Mapping the Evolving Landscape of Urban Resilience: A Scientometric Analysis Using CiteSpace

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Abstract: With the development of urbanization and the frequent occurrence of natural disasters, urban resilience has gradually become a hot topic in urban research. Over the past two decades, the literature on urban resilience has grown rapidly and has recently received significant attention from scholars. This study employs the results of CiteSpace to visually analyze cooperation analysis, intellectual bases, research hotspots, and emerging trends in 936 pieces of literature spanning from 2003 to 2023. This analysis aims to provide a deeper understanding of the current status of knowledge in the field of urban resilience.

Keywords: Urban Resilience; CiteSpace; Scientometric Analysis; Research Hotspots

1. Introduction

Urbanization has emerged as one of the most profound societal transformations of the 21st century (Korhonen and Snäkin 2015). On the one hand, it has ushered significant social, economic, and environmental shifts, offering prospects for sustainable development (GU 2019). On the other hand, it has also brought adversities, including global climate change (Piao et al. 2019), resource shortage (Li et al. 2020), and natural disaster (Susman et al. 1983). Global metropolises grapple with a growing complexity in their internal and external systems, environments, and structures, alongside the mounting uncertainty and unconventional threats (Sterzel et al. 2020). Nevertheless, contemporary cities possess the capacity for self-correction, proactive adaptation, innovation, and iteration to bolster risk mitigation and control. (Xu et al. 2022) Enhancing the capacity has become a pivotal avenue for addressing the aforementioned challenges.

Urban resilience (UR) represents a relatively new yet widely embraced multidisciplinary concept within the realm of urban research (Guo et al. 2021). Currently, the prevailing academic definition of UR encompasses the capacity of urban systems and regions to attain public safety, maintain social order, and sustain normal functioning of economic activities through rational preparedness, effective buffering, and adept responses to unforeseen disruption (Forbes and Wilson 2018).

The concept of resilience has its roots in physics, originally describing a material's ability to revert to its original state after undergoing deformation due to an external force (Hosseini et al. 2016). Over time, and with the integration of various disciplines,

the notion of "resilience" has found broader applications. In 1973, Holling expanded its usage to the field of ecology, defining resilience as the capacity of ecosystems to resist disruption and swiftly recover when confronted with external disturbances (Holling 1973). Subsequently, resilience gradually permeated research in other natural and social sciences, including soil science (Todman et. al 2016), bioclimatology (Piñar Fuentes et al. 2019), and sociology (Endress 2015), and psychology (Troy et. al 2023), among others.

Within urban studies, resilience pertains to the adaptability of urban infrastructure systems when facing external natural disasters (McDaniels et al. 2008). Urban planning scholars have introduced the concept of resilience to urban research, advocating for enhanced responsiveness within urban systems in the context of disaster risk (Shi et al. 2021). In the event of cities being exposed to external natural hazards, critical infrastructure like water, electricity and healthcare plays a primary role in addressing the risks posed by disasters and climate change (Depietri and McPhearson 2017).

In summary, numerous disciplines, including urbanology, have embraced the foundational traits of resilience while infusing it with additional layers of meaning. From their perspective, the concept of UR has evolved from engineering resilience to ecological resilience and, ultimately, to evolutionary resilience (LI et al. 2019).

Engineering resilience primarily underscores physical attributes and represents a system's resilience within a singular, stable state (Patriarca et al. 2018). Ecological resilience, on the other hand, regards disturbances as opportunities for learning and emphasizes a system's capacity to maintain stability after experiencing significant

disruptions (Holling 1996). Unlike engineering resilience and ecological resilience, which are based on equilibrium-based epistemology, evolutionary resilience is rooted in an evolutionary perspective (CHEN 2017). This concept places a distinct emphasis on the dynamic transformations within a system, as it continuously moves toward new equilibrium states in response to ongoing external changes (Davoudi et al. 2013; Martin 2012).

This concept of resilience harmonizes seamlessly with the intricate properties of urban systems, giving rise to the concept of UR (Ribeiro and Goncalves 2019; Masnavi et al. 2019). The evolution of urban systems hinges upon the continual learning, innovation, and adaptive behaviors of individual agents. Furthermore, recognizing the complexity and ever-changing nature of urban systems, an increasing number of scholars opt to view UR from the perspective of dynamic evolution. For instance, Boschma's perspective extends resilience beyond mere shock accommodation, encompassing the long-term capacity of regions to forge new avenues of growth (Boschma 2015). Abdulkareem and Elkadi (2018) propose potential strategies that draw from the principles of ecological and evolutionary resilience to enhance UR. Nunes et al. (2019) and Béné et al. (2014) assert that evolutionary resilience approach is better suited for urban development, planning, and management. Evolutionary resilience incorporates attributes such as "embracing complexity" and "non-equilibrium dynamics", making it more effective method for addressing the challenges of preparing for a dynamic and uncertain urban future.

