22%	0.0003	0.11	1	1	0	1	1	100%	0	40%	34%	0%	1892934
Green square near Piotrkowska Street	0%	0%	100%	100%	0%	60%	43%	0	0	0%	56%	0.0018	0.10	1	1	1	1	1	100%	0	15%	100%	0%	1898349
Green square near Sienkiewicz and Narutowicz Streets	0%	0%	100%	0%	0%	0%	50%	0	0	5%	45%	0.0049	0.05	1	0	1	1	1	100%	0	53%	100%	76%	1898975
Green square near Sienkiewicz and Traugutt Streets	0%	0%	100%	0%	0%	0%	74%	0	0	11%	94%	0.0146	0.10	1	0	1	1	1	100%	0	61%	100%	3%	1901736
Green square near Sienkiewicz and Tuwim Streets	0%	0%	100%	0%	0%	0%	38%	0	0	0%	57%	0.0058	0.07	1	1	1	1	1	100%	0	87%	100%	4%	1901797
Green square near Sporna and Pankieiwcz Streets	0%	38%	62%	100%	100%	0%	39%	0	0	0%	35%	0.0000	0.14	1	1	1	1	1	100%	0	100%	100%	0%	1899837
Green square near Strykowska and Oswiatowa Streets	0%	66%	34%	100%	100%	0%	63%	0	0	0%	31%	0.0000	0.14	1	1	1	1	1	100%	0	100%	0%	0%	1901201
Green square near Strykowska and Zmienna Streets	0%	0%	100%	100%	100%	50%	36%	0	0	0%	0%	0.0005	0.12	1	0	1	1	1	100%	0	81%	0%	0%	1888444
Green square near Tymieniecki and Piotrkowska Streets	0%	0%	100%	100%	0%	0%	33%	0	0	0%	46%	0.0003	0.02	0	1	1	1	1	100%	0	100%	100%	5%	1898971
Green square near Wilenska Street	0%	0%	100%	100%	100%	0%	42%	0	0	4%	46%	0.0018	0.14	1	0	0	1	0	100%	0	0%	0%	9%	1898492
Green square near Wojska Polskiego Street	0%	1%	99%	100%	100%	25%	24%	0	0	0%	16%	0.0003	0.08	1	0	1	1	1	86%	0	97%	0%	5%	1860748
Green square near Wojska Polskiego Street (near bus station)	0%	3%	97%	100%	100%	11%	40%	0	0	0%	59%	0.0014	0.10	1	0	1	1	0	100%	0	60%	87%	0%	1889260
Green square near Wojska Polskiego and Franciszkanska Streets	0%	28%	72%	100%	100%	20%	42%	0	0	0%	43%	0.0021	0.09	1	0	1	1	1	100%	0	95%	100%	2%	1894876
Green square near Wolczanska and 6 August Streets	0%	0%	100%	100%	0%	0%	38%	0	0	0%	52%	0.0099	0.07	1	0	1	1	1	100%	0	100%	100%	67%	1901925
Green squar near Wyspianski and Chodakiewicz Streets	0%	0%	100%	100%	0%	100%	65%	0	0	0%	99%	0.0004	0.09	1	0	0	1	1	100%	0	0%	0%	17%	1900172
Green square near Zachodnia ad Drewnowska Streets	0%	0%	100%	100%	0%	0%	48%	0	0	2%	39%	0.0006	0.08	1	0	1	1	1	99%	0	92%	98%	14%	1895135
Green square near Zgierska and Julianowska Streets	0%	0%	100%	100%	100%	42%	30%	0	0	0%	0%	0.0004	0.08	1	0	1	0	1	100%	0	100%	0%	0%	1892405
Green square near Zgierska and Sowinski Streets	0%	0%	100%	58%	51%	0%	23%	0	0	1%	49%	0.0001	0.11	0	0	1	1	1	100%	0	20%	0%	15%	1887323
Wodny Rynek Green square	0%	0%	100%	100%	0%	0%	61%	0	0	0%	38%	0.0020	0.12	1	1	1	1	1	100%	0	0%	100%	0%	1896834
Cyklodrom Green square	0%	0%	100%	100%	100%	67%	45%	0	0	0%	42%	0.0000	0.07	0	1	0	0	0	100%	0	5%	0%	2%	1885409

