Urban Green Space Research Progress and Hotspots Evolution Analysis: Visual Analysis based on WOS

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ABSTRACT

Background and objective: Over the past few decades, urban green space research has emerged as a pivotal field within urban planning, ecology, and environmental science, achieving substantial advancements. This study endeavors to elucidate the trajectory of development and evolving hotspots in urban green space research through a visual analysis of the Web of Science (WOS) database.

Methods: This study employs CiteSpace software to visualize the dataset, encompassing the analysis of keywords, abstracts, institutions, authors, references, and more, presenting the knowledge structure graphically. Additionally, it utilizes the LLR tag extraction algorithm to generate a keyword co-occurrence map and conduct clustering and grouping.

Results: The findings reveal that the preeminent contributors in urban green space research include Haase, Dagmar, and Nizamani, Mir Muhammad. Furthermore, the collaborative network among researchers underscores the significance of interdisciplinary and cross-border cooperation in advancing urban green space research. Keyword co-occurrence analysis identifies prevalent themes such as land surface temperature and health, highlighting the current focal points of urban green space research.

Conclusion: This study discerns heightened attention to topics encompassing the thermal environment, ecosystem services, biodiversity, green space accessibility, and vegetation. These themes mirror societal concerns regarding the influence of urban green spaces on climate change and spatial planning, thereby delineating avenues for future research.

Keywords: biodiversity, conservation, climate change mitigation, environmental sustainability, Interdisciplinary collaboration, urban green space development

Introduction

Urbanization fundamentally transforms human society, offering discernible advantages but also introducing challenges like the urban heat island effect, air pollution, and urban flooding (Dadvand et al., 2016, Gu et al., 2012). Urban green spaces, recognized as vital in the urban ecosystem (Su et al., 2011), play a pivotal role in improving the urban environment. Beyond providing ecosystem services, they serve as recreational havens, contributing to leisure and entertainment and establishing themselves as indispensable contributors to sustainable urban development (Stessens et al., 2017).

In recent years, there has been a notable surge of interest in the benefits of urban green spaces for public health and urban planning. Various green spaces, including parks, gardens, street trees, riverfronts, and private backyards, have garnered attention for their ability to directly and indirectly enhance physical and mental health. These spaces play a crucial role in facilitating physical activity, fostering social

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interaction, promoting mental relaxation, and offering respite from stress and heat. Collectively, urban green spaces contribute significantly to enhancing the overall well-being of individuals in urban settings (Vries et al., 2003, Gascon et al., 2015, Dadvand et al., 2016).

Consequently, worldwide policy changes and endeavors have been undertaken to expand urban green spaces and establish sustainable, comfortable living environments (Stessens et al., 2017).

In recent decades, Urban green space research, evolving from basic vegetation data to complex ecosystem service assessments, has gained attention from scientists, planners, and policymakers. Despite advancements, challenges like rapid urbanization, limited land, and climate change require a deeper understanding of the role and impact of urban green spaces.

In comparison to existing review studies, employing CiteSpace for knowledge graph analysis offers an innovative means of visualizing the relationships among academic documents, thereby unveiling interdisciplinary intersections and research hotspots. Unlike traditional literature reviews, the CiteSpace method boasts advantages such as comprehensiveness, objectivity, dynamics, and timeliness, alongside its visual presentation capabilities. This approach yields deeper and broader insights into the role and impact of urban green spaces.

In an effort to effectively delineate areas within the urban green space research field, the LLR (log-likelihood rate) tag extraction algorithm was applied to the keyword co-occurrence map generated by CiteSpace. The generation of clustering groups was then undertaken, with the maximum number of keyword clusters set at 6 in accordance with research requirements. The indicator module value ‘Q’ and the average silhouette value (‘S’) serve as metrics for evaluating the effectiveness of the cluster map. Q, within the interval (0,1], where Q > 0.3, signifies a significant network structure in the generated cluster map. A higher Q value indicates a more favorable clustering effect. Meanwhile, S reflects the homogeneity of the clustering map network, with S > 0.5 indicating a reasonable clustering map, and S > 0.7 suggesting high credibility (Chen et al., 2015).