Despite important advances in UR research in recent years, less attention has been

paid to the knowledge graph and evolutionary trends of UR research. Traditional literature research is limited by time and has certain limitations. It is difficult to fully and accurately grasp the overall characteristics, frontier dynamics and internal evolution laws of scientific knowledge from massive data. For this shortcoming, scientometrics can provide important guidance. The objective of this study is to conduct a comprehensive bibliometric and visual analysis of UR research spanning the past 21 years. This paper endeavors to address the following five key questions: (1) How has UR research performed across different time periods? (2) What is the extent of collaboration within the realm of UR, examined at micro-author, meso-institution, and macro-national levels? (3) What constitutes the most crucial intellectual underpinnings and research hotspots within various stages of UR research? (4) What trends characterize UR and what future trajectories can be discerned? (5) What research opportunities lie ahead in the field of UR?

In this paper, we employ CiteSpace and various technologies, including cooperation analysis, literature co-citation analysis, literature cluster analysis, keyword co-occurrence analysis and keywords burst analysis, to conduct comprehensive bibliometrics and visualization analyses. These analyses provide a holistic view of the structure and evolution of UR research from 2003 to 2023, based on the scrutiny of 936 collected literature records. The primary objective of this paper is to delve into the influential keywords and articles in the field of UR. The findings serve as a valuable resource for researchers worldwide, facilitating a better understanding of the field's knowledge landscape and the identification of cutting-edge UR research areas.

The subsequent sections of this paper are organized as follows: Section 2 introduces bibliometrics and outlines the data sources. In Section 3, we present the outcomes of the CiteSpace analysis encompassing the collaboration network, knowledge foundations, research hotspots, evolutionary trends, and the emerging frontiers in UR research. Finally, Section 4 discusses the results and concludes the study.

2. Methods and Data

2.1 Methods

CiteSpace, a powerful information visualization tool, was developed by Professor Chaomei Chen of Drexel University specifically for an in-depth academic literature analysis (Chen 2006). This versatile software excels in conducting multivariate and dynamic analyses of complex networks primarily based on co-citation analysis and pathfinding algorithms. It effectively reveals critical paths and knowledge inflection points within a given discipline or field (Chen 2010; Small 1973). CiteSpace has gained widespread adoption for detecting and analyzing evolving research frontiers within specific discipline, exploring the relationships between these frontiers and the knowledge base, and uncovering the interplay between different research areas (Wang et al. 2018; Zhang et al. 2020; Bautista-Puig et al. 2022). CiteSpace's functionality includes a range of features such as keyword analysis, cited author profiling, cited journal exploration, and cited reference tracking. Among these, the analysis of keyword co-occurrence is particularly valuable as a direct means of revealing current research hotspots and frontiers in a given field (Lozano et al. 2019; Wang 2022).

2.2 Data Sources

The interdisciplinary nature of urban resilience highlights its broad research scope, spanning multiple disciplines including sociology, economics, geography, and environmental studies (Beichler et al. 2014; Ge et al. 2023). The Social Sciences Citation Index (SSCI) database is widely recognized as a benchmark for gauging the international influence of academic disciplines and journals. It includes social science publications from diverse countries and regions, offering a comprehensive research perspective (Ye et al. 2020; Li et al. 2022; Liu and Xu 2020). Accordingly, the data sources used in this study are derived from the Social Science Citation Index (SSCI) within the Web of Science (WOS) core database. The WOS database holds a position of global influence as a journal citation database and is extensively employed for bibliometric analysis. Notably, in comparison to alternative databases, WOS stands out for its remarkable consistency and standardization of research records (Meho and Yang 2007; Falagas et al. 2008). This comprehensive database encompasses a wealth of bibliographic information, covering details about authors, citations, journals, and various other data elements that can be effectively harnessed for in-depth analysis.

To accurately capture the academic landscape of UR, a rigorous search methodology was devised, as shown in Fig. 1. The search query involved using “urban resilience” OR “resilient cit*” within the basic search category. The search was further confined to “Topic” field, while restricting the document type exclusively to articles. Concurrently, the language filter was applied to include only English-language materials. By retrieving, the first paper related to urban resilience is published in 2003, therefore, the time frame was defined from 2003 to 2023, and the search was executed

on March 31st, 2024. In order to improve the validity of the sample, the initial collection was screened by manual verification to eliminate any literature with low relevance to the topic terms. In the end, the data collection process yielded a total of 936 documents as the initial dataset for bibliometric analysis.

3. Results of Scientometric

3.1 Trends in publication number

The fluctuation in publication numbers serves as a vital indicator of the research field's development trajectory, offering insights in to the level of activity within a particular research topic during a given time period (Guo et al. 2019). Fig. 2 illustrates the dynamic shifts in publication numbers related to UR, alongside the growth rate calculated with 2012 as the baseline year.

