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Review

Research Progress of Urban Park Microclimate Based on Quantitative Statistical Software

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Abstract: Urban parks, as an important component of urban green spaces, play a crucial role in improving the urban environment and enhancing residents' quality of life. This review summarizes the main content and research progress of urban park microclimate studies through analysis and synthesis of relevant literature from academic databases such as Web of Science and Google Scholar. Using Citespace or VOSviewer for bibliometric analysis, we found that the number of academic papers on the urban park microclimate has been growing year by year. The research content primarily covers the monitoring and analysis of temperature, humidity, wind speed, and other indicators in urban parks, as well as the impact of park design and planning on the microclimate. Keyword analysis revealed that researchers have mainly focused on the cooling effects of the urban park microclimate, mitigation of the urban heat island effect, and improvement of air quality. In terms of research methods, a combination of field observations and simulation models is commonly employed, with data being analyzed and validated using mathematical and statistical methods. The research results indicate that well-designed and planned parks can significantly improve the microclimate environment, reduce temperatures, and provide comfortable climatic conditions in urban areas. Additionally, vegetation arrangements and water features in urban parks also contribute to microclimate regulation. Moreover, windbreak measures and cooling strategies in parks can help alleviate the urban heat island effect, enhance air quality, and promote the health of ecosystems. However, this review also identified some issues in urban park microclimate research, including limitations in research scope, methods, and practical applicability. Future studies could deepen the comprehensive understanding of the urban park microclimate and explore more effective strategies for park design and planning to optimize and enhance the microclimate environment. It is also important for researchers to continuously innovate in terms of research methods and verify the feasibility of practical applications to better address the challenges of urban development.

Keywords: urban park microclimate research; urban heat island effect; urban planning; bibliometric analysis

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1. Introduction

The context and purpose of microclimate research in urban parks is based on knowledge of the challenges facing cities with accelerating global urbanization [1–3]. As the center of human activities, cities not only carry the agglomeration of the population, transportation and economy, but also face the problems of environmental, ecological, and social sustainable development. In this context, urban parks, as important urban green spaces, are endowed with important ecological, environmental, and social functions [4].

The urban heat island effect refers to the phenomenon where the temperature in urban areas is higher compared to surrounding rural and suburban regions [5]. It is caused by anthropogenic factors such as high building density, population concentration, transportation activities, as well as industrial and commercial activities in cities [6]. Through their unique vegetation cover and water bodies, urban parks can absorb solar radiation and release water, thus reducing the degree of the urban heat island effect. By studying the microclimate characteristics of urban parks, we can obtain a more comprehensive understanding of their potential for reducing urban temperature, improving air quality, regulating the climate [7–10], and providing a scientific basis for urban planning and design. Urban air pollution is a serious problem faced by cities today, and the vegetation in urban parks can absorb and filter the pollutants in the air, thus reducing the degree of air pollution [11]. By studying the microclimate of urban parks, we can assess the effect of vegetation on reducing air pollution and provide guidance for park design and vegetation configuration, thus improving the living environment of urban residents [12,13].

In urban parks, water bodies typically serve aesthetic purposes, temperature regulation functions, and assist with ecological balance. Water bodies contribute to the visual appeal and landscape value of the park [14]. Elements such as fountains, lakes, and artificial streams provide visual pleasure and attractiveness, creating a pleasant atmosphere in the park. Moreover, water has good thermal capacity, allowing it to absorb and release heat, which helps regulate the surrounding air temperature. Water bodies can cool down the hot temperatures during summer, providing a refreshing microclimate in the park [15]. Additionally, water bodies support ecosystems by providing habitats for various plants and animals [16,17]. By studying the microclimate of urban parks, we can assess its impact on rainfall runoff and provide a reference for urban water resources management and rainwater utilization, which could help to solve the water resources problems faced by cities.

As urban parks are places for residents to relax, entertain, and engage in social activities, the internal microclimate characteristics of urban parks have an important influence on the comfort of residents [18,19]. Through an in-depth study of temperature, wind speed, humidity, and other factors in urban parks, we can better understand the climate conditions in parks and provide optimization suggestions for park design and planning. Through a reasonable layout of vegetation, additional shading facilities, and comfortable seats and rest areas, the comfort and quality of life of residents in the city park can be improved.

Urban parks, as important urban green spaces, are of great significance in improving the urban environment and enhancing residents' quality of life [20]. However, there are still many shortcomings in the research on the urban park microclimate. Firstly, studying the microclimate of urban parks can help us understand the microclimatic characteristics and variations within the parks [21]. By studying the changes in temperature, humidity, and wind speed within urban parks, we can uncover the environmental conditions and microclimate characteristics within these parks [6].

Such research helps us understand several aspects: Firstly, studying temperature variations reveals the differences in thermal environments throughout the park across different seasons, time periods, and locations [7,18]. This understanding contributes to assessing the comfort level within the park and providing guidance for park planning and design aimed at improving thermal conditions. Secondly, studying humidity variations reveals the degree of moisture and water environments within the park. Understanding these changes is vital for evaluating the growth and adaptability of plants [22]. It helps park managers choose suitable plant species and provides reference points for water resource management [15]. Thirdly, exploring wind speed variations enables an assessment of airflow and ventilation conditions within the park. This information plays a crucial role in managing air quality, reducing heat stress, and creating a comfortable outdoor environment [23]. Through studying these metrics, we can gain a deeper understanding of environmental features within urban parks and provide a scientific basis for park management and planning [24,25]. Meanwhile, research on the urban park microclimate is of significance for mitigating the urban heat island effect [8,26,27]. Moreover, the study of urban park microclimate has the potential to mitigate the urban heat island effect by regulating and reducing temperatures in areas where surrounding temperatures are higher [15,28]. Through an in-depth study of the microclimate characteristics of urban parks, we can effectively improve the cooling effects of parks and alleviate the impacts of the urban heat island effect on residents. In addition, research on the urban park microclimate also contributes to the development of strategies for the construction and management of urban ecosystems [26,29,30]. Understanding the effects of vegetation, water bodies, topography, and other elements within the parks on the microclimate helps with selecting suitable vegetation species, optimizing water body arrangements, and improving the quality of the ecological environment within the parks, enhancing biodiversity, and creating comfortable recreational areas [31].

2. Materials and Methods

Citespace and VOSviewer are widely used academic literature analysis tools that can be used to retrieve and visualize information such as keywords, authors, and citation networks of academic papers [10,14,17,20,32]. First, in order to study the topic of the "urban park microclimate", it was important to define the research field and determine the objectives and questions of the study. Next, we selected appropriate keywords for retrieval, such as "Urban Park", "City Park", "Microclimate", and "Climate", and conducted literature searches using combinations of these keywords. In terms of selecting databases, we chose academic databases relevant to the research field and objectives. For this study, the academic databases used for retrieval included Web of Science and Google Scholar [27]. Since different databases cover different fields and ranges of literature, it was necessary to perform multiple searches and comparisons, and exclude irrelevant papers [33]. For literature screening, we applied the selected keywords to search within the chosen databases and filtered the literature based on predetermined criteria, such as time range, article type, and language. Additionally, preliminary screening was conducted based on the abstracts or titles of the papers, selecting only those related to the research topic. Finally, we exported the filtered literature in a format suitable for analysis in Citespace or VOSviewer, such as BibTeX or EndNote. In this study, the exported format was EndNote [17,34,35].

The specific procedure was as follows:

1. Data Import: Import the selected literature data into Citespace (6.1.2 Official release) or VOSviewer (V1.6.18 official release) software. Set options according to the research needs, including time range, keyword settings, and merging author names.
2. Keyword Extraction: Extract keywords and their associations from the literature. Through keyword co-occurrence analysis and clustering analysis, reveal the relationships between keywords and the development frontiers of research topics.
3. Construction of Citation Networks: Citespace and VOSviewer can construct citation networks by analyzing citation relationships, showcasing academic communication and collaboration in the research field.
4. Visualization of Results: Citespace and VOSviewer present the results of keyword co-occurrence analysis or citation network analysis in a visual manner, such as topology maps and temporal graphs, to intuitively display the knowledge structure and development trends in the research field [36].

From three academic databases and two literature statistical software programs, the results as of February 2023 were as follows: The search result for "City Park" and "Microclimate" keywords was 210 papers. The search result for "City Park" and "Climate" keywords was 1102 papers The search result for "Urban Park" and "Microclimate" keywords was 324 papers. The search result for "Urban Park" and "Climate" keywords was 1488 papers. After removing duplicates and irrelevant papers, a total of 2241 papers related to the urban park microclimate were retained as the study objects. Through comprehensive analysis, a more comprehensive understanding of the characteristics of the urban park microclimate and its interactions with the surrounding environment was obtained [37–39]. This has significant implications for urban planning decisions, the construction of park cities, the work of environmental protection departments, and the public's experience.