The study’s data is sourced from the Web of Science (WOS) database, an academic literature repository encompassing interdisciplinary fields. The WOS is a primary data source with authority and representativeness. For the WOS, core collection consists of SCI-E, SSCI, A&HCI, etc. WOS was selected as the data source due to its extensive literature resources on urban green space research, comprising journal articles, conference papers, and review articles. To compile literature pertinent to urban green space research, the keyword “urban green space” was employed, resulting in the retrieval of 1,194 articles through the search process. Upon obtaining the search results, we initially filtered literature associated with urban green space research, excluding material unrelated to the research topic. Subsequently, we

**Research Methods**

This investigation employed CiteSpace to visualize the data set. This software facilitates an in-depth analysis of keywords, abstracts, institutions, authors, references, and other data within research documents, enabling a comprehensive understanding of the knowledge structure in related research fields, presented visually (Chen et al., 2015).

When conducting a literature review using CiteSpace, tasks such as correlation calculation, chart production, and keyword analysis are automatically handled by the software. CiteSpace utilizes sophisticated algorithms and visualization technologies to identify crucial topics and keywords within documents, presenting them in charts that aid researchers in comprehending document correlations and research hotspots. This automated functionality not only saves researchers time and effort but also enhances the objectivity and precision of the literature review process.
conducted data cleaning on the selected documents, which involved eliminating duplicates and verifying the citation format and document completeness. The focus was narrowed to paper data from the 2019 to 2023, resulting in the final selection of 1,193 relevant papers.

Following the search, knowledge mapping of the documents was generated using CiteSpace to identify highly cited documents and core concepts. Subsequently, CiteSpace was employed for keyword co-occurrence analysis to pinpoint hotspots and keywords within the realm of urban green space research. Additionally, the tool was utilized to construct collaboration networks among authors and institutions, facilitating the identification of influential researchers and teams in the field.

**Results and Discussion**

**Trends in publication**

The analysis of the number of annual literature publications and their changing trends can generally reflect the evolution of the importance and degree of attention in this field. Through literature analysis, based on the overall number of published documents, there has been a discernible upward trend in the quantity of foreign urban green space management publications over the past five years.

This trend suggests an active and growing research focus on urban green spaces during this period, indicative of increasing attention from foreign. From the standpoint of publishing disciplines, the environmental discipline stands out as the most prolific, contributing to 47.12% of the retrieved documents, totaling 581 papers. Additionally, other
noteworthy disciplines encompass urban planning, forestry, plant science, ecology, etc.

Analysis of the organizational and national structures in scholarly publications

Analysis of the distribution of collaboration between research institutions provided insights into academic support and recognition in this field (Cui et al., 2018). Establish the G-index at 25, employing document publishing institutions and their respective countries as node types, and generate a collaborative network diagram. Node size will signify the publication frequency of the institution, while the connection thickness between nodes will represent the intensity of institutional collaboration. Observing the collaborative network maps of publishing institutions and countries (Figs. 3 and 4), it is evident that within the realm of urban green space research, issuing institutions have coalesced into a discernible central collaborative network, accompanied by numerous smaller-scale cooperative networks. The publication output from foreign literature institutions is primarily led by the Chinese Academy of Sciences, contributing 99 articles, followed by the University of Chinese Academy of Sciences with 46 articles. The predominant contributors to document publication are chiefly China (592) and the United States (179), collectively constituting 65% of the total international publications in this field. Collaboration among these document-publishing countries revolves around those with higher publication volumes, resulting in a closely-knit network relationship within the landscape of publishing cooperation among nations.

Research hotspots and trend analysis

Employing CiteSpace, we generated keyword co-occurrence and clustering knowledge maps. Subsequently, we conducted a comprehensive analysis involving statistical counts, centrality, and burst stress of keywords to gain an in-depth understanding of the current hotspots within the field of urban green space research. Among these metrics, both count and centrality offer a comprehensive measure of keyword importance. In the keyword co-occurrence knowledge map, the node size corresponds to the centrality value, reflecting the magnitude of influence. A higher keyword frequency indicates increased attention or research enthusiasm, while a larger centrality value signifies a more significant contribution of the node within the co-occurrence network (Dong et al., 2023). To enhance the visualization of the keyword network and eliminate redundant statistical outcomes, specific terms such as 'urban green space', 'city' and 'green space' have been excluded from the analysis.
These terms are inherent in the search topics and lack substantial statistical significance. Additionally, keywords not closely aligned with urban green spaces have also been excluded to emphasize hot topics directly related to the research purpose.

**Analysis of the co-occurrence network of terms**

The term co-occurrence shows that two keywords exist simultaneously in numerous manuscripts. The examination of lexical co-occurrence represents frontiers and hot areas for various research eras throughout the evolution of landscape ecology research, demonstrating the fluctuating popularity of certain research subjects (Cui et al., 2018). Select the top 10 terms and sort them according to frequency (Fig. 5, Table 1). As shown in Table 1, the literature terms health has the highest frequency (170), followed by ecosystem services, biodiversity, impact, etc.