Evidently, it can be seen from the figure that the research on UR has displayed a consistent upward trajectory over the years, undergoing approximately three discernible phases from 2003 to 2023. This pattern underscores the growing prominence and emergence of UR as a prominent research focal point. The subsequent sections provide an in-depth exploration of these three distinct research stages.

(1) From 2003 to 2011, the number of publications on UR remained relatively stagnant, consistently staying below five. This suggests that research in this field was in its early stages and had yet to capture the attention of scholars.

(2) The period from 2012 and 2017 signified a phase of moderate development in the field. During this time, the world witnessed a surge in natural disasters, leading to the foundational establishment of pertinent theories. Moreover, the

emergence of severe natural disasters, a notable increase in scholarly literature, and the inception of the Asian Cities Resilience Network for Climate Change by the United Nations International Strategy for Disaster Reduction (UNISDR) in 2012 collectively propelled the growth of UR research to a certain extent, reflecting the awakening of resilience awareness (Kagawa and Selby 2012).

(3) Particularly in the years following 2017, the volume of articles on UR has surged dramatically. Notably, since 2019, the global outbreak and ongoing impact of COVID-19 elevated infectious disease prevention as an emerging aspect of resilient city research, resulting in hundreds of new international publications on the subject. By 2021, over 180 relevant articles had been published, marking the initiation of research by scholars from various countries into the adoption of sustainable urban construction policies, protocols, or regulations (Wang 2023) as a means to address the challenges posed by climate change. After 2021, the impact of COVID-19 on urban resilience research has waned, and the number of relevant publications has decreased.

3.2 Cooperation Analysis

CiteSpace offers the capacity to explore scientific research collaboration networks within literature on three distinct scales: microscopic networks of scholars, mesoscopic networks of institutions, and macroscale networks of countries (Yang and Wang 2021). The presence of various authors, institutions, and countries within the same paper is indicative of collaborative relationships (Gazni et al. 2012). In this section, we will chat the networks of micro-level collaboration, meso-level institutional cooperation, and

macro-level national cooperation.

3.2.1 Co-Authorship Network

Analyzing the author cooperation network analysis is instrumental in gaining insights into the researchers who contribute significantly to this field and the extent of their collaboration (Zhu and Guan 2013). In Fig. 3, the scientific collaborative co-authorship network is depicted, where the size of each node corresponds to the number of articles published by respective author, and links represent collaborative connections between authors.

In Fig. 3, we've applied a frequency threshold of 3, which signifies that the labeled nodes represent authors who have authored more than two articles in the field of UR research. Overall, the collaborative relationship between the authors is relatively clear: 24 authors have collaborated more than twice in the field. The most collaborative authors are Ayyoob Sharifi and Sara Meerow. Specifically, there are obvious cooperative teams among scholars, in which there is an interactive relationship among scholars, but the external cooperative relationship of each team is weak, reflecting the relative independence of each research team. This means that the topics studied in UR are multidisciplinary, but these topics are mainly studied independently by multiple teams in different disciplines. Therefore, teams in various fields should strengthen cooperation, promote interdisciplinary cooperation, and seek breakthroughs in sustainable development.

3.2.2 Cooperation of Institutions and Countries

The examination of institutional collaboration networks, as depicted in Fig. 4, which provides valuable insights into the institutions that produce a substantial volume of research in the field and can potentially take a leading role in scientific investigation (Morel et al. 2009). In Table 1, we present the top 15 institutions with the highest number of publications, along with their countries of origin. It is evident that all 15 of these institutions are universities situated in different countries, underscoring that the current research on UR predominantly thrives within universities possessing robust research capabilities. Among these top universities, seven are located in Europe, five in North America, two in Asia, and one in Australia. Notably, the majority of these institutions belong to developed countries, with the exception being the Chinese Academy of Sciences. This observation underscores the connection between the popularity of the topics studied and the state of regional development, as well as the geographical location of the institutions.

Within CiteSpace, centrality serves as a pivotal metric for gauging the significance of a node. When the centrality value surpasses 0.1, it designates the node as a central one, signifying heightened importance and a more substantial impact on the research (Chen 2005). Among the top 15 institutions, based on the number of publications, three of them exhibit centrality values exceeding 0.1: the University of Melbourne, Stockholm University and Chinese Academy of Sciences. The finding highlights their pivotal roles and substantial influence within the field of study.

We have created a network diagram illustrating country cooperation, presented in Fig. 5. As observed in the upper left corner, this national cooperation network

comprises 90 nodes and 446 connections, resulting in a density of 0.1114. This density value suggests a robust interconnection among countries engaged in UR research.

On a global scale, several countries have made significant strides in UR research, emerging as pivotal nodes in the network. The United States, the United Kingdom, Italy, Australia, Germany, the Netherlands, Spain, the South Africa, and Belgium are the forefront of UR research, boasting centrality values exceeding 0.1, signifying their close collaborations with other countries. Although China entered the field of UR research comparatively late, it has rapidly expanded its publication output in recent years and holds the highest number of papers in this domain. However, China's relatively low centrality indicates untapped potential for future advancement in international collaborations with other countries.