3. Results

3.1. Research Status of the Urban Microclimate

3.1.1. Study Scale and Scope of Influence

Through a comprehensive analysis of the articles on the "urban park microclimate" published in the literature database, we were able to understand the research scale and scope of influence in this field. From Figure 1, it can be clearly seen that from 1991 to 2023, the number of published papers on the microclimate in urban parks has been increasing year by year. There were some phased characteristics in this growth process [40]. The early research stage was from the 1980s to around 2005. With the passage of time, the enrichment of research methods and content, and the improvement of understanding of the importance of the urban park microclimate, the number of related literature publications has rapidly increased since 2006 and maintained a high development trend. In particular, the number of published articles reached a historical peak in 2021, surpassing 100 for the first time. This milestone marked the significant growth and increasing impact of microclimate research in urban parks [41] and indicates that the field remains one of the hottest research directions in academia, attracting a wide range of researchers [24,42]. This continuous growth trend indicates that as more and more researchers continue to conduct scientific research in the field of microclimate, the number of related works may continue to increase [43]. The expansion of this area of study also had a broad impact on areas such as urban planning and environmental management [44]. The results and insights of urban park microclimate research provide an important basis for urban planners and decision-makers to improve the climate environment of urban parks and thereby improve people's quality of life. In addition, these research results also provide guidance for environmental management and sustainable development and help us better understand the interaction between the urban ecosystem and climate change [45]. In summary, through a comprehensive analysis of the number of articles on the urban park microclimate in major international journals, we can see that the scale of the research field is expanding, which has had a widespread impact in academia and practice. With the deepening of the research and the continuous investment of researchers, we can expect that the research field of the urban park microclimate will continue to achieve greater development and provide more valuable insights for future urban planning and environmental management (see Figure 2).

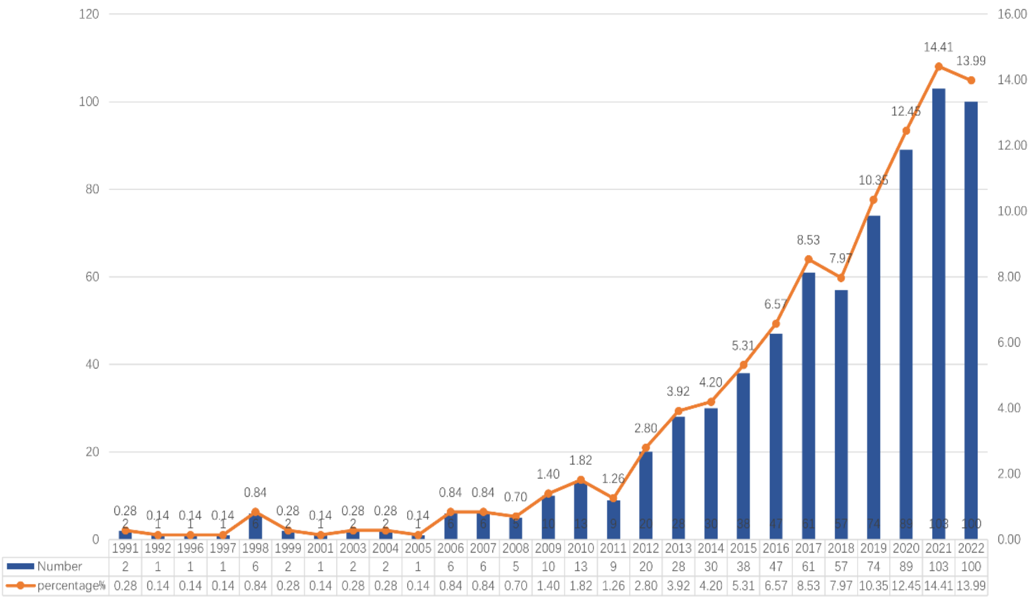

Figure 1. A number of published papers on the microclimate of urban parks.

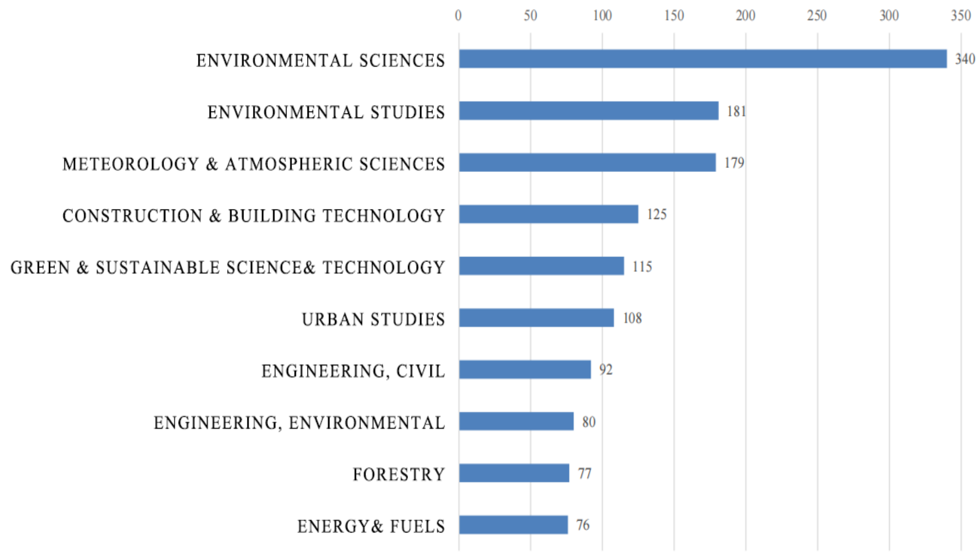

Figure 2. The number of publications on interdisciplinary research of urban park microclimate.

3.1.2. Progress

The existing microclimate research papers cover 75 research directions, mainly focusing on environmental science, environmental research, meteorological and atmospheric science, building and building technology, green and sustainable technology, and urban research [46]. Among them, the field of environmental science has the largest number of papers, totaling 340, which reflects the importance and widespread application of microclimate research in the field of environmental science.

These data (Figure 2) reveal the interdisciplinary nature of urban park microclimate research, where researchers from different disciplines have studied urban park microclimate from their respective perspectives [7,8,17]. It is evident from the figure that the combination of environmental sciences with park microclimate research is the most prominent, with as many as 340 articles. This is followed by environmental studies with 181 articles and meteorology and atmospheric sciences with 179 articles. These interdisciplinary collaborations and blends have led to a diverse and comprehensive research field [18].

From the perspective of literature sources, urban forestry and urban greening, architecture, environment, and sustainability are major research areas related to the microclimate of urban parks. According to the statistical data (see Figure 3), among the papers related to the urban park microclimate, 57 papers in the field of urban forestry and urban greening, 54 papers in architecture, and 49 papers in the environment field. Research in these areas has focused on the interrelationships between the climate environment of urban parks and urban greening, architectural design, environmental protection, and sustainable development [47].

These research results have mainly been published in journals related to urban architecture and environmental research, such as architectural journals, urban forestry journals, and urban greening journals (see Figure 4). This further proves the importance and influence of urban park microclimate research in the field of architecture and the environment.

In conclusion, microclimate research is an interdisciplinary field that covers multiple research directions. Related to urban parks, environmental science, architecture, and architectural technology play an important role in urban research [13]. These studies have been mainly published in journals related to urban architectural and environmental studies, reflecting the increasing academic progress and growing academic influence in the field.

