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| RESEARCH ARTICLE

Knowledge Map of Urban Climate Map: A Bibliometric Analysis Based on CiteSpace

Zhuoqun Qing
Faculty of Innovation and Design, City University of Macau, Macau, China
Corresponding Author: Zhuoqun Qing, **E-mail**: U20091120303@cityu.mo

| ABSTRACT
The process of urbanization is that people pay more and more attention to the sustainable development of cities and pay attention to the consideration of climate and environment in urban planning. Urban climate maps combine urban planning with urban climate and have been proposed since the 1980s. Based on the web of science database, this paper searches for documents published with the subject heading of urban climate maps since their appearance and uses Citespace to visualize the document information. The analysis content includes authors, journals, countries, publishing institutions, and keyword clustering analysis: cited literature analysis and research frontier hotspots. Through the analysis, it is found that the research fields of urban climate maps can be divided into four categories, namely research methods, healthy cities, resilient cities, and ecological bases.

| KEYWORDS
Urban planning; urban climatic map; climatopes; thermal environment; air ventilation; sustainable urban development.

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1. Introduction

Today's urbanization process is accelerating, and the subsequent urban expansion and construction are changing the human living environment (Lambin EF et al., 1999). Construction and development within the city limits will also have an impact on the climate environment and living environment of the region (Esser G, 1989), resulting in a small-scale microclimate. In addition to urbanization, natural disasters such as global warming, floods, and fires are also threatening the environment on which human beings depend. More and more scholars have begun to pay attention to the sustainable development of cities and proposed to incorporate urban climate factors into urban planning so that urban construction can adapt to climate change and resist natural disaster risks. Integrate climatic environment and urban planning and design, transform it into planning language and apply it to urban planning (VDI, 1997). The urban climate map is a map that converts factors such as climate status and urban construction environment into two-dimensional graphics and combines them for analysis. Generally, it includes the urban climate analysis map and the urban climate proposal map. Many countries have begun to attach importance to the application of urban climate maps. The first country to propose urban climate maps is Germany (Scherer D et al., 1999). Because Germany was at the end of World War II, the city was in urgent need of repair and improvement; coupled with the terrain and industrialization of the German basin, the air pollution in Germany was very serious at that time, and promoting urban ventilation through urban construction became one of the most urgent problems in Germany at that time. This paper summarizes all the articles on the web of science since the introduction of the urban climate map. The article spans more than 30 years, from 1988 to the present. It uses citespace to systematically analyze the trend of the annual publication volume of this topic, the status of journal submissions, the main author, Major institutions, and research countries, in addition to these basic analysis data, also analyzed keyword clustering, co-cited literature, and keyword frontier trends. In the field of urban climate maps, no scholar has used the citespace system to analyze a systematic review from 1988 to the present. This article is not a detailed introduction to the content of urban climate maps but a systematic presentation and overview of the research history and current situation of this topic.

2. Methodology

2.1 Materials

The data comes from the web of science core collection, which is the most widely used core journal library in the world, and the included papers have certain authority and influence. (Matzarakis A et al., 2005) It has a wide range of searches, and the time span includes from 1900 to the present. Many scholars use wos to find sources of review papers (Yang et al., 2021), and the results are representative.

2.2 Methods

Citesapce is software for quantitative literature and visualization (Singh, V.K et al., 2021). It was developed by Dr. Chen Chaomei's team, based on the java environment, for quantitative analysis and visualization of literature (Börner, K et al., 2003). The knowledge graph can not only analyze some descriptive statistical characteristics of articles, such as the trend of publication volume, important authors, major countries, major institutions, submitted journals, etc., but also analyze the keywords of research in this field, and find hot spots from the timeline graph. Frontiers, co-citation cluster analysis, can analyze the main research topics, and so on. Citespace has become one of the most used software for scholars' research papers review (Chen, Y, 2005) and has been unanimously recognized by scholars at home and abroad.