3.3 Intellectual Bases and Hotspots of Community Resilience

3.3.1 Intellectual Bases of Urban Resilience

Co-citation is a well-established phenomenon within the scientific community, and employing co-citation analysis serves the dual purpose of comprehending the knowledge foundation of a research field and anticipating potential future research directions in that domain (Serenko 2013). Clustering, an integral component of the literature co-citation analysis process, plays a crucial role in unveiling trends in the evolution of scholarly literature (Small 1981). In this section, we employ CiteSpace to execute co-citation analysis and clustering on the collected dataset.

Through co-citation analysis, we have pinpointed 18 references that have garnered more than 10 citations each (Fig. 6 and Table 2). Fig. 6 highlights that Meerow et al.

(2016) boasts the highest citation frequency. Furthermore, as detailed in Table 2, Meerow's work titled "Defining urban resilience: A review" stands out. This review examines the concept of UR, shedding light on six key conceptual tensions: the characterization of "urban", notions of equilibrium, resilience as a positive concept, pathways to UR, understanding of adaptation, timescale of action. Additionally, Meerow introduces a novel definition of UR, emphasizing a city's and its constituent networks' capacity to sustain or swiftly recover desired functions when confronted with disruption, adapt to change, and promptly eliminate adverse factors hindering current or future development.

The second most cited article is titled "Urban resilience for whom, what, when, where, and why?". This paper dissects the process of advancing UR into three key facets: the examination of UR as a boundary object, exploration of the "5Ws" framework regarding UR, and the application of a case study on Los Angeles to scrutinize UR within an empirical context (Meerow and Newell 2019).

As shown in Fig. 7, the extracted cluster labels have been visualized on a Landscape Map. During the early phase of UR research, roughly from 1998 to 2003, the references primarily centered around the issue of PM2.5, particularly its adverse health and environmental impacts. Between 2003 and 2008, there was a research hiatus, and no distinct research clusters took shape. It was not until 2008 that UR research gained traction as a hotspot, marked by the emergence of the Ankara Cluster. Between 2008 and 2013, there was a modest upsurge in research focused on flood risk management, but it gradually waned after 2013. From 2013 to 2018, several notable

research hotspots surfaced, with green infrastructure and urban ecosystem services being particularly significant, while green infrastructure remained a prominent theme during this period. It's worth highlighting that articles related to coupling coordination have held a prominent place in the research hotspot since 2015, underscoring the growing attention directed toward coupling coordination as a method for studying UR.

3.3.2 Research Hotspots of Urban Resilience

The analysis of co-occurrence keywords in a network provides fundamental insights into the core research content, assisting researchers in monitoring the evolving trends and identifying research hotspots of research topics within different stages of UR research (Meng et al. 2020). As illustrated in Fig. 8, this network comprises 256 keyword nodes and 1,465 connections, resulting in a density of 0.0449. The nodes exhibit a ring-like structure and are differentiated by various color spectrums, reflecting the year in which the keywords first appeared. Leveraging word frequency rankings, we have extracted the top 30 essential keywords and noted the earliest year of their occurrence, as presented in Table 3.

As observed in Table 3, the keywords appearing more than 100 times include "urban resilience" (428); "city" (241); "climate change" (205); "framework" (111); "management" (101). The primary keywords can be broadly categorized into five types.

(1) Keywords like "city", "systems", "community resilience" and "community". signify the objects of study within the domain of UR.

(2) Keywords such as "climate change", "risk", "challenges", and "urbanization" indicate the contextual backdrop against which UR is predominantly explored,

emphasizing the research's grounding in environmental uncertainty (Wang et al. 2018).

(3) Keywords like "adaptation", "climate change adaptation", and "vulnerability" represent the substantive content of UR research, focusing on adaptive theory and vulnerability analysis (Caldarice et al. 2019).

(4) Keywords like "management", "sustainability", and "governance" are associated with UR research aiming to achieve sustainable development through necessary management measures (Acuti et al. 2020).

(5) Keywords such as "green infrastructure", "urban planning", "indicators", "ecosystem services", "framework", "policy", and "politics" signify the various approaches employed to attain the aforementioned research objectives (Etinay et al. 2018).

3.4 Research Trends of Urban Resilience

CiteSpace's burst word analysis, as facilitated by the keyword burst map, employs a word frequency growth algorithm (burst detection) method (Liu et al. 2019). This approach identifies specialized words that experience rapid frequency changes within a short timeframe by tracking citation keywords. It presents a dynamic citation burst pattern that showcases temporal distribution and evolving characteristics, ordered by frequency. Analyzing the historical co-occurrence frequency distribution of these burst words and summarizing their temporal trends proves highly effective in assessing emerging trends and abrupt shifts in the evolution of academic disciplines (Zhang et al. 2020). Consequently, this tool provides a more accurate reflection of the research

frontiers and developmental trends within the realm of UR research.