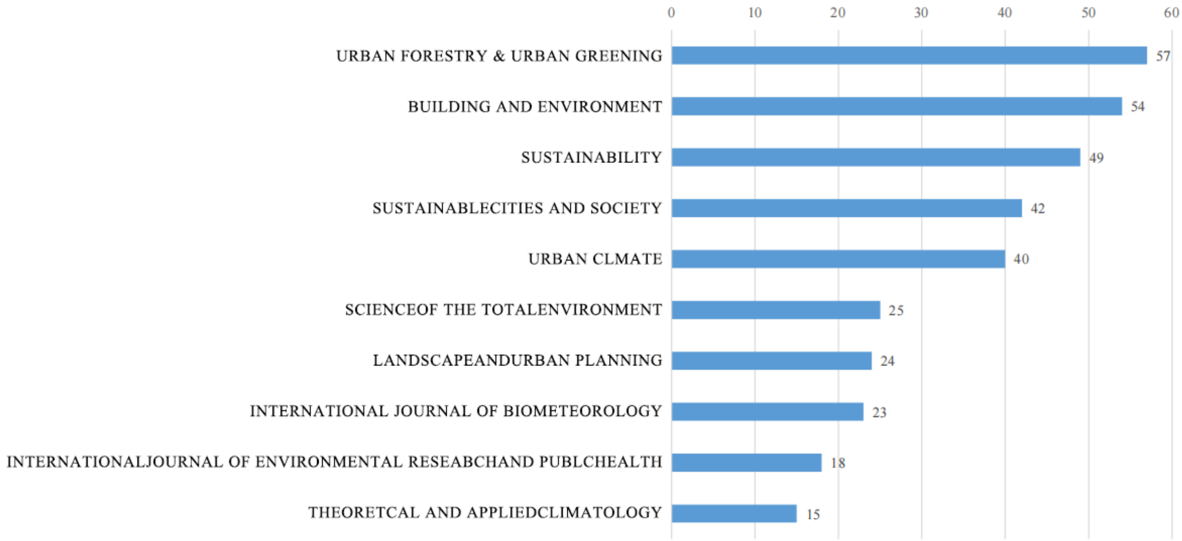

Figure 3. Number of papers published on the urban park microclimate in journals.

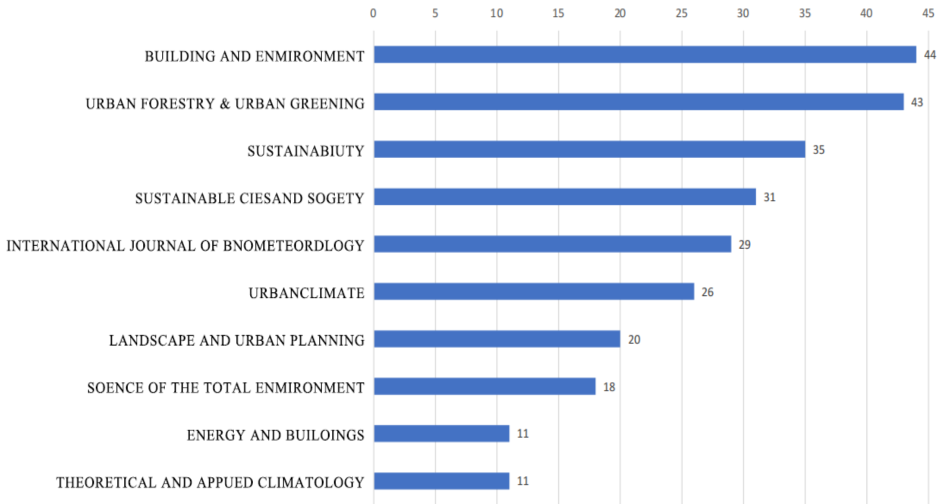

Figure 4. Number of urban microclimate papers published in journals.

3.1.3. Countries and Regions under Study

By analyzing the time series using the tidal band function, we obtained more detail about international cooperation in urban parks from the perspective of cooperative countries (Figures 5 and 6). In the figure, the size of the nodes indicates the number of published papers published in the country, while the thickness of the lines between the nodes indicates the degree of cooperation between different countries. There are 74 nodes and 211 connections in Figure 6.

From the national time zone map of urban park microclimate research in Figure 6, it can be seen that China has the highest number of published papers in the research of urban park microclimate. During the period of 2021–2022, there was a significant increase in publication output, mainly concentrated between 2018 and 2022. The second-ranking country is the United States, with publication output mainly focused between 2015 and 2020. Australia ranks third, with its journals mainly concentrated between 2018 and 2022, experiencing a sharp increase in publication output between 2018 and 2020. However, considering the influence of national conditions and population differences on the data, we have taken into account the impact of the annual average population on national publications. Taking the top five countries in terms of publication ranking (Figure 5) as examples, the United States has the highest per capita publication rate, followed by Australia, while China, with the highest population count, ranks third. These countries reflect their active participation and prominent positions in the field of urban park microclimate research in terms of scale and influence. From a centrality perspective, the number of articles published by most countries is positively correlated with their centrality in the collaboration network [45]. In other words, countries with a higher number of published papers tend to have greater influence and importance in the collaboration network.

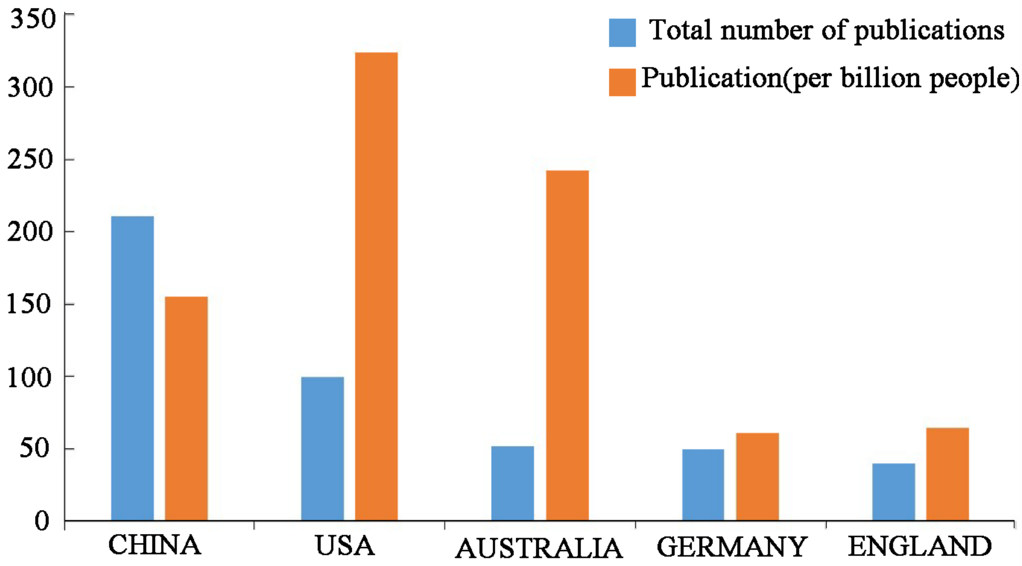

Figure 5. The total number of publications and the annual average publication rate (per billion people).

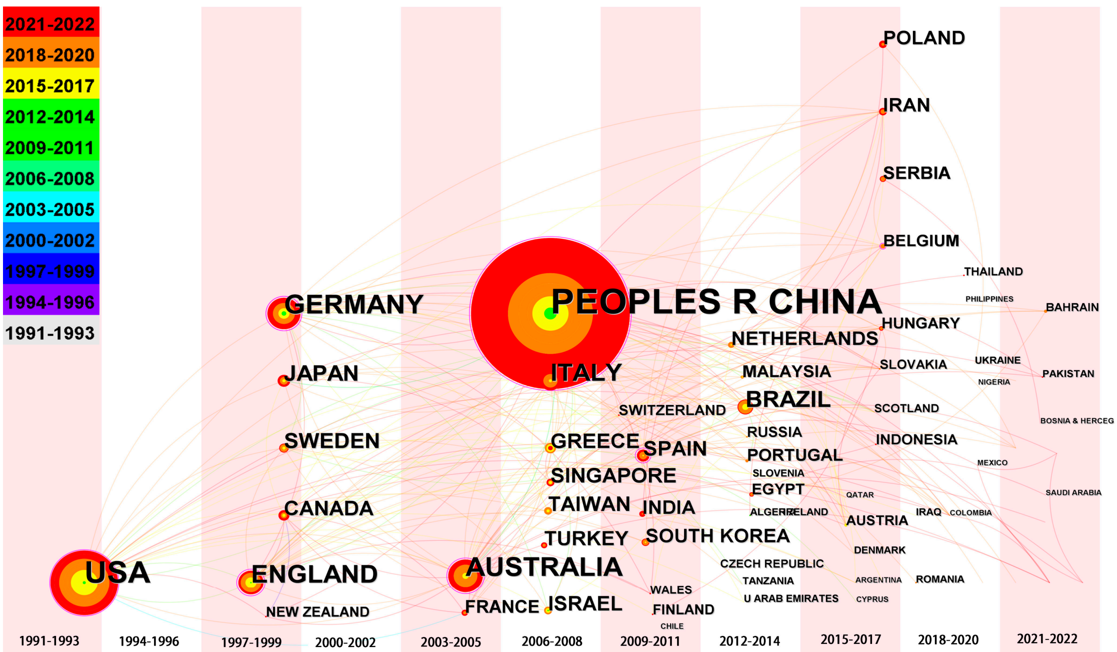

Figure 6. National time zone map for small climate studies in urban parks.