Standardized indicators

Name of park/Green square	1. New buildings	2. New roads	3. Lack of local zoning plans	4. Lack of protection in local zoning plans	5. Lack of historic preservation in local zoning plans	6. Entrances not connected with pedestrian crossings	7. Distribution of park entrances	8. Entrance fee	9. Opening hours	10. Limited accessibility of part of a park	11. Fences and buildings around a park	12. Crime in neighborhood of a park	13a. Poor existence of footpaths	13b. Poor existence of toilets	13c. Poor existence of lighting	14a. Poor existence of playgrounds	14b. Poor existence of sport facilities	14c. Poor existence of outdoor gyms	15. Poor existence of water	16. Loud outdoor events	17. Transport noise	18. Particulates in a park	19. Lack of biologically active space	20. Area of a park
Botanical Garden	0	0.03	0.97	0.04	1	0.5	0.76	1	1	0.1	0.89	0	0.83	0	0	0	1	1	0.96	1	0.03	0	0.01	0.65
Zoological Garden	0	0.21	0.79	1	0	0	0.44	1	1	0	0.99	0	0.77	0	1	0	1	1	0.98	0	0.13	0	0.03	0.91
Grabienski Forest Park	0	0	1	1	1	1	0.39	0	0	0	0.44	0	0.95	0	0	1	1	0	1	0	0	0	0	0.99
1st May Park	0	0	1	1	1	0.83	0.43	0	0	0.01	0.41	0	0.87	1	0	1	1	1	0.32	0	0	0	0	0.85
3rd May Park	0	0.26	0.74	0	0	0.5	0.4	0	0	0.33	0.41	0	0.85	0	0	0	0	1	0.99	0	0.04	1	0.22	0.88
Baden Powell Park	0	0.15	0.85	0.81	0.94	0.75	0.24	0	0	0.17	0.57	0	0.76	0	0	0	0	0	1	0	0.02	0.63	0.04	0.9
Helenow Park	0	0	1	1	0	0.36	0.19	0	0	0	0.78	0	0.7	0	0	0	0	1	0.84	0	0.16	1	0.01	0.95
Park in Lososiowa Street	0	0	1	1	1	0.36	0.17	0	0	0	0.56	0.02	0.97	1	0	1	1	0	1	1	0.02	0	0	0.97
Mickiewicz Park	0	0	1	1	0	0.69	0.21	0	0	0	0.7	0	0.81	0	0	0	0	0	0.9	0	0.04	0	0.01	0.74
Strug Park	0	0	1	1	1	0.6	0.15	0	0	0.15	0.29	0.02	0.73	0	0	0	1	0	1	0	0	0	0.02	0.99
Army of Lodz Park	0	0	1	1	1	1	0.58	0	0	0	0.75	0	0.99	1	0	0	1	1	1	0	0	0	0	0.96
Sienkiewicz Park	0	0	1	1	0	0.14	0.38	0	1	0.12	0.96	0.05	0.64	0	0	0	1	1	1	0	0.1	1	0.03	0.98
Dabrowski Park	0	0	1	1	1	1	0.27	0	0	0	0.52	0.01	0.73	1	0	1	0	0	1	0	0.08	1	0.01	0.97
Kilinski Park	0	0	1	1	0	0.25	0.28	0	0	0	0.62	0.01	0.87	1	0	1	1	0	1	0	0.48	1	0	0.99
Matejko Park	0	0	1	1	0	0.67	0.4	0	1	0	0.98	0.02	0.55	0	0	0	1	1	1	0	0.17	1	0.03	0.99
Pilsudski Park	0	0	1	1	0.06	0.24	0	0	0	0.16	0.25	0	0.86	0	0	0	0	0	0.96	1	0.04	0	0.01	0
Poniatowski Park	0	0	1	1	0	0.21	0.15	0	0	0.25	0.34	0	0.77	0	0	0	1	0	0.98	0	0.39	0.33	0.01	0.78
Slowacki Park	0	0	1	1	0	0.25	0.33	0	0	0	0.1	0.01	0.72	0	0	0	0	1	1	0	0.92	1	0.01	0.98
Klepacz Park	0	0.06	0.94	1	0	0.45	0.38	0	0	0.51	0.52	0.02	0.7	1	0	1	1	1	1	0	0.22	0.33	0.07	0.98
Zaruski Park	0	0	1	0	1	0.73	0.08	0	0	0	0.26	0	0.79	0	0	0	1	0	1	0	0	1	0	0.95
Zeromski Park	0	0	1	1	1	0	0.08	0	0	0	0.03	0.04	0.66	0	0	0	1	0	1	0	0.03	0	0.1	0.99
Moniuszko Park	0	0	1	0	0	0	0.24	0	0	0	0.21	0.05	0.57	1	0	1	1	1	1	0	0.11	1	0	0.99
Staszic Park	0	0	1	1	0	0.1	0.2	0	0	0.01	0.65	0.02	0.64	0	0	0	1	1	1	0	0.2	1	0.02	0.98
Grey Ranks Park	0	0.2	0.8	1	1	0.56	0.11	0	0	0	0.62	0.01	0.72	0	0	0	0	0	1	0	0	0	0.03	0.95
Rejtan Park	0	0	1	1	0	1	0.31	0	0	0.01	0.98	0.03	0.71	1	0	0	0	0	1	0	0.1	0	0	0.96
Anders Park	0	0	1	1	1	0.76	0.05	0	0	0.04	0.59	0.03	0.64	1	0	1	1	1	1	0	0	0	0.05	0.98
Reymont Park	0	0	1	1	0	0.73	0.26	0	0	0	0.73	0.02	0.77	0	0	0	1	1	0.75	0	0.09	1	0.01	0.97
Kielecki Park	0	0	1	1	1	0.5	0.21	0	0	0.09	0	0.03	0.73	1	0	0	1	1	1	0	0.02	0	0.16	0.99
Legions Park	0	0	1	0.31	0	0.21	0.08	0	0	0.09	0.55	0.01	0.67	1	0	0	1	1	1	0	0.14	1	0.03	0.95
Janow Park	0	0	1	1	1	0.29	0.29	0	0	0	0.5	0.01	0.78	1	0	0	1	1	1	0	0	0	0	0.97
