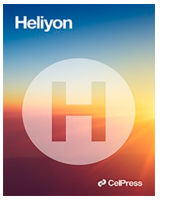
Heliyon 9 (2023) e13406

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Review article

A systematic review of urban green space research over the last 30 years: A bibliometric analysis

Jenő Zsolt Farkas [a], Edit Hoyk [a,b], Mariana Batista de Morais [c], György Csomós [d,*]

[a] Centre for Economic and Regional Studies, Great Plain Research Department, 3 Rakóczi út, Kecskemét, 6000, Hungary
[b] John von Neumann University, 10 Izsáki út, Kecskemét, 6000, Hungary
[c] University of Debrecen, Doctoral School of Earth Sciences, 1 Egyetem tér, Debrecen, 4032, Hungary
[d] University of Debrecen, Department of Civil Engineering, 2-4 Ótemető út, Debrecen, 4028, Hungary

ARTICLE INFO

Keywords:
Urban green space
Urban forest
Bibliometric analysis
Keyword cluster
Keyword burst
VOS Viewer

ABSTRACT

Worldwide, due to rapid urbanization, the provision of urban green spaces (UGSs) has become a primary goal of urban planning. As such, research on the benefits, effects, and challenges of UGSs has gained widespread attention among scholars. This paper comprehensively analyzes three decades of UGS research and its evolution; it conducts a bibliometric analysis of approximately 4000 articles and reviews from the Web of Science platform to discover the patterns and trends characterizing UGS research over time. We found that the pioneers of initial UGS research were the United States and Canada, whereas recently the European Union and China have become the global engines of research in the field. UGS research initially focused on studying urban forests, gradually shifting toward green spaces located in inner urban areas. Early on, researchers investigated UGSs (i.e., urban forests) from an ecological perspective. However, the most current research phase focuses on the social aspects of UGSs, characterized by such keywords as environmental justice and accessibility. Furthermore, the introduction of geographic information systems (GIS) has given new impetus to the evolution of UGS research and has remained the most used technological advancement besides remote sensing techniques. As the social aspects of UGS research have gained importance, new research methods have been employed, such as machine learning, big data and social media data analysis, and artificial intelligence, most recently.

1. Introduction

In the last decades, urbanization has witnessed an unprecedented growth rate. According to the United Nations, currently, 55% of the global population lives in cities, and the urban population is expected to increase to nearly 70% by 2050 [1]. Due to the increasing number and density of urban people, (over)urbanization has resulted in many problems, such as the widening social inequalities, limited access to public amenities, and relative disregard of environmental aspects which altogether threaten cities' livability (see, for example, Knox and McCarthy [2]). Many studies have demonstrated that (over)urbanized areas, especially in developing countries, lack UGSs in adequate quality and quantity [3–5]. Furthermore, the densification of urban areas, even in developed countries, is often accompanied by the removal of existing UGSs [6,7]. However, many studies and research reports have called attention to the benefits and positive impacts of UGSs they can provide for urban residents.

* Corresponding author.
E-mail address: csomos@eng.unideb.hu (G. Csomós).

https://doi.org/10.1016/j.heliyon.2023.e13406
Received 20 October 2022; Received in revised form 29 January 2023; Accepted 30 January 2023
Available online 1 February 2023

According to WHO, green spaces and other nature-based solutions can increase the quality of urban settings, enhance local resilience, promote sustainable lifestyles, and improve the health and well-being of urban residents [8]. UGSs, primarily urban forests, positively affect the local climate of urban areas and help reduce the urban heat island effect [9–13]. Urban forests absorb a significant amount of hazardous substances from the air as the trees' leaves act as natural air filters [14,15]. Street trees and urban parks help reduce the sound emission generated by road traffic [16,17]. UGSs stimulate cognitive, emotional, and psycho-sociological benefits of park users, thereby reducing constant stress and mental tiredness and improving of attention and memory [18–22]. UGSs provide recreational opportunities for inhabitants [23,24], positively impacting park users' physical activity and health conditions [25–28] and contributing to the reduction of chronic diseases and mortality [29]. During the Covid-19 lockdowns, the importance of UGSs was further emphasized as being essential places in urban areas promoting human health and well-being (see, for example, Marconi et al. [30], Maury-Mora et al. [31], Talal and Gruntman [32], Venter et al. [33]). In conclusion, UGSs can help cities to be more sustainable and livable and provide a healthy environment for their residents [34].

Recognizing the benefits and positive impacts of UGSs on urban residents, cities across the world have taken measures to increase the number and accessibility of such areas (see, for example, Farkas et al. [35], Martins [36], Şenik and Uzun [37]). Researchers worldwide support municipalities' efforts by not only demonstrating the problems caused by the lack of UGSs and the benefits they bring to the community but also providing scientific knowledge for planners and decision makers how to create an efficient UGS network. Therefore, UGS research has gained widespread attention among scholars. The increased importance of the research topic has resulted in a surge in scientific publications focusing on such areas.

In this paper, we analyze approximately 4000 articles retrieved from the Web of Science to discover trends and patterns characterizing three decades of UGS research. More specifically, we sought to answer the following research questions.

- What geographic patterns characterize UGS research, and how have these patterns changed over time? Which countries pioneered UGS research, and which countries have produced the most publications recently?
- What are the focus areas of UGS research, and how the focus areas have changed over time?
- What technological advancements have been used in UGS research, and what new technologies may give a new impetus to urban UGS research?