The data retrieval was carried out on March 7, 2022, and the retrieval formula was "(TS = ("urban climate map" or "UCMap")). Since 1900, a total of 4011 papers have been obtained. Each document information contains all the Records and references. Cleaned and deduplicated in citespace, removed duplicate papers, and formed the final collection of urban climate maps, including a total of 3505 valid papers from 1988 to 2022.

3. Results and Discussion

3.1 Descriptive Analysis

3.1.1 Post volume trends

According to figure1, we can see the development history and popularity of this field. After the statistics of the number of journal articles published each year, from the appearance of the keywords to March 2022, the research on the urban climate map can be divided into three stages. The first stage is the initial stage. From 1988 to 2007, most of the papers published during this period were below 20. In some years, no papers were published, and the research was relatively small; the second stage was the development stage, from 2008 to 2014; the number of published articles has grown slowly; the third stage is the outbreak stage. From 2015 to the present, the annual growth rate has been very high, and the number of published articles has continued to rise, exceeding 600 in 2021. This shows that urban climate maps have attracted more and more attention from scholars all over the world. Research in this field is in a vigorous development stage, the number of published papers will continue to rise, and new hotspots will continue to emerge.

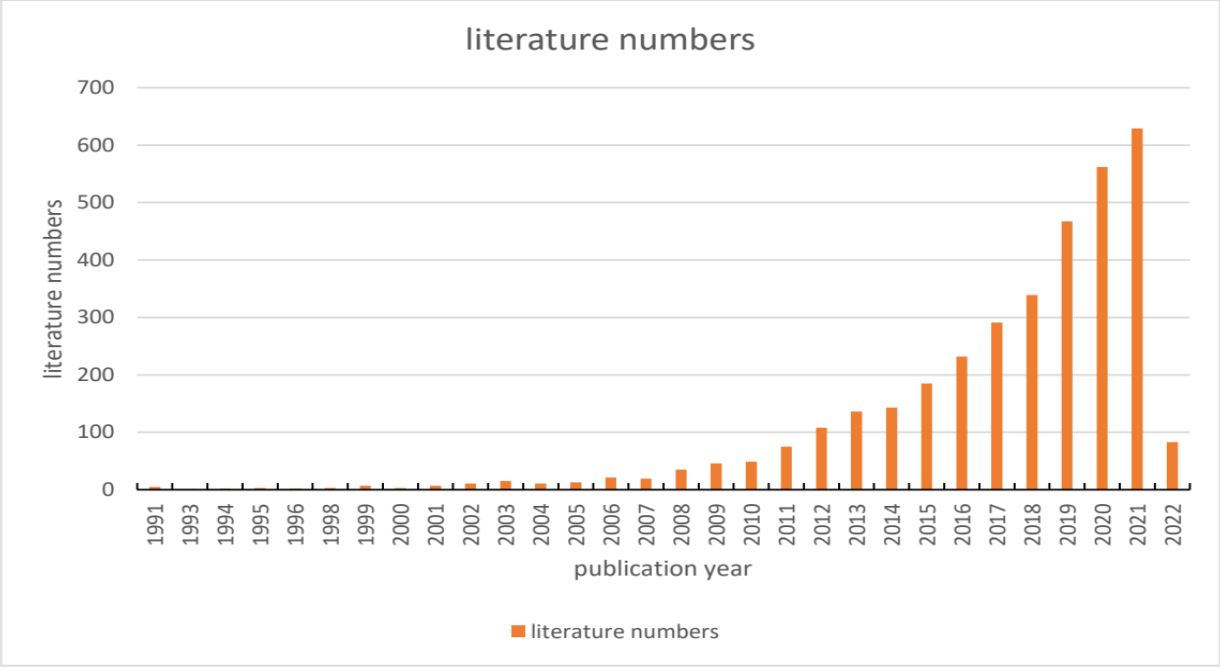


Figure1 Annual distribution of the bliographic dataset
(Image source： The author intercepted according to citespace ）