Mlynek Park	0	0	1	1	1	1	0.25	0	0	0.01	0.19	0	0.87	1	0	1	1	1	0.69	0	0	0	0.02	0.92
Smulsko Park	0	0	1	1	1	1	0.45	0	0	0	0.84	0	0.88	1	0	0	1	1	1	0	0	0	0	0.96
Park on Jasien River	0	0.09	0.91	1	0.97	0.86	0.2	0	0	0	0.48	0.01	0.85	0	0	0	0	0	0.91	0	0.03	0.02	0.01	0.92
Survivors Park	0.02	0	1	1	1	0.5	0.32	0	0	0.01	0.59	0	0.6	0	0	1	1	1	0.96	0	0.16	0.2	0.12	0.96
Park on Ner River	0	0	1	1	1	1	0.22	0	0	0	0.07	0	0.94	0	0	0	0	0	1	0	0.02	0	0.02	0.95
Piastowski Park	0	0	1	1	1	0.85	0.18	0	0	0.03	0.5	0.01	0.83	1	0	0	1	0	1	0	0	0	0.02	0.97
Podolski Park	0	0	1	1	1	0.69	0.04	0	0	0	0.42	0.03	0.66	0	0	0	0	0	1	0	0.2	0	0.02	0.94
Park in Lecznicza Street	0	0	1	1	1	0	0.22	0	0	0	0.24	0.05	0.63	0	0	0	1	1	1	0	0	1	0.02	0.99
Park in Skrzywana Street	0	0.07	0.93	1	0	0.5	0.43	0	0	0	0.78	0.05	0.8	0	0	1	1	1	0.98	0	0.12	0	0	1
Sielanka Park	0	0	1	1	0	0.36	0.15	0	0	0	0.18	0.02	0.55	1	0	0	0	1	0.82	0	0.92	0	0.01	0.98
Staromiejski (Old Town) Park	0	0	1	1	0	0.17	0.04	0	0	0	0.17	0.03	0.63	0	0	0	1	0	0.97	0	0.38	1	0.03	0.95
Jan's Ponds Park	0	0	1	1	0.97	0.45	0.19	0	0	0.39	0.42	0	0.76	1	0	1	1	1	0.6	0	0.77	0	0.01	0.91
Widzewska Gorka Park	0	0	1	1	1	0.44	0.13	0	0	0.4	0.49	0.03	0.61	0	0	0	0	0	1	0	0	0	0.08	0.96
Widzew Park	0	0	1	1	1	0.71	0.22	0	0	0.06	0.6	0	0.74	0	0	0	1	0	0.77	0	0.22	0	0	0.97
Wiejski Brojecka Park	0	0	1	1	1	0.67	0.38	0	0	0	0.33	0	0.84	1	0	0	1	0	1	0	0.38	0	0	1
Zrodliska I Park	0	0	1	1	0	0.33	0.37	0	1	0.23	0.98	0	0.73	0	0	0	0	1	0.97	0	0.26	1	0.03	0.95
Zrodliska II Park	0	0.02	0.98	1	0	1	0.47	0	1	0	0.99	0.02	0.85	1	0	1	1	1	0.99	0	0	1	0.01	0.97
Olechowka Springs Park	0	0	1	1	1	0.62	0.38	0	0	0	0	0	0.84	1	0	0	1	0	0.99	0	0.01	0	0.03	0.91
Abramowski green square	0	0.1	0.9	1	0	0	0.52	0	0	0	0.89	0.06	0.57	1	0	0	1	1	1	0	0.06	1	0.09	0.98
Rynkowska green square	0	0	1	1	0	1	0.49	0	0	0	0.79	0	0.54	1	0	1	1	1	1	0	0.53	1	0.16	1
Jozewski green square	0	0	1	1	0	0.75	0.66	0	0	0	0.63	0.23	0.22	1	0	1	1	1	1	0	0.37	1	0.56	1
Rubinstein green square	0	0	1	0	0	0	0.42	0	0	0	0.81	0.33	0.37	1	0	0	1	1	1	0	0.18	1	0.22	1
Haller green square	0	0	1	1	1	0	0.54	0	0	0.48	0.42	0.09	0.66	1	0	0	1	1	1	0	0.74	1	0.07	1
John Paul II green square	0	0	1	1	0	0.5	0.35	0	0	0	0	0.04	1	1	0	1	1	1	1	0	0.07	1	0.05	1
Reymont green square	0	0	1	1	0	0	1	0	0	0	0.96	0.38	0.57	1	0	1	1	1	1	0	1	1	0	1
Rudzka Gora Park	0	0	1	1	1	1	0.29	0	0	0.05	0.75	0	0.88	1	0	1	1	1	1	0	0.02	1	0.02	0.94
Gdansk green square	0	0	1	1	1	0.33	0.29	0	0	0	0.55	0.04	0.59	1	0	1	0	1	1	0	0.15	0	0	0.99
Gdynia scymen green square	0	0	1	1	1	0.67	0.15	0	0	0	0.07	0.02	0.86	1	0	1	1	1	1	0	0.12	0	0.11	0.98
Dubaniewicz green square	0	0	1	1	1	0.4	0.17	0	0	0	0.54	0.02	0.62	1	0	1	0	0	1	0	0.51	1	0.13	0.98
Szustrowa green square	0	0.11	0.89	1	1	0	0.81	0	0	0	0.54	0.01	0.94	1	1	1	1	1	0.98	0	0.54	0.12	0	0.99
Linke green square	0	0	1	1	0	0	0.82	0	0	0	1	0.58	0.73	1	0	1	1	1	1	0	0.97	1	0.22	1
Hungarian Revolution of 1956 green square	0	0	1	1	0	0	0.71	0	0	0	0.4	0.47	0.44	1	0	1	1	1	1	0	0.88	1	0.28	1
Kolbe green square	0	0	1	1	1	0.86	0.18	0	0	0	0.6	0.04	0.78	1	0	0	1	1	1	0	0.52	0	0.03	0.99
Strzeminski green square	0	0	1	1	1	1	0.63	0	0	0	1	0	0.93	1	1	1	1	1	1	0	0	1	0	1
Strzelec green square	0	0.1	0.9	0.02	0	0.5	0.37	0	0	0	0.33	0.03	0.84	1	0	1	1	1	1	0	0	1	0.14	1
Forest green square near Odrzanska Street	0	0	1	1	1	0.4	0.34	0	0	0	0	0.03	1	1	0	1	1	1	1	0	0.01	0	0	0.99
Niemczyk green square	0	0.07	0.93	1	0	1	0.4	0	0	0	0.63	0.02	0.93	1	0	1	1	1	1	0	0.91	1	0	0.99