By answering these questions, we can obtain a comprehensive picture of the evolution of UGS research in the past 30 years. The paper's organization is as follows: After the Introduction, we demonstrate how the data were collected and what methodology we used to process the data. Then, in the Result section, the geography of UGS research will be presented, followed by the analysis of the focus areas and technological advancements. Finally, in the Discussion section, we explain the patterns and trends of UGS research we

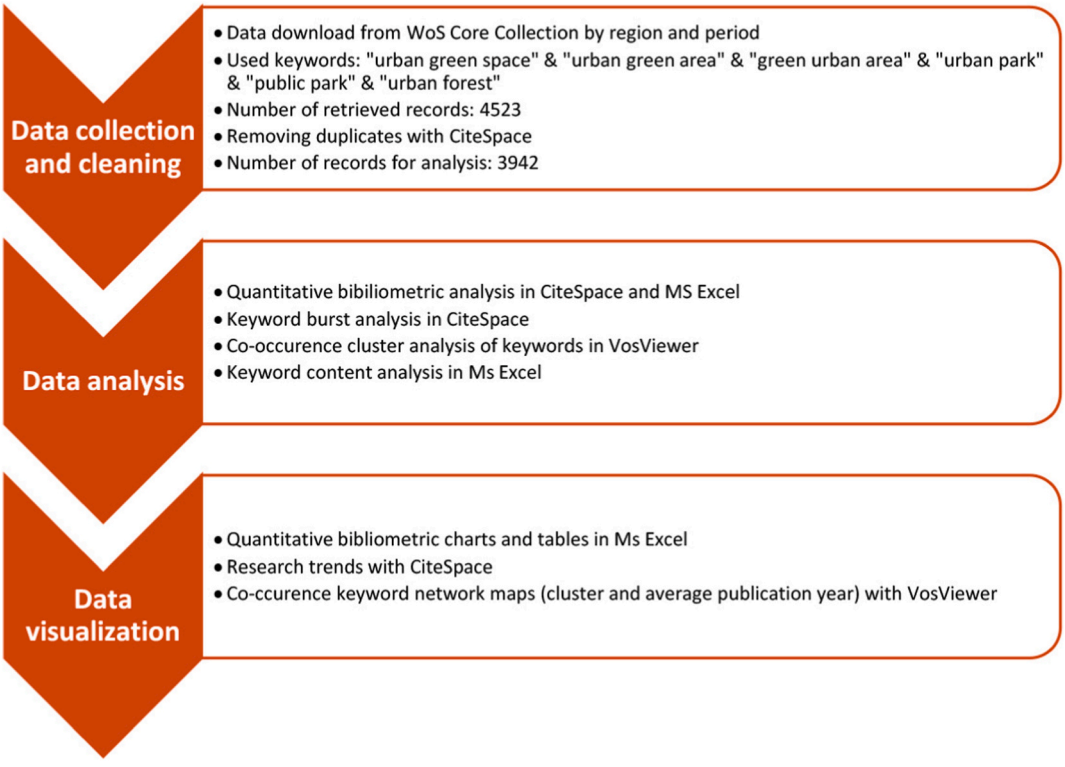


Fig. 1. Research flow chart showing the main research phases and tasks.

discovered.

2. Data and methodology

We used Clarivate's Web of Science (WoS) Science Citation Index Expanded (SCI-E) and Social Science Citation Index (SSCI) as the primary data sources of the analysis (see the research flow chart in Fig. 1). For the document types to be investigated, we considered only articles and review articles (henceforward: articles) published between 1991 and 2020. Only those items were involved in the analysis that contained one of the following expressions in the title, abstract, or keywords: "urban green space", "urban green area", "green urban area", "urban park", "public park", and "urban forest". Naturally, these expressions are not synonyms; however, they are generally applied to refer to urban areas that are partly or entirely covered by vegetation (e.g., grass, trees, and shrubs) [38] and provide multiple ecosystem services [39–42]. Henceforward, in the analysis, we use the term "urban green space" to refer to all the above types of areas (see, for example, Panduro and Veie [43], Wu and Kim [44]).

After implementing the necessary adjustments to the WoS search site, a total of 3942 items were retrieved. To investigate the evolution and milestones of UGS research, we classified the downloaded documents into three time periods: 1991–2000, 2001–2010, and 2011–2020. For the examination of the geography of UGS research, we grouped the countries into four major macro-regions, which are as follows: 1) the United States and Canada, 2) Australia and New Zealand, 3) China and Hong Kong (between 1990 and 1998, the publication data of China and Hong Kong were indicated separately in WoS), and 4) the European Union (the EU-28) and Iceland, Norway, and Switzerland. Without collaborations with researchers from the core regions, researchers from the rest of the world (e.g., Latin America, Africa, and the rest of Asia) produced only a small proportion of articles focusing on UGS research. More precisely: out of the 3942 articles published between 1991 and 2020, only 714 items (18%) did not contain an author from the core regions.

The quantitative bibliometric analysis was conducted using CiteSpace version V [45], VOSviewer 1.6.18 [46], and MS Excel 2022 (Fig. 1). In ecological research and urban planning, both software tools are frequently used to analyze scientific literature and visualize keyword co-occurrence maps, thematic clusters, and collaboration networks. In the followings, we demonstrate some recent studies that use VOSviewer and CiteSpace to review relevant literature:

In a study, Kong et al. [47] reviewed the literature on urban forests and trees and used CiteSpace V to map major keywords of nature-based solution research. Manningtyas and Furuya [48] investigated 56 documents and used VOSviewer for keyword mapping to reveal the distinction between traditional ecological knowledge and ecological wisdom. Meng et al. [49] analyzed 4552 papers to determine the relationship between international urban street space and residents' health. They used VOSviewer and CiteSpace to study countries, institutions, literature keywords, and co-citation networks. Shao et al. [50] used CiteSpace to analyze 5420 papers indexed in Web of Science to understand the development of green infrastructure research. By reviewing 589 articles from Scopus, Tirri et al. [51] investigated the emotional components of biophilic urban planning. For the visualization of the results and the identification of thematic, geographic, authorship/co-authorship, publication, and temporal trends, they used VOSviewer. A study by Zhang et al. [52] aimed to uncover global research status, trends, and future prospects in green spaces and health. They involved almost 19,000 Web of Science-indexed publications in the analysis and used CiteSpace to conduct the bibliometric analysis and VOSviewer to conduct author keyword cluster analysis. In another study by Zhang et al. [53], CiteSpace was used to conduct a visual knowledge map analysis of the literature on global spatial planning and China from 2006 to 2021. In conclusion, many studies from different research fields use