3.1.2 Contributing country

Table 1 shows the top 20 countries that publish the most journals related to urban climate maps. The country with the most publications is the United States, China ranks second, and Germany ranks third. The number of articles contributed by the United States and China far exceeds that of other countries, indicating that the United States and China have contributed the most to the research on urban climate maps, and the remaining seventeen countries are ENGLAND, ITALY, CANADA, AUSTRALIA, NETHERLANDS, SPAIN, FRANCE, INDIA, SOUTH KOREA, JAPAN, BRAZIL, SWEDEN, SWITZERLAND, BELGIUM, IRAN, TURKEY, PORTUGAL. These countries have done some research in the field of urban climate maps.

countries	*year*	*records*
USA	1995	915
PEOPLES R CHINA.	2008	797
GERMANY.	2008	298
ENGLAND.	2008	284
ITALY.	2008	230
CANADA.	2008	192
AUSTRALIA.	2008	190
NETHERLANDS.	2008	159
SPAIN.	2008	157
FRANCE.	2008	149
INDIA.	2009	144
SOUTH KOREA.	2011	124
JAPAN.	2007	112
BRAZIL.	2009	111
SWEDEN.	2008	99
SWITZERLAND.	2008	94
BELGIUM.	2009	81
IRAN.	2013	75
TURKEY.	2009	69
PORTUGAL.	2009	63

Table1.A list of contributing countries (Image source： The author intercepted according to citespace ）

3.1.3 Distribution of submitted journals

Table 2 shows the distribution of submitted journals. The top 20 journals with the most submissions are selected. Looking at the topics of the top 20 journals, the coverage is relatively wide, mainly in the fields of urban planning, remote sensing, meteorology, environmental science, ecology, and so on. The journal with the most submissions is LANDSCAPE AND URBAN PLANNING, with 19 articles. Urban climate maps are mainly to promote the connection between urban climate and urban planning, so now the researchers in this field are mainly urban planning-related scholars. The second and third places are ATMOSPHERIC ENVIRONMENT and JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES, respectively. The number of submissions is 17, and the topics are all related to meteorology.

Journal	*records*
LANDSCAPE AND URBAN PLANNING	19
ATMOSPHERIC ENVIRONMENT	17
JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	17
INTERNATIONAL JOURNAL OF APPLIED EARTH OBSERVATION AND GEOINFORMATION	14
ENVIRONMENTAL MONITORING AND ASSESSMENT	13
ENVIRONMENTAL RESEARCH LETTERS	13
NATURAL HAZARDS	13
SCIENCE OF THE TOTAL ENVIRONMENT	13
ATMOSPHERIC CHEMISTRY AND PHYSICS	12
INTERNATIONAL JOURNAL OF BIOMETEOROLOGY	12
JOURNAL OF HYDROLOGY	12
REMOTE SENSING	12
REMOTE SENSING OF ENVIRONMENT	12

THEORETICAL AND APPLIED CLIMATOLOGY	12
BUILDING AND ENVIRONMENT	11
CLIMATE RESEARCH	11
ENVIRONMENTAL EARTH SCIENCES	11
IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING	11
JOURNAL OF ENVIRONMENTAL MANAGEMENT	11
NATURAL HAZARDS AND EARTH SYSTEM SCIENCES	11

Table2 A rank of contributing journals
(Image source： The author intercepted according to citespace ）

3.1.4 Distribution of research institutions

Table 3 shows the distribution of institutions that study urban climate maps. The institution with the most research is the Chinese Academy of Sciences, which contributed 349 articles, followed by Peking University, and the third is Arizona State University. Of the top 10, seven are from China, and three are from the United States. This shows that there are many institutions studying urban climate maps in China, and they pay more attention to the application of urban climate maps. They are mainly university research institutions. Beijing has the most distribution, including the Chinese Academy of Sciences, Peking University, Beijing Normal University, and Tsinghua University. A total of Four.