In addition, countries that have started research in recent years include Bahrain, Pakistan, and Bosnia. The participation of these countries in the field of microclimate research in urban parks shows that the field is attracting attention from international scholars and has entered a leapfrog stage of development [48–50]. As more countries and regions join this research field, it is expected that urban park microclimate research will continue to flourish and achieve greater global influence in the coming years.

3.2. Cluster Analysis of Keyword Co-Citation

Research hotspots are the focus of scholars in specific academic fields, which reflect the main issues discussed in the field over a certain period of time [25,51–53]. As an important part of academic papers, keywords are often used to study the research focus of a certain field when condensing the essence of papers. In order to reveal the research hotspots in the field of the urban park microclimate, this study used CiteSpace software to conduct keyword co-occurrence clustering analysis [41] and presents the clustering view of keywords in a visual way, as shown in Figure 6. Different color blocks represent different clustering regions.

In Figure 6, the number of nodes (N) of the network is 553, the number of connecting lines (E) is 2342, and the network is 0.0153. The size of the module value Q correlates with the sparsity of the nodes, and the larger the Q value, the better the clustering effect, which can be used for scientific cluster analysis. The size of the mean contour value S can measure the homogeneity of the cluster, and the larger the S value, the higher the homogeneity of the network, indicating that the cluster has a high confidence. According to the results of Figure 7, we can see that the Q value was 0.493, which indicates good clustering of network structure, while the S value was 0.767, indicating the high consistency of different clusters.

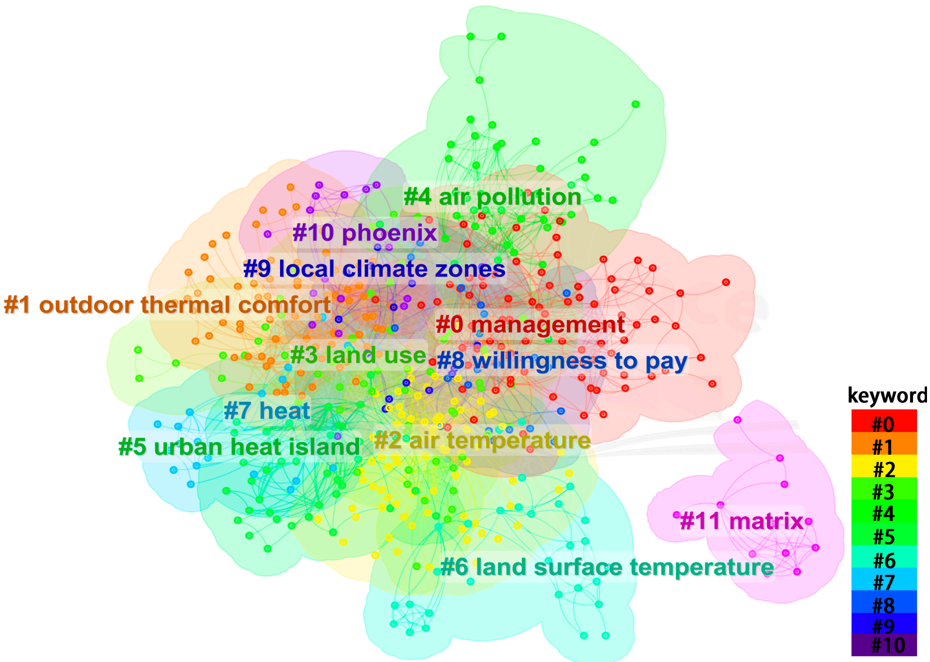

Figure 7. Co-occurrence cluster map of keywords in microclimate research in urban parks.

The figure shows ten major keyword clusters, with "management", "outdoor thermal comfort", and "air temperature" as the primary focus. These clusters were mainly concentrated in time between 2010 and 2017, showing that the research field was relatively mature during this period. The largest cluster was "management", which was formed in 2004 and contains 90 keywords involving nature-based solutions, ecosystem services, cultural ecosystem services, and other related concepts. The top five clusters mainly cover topics such as outdoor thermal comfort, air temperature, and land use (see Table 1).

In conclusion, the keyword co-occurrence cluster analysis revealed the research hotspots in the field of the urban park microclimate and the key issues that scholars paid attention to in a specific time period [12,54,55]. The discovery of these research hotspots has important implications for future research directions and priority areas and will contribute to further development and maturation [56].

Table 1. Important words used by the cluster.

Rank	Cluster Name	The Main Keywords	Mean Number of Years	Number of Keywords
1	manage	Management (11.99, 0.001); Nature-based solutions (8.71, 0.005); Ecosystem Services (8.21, 0.005); Cultural Ecosystem Services (7.99, 0.005); Twitter (7.99, 0.005)	2017	90
2	Outdoor thermal comfort	Outdoor Thermal Comfort (72.43, 1.0×10^{-4}); Pet (24.34, 1.0×10^{-4}); UTCI (16.57, 1.0×10^{-4}); thermal adaptation (13.66, 0.001); Thermal sensation voting (10.97, 0.001)	2011	80
3	air temperature	Air temperature (22.04, 1.0×10^{-4}); surface temperature (11.05, 0.001); outdoor thermal comfort (10.47, 0.005); thermal environment (9.75, 0.005); cooling effect (7.5, 0.01)	2014	79
4	land use	Land use (8.48, 0.005); Park (8.04, 0.005); Ecosystem Services (7.6, 0.01); ecosystem service (7.46, 0.01); thermal comfort (7.32, 0.01)	2010	62
5	air contamination	Air pollution (29.25, 1.0×10^{-4}); Particulate matter (18.48, 1.0×10^{-4}); Urban cooling (12.31, 0.001); Environmental management (12.31, 0.001); Urban form (12.31, 0.001)	2012	44

3.3. Research and Development Stage of the Microclimate in Urban Parks

3.3.1. Dynamic Changes and Differentiation of Keywords

Frontier trend analysis is a literature cluster that consistently cites a fixed set of basic literature, mainly based on co-citation clustering and citation analysis, to describe the transition and nature of a specific type of research field [36,57,58]. Timeline mapping demonstrates the keyword clustering of the literature on a two-dimensional timeline so that researchers can explore the evolutionary and frontier trends of specific clusters. The largest cluster in the literature related to the urban park microclimate was "management", which contains 90 keywords with the average year of 2017, including keywords "management" proposed around 2004 (Figure 8). Over time, keywords have expanded to include "nature-based solutions", and "ecosystem services", largely focused on the evolution of microclimate studies in urban parks. According to the recent clustering results in the figure, the new keywords include "air pollution", "outdoor hot comfort", "residents", etc. According to the systematically generated cluster report, the literature best matching the cluster keywords was "The impact of plant clusters on the cooling effect: a case study of a subtropical island park, China's global ecology and conservation". Its rich connectivity with clusters such as the urban park microclimate suggests a degree of multi-topic co-occurrence [42].

The keywords of urban park microclimate were used to map the distribution, which was also one of the key elements of the analysis (Figure 9). Each node in the time zone plot represents a keyword, and the node size indicates how often that keyword appears [59]. Larger nodes represent hotspots for microclimate research, and red nodes indicate the occurrence of emergent keywords [60]. The analysis showed extensive studies of the urban park microclimate, and that keywords gradually began to move from the initial focus on the urban climate, urban park, human thermal comfort, and heat island effect to the multidisciplinary study of outdoor thermal comfort [61], climate change, green infrastructure, ecosystem services, and the urban microclimate between 1991 and 2023.