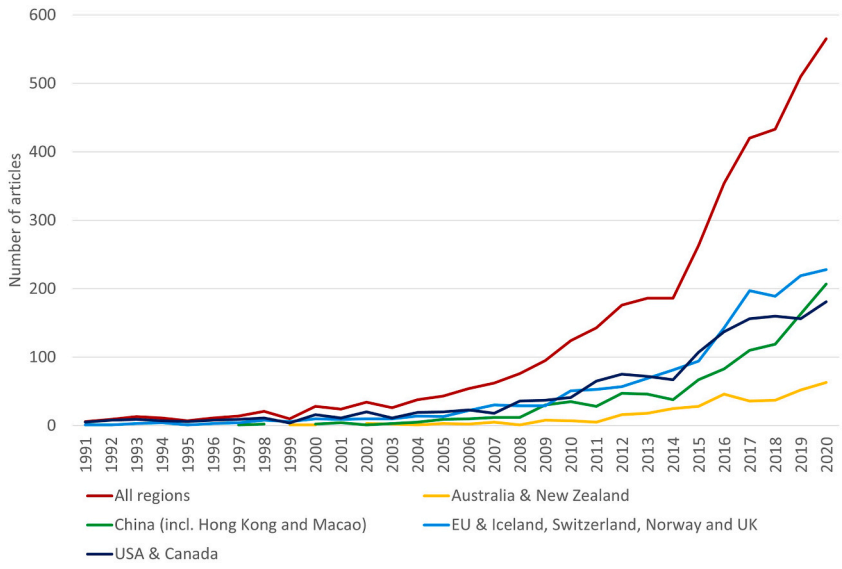


Fig. 2. Annual growth of articles dealing with UGS research by regions.

VOSviewer and CiteSpace as the primary analytical tool for reviewing the literature.

In this study, we used CiteSpace to find and remove duplicates and conduct quantitative publication output analysis and keyword burst analysis to identify trends in UGS research. In addition, VOSviewer was chosen to perform a co-occurrence analysis of keywords and their average publication year and map the keywords' network. Finally, we used MS Excel for keyword thematic analysis and data visualization.

3. Results

3.1. Geography of UGS research

Since the beginning of the 1990s, a growing number of articles dealing with UGS research have been indexed in WoS. On the one hand, the explosive growth in the number of articles, primarily in the last decade, reflects the rising importance of the topic worldwide and, on the other hand, the increasing number of documents indexed in WoS. Between 1991 and 2000, 130 papers were produced containing UGS keywords which increased by 443% to 576 in the next decade (Fig. 2). However, between 2011 and 2020, researchers across the world authored 3236 papers focusing on UGSs (i.e., 562% increase from the previous decade). The current popularity of the topic is well demonstrated by the fact that 27.3% of all articles involved in the analysis were produced in 2019 and 2020.

Publication data show that the United States and Canada, along with some Western and Northern European countries, can be considered the pioneers of UGS research (Fig. 3). In the first decade, we investigated, these two regions produced almost all WoS articles dealing with UGSs. China (and Hong Kong), Australia and New Zealand joined the arena of international UGS research in the late 1990s, but they remained less significant players until the middle of the first decade of the 21st century. Parallel with the accelerating urbanization of China [54,55], the provision of UGSs has gained crucial importance [56], which is also reflected in the remarkably growing number of articles published since 2004–2005. While currently, most papers dealing with UGS research come from the European region (396 papers in 2020), in 2019, China surpassed the United States and Canada and became the second-ranked country/region of UGS research in terms of publication output (295 papers in 2020).

Fig. 4 demonstrates the total publication output of countries and the average publication year of documents authored by researchers from those countries. With incredibly high publication outputs (i.e., 45% of the total publication output combined), the United States and China excel among the countries involved in UGS research. However, there is a significant difference between the United States and China: for the United States, the average publication year is 2014.21, whereas this value is 2016.02 for China. This pattern suggests that UGS research has just recently gained impetus in China, and due to the difference in the publication dynamism of the two countries, China may soon be the world's top advocate of UGS research.

Fig. 4 also shows that most European countries (e.g., England, Italy, Germany, Spain, Sweden, and the Netherlands) belong to the second line of UGS research in terms of publication output. The Western European countries are the pioneer representatives of UGS research in the continent. The average publication years are the lowest for Finland (2014.40), Sweden (2014.47), and Denmark (2014.54), three Northern European countries. With 133 documents, one of the top actors of UGS research in Europe is Poland (ranked 9th worldwide and 5th in Europe). However, considering the average publication year (2017.62), Poland can be classified as one of the newest engines of European UGS research.

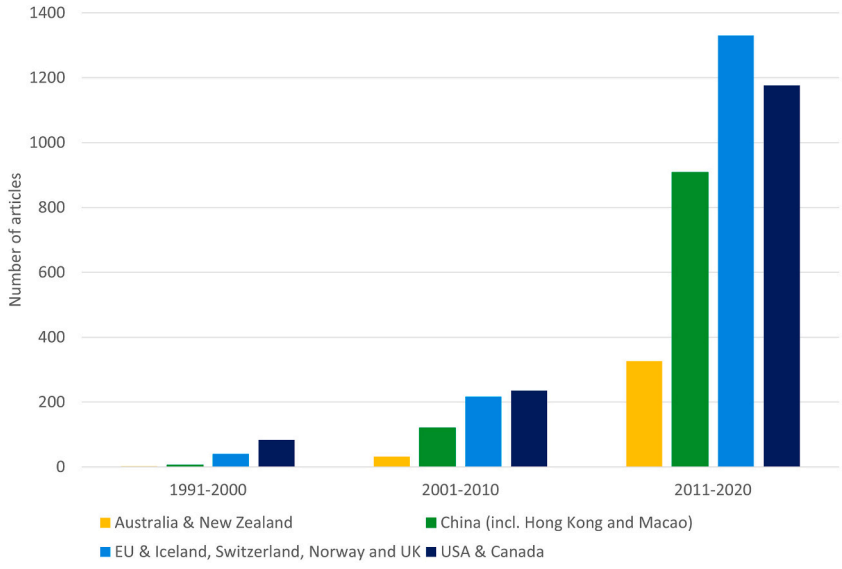


Fig. 3. Growth of articles dealing with UGSs by decade and region.