Name of park/Green square	1. New buildings	2. New roads	3. Lack of local zoning plans	4. Lack of protection in local zoning plans	5. Lack of historic preservation in local zoning plans	6. Entrances not connected with pedestrian crossings	7. Distribution of park entrances	8. Entrance fee	9. Opening hours	10. Limited accessibility of part of a park	11. Fences and buildings around a park	12. Crime in neighborhood of a park	13a. Poor existence of footpaths	13b. Poor existence of toilets	13c. Poor existence of lighting	14a. Poor existence of playgrounds	14b. Poor existence of sport facilities	14c. Poor existence of outdoor gyms	15. Poor existence of water	16. Loud outdoor events	17. Transport noise	18. Particulates in a park	19. Lack of biologically active space	20. Area of a park
Olszynka Grochowska green square	1	0	1	1	1	0.8	0.2	0	0	0	0.72	0.07	0.79	1	0	1	1	1	1	0	0	0	0.06	0.99
Primate of the Millennium green square	0	0	1	1	1	0.17	0.37	0	0	0	0	0.06	0.74	1	0	1	1	1	1	0	1	0	0.1	0.99
Wiskitno pond green square	0	0	1	1	1	0	0.71	0	0	0	0.97	0	0.72	1	0	1	1	0	0	0	0.11	0	0	1
Green square near Palka and Pankiewicz Streets	0	0	1	1	1	0	0.51	0	0	0	0.16	0.08	1	1	1	1	1	1	1	0	1	1	0	1
Green square near Palka Street	0	0.13	0.87	1	1	0	0.75	0	0	0	0.4	0	0.82	1	1	1	1	1	1	0	1	1	0	1
Aleja PCK green square	0	0.04	0.96	1	0	0.5	0.24	0	0	0.18	0.81	0.09	0.72	1	0	1	1	1	1	0	0.07	1	0.61	0.99
Lodzkie Blonia green square	0	0.14	0.86	0.38	0	0.63	0.32	0	0	0	0.42	0.15	0.63	1	0	1	1	1	1	0	0.11	1	0.1	1
Hotel Centrum green square	0	0	1	1	1	1	0.21	0	0	0	0.28	0	0.91	1	0	1	1	1	1	0	0.06	0	0	0.8
Paris Commune green square	0	0	1	1	0	0	0.22	0	0	0	0.41	0.39	0.47	1	0	1	1	1	1	0	0.05	1	0.11	1
Independence green square	0	0	1	0	0	0.43	0.26	0	0	0	0.33	0.17	0.57	1	0	1	1	1	1	0	0.78	1	0.12	1
Piastowski green square	0	0.36	0.64	1	1	0	0.16	0	0	0	0	0.16	0.68	1	0	0	0	0	1	0	0.51	1	0.23	1
Green square near Grey Ranks Park	0	0.11	0.89	1	1	1	0.48	0	0	0	0.53	0.02	0.6	1	1	1	1	1	1	0	0	0	0	0.99
Green square near Survivors Park	0	0	1	1	1	1	0.83	0	0	0	0.7	0.02	0.91	0	0	1	1	1	1	0	0.06	0.98	0.11	1
Green square near Switezianki Street	0	0	1	1	1	0.8	0.27	0	0	0	0.78	0.02	0.97	1	0	1	1	1	1	0	0.23	0	0.01	0.98
Green square near Hipoteczna Street	0	0	1	1	1	0.4	0.35	0	0	0	0.32	0.01	0.78	0	0	0	1	1	1	0	0.29	0	0.01	0.97
Green square near Aleksandrowska Street	0	0	1	1	1	1	0.29	0	0	0	0.4	0.04	0.83	1	1	1	1	1	1	0	0.54	0	0	0.99
Green square near Brzezna Street	0	0	1	1	0	0	0.77	0	0	0	0.11	0.39	0	1	1	1	1	1	1	0	1	1	0.19	1
Green square near Drewnowska and Wlokniarzy Streets	0	0.77	0.23	1	1	0.25	0.41	0	0	0	0.38	0	0.83	1	1	1	1	1	1	0	1	0	0	0.99
Green square near Gdanska and Kopernik Streets	0	0	1	1	0	0.33	0.37	0	0	0	0.89	0.14	0.62	1	1	0	1	0	1	0	0.08	1	0.35	1
Green square near Gdanska and Wolczanska Streets	0	0	1	1	0	1	0.49	0	0	0	0.83	0.18	0.68	1	1	0	0	0	1	0	0.22	1	0.1	1
Green square near Junacka Street	0	0	1	0	1	1	0.5	0	0	0	0.98	0	0.79	0	0	0	0	0	1	0	0	0	0.01	1
Green square near Kalinowa Street	0	0	1	1	0.22	1	0.31	0	0	0	0.68	0	0.94	1	0	1	1	1	1	0	0.19	0	0	1
Green square near Konstytucyjna and Malachowski Streets	0.03	0.19	0.81	1	1	1	0.54	0	0	0	0.56	0.01	0.99	1	0	1	1	1	1	0	0.02	1	0	0.95
Green square near Lisciasta Street	0	0	1	1	1	0.95	0.26	0	0	0	0.57	0.01	0.84	1	0	0	0	0	0.78	0	0.12	0	0.01	0.92
Green square near Lutomierska and Dewnowska Streets	0	0.72	0.28	1	1	0.27	0.24	0	0	0	0.54	0.01	0.7	1	0	0	1	1	1	0	0.16	0	0.02	0.97
Green square near Maratonska Street	0.34	0.87	0.13	1	1	0.44	0.13	0	0	0	0.21	0.01	0.89	1	0	0	1	0	1	0	0.66	0	0.12	0.95
Green square near Mazowiecka and Lawinowa Streets	0	0.63	0.37	1	1	1	0.55	0	0	0	0.28	0	1	1	0	1	1	1	1	0	0	1	0	1
Green square near Narutowicz Street	0	0	1	0	0	0	0.24	0	0	0	0	0.32	0.75	1	1	1	1	1	1	0	0.54	1	0.35	1
Green square near Paris Street	0	1	0	1	0.99	0.5	0.54	0	0	0	0.22	0.02	0.84	1	1	0	1	1	1	0	0.4	0.34	0	1
Green square near Piotrkowska Street	0	0	1	1	0	0.6	0.42	0	0	0	0.56	0.12	0.77	1	1	1	1	1	1	0	0.14	1	0	1
Green square near Sienkiewicz and Narutowicz Streets	0	0	1	0	0	0	0.5	0	0	0.45	0.45	0.34	0.4	1	0	1	1	1	1	0	0.52	1	1	1
Green square near Sienkiewicz and Traugutt Streets	0	0	1	0	0	0	0.8	0	0	1	0.94	1	0.74	1	0	1	1	1	1	0	0.61	1	0.04	1
Green square near Sienkiewicz and Tuwim Streets	0	0	1	0	0	0	0.36	0	0	0	0.57	0.4	0.49	1	1	1	1	1	1	0	0.87	1	0.06	1
Green square near Sporna and Pankiewicz Streets	0	0.53	0.47	1	1	0	0.37	0	0	0	0.35	0	1	1	1	1	1	1	1	0	1	1	0	1
Green square near Strykowska and Oswiatowa Streets	0	0.93	0.07	1	1	0	0.66	0	0	0	0.31	0	1	1	1	1	1	1	1	0	1	0	0	1
Green square near Strykowska and Zmienna Streets	0	0	1	1	1	0.5	0.34	0	0	0	0	0.03	0.86	1	0	1	1	1	0.99	0	0.8	0	0	0.99
Green square near Tymieniecki and Piotrkowska Streets	0	0	1	1	0	0	0.3	0	0	0	0.46	0.02	0.16	0	1	1	1	1	1	0	1	1	0.07	1
Green square near Wilenska Street	0	0	1	1	1	0	0.4	0	0	0.35	0.46	0.13	1	1	0	0	1	0	1	0	0	0	0.13	1
Green square near Wojska Polskiego Street	0	0.02	0.98	1	1	0.25	0.2	0	0	0	0.16	0.02	0.62	1	0	1	1	1	0.77	0	0.97	0	0.07	0.98
Green square near Wojska Polskiego Street (near bus station)	0	0.04	0.96	1	1	0.11	0.39	0	0	0	0.59	0.1	0.71	1	0	1	1	0	1	0	0.6	0.87	0	0.99
Green square near Wojska Polskiego and Franciszkanska Streets	0	0.4	0.6	1	1	0.2	0.41	0	0	0	0.43	0.15	0.7	1	0	1	1	1	1	0	0.95	1	0.03	1
Green square near Wolczanska and 6 August Streets	0	0	1	1	0	0	0.37	0	0	0	0.52	0.68	0.49	1	0	1	1	1	1	0	1	1	0.89	1
Green squar near Wyspianski and Chodakiewicz Streets	0	0	1	1	0	1	0.69	0	0	0	0.99	0.03	0.68	1	0	0	1	1	1	0	0	0	0.22	1
Green square near Zachodnia ad Drewnowska Streets	0	0	1	1	0	0	0.48	0	0	0.17	0.39	0.04	0.62	1	0	1	1	1	0.98	0	0.92	0.98	0.19	1
Green square near Zgierska and Julianowska Streets	0	0	1	1	1	0.42	0.27	0	0	0	0	0.03	0.61	1	0	1	0	1	1	0	1	0	0	0.99
Green square near Zgierska and Sowinski Streets	0	0	1	0.58	0.51	0	0.18	0	0	0.08	0.49	0	0.84	0	0	1	1	1	1	0	0.2	0	0.2	0.99
Wodny Rynek Green square	0	0	1	1	0	0	0.64	0	0	0	0.38	0.14	0.9	1	1	1	1	1	1	0	0	1	0	1
Cyklodrom Green square	0	0	1	1	1	0.67	0.45	0	0	0	0.42	0	0.54	0	1	0	0	0	1	0	0.05	0	0.03	0.99