Institutions	**Records**
Chinese Academy of Sciences	349
Peking University	110
Arizona State University	76
Beijing Normal University	67
Chinese University of Hong Kong	46
Sun Yat Sen University	46
University Wisconsin	32
Wuhan University	31
US Geol Survey	31
Tsinghua University	31

Table3 A ranking of contributing institutions by number of records
(Image source： The author intercepted according to citespace ）

3.1.5 Distribution of study authors

Table 4 shows the top ten authors who contributed to the urban climate map, among which CHAO REN contributed 22 papers. The author is from the Chinese University of Hong Kong, who developed the Hong Kong urban climate map with his research team. In the field of the urban climate, maps have a greater contribution. The second to tenth places are EDWARD NG, PHILIPPE CIAIS, BENJAMIN BECHTEL, BOJIE FU, ALEXANDRA D SYPHARD, BISWAJEET PRADHAN, JUNGHO IM, JANET FRANKLIN, SHUSHI PENG.

Authors	Records
CHAO REN	22
EDWARD NG	15
PHILIPPE CIAIS	13
BENJAMIN BECHTEL	12
BOJIE FU	12
ALEXANDRA D SYPHARD	12

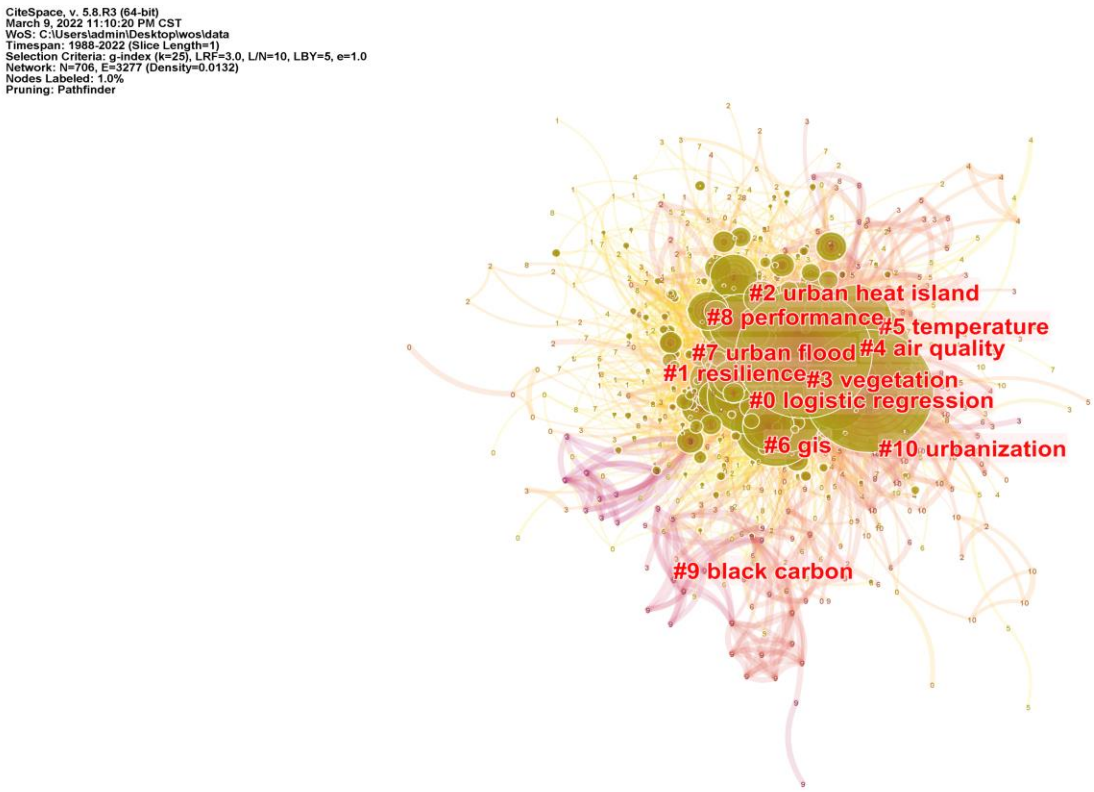
BISWAJEET PRADHAN	10
JUNGHO IM	10
JANET FRANKLIN	10
SHUSHI PENG	9

Table4 Top ten authors ranked by number of contributions(Image source： The author intercepted according to citespace）