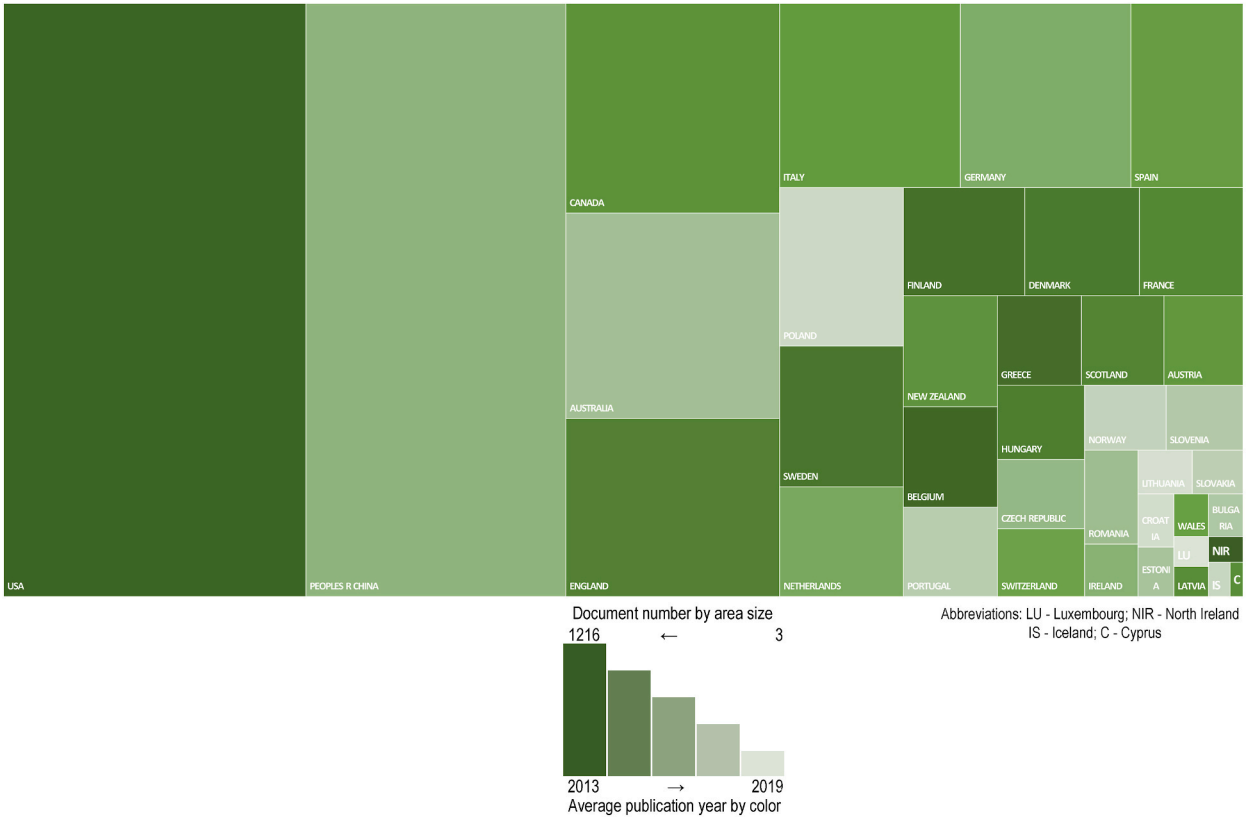


Fig. 4. Tree map visualizing the average publication year of articles and the total output by country.

3.2. Mapping changing focus areas of UGS research

A cluster analysis of keyword co-occurrence was conducted to shed light on the relationships between the keywords appearing in the title, abstract, and author keywords of articles. A total of 469 relevant keywords with at least five occurrences were extracted from the above components of articles which were then organized into four main and two relatively marginal clusters by VOSviewer. Cluster #1 is the largest in terms of the number of keywords (N = 168) and is centered on the term "urban forest" (Fig. 5). In the cluster, the top-10 keywords in terms of occurrence frequency are as follows: "urban forest" (N = 367), "ecosystem services" (N = 150), "urban forestry" (N = 125), "green infrastructure" (N = 99), "urban ecology" (N = 90), "urban forests" (N = 77), "climate change" (N = 62), "urban trees" (N = 58), "remote sensing" (N = 55), and "air pollution" (N = 40). The average publication year of keywords in Cluster #1 is 2015.00, the lowest among the clusters (Fig. 6). This suggests that the global UGS research of our age started with the research of urban forests primarily from an ecological perspective. Furthermore, based on the number of keywords in Cluster #1, we can conclude that the topics of forestry and urban forests still dominate UGS research. Cluster #2 contains 146 keywords making it the second largest cluster. With a total occurrence number of 286, "urban green space" is the top keyword in the cluster, followed by the closely related term "green space" (N = 186), and then "urban parks" (N = 93), "urban planning" (N = 84), GIS" (N = 57), "environmental justice" (N = 53), "urban" (N = 51), "China" (N = 49), "physical activity" (N = 47), and "parks" (N = 46). As Fig. 5 shows, the "urban green space" keyword cluster encompasses such keywords that belong to the second major branch of UGS research. Keywords in Cluster #2 tend to relate to research on the social aspects of UGSs, which is a major difference from those in Cluster #1. The average publication year of keywords in Cluster #2 is 2015.83, the highest among the clusters (Fig. 6). Based on this information, we can conclude that most recently, in parallel with the accelerated urbanization worldwide, the investigation of the relationship between UGSs and urban society has gained widespread attention among researchers, relegating urban forestry research to the background. The 75 keywords in Cluster #3 strongly relate to those in Cluster #2. Cluster #3 is centered on the keyword "urban park" (157 occurrences), but the keyword "urban green spaces" (N = 46) also frequently occurs in the cluster. The top keywords are related to land use (e.g., "land use": N = 30; "landscape metrics": N = 29; and "landscape pattern": N = 23), urban climate (e.g., "urban heat island": N = 53; "land surface temperature": N = 27; and "thermal comfort": N = 26), and urban soil (e.g., "soil": N = 26; "urban soils": N = 20; "urban soil": N = 16). The average publication year of keywords is 2015.61. With 28 occurrences, Beijing is the top geographical keyword in the cluster. Cluster #4 is constituted by 68 keywords. In terms of occurrence frequency, the core keyword in Cluster #4 is "urbanization" (N = 98), followed by "biodiversity" (N = 74), "conservation" (N = 32), "species richness" (N = 28), "ecosystem service" (N = 26), "fragmentation" (N = 24), "landscape" (N = 20), "diversity" (N = 15), "urban green infrastructure" (N = 15), and "disturbance" (N = 14).