Maps

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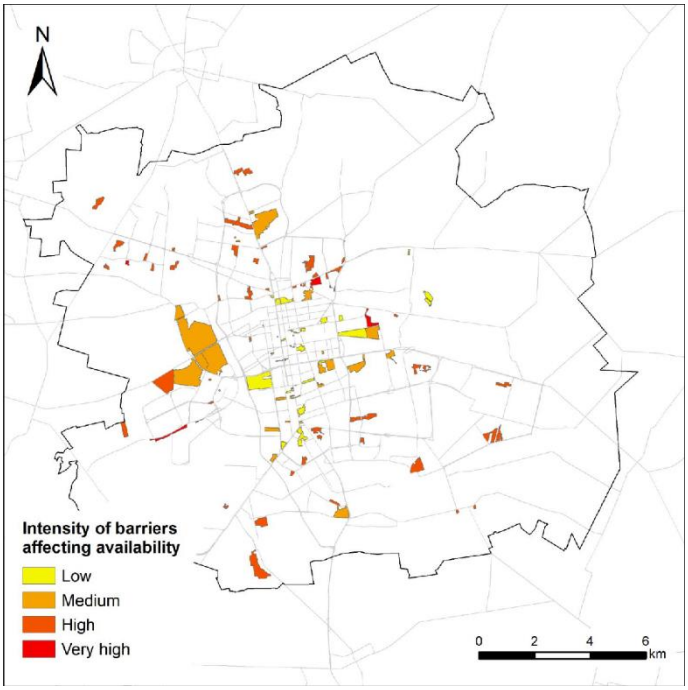
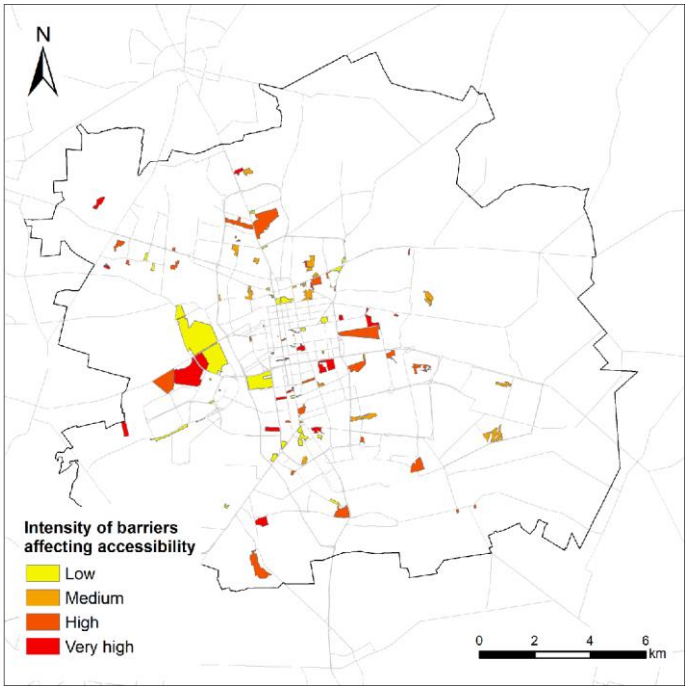
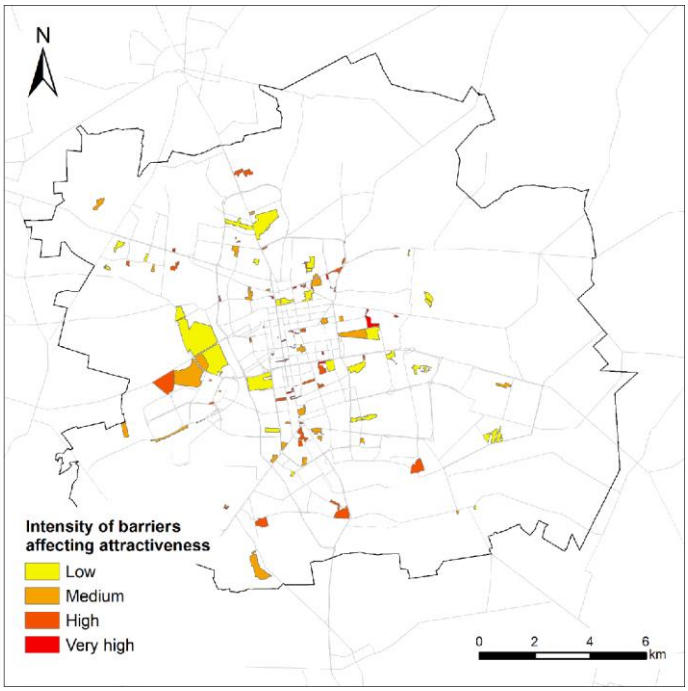
1. Map presenting intensity of bariers affecting the availability of urban parks and green squares in Lodz



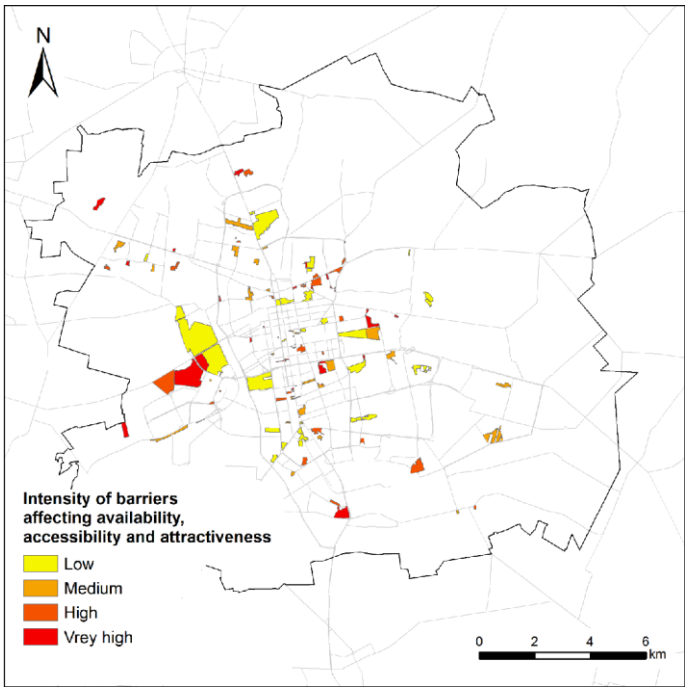
2. Map presenting intensity of bariers affecting the accessibility of urban parks and green squares in Lodz



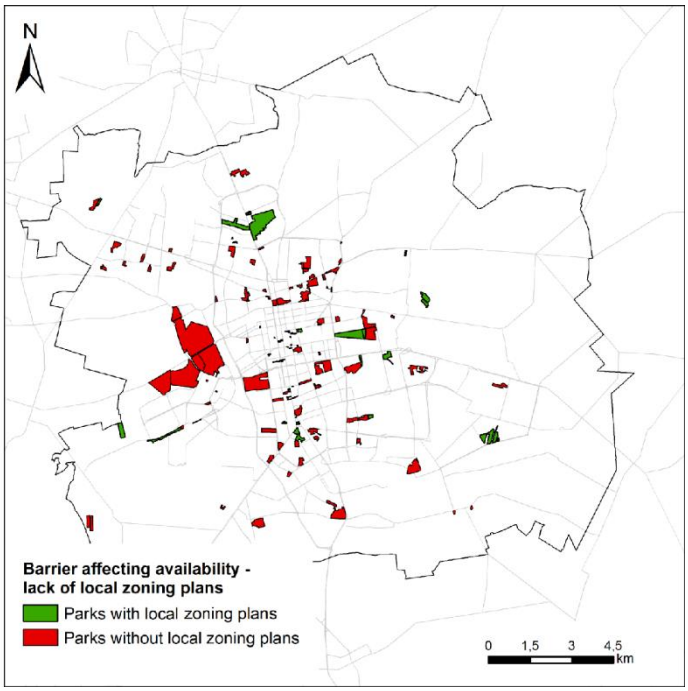
3. Map presenting intensity of bariers affecting the attractiveness of urban parks and green squares in Lodz



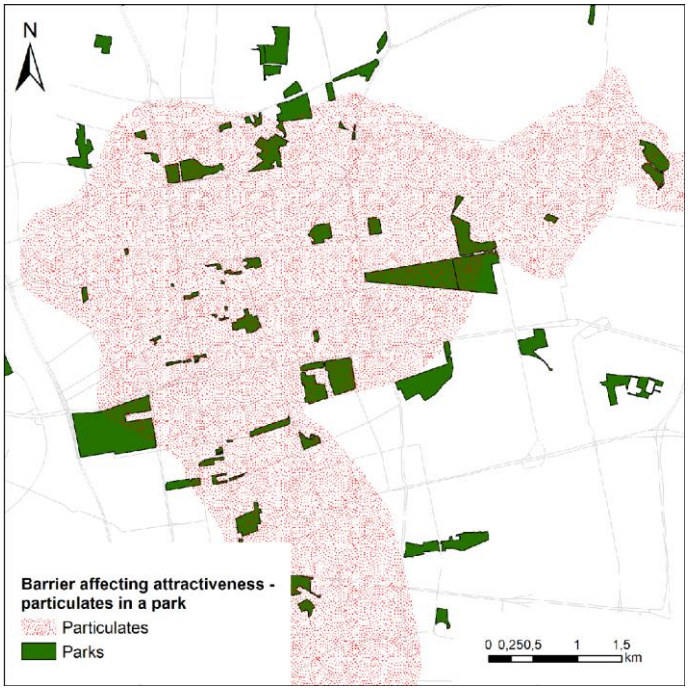
4. Map presenting intensity of bariers affecting the availability, accessibility and attractiveness of urban parks and green squares in Lodz