Fig. 9 provides a summary of the top 15 keywords with the most significant bursts. A majority of these 15 keywords emerged after 2010, signifying that UR progressively evolved into a prominent research topic post-2010. In Fig. 9, "Year" corresponds to the data collection year, while "Strength" reflects the burst rate, indicating the intensity of keyword bursts. Among these keywords, "vulnerability", "urban planning", "thinking", "urban sustainability", and "environmental justice" exhibit the highest burst intensity, underscoring their prominence within the specified timeframe. It's noteworthy that "vulnerability" stands out not only as a popular keyword but also as a long-lasting one, underscoring its significant role in the study of UR.

The appearance of keywords such as "environmental justice", "urban agriculture", and "index" has shown a steady rise from 2021 to 2023, signifying a shift in research focus among scholars. These emerging research trends are briefly outlined below.

(1) Environmental Justice: Robert Bullard's definition of environmental justice as. the principle that "all people and communities are entitled to equal protection of environmental and public health laws and regulations" (Evans and Kantrowitz 2002) indicates that the recent research in UR has increasingly concentrated on the needs of disadvantaged and vulnerable groups (Meerow et al. 2019).

(2) Urban Agriculture: Urban agriculture holds immense significance in promoting the sustainable development of urban economies, societies, and ecologies (Azunre et al. 2019).

(3) Urban Resilience Index: The urban resilience index is regarded as a theoretical framework for assessing resilience within urban social-ecological systems (Suárez et al. 2016).

4. Conclusions and prospects

4.1 Conclusions

Based on a comprehensive review of UR literature spanning the past 23 years, this study employs bibliometric and visualization techniques to identify key research hotspots and emerging trends within the field. Our findings reveal the following key conclusions:

(1) The research on UR can be categorized into three distinct phases, characterized by the volume of published literature. These phases are:

- Initial Stage: From 2003 to 2011, the discourse surrounding UR was limited, reflecting the nascent stage of research in this area.
- Gentle Development Stage: The period from 2012 to 2017 saw a gradual increase in the body of literature focused on UR, indicating the field's steady development.
- Rapid Growth State: Since then, UR research has experienced a phase of rapid expansion. Notably, in 2018, the annual output of research papers exceeded 200.

This analysis highlights the dynamic evolution of UR research over the past two decades.

(2) In the field of UR research, distinct cooperative characteristics emerge at

various levels. First and foremost, in terms of author collaboration, the cooperative relationship in this field is relatively obvious, and several cooperative groups with a certain size have been formed, but the research of each cooperative group is relatively independent, and no further cooperation has been formed with other groups. Secondly, the popularity of research topics appears to be closely linked to the development status of regions and the geographical locations of participating institutions. Notably, institutions generating a significant volume of research papers are primarily suited within universities known for their robust research capabilities in developed countries, particularly across Europe and the United States.

When considering the level of national cooperation, it becomes evident that certain countries are more tightly interconnected. The United States, the United Kingdom, Italy, Australia, Germany, the Netherlands, Spain, and others have forged robust collaborative networks, produced a substantial number of research papers, and established themselves as leaders in the field of UR research.

Moreover, China has demonstrated impressive growth in UR research in recent years, contributing a substantial volume of articles. However, its level of collaboration with other countries remains less pronounced compared to the leading nations in the field.

(3) By employing literature co-citation analysis, literature cluster analysis, and. keyword co-occurrence analysis, this study unveils the foundational principles

and dynamic research hotspots in the domain of UR research were revealed.

In the literature co-citation analysis, we identified 18 articles cited more than 10 times. Approximately two-thirds of these articles were of a theoretical nature, primarily concentrated on defining UR and establishing relevant conceptual frameworks. The remaining one-third encompassed applied articles, including resilience assessments and case studies of resilient city development. These two core components collectively form the knowledge base of UR research.

Our cluster analysis indicated that research hotspots in UR have evolved over different periods. In the early stages of UR research, the literature primarily emphasized risk management aspects such as PM2.5 and flood risk management, etc. In the middle of the research period, research hotspots expanded, with a notable focus on articles related to green infrastructure and urban ecosystem services. More recently, research on UR methodologies, including topics like coupling coordination and cascading effects, has gained prominence.

Additionally, the keyword co-occurrence analysis illuminated the evolving research hotspots within UR. Main keywords could be categorized into five groups, encompassing research subjects, research background, research contents, research objectives and research methodologies employed in UR studies.

(4) In the keywords burst map, a notable trend with most burst words appearing after 2010, signifying the gradual ascendancy of UR research as a prominent

field since that year. Moreover, these distinctive stages have witnessed shifts in the central themes of inquiry. Notably, the most prevalent keywords at each stage included “vulnerability”, “urban planning”, “thinking”, “urban sustainability”, and “environmental justice”.