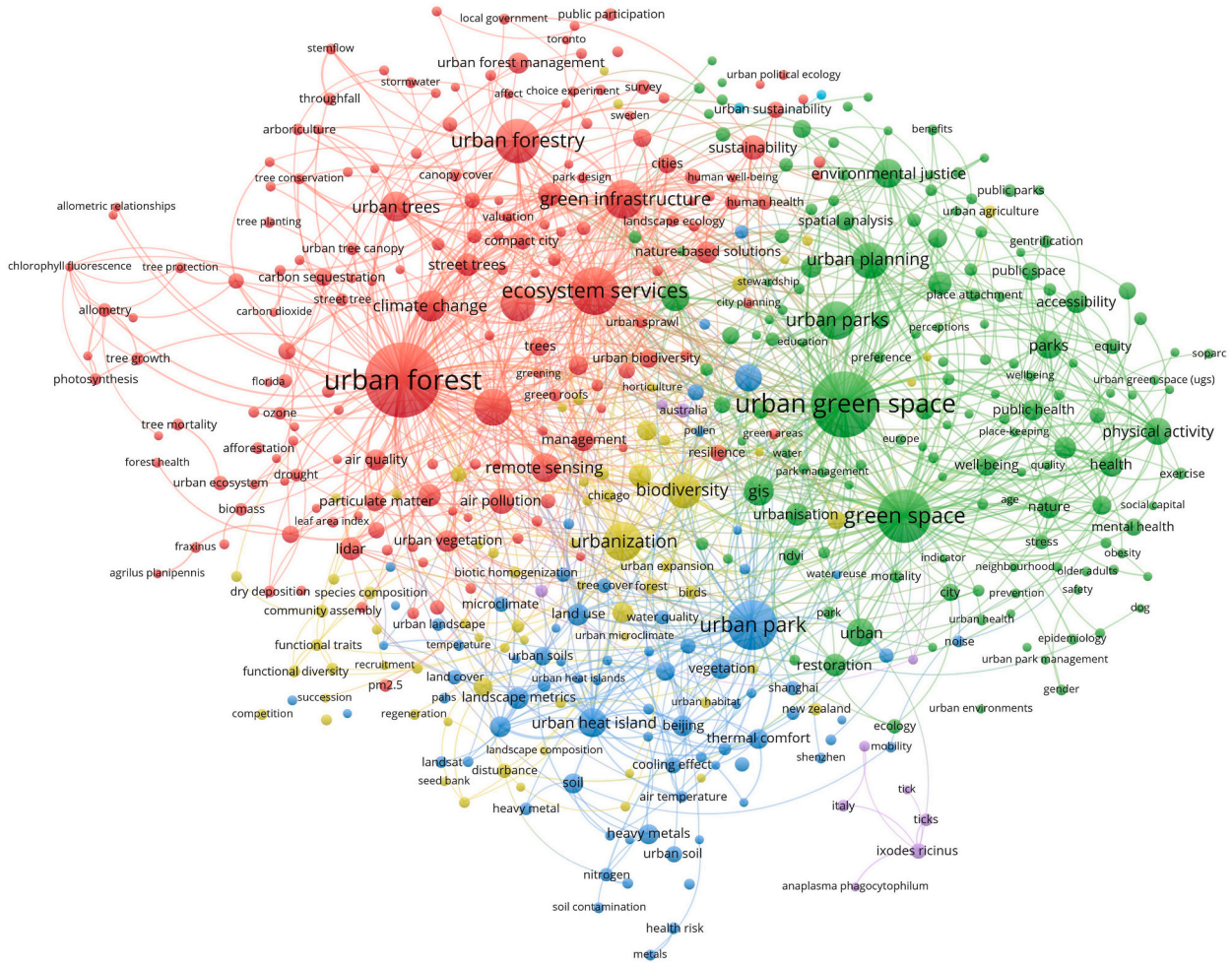


Fig. 5. Mapping co-occurrence keyword network.

The keywords in this cluster belong to the ecological branch of UGS research. The average publication year of keywords is 2015.09, which is the second lowest after the average publication year of those located in Cluster #1 (Fig. 6).

As Fig. 6 shows, UGS research has been experiencing a shift in its main research topics: from "urban forestry", the research focus has gradually been replaced by "urban green space". That is, the social aspects of UGS research have gained as much attention as the ecological approach. For example, with an average occurrence date of 2019.60, "inequality" is the newest keyword referring to the disparities in the availability of UGSs for different socio-economic groups [35,57,58].

3.3. Changing trends in UGS research

We conducted a keyword burst analysis to reveal the long-term evolution of topics and hotspots of UGS research. Fig. 7 shows the keywords with the strongest citation burst from 1994 to 2020. We classified keywords into three major evolution phases based on the keyword burst pattern. As a reaffirmation of the findings in the previous section, the earliest keywords in Phase #1 are related to "urban forest" and "urban forestry", the strongest keywords in the first period. "Compact city" and "open space" are the only keywords that somehow fall in the domain of urban planning, but most of the keywords in Phase #1 represent the ecological aspect of UGS research. The keywords in Phase #2 belong to two main classes. One line of the keywords is related to air pollution ("emission"), its effects ("mortality"), and its possible reduction by nature-based solutions ("plants", "sequestration", and "recovery"). Another major branch of the keywords in Phase #2 is related to planning ("community structure", "garden", and "participation"). With a strength of 5.65, North America is the strongest geographical keyword in this phase. Although Phase #3 contains substantially more keywords than the preceding phases, we can conclude that the scope of UGS research has become relatively concentrated. The keywords in Phase #3 represent the social aspect of UGS research; however, the strongest keyword in this period is "land surface temperature", with a burst strength of 6.87. The most recent keywords in Phase #3 (see the keywords of "access", "street", "disparity", and "accessibility") are in line with an emerging concept in urban planning; that is, the provision of UGSs for people within a reasonable walking distance