3.2 Research Topics

3.2.1 Research Hotspots Analysis

Keywords can reflect the theme of the article to a certain extent, and analyzing keywords can grasp the field of research. Citespace can perform cluster analysis on the keywords that appear in similar fields, extract a central word, and summarize the research topic. After the keyword clustering analysis of the urban climate map research, as shown in Figure 2, the top 11 clustering keywords can be found, namely logistic regression, resilience, urban heat ialand, vegetation, air quality, temperature, gis, urban flood, performance, black carbon, urbanization. These keywords include research methods, such as logistic regression, gis; resilient cities, such as urban flood, resilience; healthy cities, such as air quality, urban heat ialand. By generating a time zone map to analyze the time when each keyword appears, and the size of the circle represents the number of times the keyword appears, that is, the popularity, you can find out at which time each keyword is a hot topic. It can be seen that the first hot topic was vegetation, and the same hot topics as its research in a period were temperature and air quality. After that, new research methods such as gis and logistic regression have attracted the attention of scholars. urban heat ialand is the center of attention, and the attention of resilience is not particularly great, but it has always maintained a high level. It can be seen that in the study of urban climate maps, scholars most realistically pay attention to ecological protection and the environment of daily human life and begin to study new technologies to realize climatic events.



Figre2 Map of co-occurring keywords on urban climate map(Image source： The author intercepted according to citespace ）