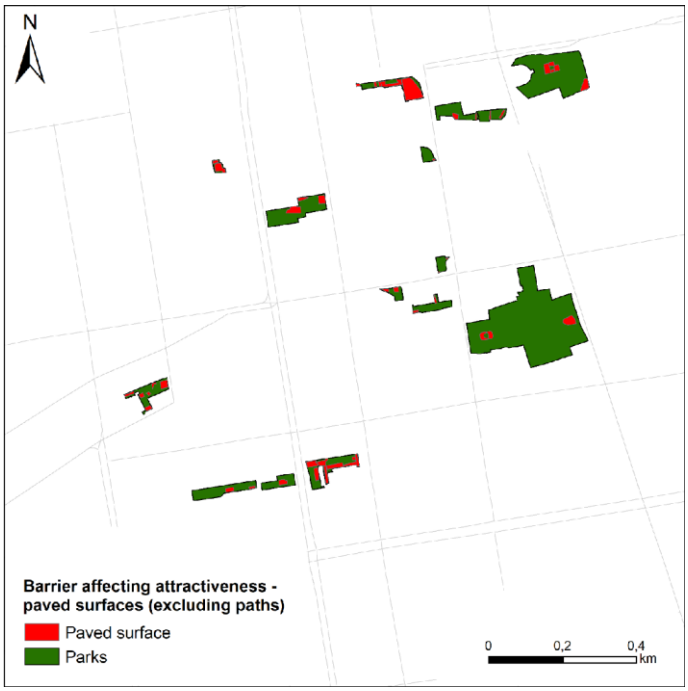
5. Map presenting an examplary barrier affecting the availability of parks and green squares in Lodz – lack of local zoning plans



6. Map presenting an examplary barrier affecting the attractiveness of parks and green squares in Lodz – particulate matter pollution



7. Map presenting an examplary barrier affecting the attractiveness of parks and green squares in Lodz – paved surface (excluding paths)



Appendix 2 – Supplementary Material to Article 4

Four categories of parks, their numbers and names differentiated by their area

Park categories, average area of parks (ha)	Number of parks	Parks included in a given category
Very large parks, 71.6	6	3rd May Park and Baden Powell Park; Poniatowski Park; Pilsudski Park; a complex of Lodzkie Blonia; the Botanical Garden; Mickiewicz Park
Large parks, 8.9	42	1st May Park; Zoological Garden; Helenow Park; Park in Lososiowa Street; Army of Lodz Park; Sienkiewicz Park; Dabrowski Park; Slowacki Park; Klepacz Park; Zaruski Park; Staszic Park; Rejtan Park; Anders Park; Reymont Park; Legions Park; Janow Park; Mlynek Park; Smulsko Park; Piastowski Park; Podolski Park; Sielanka Park; Staromiejski (Old Town) Park; Jan's Ponds Park; Widzewska Gorka Park; Widzew Park; Zrodliska I Park; Zrodliska II Park; Olechowka Springs Park; Rudzka Gora Park; Gdynia scymen green square; Dubaniewicz green square; Green square near Switezianki Street; Green square near Hipoteczna Street; Green square near Lisciasta Street; Green square near Konstytucyjna and Malachowskiego Streets; Green square near Lutomierska and Drewnowska Streets; Green square near Maratonska Street; Green square near Wojska Polskiego Street; Survivors Park; Grey Ranks Park; Park on Jasien River and green square near Paryska Street; Park on Ner River
Medium parks, 1.8	25	Grabienski Forest Park; Strug Park; Matejko Park; Zeromski Park; Moniuszko Park; Kielecki Park; Park in Lecznicza Street; John Paul II green square; Gdansk green square; Szustrowa green square; Kolbe green square; Forest green square near Odrzanska Street; Niemczyk green square; Olszynka Grochowska green square; Primate of the Millenium green square; Aleja PCK green square; Green square near Aleksandrowska; Green square near Drewnowska and Wlokniarzy Streets; Green square near Junacka Street; Green square near Wojska Polskiego Street (near bus station); Green square near Zgierska and Julianowska Streets; Green square near Zgierska and Sowinski Streets; Cyklodrom green square; Kilinski park and Strzeminski green square; Abramowski green square
Small green squares, 0.5	34	Park in Skrzywana Street; Wiejski Brojecka Park; Rynkowska green square; Jozewski green square; Rubinstein green square; Haller green square; Reymont green square; Linke green square; Hungarian Revolution of 1956 green square; Wiskitno pond green square; Paris Commune green square; Independence green square; Piastowski green square; Green square near Brzezna Street; Green square near Gdanska and Kopernika Streets; Green square near Gdanska and Wolczanska Streets; Green square near Kalinowa Street; Green square near Mazowiecka and Lawinowa Streets; Green square near Strykowska and Zmienna Streets; Green square near Piotrkowska Street; Green square near Sienkiewicz and Traugutt Streets; Green square near Sienkiewicz and Tuwim Streets; Green square near Sporna and Pankiewicz Streets; Green square

		near Strykowska and Oswiatowa Streets; Green square near Tymieniecki and Piotrkowska Streets; Green square near Wilenska Street; Green square near Wojska Polskiego and Franciszkanska Streets; Green square near Wolczanska and 6 August Streets; Green squar near Wyspianski and Chodakiewicz Streets; Green square near Zachodnia and Drewnowska Streets; Wodny Rynek green square; Hotel Centrum green square and Strzelec green square; Green squares near Narutowicz and Sienkiewicz Streets; Green squares near Palka and Pankiewicz Streets

Classification of barriers and indicators derived from Biernacka et al. (2020)