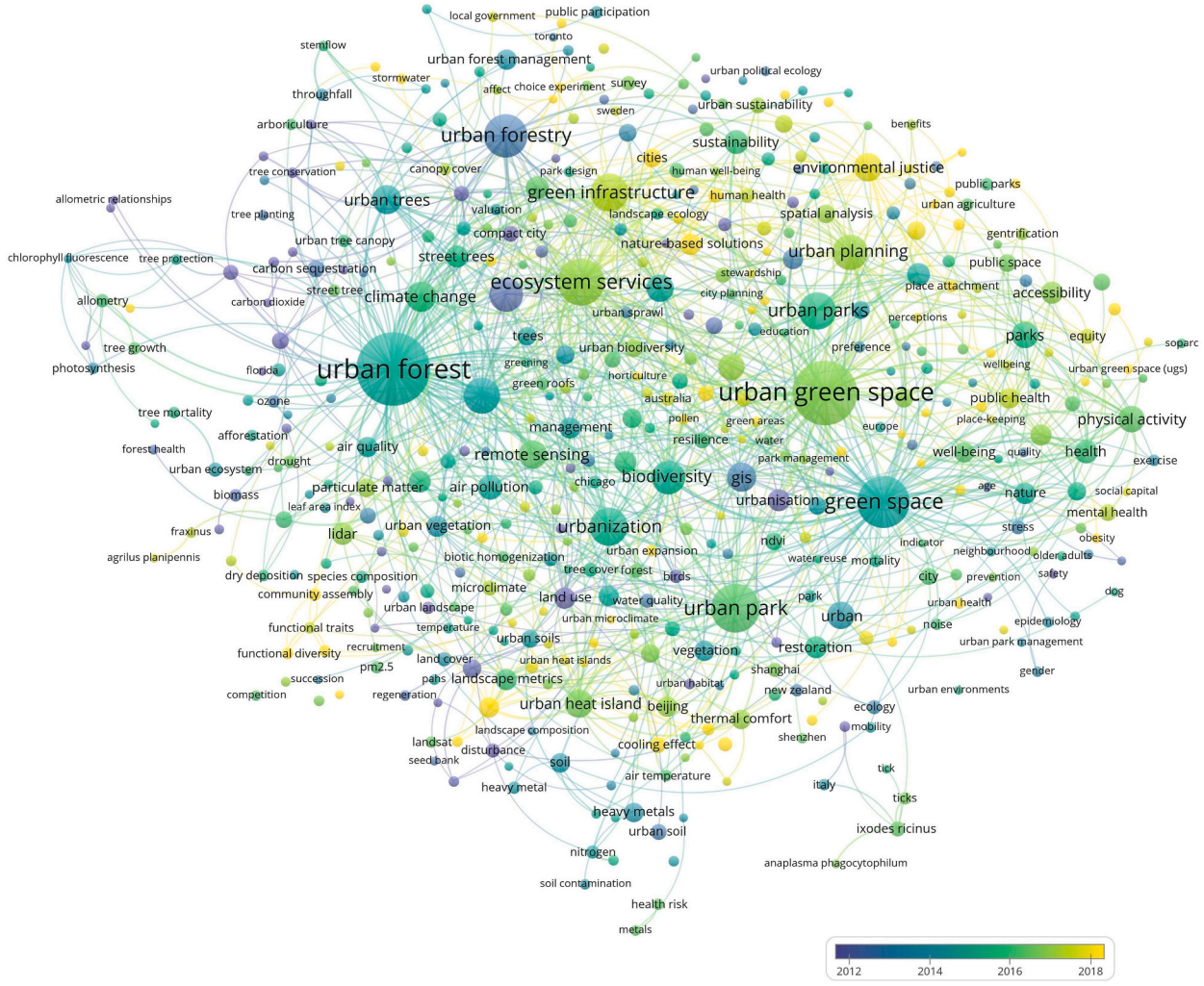


Fig. 6. Mapping periods of keyword occurrences.

and time [59–63]. In Phase #3, China replaced North America as the top geographical keyword.

3.4. Technological advancements used in UGS research

As we wrote in Section 3.2, the research on UGSs began with examining urban and suburban forests. Similarly to the land registry, the forestry sector is one of the earliest users of geographic information systems (GIS) [64], so it is no coincidence that their application appeared at the beginning of UGS research (average publication year: 2013.0) (Table 1). GIS is primarily used to map urban green areas and inventory and monitor forest resources because their spatial characteristics and changes are crucial for forest management [65,66].

In addition to their registration/mapping functions, GIS systems let researchers conduct different analyses. Satellite images also supported forestry research because they enabled fast and efficient data collection from large areas. The keyword analysis shows that Landsat (2016.33) and later MODIS (Moderate Resolution Imaging Spectroradiometer) (2018.00) satellite families were used for this purpose. The former satellite family has been operating continuously since 1972 and can be considered an essential tool for environmental data collection. MODIS began to collect data in 2000 (as a successor to Advanced Very-High-Resolution Radiometer–AVHRR), and many data products from land cover to net primary production can be found in its product catalog. With the advent of active remote sensing technologies, such as LIDAR (light detection and ranging) (2015.40, 2016.76), the role of remote sensing has increased even further. Methodological developments in evaluating remotely sensed images also appear in UGS research, such as object-based image analysis (2017.13). The latest trend in GIS is participatory GIS; that is, the use of GIS data collected by the community (see, for example, OpenStreetMap). This technological phase has been followed by the emergence of big data applications, the newest direction in methodology. The average publication years of the related keywords are between 2018.17 and 2019.29. Data provided by Twitter and other social media services (also mobile phone data) are processed by such indispensable methods as machine

	Keyword	Burst strength	Burst begin	Burst end
1st Phase	community	3.76	1994	2009
	urban forest	18.57	1997	2010
	heat island	3.57	1997	1999
	urban forestry	11.01	1998	2004
	forest	3.94	1999	2009
	model	3.55	2000	2009
	habitat fragmentation	5.79	2001	2011
	land use	4.43	2001	2010
	green space	6.98	2004	2010
	diversity	3.64	2005	2009
	open space	6.57	2006	2012
	inner city	5.41	2006	2012
	habitat	4.21	2006	2012
	compact city	4.03	2006	2015
	bioma	6.87	2008	2015
	coleoptera	4.68	2008	2012
	urban ecology	3.57	2009	2010
2nd Phase	sequestration	4.23	2010	2015
	recovery	4.07	2010	2011
	pattern	3.79	2010	2011
	emission	4.62	2011	2012
	north america	5.65	2012	2016
	participation	4.12	2012	2014
	mortality	3.53	2012	2014
	plant	5.73	2013	2016
	garden	3.95	2014	2016
	community structure	3.93	2014	2015
3rd Phase	governance	3.68	2016	2018
	china	4.64	2017	2018
	spatial distribution	4.39	2017	2020
	public space	4.28	2017	2020
	mental health	4.23	2017	2020
	justice	4.12	2017	2020
	place	4.09	2017	2018
	service	3.86	2017	2020
	cultural ecosystem service	3.83	2017	2020
	policy	3.54	2017	2018
	infrastructure	3.53	2017	2020
	land surface temperature	6.87	2018	2020
	urban greenspace	4.56	2018	2020
	access	4.31	2018	2020
	street	4.31	2018	2020
	crime	4.05	2018	2020
	disparity	4.05	2018	2020
	accessibility	3.85	2018	2020
	public open space	3.63	2018	2020

Fig. 7. Keyword occurrence list ordering by burst strength.

learning, for instance (see, for example, Cui et al. [67], Guan et al. [68], Lambert et al. [69], Roberts et al. [70]).