After a comprehensive analysis, it is determined that the primary focal points of urban green space research over the past five years (2019 - 2023) center around health, ecosystem services, biodiversity, accessibility, vegetation, etc. The research content is diverse, showcasing substantial collaboration across multiple fields.

The genesis of this research trend may be attributed to the COVID-19 pandemic, particularly within the context of heightened attention to public health and increased health awareness. The COVID-19 pandemic has exacerbated public health concerns, intensifying individuals' focus on the repercussions of urban environments on health. Social distancing and mental health have assumed central importance during the pandemic, elevating urban green spaces to heightened prominence as areas conducive to outdoor recreation. Research findings indicate that engaging in outdoor exercise within natural environments can contribute to immune system enhancement. Consequently, amid the pandemic, there has been a heightened emphasis on harnessing these health benefits through the utilization of urban green spaces. In addition, the pivotal role of urban planning in public health and societal well-being has become increasingly evident amid the epidemic. Therefore, the COVID-19 pandemic has potentially catalyzed the advancement of research pertaining to urban green spaces within the health domain, thereby accentuating the pivotal role of these spaces in contributing to residents’ health outcomes.

For example: In a 2019 article by Gregory N. Bratman, Researchers utilize natural experiments in urban greening to evaluate the impact of such initiatives on mental health. They propose evolving conceptual models that could expand current ecosystem services models by incorporating the effects of nature exposure on mental health (Bratman et al., 2019); Farshid Aram et al. employed a sample evaluation method to assess and deduced that large urban parks exceeding 10 hectares exhibit the most substantial cooling effect distance and intensity. Their findings also suggest that, beyond size, the cooling effect of urban green spaces is significantly influenced by natural elements, quality, and climate characteristics (Aram et al., 2019); Friederike Enssle et al. advocated for an urban planning approach that perceives the city as a holistic social-ecological system. Their

<table>
<thead>
<tr>
<th>rank</th>
<th>keyword</th>
<th>count</th>
<th>centrality</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>health</td>
<td>170</td>
<td>0.02</td>
</tr>
<tr>
<td>2</td>
<td>ecosystem services</td>
<td>165</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>biodiversity</td>
<td>122</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>impact</td>
<td>120</td>
<td>0.03</td>
</tr>
<tr>
<td>5</td>
<td>accessibility</td>
<td>94</td>
<td>0.02</td>
</tr>
<tr>
<td>6</td>
<td>vegetation</td>
<td>92</td>
<td>0.02</td>
</tr>
<tr>
<td>7</td>
<td>environmental justice</td>
<td>83</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>quality</td>
<td>82</td>
<td>0.02</td>
</tr>
<tr>
<td>9</td>
<td>urbanization</td>
<td>81</td>
<td>0.03</td>
</tr>
<tr>
<td>10</td>
<td>parks</td>
<td>80</td>
<td>0.03</td>
</tr>
</tbody>
</table>
proposal emphasizes urban green space planning and design that not only prioritizes the provision of ecosystem services but also fosters the development of social networks to enhance both social and environmental justice (Enssle and Kabisch, 2020).

**Cluster analysis results**

As depicted in Fig. 6, the Q value of the WOS document keyword clustering map created in this study is 0.4059, and the S value is 0.7349. These values indicate that the network structure of the keyword clustering map is effectively realized, enabling the delineation of specific clusters. "As indicated in Table 2, the six prominent clustering themes, characterized by larger outline values, encompass land surface temperature, physical activity, accessibility, urban ecology, green infrastructure, and urban greening. The outline values for these themes are 0.75, 0.733, 0.744, 0.691, 0.764, and 0.717, respectively. It can be inferred that these six major clusters exhibit higher keyword density, distinct themes, and substantial homogeneity, marking them as significant research areas within urban green space.

Integrating the aforementioned content, it is evident that:

**#0 land surface temperature**

The largest and most significant cluster is land surface temperature, encompassing 71 core keywords. The most frequently cited keywords within this cluster include 'impact,' 'vegetation,' and 'land surface temperature'. In a related context, Mahyar Masoudi and colleagues proposed in 2019 that optimizing the spatial pattern of green space can yield heightened cooling effects (Masoudi and Tan, 2019).

**#1 physical activity**

The 'physical activity' cluster comprises 59 core keywords, with the most frequently cited terms being 'physical activity,' 'green space' and 'benefits'. Among them, Bratman et al. proposed that mental health benefits associated with urban green spaces typically manifest concurrently with other ecosystem service benefits, thus being deemed as 'co-benefits' of services with a well-established research history (Bratman et al., 2019).