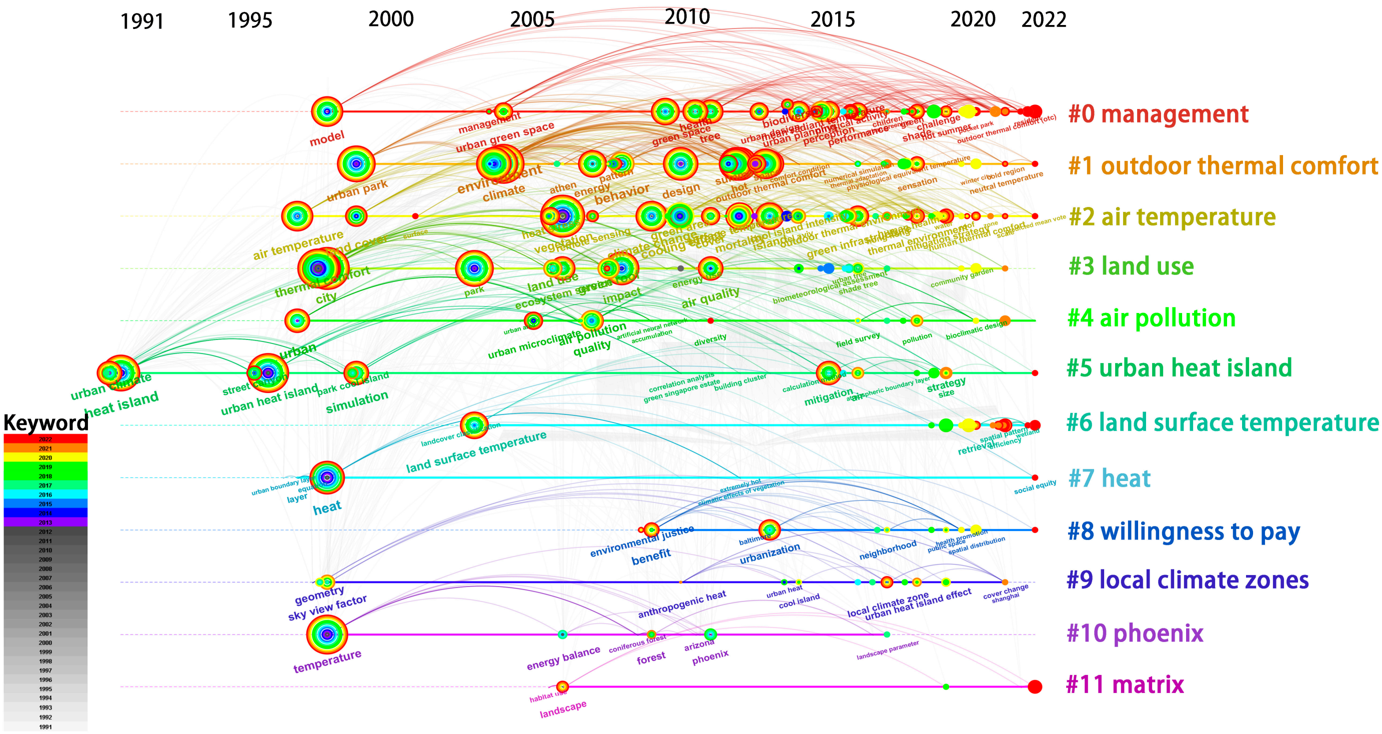

Figure 8. Keyword timeline mapping.

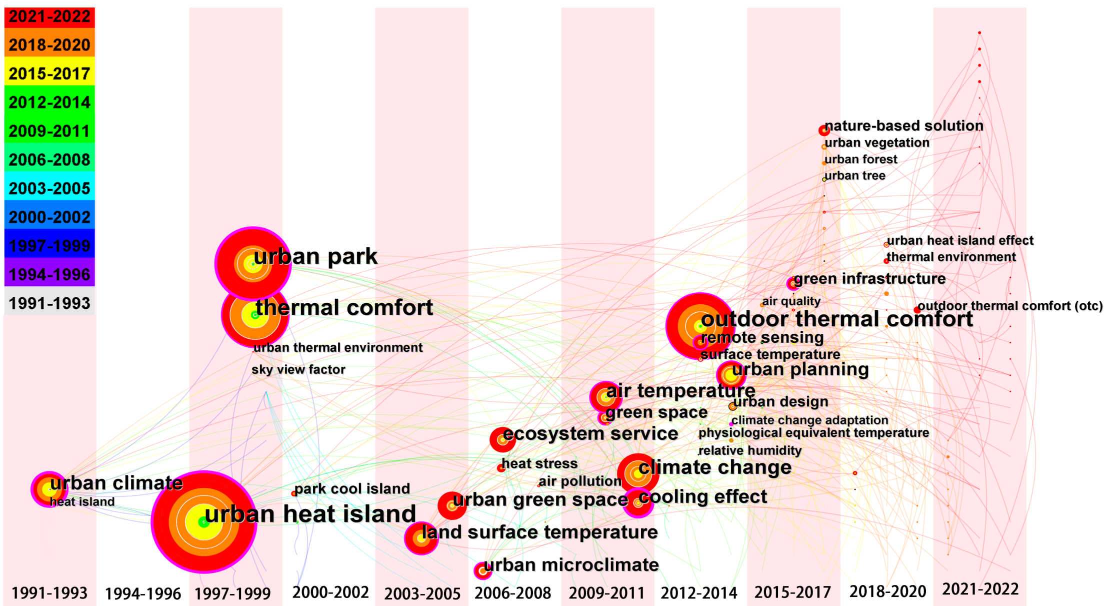

Figure 9. Keyword time zone map of the urban park microclimate.

3.3.2. Four Stages of Microclimate Research in Urban Parks

From 1991 to 1998, the high-frequency keywords were heat island effect, urban effect, and thermal effect (Table 2), indicating that the research on the urban park microclimate was mainly focused on the understanding and analysis of the urban climate, without in-depth analysis of the microclimate in specific urban locations [62]. However, the relevant literature and attention in this period were limited; papers mainly focused on climate change across the whole city, and no systematic model of microclimate research had been established.

Table 2. Distribution table of high-frequency keywords in urban park microclimate studies.

Phase Position	Year	Frequency	Keywords
1991–1998	1991	4	heat island
	1997	3	urban
	1998	3	heat
	1997	2	layer
	1996	1	urban heat island
	1998	1	heat comfort
	1996	1	canyon geometry
	1998	1	car through
	1998	1	objective lag model
	1998	1	Shuifen
1999–2006	2004	3	area
	1999	3	heat island
	2004	3	climate
	2004	2	environment
	1999	2	urban park
	2006	2	plant
	2003	2	city
	2006	1	ecosystem service
	1999	1	boundary layer resistance
	2003	1	coastal area
	2004	3	area
2007–2016	2008	57	city
	2007	54	climate
	2009	47	park
	2007	37	urban heat island
	2009	35	temperature
	2011	35	heat comfort
	2009	34	plant
	2008	32	influence
	2007	29	area
	2010	28	heat island
2017–2022	2017	128	influence
	2017	125	city
	2017	100	urban heat island
	2017	99	park
	2017	98	climate
	2017	93	temperature
	2017	85	urban park
	2017	82	plant
	2017	79	heat comfort
	2017	79	climate change

During 1999–2006, the frequent keywords were region, heat island, climate, environment, and urban parks (Table 2). Many studies at the time included urban vegetation, architecture, and air in the urban microclimate research system [63]. We continued to study the interaction between the urban microclimate and urban environment and build urban microclimate models using environmental conditions and impact indicators [63]. Some studies also included small areas of the city (indoor environments, such as houses, parks, etc.) as research subjects of microclimate research [14,64]. The number of research papers at this stage increased and attracted a certain degree of academic attention. However, based on a few previous studies, the research system of the urban park microclimate was not mature, and its value remained unclear.

In the study of urban parks from 2007 to 2016, the keywords mainly focused on cities, climate, parks, and urban heat islands (Table 2). There is no doubt that research at that time began to focus on thermal comfort, combining the human experience, urban construction, and microclimate research [65–67]. At the same time, extensive academic research led to the strengthening and development of research technologies and factors affecting the microclimate in urban parks [68]. At this stage, the number of documents increased significantly (Figure 1). The research methods and value system of the urban park microclimate gradually improved, the research system became more mature, and the theoretical basis was more in-depth [69].

From 2017 to 2023, the high-frequency keywords were influencing factors: city, urban heat island, and park (Table 2). At this stage, the main direction of research was to improve thermal comfort for humans through ecological synergies and modeling techniques for interdisciplinary research [70]. At the same time, the ecological construction and landscape design of cities became more highly valued [71]. During these five years, the theoretical research and practical application of the urban park microclimate were closely combined with the environment and ecology, the subject scope was wider, and the relevant research results and technical methods also developed rapidly.

4. Research Hotspots

4.1. Distribution of Research Hotspots Based on Keyword Clustering

In the process of finding research hotspots, the word frequency analysis of keywords is an essential tool to effectively and accurately reveal their distribution [72]. In this study, keyword mapping analysis using VOSviewer software selected the top 54 keywords with high frequency in urban park microclimate studies. The word frequency threshold was set through the analysis of these high-frequency keywords; we revealed the research hotspots of microclimate research in urban parks [16,73].

According to the results of Figure 10, it can be seen that the most frequently occurring keywords from 1991 to 2006 include 'microclimate', 'heat island', 'urban parks', and 'urban climatology'. From the results of Figure 11, it is evident that the most frequently occurring keywords between 2007 and 2022 are 'urban heat island', 'urban parks', 'human thermal comfort', 'outdoor comfort', 'climate change', and 'urban planning'. These keywords reflected the focus and main issues of scholars on microclimate research in urban parks at this time [74]. Through the keyword analysis and mapping of the study time division axis, we were able to further explore the distribution of research hotspots (see Figure 12).