Among the methodological keywords, we should also highlight i-Tree (2015.21) and its newer version, i-Tree eco (2018.43). These applications have been developed by the United States Forest Service to assess the impact of trees. This lets us conclude that modeling and assessing the impacts of urban green areas have also become a key direction of UGS research.

Finally, the most recent innovation among the research methods could be the use of artificial intelligence (AI) (see, for example, Ghahramani et al. [71,72]). We found 17 articles containing the term "AI", out of which 11 were produced in 2021. In the analysis, we

Table 1
Technology related keywords in UGS research.

Keyword	Average publication year
GIS	2013.00
geographic information systems	2013.75
satellite imagery	2014.67
geographic information system (GIS)	2015.20
I-tree	2015.21
airborne lidar	2015.40
remote sensing	2016.18
Landsat	2016.33
Lidar	2016.76
object-based image analysis	2017.13
mapping	2017.67
PPGIS	2017.86
land surface temperature	2017.93
Modis	2018.00
machine learning	2018.17
I-tree eco	2018.43
Twitter	2018.67
big data	2019.29

did not involve the year of 2022; however, it is worth noting that 10 papers focusing on UGS research and containing the keyword "AI" were produced in the first half of the year.

4. Discussion

Urban areas worldwide face major challenges, including rapid population growth, massive urban sprawl and uncontrolled expansion of the urban fabric, increasing air pollution emitted by transportation and poor heating technologies, the urban heat island effect, and multiple health issues affecting the urban population. However, there is a consensus between researchers that UGSs can mitigate the adverse effects of urbanization: they can help alleviate the urban heat island effect [73,74], support air cleaning and filtering [75], and contribute to carbon sequestration [76,77] and rainwater-runoff reduction [78]. Moreover, they provide habitats for animals helping conserve biodiversity [79] and room for people to do sports and other outdoor activities [29,80].

The provision of UGSs in adequate quantity and quality for urban residents has gained crucial importance for cities worldwide [81]. In this paper, we conducted a bibliometric analysis to discover patterns and trends in worldwide UGS research and demonstrate the evolution of the field in terms of geography, research topics, and technological advancements. Accordingly, in the followings, we discuss the results.

4.1. Changes in the focus of international UGS research

After reviewing the bibliometric data, we found that modern UGS research started in the early 1990s in the United States and Canada with the investigation of urban forests from an ecological perspective (see, for example, Rowntree [82], Schoeneman and Ries [83]). Since then, urban forest research has remained an important topic within the field, but, on the one hand, the geographical focus of the research has experienced a shift from developed countries to developing ones, and, on the other hand, it has lost its dominant position within UGS research. Due to the rapid urbanization of developing countries characterized by an explosive urban population growth and a massive urban expansion, urban forests have faced major challenges such as deforestation and degradation [84,85]. As an outcome of accelerating urbanization, the urban fabric has been occupying many UGSs and the previously continuous green areas have started to show a highly fragmented pattern [86]. Therefore, urban forest research has gained impetus in developing countries experiencing a major degradation of tropical forests and countries significantly affected by urbanization. While research related to deforestation seems to be the main driver of urban forest research in general, it must be noted that in developed countries (primarily in European countries), and some developing countries (such as China and Brazil), afforestation and its impacts have also attracted researchers' attention (see, for example, Madsen [87], Oldfield et al. [88], Præstholm et al. [89], Sagebiel et al. [90], Zhang and Song [91]).

Further investigating the keyword occurrence trends of three decades of UGS research, we can conclude that the dominance of urban forest research has been challenged by the research of UGSs located in urban core areas. Whereas forests adjacent to urban areas still face major threats due to urban sprawl [92], many cities worldwide rather focus on creating new UGSs within the city limits [93,94]. Parallel to this paradigm shift, UGS research has experienced a change in its perspective: the investigation of the social aspects of UGSs has become as important (or more crucial) than the ecological ones. The early keywords of UGS research were related to urban forests investigated from an ecological perspective which have gradually been replaced with keywords related to inner UGSs providing recreational opportunities for people.

4.2. Change in the geographical scope of UGS research

Changes in the geographical keywords can also be discovered: in the 1990s, the names of Northern American and Western European countries and cities occurred most frequently, whereas China and some major Chinese cities dominated the 2010s. To explain this development, we must investigate these countries' and regions' socio-economic and environmental challenges.

In China, rapid urbanization has resulted in many environmental problems affecting the urban climate [95,96], land use [97], air and water quality [98,99], and biodiversity [74]. Parallel with the robust growth of the Chinese economy, the urban middle class with considerable spending power has been emerging for a while [100]. According to Wang et al. [2, 101] "Chinese residents' sedentary behavior (such as going out with the car, watching TV, and using computers) has constantly increased and their physical activity (such as walking and physical exercise) has decreased." Because urban health issues (e.g., chronic diseases, mental stress, obesity) in China have been affecting a growing number of people, the provision of UGSs has become a focus area of urban planning and a major topic for researchers (see, for example, Chen et al. [102], Wang et al. [103], Xing et al. [104], Yu et al. [105]).

Many studies have demonstrated that Chinese urban areas have been facing an increasing temperature enhancing the urban heat island (UHI) effect [106–108]. As Cao et al. [109], Lin et al. [110], Vaz Monteiro et al. [111], and Yu et al. [112] put forth, UGSs, even small ones, can cool adjacent areas and thus mitigating the urban heat island effect. Therefore, it is not surprising that another line of studies dealing with the increasing significance of UGSs in China focuses on the positive impact of UGSs on the local climate. This argument is underpinned by the fact that 33% of all articles containing the keyword "urban heat island" also contain the keyword "China", while, for example, the keyword "USA" only appears in 24% of the articles.