**#2 accessibility**

The 'accessibility' cluster comprises 58 core keywords, with the most frequently cited terms being 'urban green space', 'city' and 'spatial differentiation'. In this context, Peng Cheng, Min- Min, and others quantified the changes in green space equity in the Wuhan metropolitan area in 2021. They emphasized that most cities have not achieved satisfactory results in ensuring residents have sufficient green space (Cheng et al., 2021).

**#3 urban ecology**

The 'urban ecology' cluster comprises 45 keywords, with the most frequently cited terms being 'urban conservation', 'breeding success', 'apex predator', 'luxury effect', 'environmental justice', 'life expectancy', 'woody species,' etc.
#4 green infrastructure
The 'green infrastructure' cluster includes 36 keywords, with the most frequently cited terms being 'ecosystem services', 'green infrastructure' and 'bibliometric analysis'. In this regard, Preston et al. (2023) introduced a novel parcel typology that integrates various physical characteristics of brownfields. Their proposition underscores the existence of a considerable number of "hidden" green spaces on brownfields, a significant contribution to the broader green infrastructure network (Preston et al., 2023).

#5 urban greening
The 'urban greening' cluster comprises 28 keywords, with the most frequently cited terms being 'urban green space', 'public health', 'discrete choice experiment' and 'landscape architecture'. In this context, Ugolini et al. (2020) suggested that to foster resilient cities, urban planning and design should incorporate a diverse mix, encompassing large parks that offer expansive open-air green environments, as well as smaller pocket parks and gardens. This approach ensures that all residents have access to green space within walking distance of their homes (Ugolini et al., 2020).

Analysis of the time series evolution characteristics of core keywords
The keyword timeline chart illustrates the connection between each keyword cluster and the publication time span of the corresponding documents (Zhang et al., 2023). Utilizing CiteSpace software for co-occurring keyword analysis, keyword clusters ranked #0 to #5 were chosen to construct a keyword timeline diagram, segmented into 5-year intervals. This diagram, illustrated in Fig. 7, facilitated the analysis of research topics, including their initiation time and developmental trends, within each respective keyword cluster. Based on the initiation time, duration, and node density on the timeline of each keyword cluster study, the urban green space theme is categorized into six distinct groups. From the figure, it is evident that since 2019, the overall popularity of urban green space research has been on the rise. However, there has been a decline in the popularity of research trends related to accessibility, as represented by cluster number #2, over the past two years. The research trends across various fields remain relatively stable, showcasing an increasing number of research results. Earlier research hotspots continue to be inherited and developed. This indicates an overall upward trajectory in the research trend of urban green spaces, signifying substantial development potential in this field.

Trending topics in urban green space research in the past five years
Burst term are those that experience a sudden increase in frequency during a specific period. Burst term serve as indicators of research hotspots at particular stages. Keyword burst analysis is employed to capture the evolving research development trends within a specific research field (Hou and Hu, 2013).

Fig. 7. Clusters of urban green space research based on term.
To analyze the development trend of urban green space research, filtered literature data was imported into CiteSpace software, with analysis parameters set to 'Burst terms' to generate a keyword emergence map spanning from 2019 to 2023. In the figure, 'begin' and 'end' respectively indicate the start and end times of Burst keywords. 'Strength' represents the intensity of keyword emergence, where greater strength correlates with more citations and higher document influence (Li and Chen, 2016).

Among the top 10 emerging keywords in urban green space research from 2019 to 2023 (Fig. 8, Table 3), the terms with the highest intensity include 'environment', 'valuation', 'carbon', and 'ecology'. Combining the literature, it is evident that from 2019 to 2020, researchers primarily focused on the ecological valuation of urban green spaces. During this period, carbon sinks garnered significant attention.

Core keywords for 2020-2021 encompass older adults, ecosystem services, park access, energy, biodiversity conservation, and accessibility. Combining the literature, it is evident that these keywords emphasize research on creating an urban environment more suitable for the elderly through ecosystem services, green space design, and improved accessibility in urban planning and design. Such research contributes to understanding how urban spaces influence the health, social activities, and overall life experience of older adults. It also mirrors societal concerns regarding the aging population and the pursuit of sustainable urban development.

In the research conducted from 2021 to the present, the frequency of hotspots related to the thermal environment has significantly surpassed the expected level. This suggests that, during this period, the thermal environment has become a prominent topic in the research field. Academic research on the thermal environment has garnered greater attention, reflecting growing concerns about climate change and thermal conditions in urban environments.