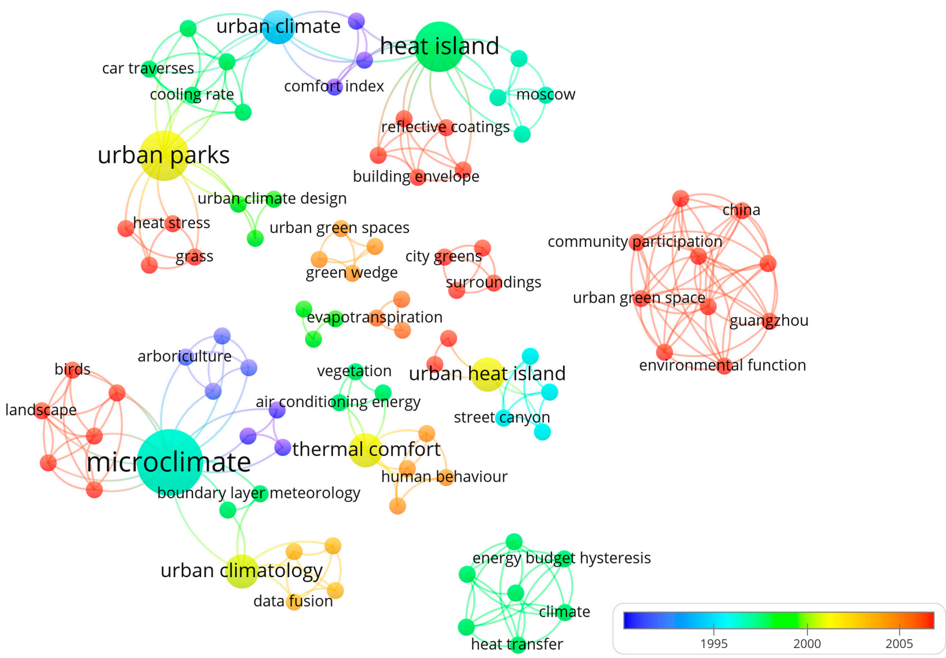

Figure 10. Co-occurrence network of urban park microclimate research from 1991 to 2006.

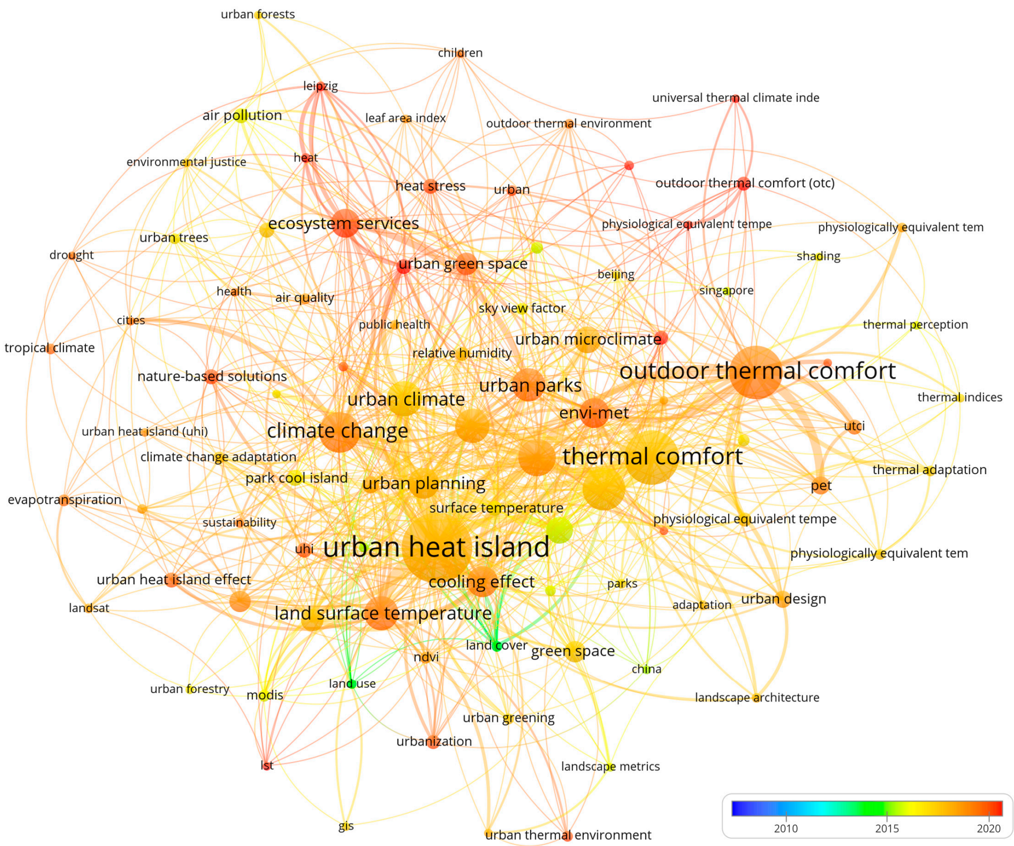

Figure 11. Co-occurrence network of urban park microclimate research from 2007 to 2022.

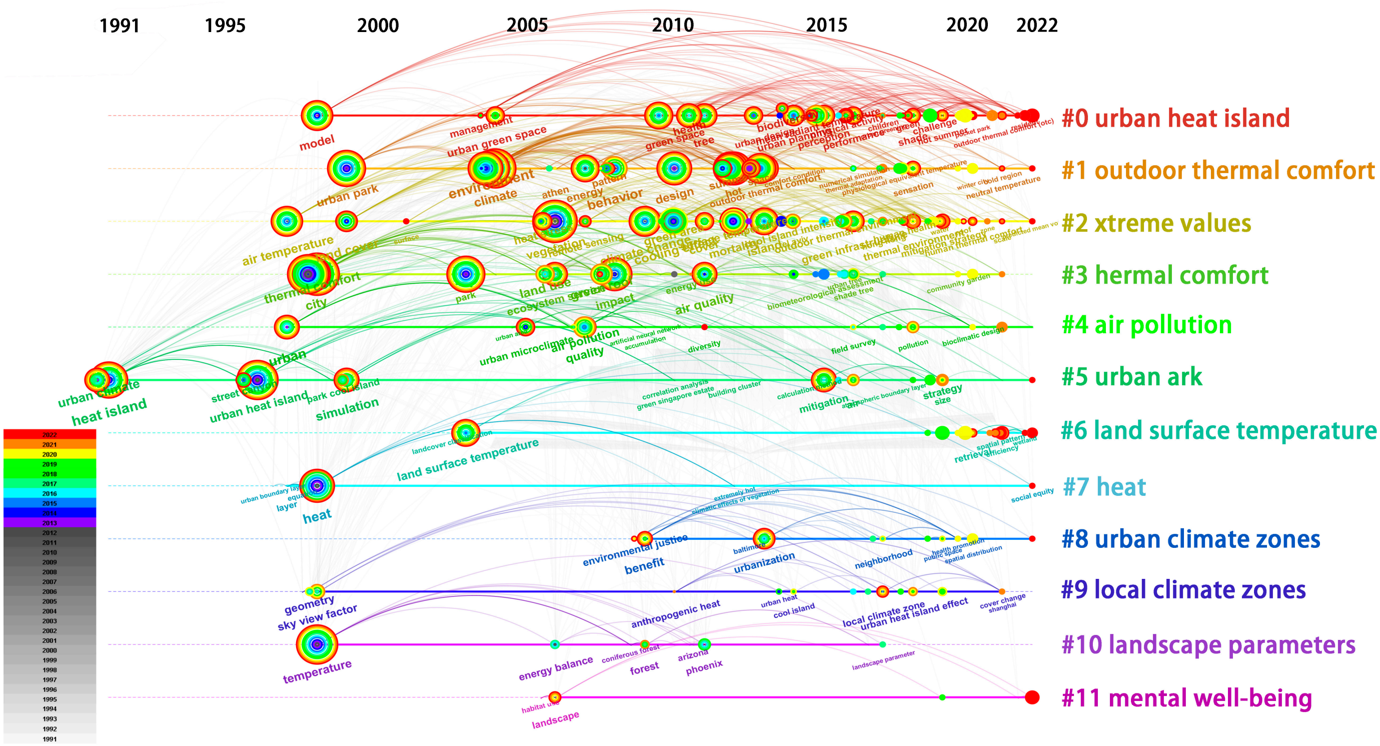

Figure 12. Axial axis diagram of microclimate research in urban parks (12 categories).