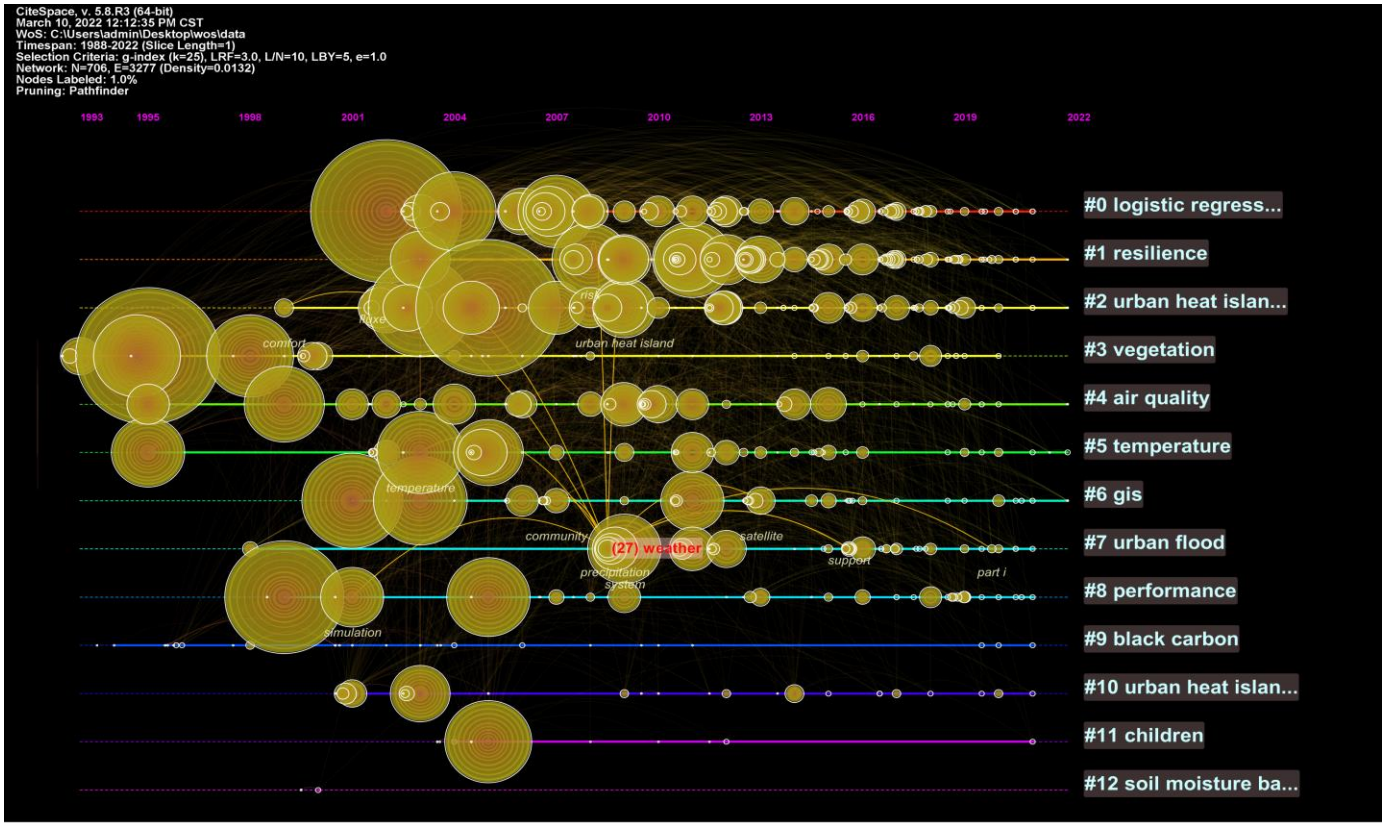


Figure3 Co-appearance timeline map of keywords(Image source： The author intercepted according to citespace ）

3.2.2 Co-Citation Analysis of Literature

Cluster analysis of co-cited documents is one of the most distinctive functions of citespace to analyze documents. By analyzing the clustering topics of co-cited documents, the research clusters of the research network can be analyzed. Through the network cluster analysis of the co-cited documents of the urban climate map, the first 11 clustered subject headings were obtained. There are local climate zone, ecosystem services, statistical downscaling, urban cool ialand, comparative study, wildland-urban iterface, remote sensing, gis, floods, urban ecology, heat vulnerability index. These topics can be divided into four categories, respectively For research methods, healthy cities, resilient cities, ecological bases.

In terms of research methods, remote sensing images are the main source of data for research on climate change, sustainable development, and other themes and are the data basis for research. Many scholars have used remote sensing images to develop new technologies to obtain more accurate analysis data, which has brought great help to research progress. In the current research data, the temperature is the basic data for studying the urban thermal environment, but the surface temperature obtained through remote sensing images is different from the air temperature closely related to pedestrian life (Yao & Rui, 2021), but it is difficult for the air temperature to be limited by the observation station. Get complete data. Some scholars have used remote sensing images to develop a simulation model for predicting air temperature with a higher correlation than multiple linear regression (Oukawa & Gabriel Yoshikazu, 2020) or by establishing a model to invert the air temperature from the surface temperature derived from a temperature inversion. At the same time, information such as terrain and vegetation can be obtained (Jin & Zhihao, 2022). In addition to air temperature, accurate land use maps are the first step in studying urban climate maps and other studies related to climate change. Remote sensing images can accurately identify land-use types in large-scale cities (Khatami & Reza, 2020). By observing the surface changes of remote sensing images for a long time, the trend of surface changes can be observed, and ecological warning and protection measures can be made (Zhang & Guoqing, 2019; Xia & Haoming, 2019). In addition to remote sensing images, novel climate unit partitioning methods local climate zone, prediction models random forests (Rather & Tahir Ali, 2020), and commonly used gis (Chen & Liang, 2012) are also included. The classification method of local climate zone has proposed to use deep learning to classify (Yoo & Cheolhee, 2019), which can be used for long-term automatic mapping of urban morphology in areas with slow growth rates and small areas (Chen & Tzu-Hsin Karen, 2020)—using cellular automata and land-use change models to predict future changes in local climate zones (Huang, Kangning, 2021).

In the healthy city theme, urban cool ialand is included. Urban cold islands and urban heat islands also focus on the effects of temperature on humans in microclimates. The causes of urban coldness and urban heat islands include anthropogenic heat emissions, land use types, surface features (Klok & Lisette, 2012), etc.