In regard to the cutting-edge research frontiers within UR, the last three years have seen significant attention directed towards “environmental justice”, “urban agriculture”, and the “urban resilience index”. More specifically, “environmental justice” highlights an emerging focus on the welfare of the less privileged and vulnerable segments of society. Scholars are advocating for universal rights to environmental and public health protection, along with the formulation of relevant legislation and regulations to support these rights.

The concept of “urban agriculture” has gained prominence as it is recognized for its capacity to generate diverse ecosystem services. In the face of mounting environmental uncertainties, leveraging ecosystems to directly provide essential services to human populations is imperative for sustaining environmental, social, and economic well-being.

Additionally, the development of an index system for measuring UR serves as a valuable resource for policymakers. This system offers clear and comprehensive insights into the resilience of development projects, equipping decision-makers with essential information to make informed choices and guide urban development.

4.2 Research prospects

4.2.1 Establishing a Comprehensive Urban Resilience Evaluation System

The establishment of a UR evaluation system is crucial for enhancing the capacity for self-correction, proactive adaptation, innovation, and iterative development (Li et al. 2019). Currently, some scholars have developed evaluation systems based on social, economic, infrastructure, and other dimensions to measure general UR and monitor adaptation efforts (Suárez et al. 2016; Feldmeyer et al. 2019; Zhao et al. 2022; Kochskämper et al. 2024). Other scholars have created evaluation systems encompassing adaptability, resistance, and recovery to reflect UR changes in response disasters (Chen et al. 2020; Zhang et al. 2021; Lu et al. 2022; Liu et al. 2023). Furthermore, accurate quantification of UR is essential for effectively guiding urban construction and development (Lu et al. 2022). The entropy method, a multivariate statistical analysis technique commonly used in UR quantification (Deng et al. 2021; Cao et al. 2023), calculates weights based on the degree of data dispersion, ensuring objective and fair quantitative results (Zou et al. 2006).

4.2.2 Expanding the Practical Application of Urban Resilience

While cities in developed countries lead in areas such as urban climate change adaptation (Araos et al. 2016), cities in the Global South are more effective in integrating sustainable development and urban resilience into their planning documents (Kochskämper 2024). To unlock broader development prospects, it is essential to expand the practical application of urban resilience across diverse urban contexts (Kochskämper et al. 2024). This expansion aims to validate the feasibility and universality of the UR methodological model while enriching and broadening the

theoretical framework of UR (Feagan et al. 2019). In the era of global intelligence, the integration of big data and artificial intelligence will broaden the scope of UR research, with technology providing crucial support for the development of resilient cities (Liu et al. 2022; Zhang et al. 2023). Given that urban resilience encompasses multiple dimensions of social-ecological systems, an effective combination of quantitative and qualitative methods can make UR research more practical and actionable (Sondershaus and Moss 2014; Tong 2021). In addition, the use of participatory and interdisciplinary methods will play a significant role in advancing UR research (Palla et al. 2024; De Luca et al. 2021).

4.2.3 Emphasizing International Exchange and Cooperation

The vision of resilient cities is a shared aspiration among nations and municipalities (Croese et al. 2020). Yet, the realm of UR research lacks a robust collaborative network among scholars. Presently, UR research is predominantly centered within universities, with limited cross-border collaborative studies. As awareness of sustainable urban development grows and the importance of UR deepens, collaborative coordination among various countries and regions will emerge as a predominant trend for enhancing UR (Gavari-Starkie et al. 2021).