Through the analysis of CiteSpace software, we obtained 12 research hotspots related to urban park microclimate clustering: #0 city heat island, #1 outdoor hot comfort, #2 extreme, #3 thermal comfort, #4 air pollution, #5 city park, #6 surface temperature, #7 heat, #8 urban climate, #9 local climate zone, #10 landscape parameters, and #11 mental health. Through the keyword analysis of these research hotspots, we achieved a deeper understanding of the research priorities and hot issues in the field of the urban park microclimate.

In particular, urban heat island, as a long-term research keyword with high vocabulary centrality, is considered one of the important research hotspots of microclimate research in urban parks [75–77]. It involves the heat distribution within the city, the formation mechanism of the urban thermal environment, and the control of the heat island effect in urban planning and design [78]. This indicates that scholars have paid continuous attention to the study of urban heat islands and have made important contributions to this concept in the field of the urban park microclimate.

In conclusion, the distribution of research hotspots in urban park microclimate research could be clearly revealed by keyword clustering analysis [79]. These research hotspots included urban heat islands, outdoor heat comfort, climate change, urban planning, and other keywords, reflecting the main topics that scholars have focused on in this field [80]. These research hotspots provide important guidance and reference for further exploring the microclimate of urban parks.

4.2. Frontier Analysis and Hot Spot Prediction Based on Keyword Emergence

Keyword bursts provide evidence that specific keywords are associated with a surge in frequency and indicate that a potential topic at a particular time attracts or is attracting unusual attention from researchers [55]. Burst detection is therefore considered an indicator of highly active research areas and allows for the exploration of emerging trends.

Sudden words refer to the words that appear frequently in a certain period of time. Their changes can reflect the hot spots of scholars in the field in this period, and they are also a basis for judging the evolutionary development trend of this field [81,82]. To achieve a deeper understanding of the evolutionary trends of the urban park microclimate [38], the results of the sudden word field, which are presented in Figures 13 and 14, included the sudden onset, duration, and intensity of sudden emergence. On this basis, this paper presents the development trend of urban park microclimate research from the perspectives of occurrence intensity, duration, and occurrence time.

From the time series from 1991 to 2006 (Figure 13), “heat island”, “diurnal change”, “urban park”, “urban green space”, “urban microclimate”, and “urban microclimate” appeared for the first time. “Urban green space”, “urban microclimate”, and “water balance” emerged in the later period and continued until 2006. This will be a point of follow-up for future studies. In terms of the duration of the emergence, “hot island”, “urban climatology”, and “urban green space” were notable. The long occurrence of “heat islands”, “urban climatology”, and “urban green space” indicated that they have long been the focus of related research. Based on the intensity of emergent words, we found that “heat island” (Strength = 0.77), “urban microclimate” (Strength = 0.68), and “water balance” (Strength = 0.66) had very high emergent intensity, indicating a significant change in frequency.

From the time series from 2007 to 2023 (Figure 14), “heat island”, “daily change”, “urban park”, “urban green space”, “urban microclimate”, and “urban microclimate” emerged for the first time. “Urban green space”, “urban microclimate”, and “water balance” were updated and have continued until now. This will be a point of follow-up for future studies. In terms of the duration of the emergence, “heat islands”, “urban climatology”, and “urban green space” were notable. The terms “heat island”, “urban climatology”, and “urban green space” appeared for longer, indicating that they have long been the focus of relevant research studies. Based on the emergent intensity of emergent words, we found that “heat island” (Strength = 0.77), “urban climatology” (Strength = 0.65), and “urban green space” (intensity = 0.6) had very high emergent intensity, indicating a significant change in frequency. Overall, “urban green space”, “urban microclimate”, and “water balance" are considered the latest hotspots, not only because of their high occurrence intensity but also due to their proximity to time.

In general, with the passage of time, the progress of society, and the change in the external environment [83], the research content and hotspot degree of the "urban park microclimate" are constantly changing, which also shows that the "urban park microclimate" is a topic with research value from other perspectives.

Figure 13. Appearance of keywords from 1991 to 2006. (The higher the intensity of an emerging term, the more significant the frequency change.)

Figure 14. Appearance of keywords from 2007 to 2022. (The higher the intensity of an emerging term, the more significant the frequency change.).

5. Future Directions

5.1. Future Research Directions

The impact of climate change on the microclimate of urban parks: With global warming, the microclimate of urban parks will also be affected. Future research could explore multiple aspects, including the impact of climate change on factors such as temperature, humidity, and wind speed in urban parks [2,6,84]. Further studies should also examine specific adaptation strategies to mitigate these effects. For instance, investigating the influence of green space design and layout on the microclimate of urban parks [85], the interaction between buildings and vegetation on the microclimate of urban parks [8,12], the spatial scale impact on the microclimate of urban parks [11,86], and the relationship between urban park microclimate and human health [1,7,9,87]. As shown in Figure 15, we utilized the visual aid tool Citespace to create a cluster analysis diagram that illustrates the future development trends of microclimate in urban parks. This diagram visually presents the interrelationships between architecture and vegetation in urban park microclimate, the influence of spatial scale on microclimate in urban parks, the relationship between microclimate in urban parks and human health, as well as the application and development perspectives of numerical simulations. In summary, this cluster analysis diagram provides an intuitive interpretation of the future development trends of microclimate in urban parks.

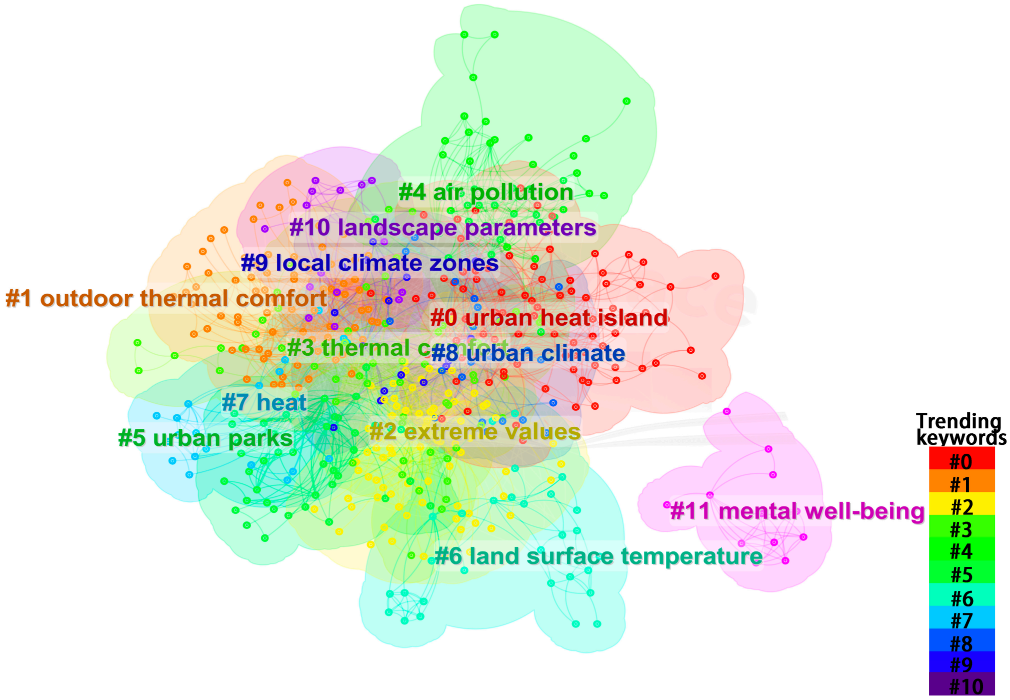

Figure 15. Key trends in the development of microclimate in urban parks.

The impact of green space design and layout on the microclimate of urban parks: Different types and layouts of green spaces may have different effects in improving the microclimate of urban parks. Further research could explore the optimal green space design and layout strategies to maximize the improvement of microclimate conditions in urban parks [83].

The impact of the interaction between buildings and vegetation on the microclimate of urban parks: There are complex and subtle interactions between buildings and vegetation, which may have significant impacts on the microclimate of urban parks [43,46,87]. Future research could delve into the impact mechanism of the interaction between buildings and vegetation on parameters such as temperature, humidity, and wind speed in urban parks.

The impact of spatial scale on the microclimate of urban parks: Factors such as the size, shape, and spatial distribution of urban parks may have an impact on their microclimate conditions [83]. Further research can explore the differences in microclimate in urban parks at different spatial scales and propose corresponding planning and design suggestions.

The relationship between urban park microclimate and human health: There is a close connection between urban park microclimate and human health [84]. Future research could delve into the impact mechanisms of the urban park microclimate on human comfort, mental health, and physiological health, providing a scientific basis for improving the quality of life of urban residents.