Lev.	Barriers and brief comment	Indicators
AVAILABILITY	1. New investments – buildings Larger new investments (e.g., supermarkets, warehouses, residential buildings) may potentially affect the existence of urban green spaces (UGS)	$New\ buildings_i = \frac{Invest_i}{Area_i} \times 100\%,$ where: $Area_i$ is area of the *i*-th UGS, $Invest_i$ is common part of the *i*-th UGS and new investment in a 10 m buffer.
	2. New investments – roads New road investments may potentially affect the existence of UGS	$New\ roads_i = \frac{Road_i}{Area_i} \times 100\%,$ where: $Road_i$ is common part of the *i*-th UGS and new investment in a 25 m buffer.
	3. Lack of local zoning plans for UGS Without local zoning plans, UGS are less protected in formal way	$Lack\ of\ local\ zoning\ plans_i = \left(1 - \frac{Plan_i}{Area_i}\right) \times 100\%,$ where: $Plan_i$ is part of the *i*-th UGS which is covered by the local zoning plan.
	4. Lack of protection of trees/UGS in existing local zoning plans for UGS Without special provisions in local zoning plans, UGS are less protected in a formal way	$Lack\ of\ protection\ in\ local\ zoning\ plans_i = \left(1 - \frac{PlanP_i}{Area_i}\right) \times 100\%,$ where: $PlanP_i$ is part of the *i*-th UGS which is covered by the local zoning plan in which there are specific provisions regarding the protection of the *i*-th UGS.
	5. Lack of historic preservation in existing local zoning plans for UGS Without historic preservation in local zoning plans, UGS are less protected in a formal way	$Lack\ of\ historic\ preservation\ in\ local\ zoning\ plans_i = \left(1 - \frac{Protect_i}{Area_i}\right) \times 100\%,$ where: $Protect_i$ is part of the *i*-th UGS which is covered by historic preservation.
ACCESSIBILITY	6. UGS entrances not connected with pedestrian crossings Busy roads can significantly hinder access to UGS, especially when there are no pedestrian crossings	$Entrances\ not\ connected\ with\ pedestrian\ crossings_i = \frac{EntrH_i}{Entr_i} \times 100\%,$ where:

		$EntrH_i$ is number of entrances to *i*-th UGS which are more than 100 m from the nearest pedestrian crossing near the *i*-th UGS, $Entr_i$ is number of entrances to the *i*-th UGS.
	7. Uneven distribution of UGS entrances Uneven distribution of entrances to UGS may make it difficult to enter UGS	$$Distribution\ of\ UGS\ entrances_i = \frac{Acc_i}{Cir_i},$$ where: Cir_i is circumference of the *i*-th UGS, Acc_i is the longest distance between two entrances to the *i*-th UGS.
	8. Entrance fees Entrance fees can be a significant barrier for people with low incomes	$$Entrance\ fee_i = \begin{cases} 1 \text{ if there is a fee in the } i\text{th UGS} \\ 0 \text{ if there is no fee in the } i\text{th UGS} \end{cases}$$
	9. Opening hours, temporarily closed Closing UGS in the evenings, may make it difficult to use it	$$Opening\ Hours_i = \begin{cases} 1 \text{ if there are opening hours in the } i\text{th UGS} \\ 0 \text{ if there are no opening hours in the } i\text{th UGS} \end{cases}$$
	10. Limited accessibility of part of UGS Buildings located in UGS (e.g., private buildings, garages) limit its area	$$Limited\ accessibility\ of\ part\ of\ UGS_i = \frac{Built_i}{Area_i} \times 100\%,$$ where: $Built_i$ is area covered by buildings inside of the *i*-th UGS.
	11. Restricted entrance opportunities due to fences and buildings around UGS Fences and dense buildings around UGS constitute physical obstacles in reaching these spaces	$$Fences\ and\ buildings\ around\ UGS_i = \frac{FencBuilt_i}{Cir_i} \times 100\%,$$ where: $FencBuilt_i$ is length of buildings and fences located around the *i*-th UGS.
	12. Repetitive crime in close neighbourhood of UGS Due to crimes in UGS neighbourhood, it is perceived as dangerous	$$Crime\ in\ neighborhood\ of\ UGS_i = \frac{NumbC_i}{Area_i},$$ where: $NumbC_i$ is number of recorded criminal acts in the buffer around the *i*-th UGS,
ATTRACTIVENESS	13. Limited park infrastructure (footpaths, lighting and toilets) Lack of basic park infrastructure reduces UGS attractiveness	$$Poor\ existence\ of\ footpaths_i = \max_i\left\{\frac{Length_i}{Area_i}\right\} - \frac{Length_i}{Area_i},$$ where: $Length_i$ is length of footpaths in the *i*-th UGS.
		$$Poor\ existence\ of\ toilets_i = \begin{cases} 1 \text{ if there are no toilets in the } i\text{th UGS} \\ 0 \text{ if there are toilets in the } i\text{th UGS} \end{cases}$$
		$$Poor\ existence\ of\ lighting_i = \begin{cases} 1 \text{ if there is no lighting in the } i\text{th UGS} \\ 0 \text{ if there is lighting in the } i\text{th UGS} \end{cases}$$

	14. Limited leisure equipment in UGS (playgrounds, sports facilities, outdoor gyms) Lack of basic equipment in UGS reduces its attractiveness	$Poor\ existence\ of\ playgrounds_i = \begin{cases} 1 \text{ if there are no playgrounds in the } i\text{th UGS} \\ 0 \text{ if there are playgrounds in the } i\text{th UGS} \end{cases}$
		$Poor\ existence\ of\ sport\ facilities_i = \begin{cases} 1 \text{ if there are no sport fields in the } i\text{th UGS} \\ 0 \text{ if there are sport fields in the } i\text{th UGS} \end{cases}$
		$Poor\ existence\ of\ outdoor\ gyms_i = \begin{cases} 1 \text{ if there are no outdoor gyms in the } i\text{th UGS} \\ 0 \text{ if there are outdoor gyms in the } i\text{th UGS} \end{cases}$
	15. Limited availability of water in UGS Lack of blue infrastructure limits the attractiveness of UGS	$Poor\ existence\ of\ water_i = \left(1 - \frac{AreaPR_i}{Area_i}\right) \times 100\%,$ where: $AreaPR_i$ is surface of ponds and other water reservoirs, as well as, rivers and canals in the i-th UGS.
	16. Repetitive loud and crowded outdoor events in UGS: festivals, popular music concerts, picnics Loud events may reduce the attractiveness of UGS	$Loud\ outdoor\ events_i = \begin{cases} 1 \text{ if there is loud outdoor event in the } i\text{th UGS} \\ 0 \text{ if there is no loud outdoor event in the } i\text{th UGS} \end{cases}$
	17. Road, rail, tram noise in UGS Noise may reduce the attractiveness of UGS	$Transport\ noise_i = \frac{Noise_i}{Area_i} \times 100\%,$ where: $Noise_i$ is part of the i-th UGS area exposed to exceeded noise levels.
	18. Particulates (PM 10, PM 2.5) in UGS Air pollution may discourage the use of UGS	$Particulates\ in\ UGS_i = \frac{Partic_i}{Area_i} \times 100\%,$ where: $Partic_i$ is part of the i-th UGS area exposed to exceeded PM 10 and PM 2.5 levels.
	19. Share of area inside of UGS covered with concrete Lack of biologically active space may reduce the attractiveness of UGS	$Lack\ of\ biologically\ active\ space_i = \frac{Con_i}{Area_i} \times 100\%,$ where: Con_i is area inside of UGS covered with concrete, lack of biologically active space inside of the i-th UGS.
	20. Area of UGS UGS size is crucial, especially when it comes to its multifunctionality	$Area_i = \max_i\{Area_i\} - Area_i,$ where: $Area_i$ is area of the i-th UGS.