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Figures

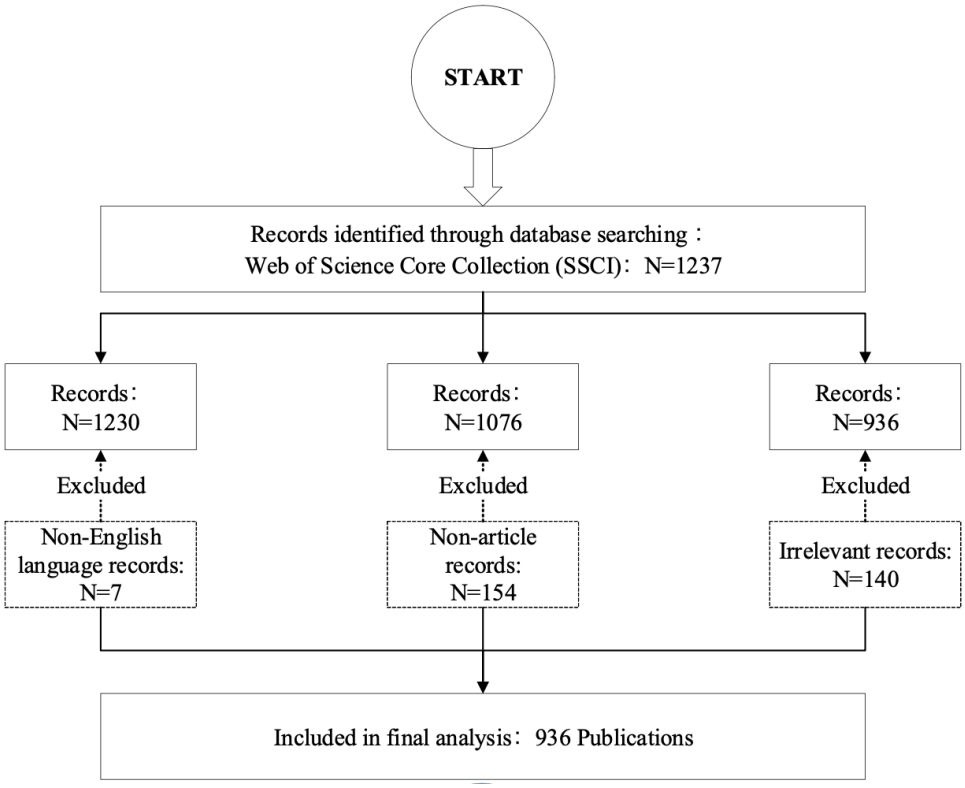

Fig. 1 Data retrieval program

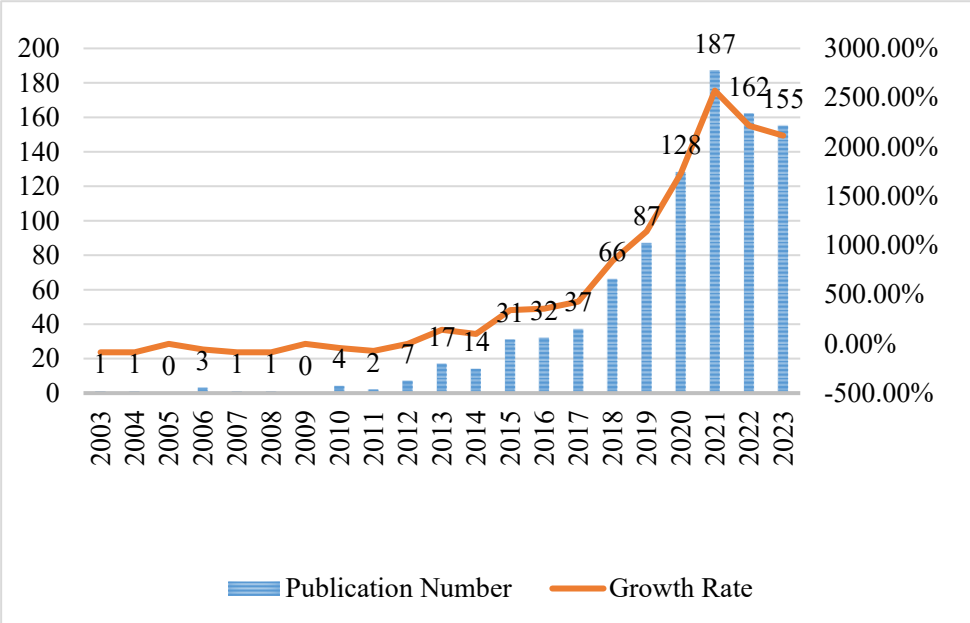

Fig. 2 The change of publication number