If reviewing the average publication year of keywords, it turns out that such US cities as New York and Chicago have remained popular research areas; moreover, the average publication year of the keyword "Los Angeles" is quite the same as that of "Beijing". As the investigation of UGSs started much earlier in the United States than in China, this finding suggests that US cities have remained at the frontline of UGS research. Whereas "accessibility" is one of the top keywords in articles produced by China-based researchers, this keyword is less significantly represented in articles published by US-based researchers. In contrast, the keyword "gentrification" is marginal in Chinese UGS research but frequently occurs in research articles from the United States. The term "environmental gentrification" was coined by Sieg et al. [113]. It describes a process when public investments in urban green developments are accompanied by the upgrade of the housing stock in the surroundings [114]. The process results in an increasingly livable and desirable neighborhood, eventually facilitating the displacement of low-income residents and the influx of more affluent and educated (often white) people (see, for example, Black and Richards [115], Harris et al. [116], Pearsall and Eller [117], Rigolon and Németh [118], Rigolon et al. [119]).

To further strengthen our argument, we must add that 54% of the WoS-indexed articles containing the terms "eco-/environmental/green gentrification" were authored/co-authored by US-based researchers. In contrast, China-based researchers produced only 4% of those articles (which exactly corresponds to the ratio of articles published by Scotland-based researchers). Considering the research perspectives, UGS research in Europe shows similar trends and patterns to the ones conducted in the United States and China. Regarding publication output, the engine of the European UGS research has recently become Poland, surpassing the Northern European countries and approaching the Western European countries. We found two basically different explanations for Poland's gradually strengthening position in the field. In the communist era (between the late 1940s and 1990), urban planning in Central and Eastern European (CEE) countries mainly focused on finding the best locations for heavy industrial and manufacturing facilities and large-scale housing estates (see, for example, Csomós et al. [57], Stătică [120]). Although the new socialist neighborhoods were equipped with some UGSs, the provision of such amenities was relatively marginal. After the collapse of the communist regime, most cities in CEE countries faced a severe shortage of UGS. We can consider the past 30 years as a catch-up period during which the local governments put significant efforts into creating new UGSs and revitalizing deprived and abandoned ones. To help local governments create an efficient UGS network and provide a scientific background for planning, scholars have conducted many pieces of research and have published many articles focusing on UGSs. Because Poland has the largest urban network among the CEE countries, it is not surprising that most papers from the region deal with Poland and Polish cities. In addition, Poland's strengthening position in the field is significantly supported by Jakub Kronenberg, a researcher affiliated with the University of Lodz, who is one of the most prolific authors of contemporary UGS research worldwide.

4.3. Changes in the technologies used in UGS research

The change experienced in the research perspective has also affected the methodologies and technologies used in UGS research. Modern UGS research has started with the widespread application of geographic information systems (GIS), which have remained the cornerstones of all branches of UGS research. With the development of satellite-based sensor technologies, remote sensing has become one of the most important methods in UGS research. Since the social aspects of the research have gained importance, the methods have also changed: UGS research has gradually adapted and combined the research methods of social sciences (e.g., sociology, geography, urban planning) with those already used. Social media data from Twitter and Facebook, for instance, are collected to conduct sentiment analysis of park users (Plunz et al. [121], Roberts et al. [122]), questionnaire surveys are conducted to determine visitors' satisfaction with UGSs [123,124], and mobile phones' GPS data are processed to map how and when people use the parks [125,126]. In addition, new methods such as modeling and machine learning (see, for example, Wang et al. [56], Sun et al. [127]) have been adapted to study and optimally design UGSs. Artificial intelligence seems to be the most recent milestone of the methodological evolution of UGS research (see, for example, César de Lima Araújo et al. [128], Ghermandi et al. [129]).

5. Conclusions

As urbanization has accelerated, natural resources such as clean air and fresh water have become scarce in many urban areas worldwide. As a result, people's demand for a healthy and livable urban environment has increased. UGSs are regarded as precious resources [130], whose existence is jeopardized by the rapid expansion of the urban fabric, especially in developing countries [131]. Cities worldwide have recognized that UGSs (i.e., urban parks, forests, or other green areas) can be effective tools for becoming more sustainable and livable. Furthermore, these green areas provide room for people where they can spend their leisure time. As concerns about UGSs grow, academic research has focused on various aspects of the topic. Over the last three decades, researchers' main interest has gradually shifted from an ecological perspective of UGS research to a social one. Due to crises affecting urban populations, such as the COVID-19 pandemic, the benefits of UGSs have become even more apparent in recent years (see, for example, Lopez et al. [132], Noszczyk et al. [133]). For example, with the energy crisis in Europe, it is assumed that the research of UGSs will generate further studies to examine how energy concerns interact with green spaces.

We must note some limitations of our research. In a particular city, the number and size of UGSs may largely be influenced by historical, topographical, and socio-economic factors, the city's geographical location, the climatical conditions, and urban planning. Therefore, we should have extracted the names of many cities from the keyword database, after which we should have conducted a cluster analysis to explore how these factors affect the features of UGSs. Unfortunately, we managed to find out only the following cities' names: Beijing, Guangzhou, Shanghai, Hong Kong, Shenzhen (each from China), New York City, Chicago, Los Angeles, Toronto, Detroit, (each from Northern America), Berlin, Rome, and Vienna (each from Europe). These urban areas are considered global cities with high populations and population density. To understand the effects of other factors, we should dig slightly more deeply—not stopping at reviewing articles' titles, abstracts, and keywords, but ensuring to view them holistically. Furthermore, because the Web of Science SCI and SSCI databases are demonstrably biased toward the English language [134], we should consider using others (e.g., Emerging Source Citation Index of WoS, and Scopus) that include more journals published in other languages.

Overall, we have provided a detailed understanding of the trends and patterns characterizing three decades of research focusing on urban green spaces, urban forests, and other green areas.

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Funding statement

Dr. Csomós György was supported by Hungarian Scientific Research Fund [K142121].

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

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