Include floods, heat vulnerability index in resilient cities topic. In addition to urban heat islands, urban heat waves and extremely hot weather have begun to be paid attention to by scholars. Urban climate maps are beginning to incorporate projected temperature and socioeconomic status, extreme age, building obsolescence, and population density to produce heatwave health risk maps (Buscail & Camille, 2012). To assess the vulnerability of different regions to extremely hot weather, some scholars form a heat stress map based on temperature and humidity and then combine time to develop a spatially explicit thermal vulnerability assessment tool (Kershaw, & Suzanne E, 2012).

Some scholars have proved that sensible heat distribution can better reflect thermal vulnerability than temperature distribution and began to study and make more accurate thermal vulnerability maps (Kwon & You Jin, 2020). Studying thermal vulnerability maps can help assess the ability of different regions to withstand heatwave hazards and make cities more resilient (Conlon & Kathryn C, 2020). Cities of different scales have begun to conduct research on urban thermal vulnerability (Wilson, Bev, 2019; Reischl & Christiane, 2018).

Ecosystem services, wildland-urban iterface, urban ecology are included in the ecological base. Scholars have studied the collaborative mapping of ecosystem services by different stakeholders (Helmer & Eileen H, 2018). There is also a focus on the link between tree category change and sustainable development (Santos & Artur, 2017) or its role in mitigating the impact of atmospheric dust pollution in mixed landscapes (Mitsopoulos & Ioannis, 2015). Wildland is also an important factor affecting urban ecology. Some scholars have explored the causes of summer fires, including the effects of temperature and wildland on fires (Franklin & Janet, 2011). Conduct wildfire risk assessments on different types of land (Alcasena, & Fermin J, 2015) and explore measures for wildfire disruption (Syphard & Alexandra D, 2011; Syphard, Alexandra D, 2011).

Figure4 map of co-cited references on urban climate map(Image source： The author intercepted according to citespace ）

3.2.3 Research Frontiers Analysis

The hot industry changes and research frontiers can be analyzed through the emergent words. By analyzing the timelines of all 33 emergent words generated, we can see the changes in industry research. According to the emergent words in the past five years,

the words that appeared briefly in the past few years are surface water, time series, form, evapotranspiration. Urban climate In the past three or four years, local climate zone, ahp, and randonforest have appeared in map research. These keywords are emerging hotspots of urban climate maps in recent years and have certain innovation and research significance.