Through in-depth exploration of the above research directions, we could better understand the microclimate characteristics and influencing factors of urban parks, providing scientific support and guidance for improving urban environmental quality and enhancing people's quality of life.

5.2. Multidisciplinary Convergence Analysis Study

Micro-research in urban parks requires the synthesis of multidisciplinary knowledge and methods to conduct convergence analysis research. This integrated approach can provide a comprehensive understanding and the ability to address microclimate problems in urban parks [85]. The following are some of the main areas of multidisciplinary convergence analysis in the microclimate of urban parks:

Meteorology and Climatology: Knowledge of meteorology and climatology is essential for microclimate research in urban parks. These disciplines can provide a theoretical basis for meteorological parameters such as temperature, humidity, precipitation, and wind speed, and reveal the climate characteristics and change laws in urban parks through observation, data analysis, and numerical simulation.

Geography and Topography: Geography and topography provide information on the spatial distribution of the microclimate in urban parks. Through the analysis of topography, geomorphology, and geographic information systems (GIS) [87], the influence of the surface characteristics, vegetation coverage, water distribution, and other factors on the microclimate can be determined, providing a spatial reference for the planning design of urban parks.

Botany and Ecology: Knowledge of botany and ecology is critical to understanding the physiological properties and ecological functions of vegetation in urban parks. Investigation and analysis of the plant community structure, vegetation type, and vegetation coverage in urban parks can elucidate the role of vegetation in regulating their microclimate, such as the effects on temperature, humidity, and wind speed [86].

Architecture and Urban Planning: The perspectives of architecture and urban planning contribute to understanding the interaction between urban parks and the surrounding built environment. By analyzing the layout of urban parks, the height of buildings, shadow effects, and other factors, we can evaluate their impact on the microclimate and propose corresponding design strategies to optimize the climate environment of urban parks.

Sociology and Human Geography: Studies of sociology and human geography can focus on the users of urban parks and their perception and adaptation to the microclimate. Through social surveys, interviews, and behavioral observations, we can understand the needs, preferences, and comfort levels of park users, providing a social sustainability perspective for park design and planning [13,45,48].

By combining knowledge and methods from these disciplines, urban park microclimate research can be analyzed and addressed based on multiple dimensions. Such a multidisciplinary convergence analysis study can provide a comprehensive understanding of the microclimate problems in urban parks and thus provide a scientific basis for the planning, design [49], and management of urban parks, creating a healthier, more comfortable, more sustainable urban environment.

5.3. Prospects of Numerical Simulation Studies

Numerical simulation plays an important role in the microclimate study of urban parks [50]. They can simulate and predict microclimate parameters such as the temperature distribution, wind field characteristics, and humidity variation in urban parks. In the future, numerical simulation research has the following prospects in the field of the urban park microclimate:

Refined Simulation: The current numerical simulation method has been able to simulate the microclimate of urban parks on a larger scale, but with the improvement of computing power, higher resolution and more refined simulation could be achieved in the future. By increasing the spatial resolution and the temporal resolution of the model, it could more accurately simulate the meteorological changes at different locations within the urban park, providing more detailed microclimate information.

Model Validation and Optimization: The accuracy and reliability of numerical simulations are critical to the validity of the study results [88]. Future studies could strengthen the validation of the numerical simulation results and improve the credibility of the models by comparing and verifying them with field observation data. At the same time, they could also improve and optimize the numerical model to reduce errors and uncertainty.

Multi-actor Coupling Simulation: The urban park microclimate is comprehensively affected by a variety of factors, including vegetation, water bodies, buildings, terrain, etc. [11,19]. Future numerical simulation studies could further strengthen the coupled simulations of these factors, considering the interactions and complexities between them. By simulating the changes and combinations of different factors [89], we could gain insight into the impact of each factor on the microclimate of urban parks, providing more precise guidance for optimizing park design and planning.

Scenario Simulation and Decision Support: Numerical simulation can be used to simulate the urban park microclimate under different scenarios, such as different vegetation configurations, different building layouts [56], etc. Future studies could use numerical simulation techniques to provide support to policymakers to assess the impact of different planning strategies and measures on the urban park microclimate and to optimize park design for better climate adaptation and ecological sustainability.

Model Integration and Comprehensive Application: The research of the urban park microclimate requires the comprehensive application of multiple models and methods. In the future, numerical simulations could be integrated with other models and methods, such as remote sensing data, GIS, social survey data, etc. [3–5]. Through the comprehensive application of different models and methods, a more comprehensive study of urban park microclimate problems and a deeper understanding of the complex relationships with the urban environment, ecosystem, and human activities could be achieved [86].

Overall, numerical simulations have great potential for microclimate research in urban parks [42]. Future developments will further improve simulation accuracy and credibility, deeply explore the coupling effects of different factors, provide more specific and reliable information for decision-makers, and promote the climate adaptability and sustainable development of urban parks.

This study will support further investigations into the relationship between urban park microclimate and the urban ecosystem. It will enable us to explore the dynamic interaction between vegetation and climate, examine the contribution of vegetation ecosystem services, and evaluate the role of urban parks in biodiversity conservation. On the one hand, we will extend our research to investigate the impacts of climate change on microclimate conditions in urban parks. This will involve studying the vulnerability of urban parks to climate change and developing adaptive strategies to mitigate its negative effects, promoting enhanced climate adaptability [59–61].

On the other hand, we aim to explore the application of intelligent technologies in managing microclimate within urban parks. By utilizing the Internet of Things, sensor networks, and artificial intelligence, we can establish real-time monitoring systems, early warning mechanisms, and automatic regulation approaches. These advancements will significantly enhance the efficiency and accuracy of park microclimate management. Furthermore, we will emphasize the integration of microclimate planning with urban park design. By incorporating microclimate considerations in the early stages of park planning and design, we can optimize the park microclimate environment through rational layouts, strategic vegetation configurations, and appropriate architectural designs [77]. Through international cooperation and experience-sharing, we will jointly study the microclimate of urban parks and provide intellectual support for the climate adaptability and sustainable development of urban parks around the world.

In conclusion, the study of the microclimate in urban parks is of great significance in improving urban environmental quality, improving residents' quality of life, and promoting urban sustainable development. Future research should continue to explore the associations of the microclimate with urban ecosystems, climate change, and smart technologies and strengthen the practical application of microclimate planning and design to contribute to the creation of a healthier, habitable, and sustainable urban park environment.

6. Conclusions

In-depth research on the microclimate characteristics of urban parks has significant practical importance. By understanding and exploring the microclimate variations in urban parks, scientific evidence can be provided for urban planning, environmental improvement, and ecological conservation. As an integral component of urban green spaces, urban parks play a crucial role in enhancing the urban environment and improving residents' quality of life through their microclimate conditions [35]. Studying the microclimate of urban parks helps to reveal air circulation patterns and heat distribution patterns and provides scientific references for park design and planning.

Based on the impact of specific green space design and layout, the interaction between buildings and vegetation, the influence of spatial scale, and the relationship between urban park microclimate and human health, we propose the following strategies for the development of urban park microclimate:

Optimize Green Space Design and Layout: Careful consideration should be given to the arrangement and distribution of vegetation within urban parks. Strategic placement of trees and shrubs can help provide adequate shade, promote natural ventilation, and mitigate heat island effects.

Enhance Building–Vegetation Interactions: Incorporating green roofs and vertical gardens into building designs can enhance the cooling effect and air quality improvement of urban parks. It is important to explore and implement innovative architectural and landscaping techniques that maximize the mutual benefits between buildings and vegetation.

Consider Spatial Scale: When planning and designing urban parks, it is crucial to consider the appropriate spatial scale to achieve desired microclimate conditions. The size and layout of park elements, such as open green spaces, water features, and tree-lined paths, should be carefully balanced to ensure effective microclimate regulation.

Promote the Link between Urban Park Microclimate and Human Health: Recognizing the positive impacts of urban park microclimate on human well-being, efforts should be made to raise awareness and promote the use of parks for recreational activities, relaxation, and social gatherings. This includes providing amenities like shaded seating areas, water fountains, and fitness facilities to encourage physical activity and improve overall health outcomes. By implementing these strategies, urban park planners and designers can create more comfortable and sustainable microclimates that benefit both the environment and the well-being of residents.

In summary, strengthening research on the microclimate of urban parks can provide information for enhancing urban comfort and improving the urban climate environment in urban planning. It also contributes to enhancing the ecological functionality and social benefits of parks. Therefore, the significance of studying the microclimate of urban parks should not be overlooked, as it helps to promote sustainable urban development and improves people's quality of life.

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