**Top 10 Keywords with the Strongest Citation Bursts**

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Year</th>
<th>Strength</th>
<th>Begin</th>
<th>End</th>
<th>2019 - 2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>valuation</td>
<td>2019</td>
<td>3.39</td>
<td>2019</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>carbon</td>
<td>2019</td>
<td>2.31</td>
<td>2019</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>ecology</td>
<td>2019</td>
<td>2.10</td>
<td>2019</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>older adults</td>
<td>2019</td>
<td>2.05</td>
<td>2019</td>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>ecosystem service</td>
<td>2020</td>
<td>2.64</td>
<td>2020</td>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>park access</td>
<td>2020</td>
<td>2.35</td>
<td>2020</td>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>energy</td>
<td>2020</td>
<td>2.35</td>
<td>2020</td>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>biodiversity conservation</td>
<td>2020</td>
<td>2.35</td>
<td>2020</td>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>proximity</td>
<td>2020</td>
<td>2.05</td>
<td>2020</td>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>thermal environment</td>
<td>2021</td>
<td>2.52</td>
<td>2021</td>
<td>2023</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 8.** High-frequency terms and their burst time. 'Terms' represents the burst noun terms.

**Table 3.** Burst term

<table>
<thead>
<tr>
<th>Rank</th>
<th>Hotspots</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>valuation</td>
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<tr>
<td>2</td>
<td>carbon</td>
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<td>ecosystem service</td>
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<tr>
<td>6</td>
<td>park access</td>
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<tr>
<td>7</td>
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<td>8</td>
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<td>9</td>
<td>proximity</td>
<td>2.05</td>
</tr>
<tr>
<td>10</td>
<td>Thermal environment</td>
<td>2.52</td>
</tr>
</tbody>
</table>

**Conclusion**

Based on the analysis of relevant literature on WOS from 2019 to 2023 using CiteSpace software, this study summarizes the research progress and trends in the field of urban green space research through the interpretation of knowledge maps, including authors, institutions, and keywords of the articles. Currently, research on urban green space has established a relatively comprehensive network system, encompassing not only the distribution relationships of key research areas but also cross-integration with other fields of knowledge throughout the research and development process.

(1) According to research, research institutions with a large number of publications are mainly from the United States and China. The authors of articles serve as the primary driving force behind the advancement of this research field and play a pivotal guiding role (Lin et al., 2022). In accordance with Price's Law, the minimum number of publications by core authors (M) can be calculated using the formula: \( M = 0.749 \sqrt{N_{\text{max}}} \) (Hu, 2016) Drawing upon
Price's Law, in this study, M is approximately 2.37. Consequently, individuals who have authored no fewer than 2 papers and garnered a substantial number of citations can be identified as core authors.

The density of cooperation networks among authors and institutions is relatively low, suggesting that the core group of authors and research institutions in the field of urban green space research is relatively loosely connected and has not yet formed a mature cooperation network.

(2) The perspective of urban green space research exhibits diversified development, encompassing disciplinary knowledge in fields such as environmental science, urban studies, forestry, ecology, and other related domains. Notably, environmental science emerges as a core subject in the field of urban green space research, with 814 articles related to this domain.

(3) CiteSpace automatically generates six major theme clusters: land surface temperature, physical activity, mental health, bird community, hidden green space, and undergraduate stress relief. The research field exhibits depth, and the vitality of the research cycle continues to the present day. Due to factors such as climate and land use changes, the research focus has shifted towards hidden green space. Consequently, the issue of green space planning will be the primary direction for expanding the research content and pushing the research frontiers of urban green space.

Further analysis unveiled a robust connection between urban green space areas, urban development, and climate change. This highlights the importance of future research directions concentrating on the intersection of the thermal environment and urban green space planning. Given the escalating challenges posed by climate change, including issues such as the heat island effect, there is a pressing need to deepen our understanding of the potential role of urban green spaces. This understanding is crucial for mitigating these problems, enhancing climate adaptability, and fostering ecological balance in cities.

Furthermore, this study aims to delve into the latest advancements in foreign urban green space research from 2019 to 2023, underscoring the significance of urban green space in the sustainable development of global cities. It is noteworthy that our data analysis and literature review were exclusively conducted on the documents included in the WOS database. Although the Web of Science (WOS) database is a widely used resource, it does not cover all relevant research literature. Other databases or literature not included in WOS may provide different perspectives and findings. This study is limited to the time range from January 1, 2019 to November 20, 2023. Therefore, important research results published after this period may be missed. Therefore, there are certain limitations in summarizing the comprehensive landscape of urban green space research.

References