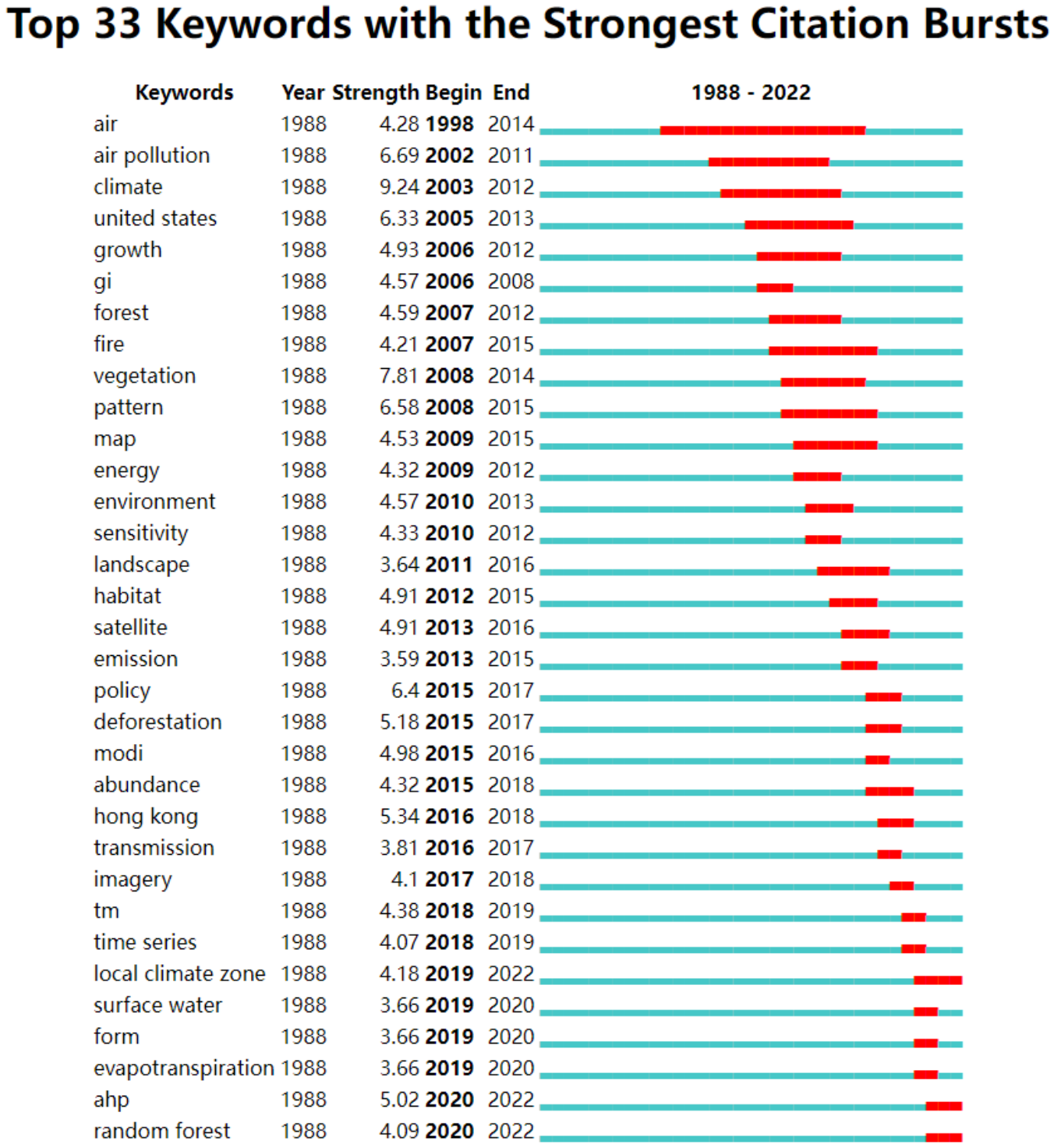


Figure5 keywords with the strongest citation bursts
(Image source： The author intercepted according to citespace ）

4. Conclusion

The Urban Climate Map is a tool for promoting sustainable urban development. It combines urban climate and urban planning and design, transforms climate into a planning language, and helps formulate plans that promote ecological construction and human health. Search the web of science for articles related to the topic of urban climate map, get a total of 3505 articles from

1988 to March 7, 2022, and analyze the data through citesapce. The basic descriptive analysis includes the number of articles published, journal submissions, research Institutions, main authors and main countries, subject statistics, including keyword clustering analysis, co-cited literature analysis, frontier hotspot analysis. After various analyses, it is found that the urban climate map has relatively few studies from the initial stage, from 1988 to 2007, the development stage grew slowly from 2008 to 2014, and the outbreak stage from 2015 to the present, the annual growth rate has continued to climb. It will exceed 600 articles in 2021. The journal with the most contributions is LANDSCAPE AND URBAN PLANNING; most of the research institutions are in China, the research countries are mainly the United States and China, and the main author is CHAO REN. Among the keywords, urban heat ialand is the central word of concern, and the popularity of resilience has always maintained a stable and high level. The clustering times of co-cited documents are divided into four parts, namely research methods, healthy cities, resilient cities, and ecological bases. Through the analysis of the emergent words, it is found that local climate zone, ahp, randonforest have been the hotspots of the emergent words in the past five years. A systematic study of urban climate map articles can help to grasp the research history and current situation in general and have an understanding of cutting-edge research. The shortcomings of this study include that it does not consider papers from other paper search sites and only uses citespace for visual analysis and statistics. The search scope can be expanded, such as CNKI, and visualization software such as VOSviewer can be added.

Conflicts of Interest: Declare conflicts of interest or state, "The authors declare no conflict of interest."

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