Sensitivity analysis of the results

We analysed the sensitivity of the results by performing additional correlation analyses for different variants of park size and SA ranges. In the main part of analysis, we examined the correlations for all parks (107) in four different SA ranges (200, 400, 800, and 1200). For the purposes of sensitivity analysis, we examined additional correlations for 59 larger parks (over 1.8 ha), eliminating the smallest ones. Moreover, we tested additional indicators representing availability and attractiveness for these different variants of park sizes and SA ranges (both in 200, 400, 800, and 1200 separately for parks of different size, as well as in 300 for all categories of parks). We deliberately omitted accessibility indicators due to the lack of correlation in most cases. For sensitivity analysis, we selected only non-binary indicators for availability and attractiveness (Biernacka et al., 2020), such as:

- percentage of the park area covered with new investments (roads, buildings);
- percentage of the park area not covered by: local zoning plans; local zoning plans with protection of UGS, and local zoning plans with historic preservation of UGS;
- percentage of the park area not covered by water;
- percentage of the park area in which the allowed noise limits are exceeded;
- percentage of the park area in which particulate matter pollution was recorded;
- share of area inside of a park covered with concrete;
- park area.

Moreover (as part of the sensitivity analysis), we tested additional data from the real estate market by calculating various indicators, e.g., percentile 85^{th} and 90^{th} divided by the number of all transactions, average price per square meter, and number of transactions divided by residential buildings. Finally, in the sensitivity analysis, we used only the highest percentile – 95^{th}, median of prices and primary market transactions. These indicators reflect the highest apartment prices and real estate market dynamics in a given part of the city (in a particular SA around a park), and thus represent the location of the most affluent groups of inhabitants.

The results for different variants of park size, SA ranges, and the selected indicators are consistent with the main part of results. For example, correlation of the three levels of UGS provision for parks larger than 1.8 ha (SA 200, 400, 800, and 1200) shows that the most economically vulnerable (people receiving targeted or permanent benefits) have worse provision of parks with a small number of barriers affecting their attractiveness, but good parks' availability. Meanwhile older adults live close to parks whose availability is threatened.

For indicators related to the real estate market representing the least economically vulnerable group (e.g., highest percentile, median price, and primary market transactions), there are no statistically significant correlations on any of the three levels of UGS provision (Table 1).

Table 1. Correlation of the three levels of UGS provision (availability, accessibility, and attractiveness) with the indicators representing the most economically vulnerable, the vulnerable age groups, and least economically vulnerable groups of inhabitants for parks larger than 1.8 ha (SA 200, 400, 800, and 1200).

	Availability	*Accessibility*	*Attractiveness*
The most economically vulnerable			
Unemployed/total	-0.36**	0.11	0.15
Long-term unemployed/total	-0.33**	0.19	0.11
Total number of welfare benefits/total	-0.28*	0.11	0.23
Targeted benefit/total	-0.35**	0.15	0.28*
Periodic benefit/total	0.10	-0.09	0.06
Permanent benefit/total	-0.44**	0.29*	0.25*
Allowance for meals for children/total children (0–10)	-0.41**	0.13	0.17
The vulnerable age groups			
Children and youth 0–20/total	-0.19	0.03	0.15
Seniors 61–80/total	0.40**	-0.07	-0.21
The elderly 81+/total	0.21	-0.14	-0.15
The least economically vulnerable			
95^{th} percentile/number of transactions	-0.16	0.15	0.16
Median – real estate prices per square meter	-0.15	0.11	0.21
Primary transactions/number of transactions	-0.21	0.12	0.17

*Significance level: 0.01'**', 0.05'*'.*

Appendix 3 – Authors' declaration (Article 1)

…….. ……

imię i nazwisko *miejscowość i data*

…….

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy:

Autorzy: mgr Magdalena Biernacka, dr hab. Jakub Kronenberg

Rok publikacji: 2018

Tytuł: Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces

Czasopismo: Urban Forestry & Urban Greening

Tom: 36

Strony: 22–33

mój udział polegał na:

przeprowadzeniu szczegółowego przeglądu literatury naukowej, przygotowaniu koncepcji artykułu, opracowaniu ram analitycznych – trzech poziomów podaży terenów zieleni wraz z ich prezentacją graficzną, przeprowadzeniu wszystkich analiz, przygotowaniu manuskryptu, wizualizacji wyników. Mój udział w powstaniu artykułu szacuję na 75%.

Imię i nazwisko współautora	Procentowy udział	Podpis
mgr Magdalena Biernacka	**75%**	
dr hab. Jakub Kronenberg	**25%**	

Appendix 4 – Authors' declaration (Article 2)

…….. ……

imię i nazwisko *miejscowość i data*

…….

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy:

Autorzy: mgr Magdalena Biernacka, dr hab. Jakub Kronenberg

Rok publikacji: 2019

Tytuł: Urban green space availability, accessibility and attractiveness, and the delivery of ecosystem services

Czasopismo: Cities and the Environment

Tom: 12

Dostęp: https://digitalcommons.lmu.edu/cate/vol12/iss1/5

mój udział polegał na:

przeprowadzeniu szczegółowego przeglądu literatury naukowej, przygotowaniu koncepcji artykułu, przeprowadzeniu wszystkich analiz, przygotowaniu manuskryptu, wizualizacji graficznej wyników, przygotowaniu i przeprowadzeniu ankiety wśród użytkowników Lasu Łagiewnickiego. Mój udział w powstaniu artykułu szacuję na 80%.

Imię i nazwisko współautora	Procentowy udział	Podpis
mgr Magdalena Biernacka	**80%**	
dr hab. Jakub Kronenberg	**20%**	

Appendix 5 – Authors' declaration (Article 3)

…….. ……

imię i nazwisko *miejscowość i data*

…….

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy:

Autorzy: mgr Magdalena Biernacka, dr hab. Jakub Kronenberg, dr Edyta Łaszkiewicz

Rok publikacji: 2020

Tytuł: An integrated system of monitoring the availability, accessibility and attractiveness of urban parks and green squares

Czasopismo: Applied Geography

Tom: 116

Dostęp: https://doi.org/10.1016/j.apgeog.2020.102152

mój udział polegał na:

przeprowadzeniu szczegółowego przeglądu literatury naukowej, przygotowaniu koncepcji artykułu, zaproponowaniu sposobu obliczenia wskaźników, przeprowadzeniu wszystkich analiz, przygotowaniu manuskryptu, wizualizacji graficznej wyników. Mój udział w powstaniu tego artykułu szacuję na 75%.

Imię i nazwisko	Procentowy udział	Podpis
mgr Magdalena Biernacka	**75%**	
dr hab. Jakub Kronenberg	**5%**	
dr Edyta Łaszkiewicz	**20%**	

Appendix 6 – Authors' declaration (Article 4)

…….. ……

imię i nazwisko *miejscowość i data*

…….

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy:

Autorzy: mgr Magdalena Biernacka, dr Edyta Łaszkiewicz, dr hab. Jakub Kronenberg

Rok publikacji: 2022

Tytuł: Park availability, accessibility, and attractiveness in relation to the least and most vulnerable inhabitants

Czasopismo: Urban Forestry & Urban Greening

Tom: 73

mój udział polegał na:

przeprowadzeniu szczegółowego przeglądu literatury naukowej, przygotowaniu koncepcji artykułu, przeprowadzeniu wszystkich analiz, przygotowanie manuskryptu, wizualizacja wyników. Mój udział w powstaniu tego artykułu szacuję na 80%.

Imię i nazwisko współautora	Procentowy udział	Podpis
mgr Magdalena Biernacka	**80%**	
dr Edyta Łaszkiewicz	**15%**	
dr hab. Jakub Kronenberg	**5%**	