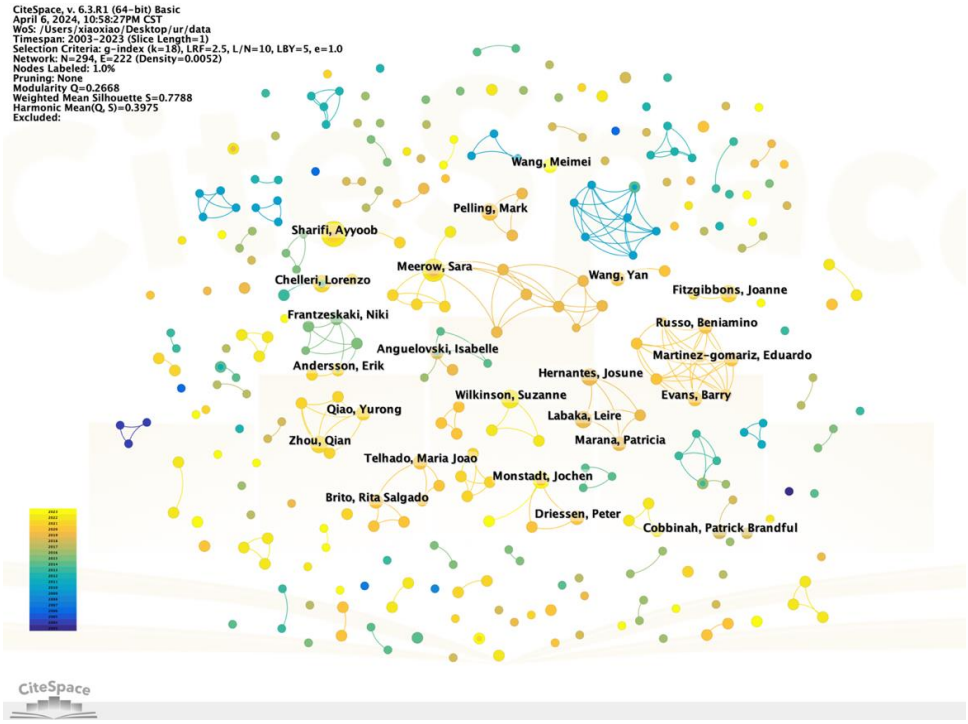

Fig. 3 Co-authorship network

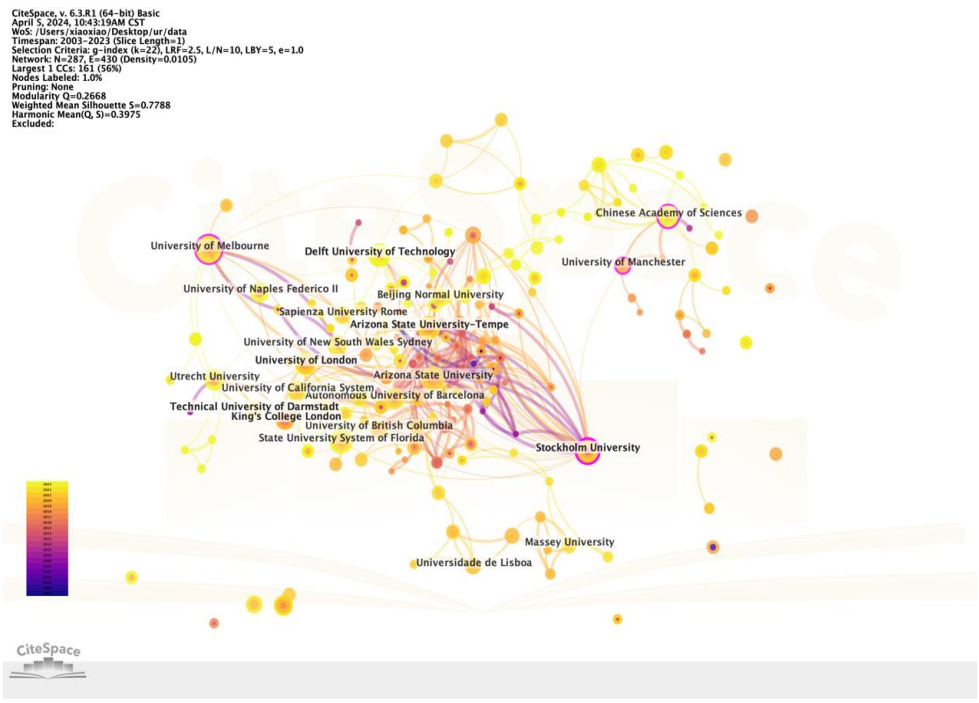

Fig. 4 Network of institutions

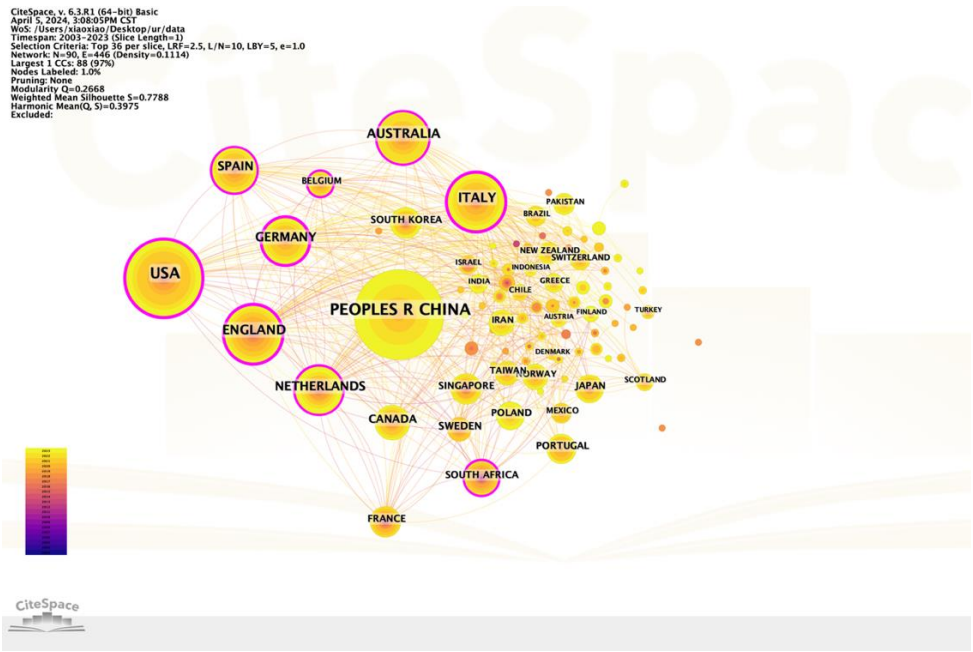

Fig. 5 Network of countries

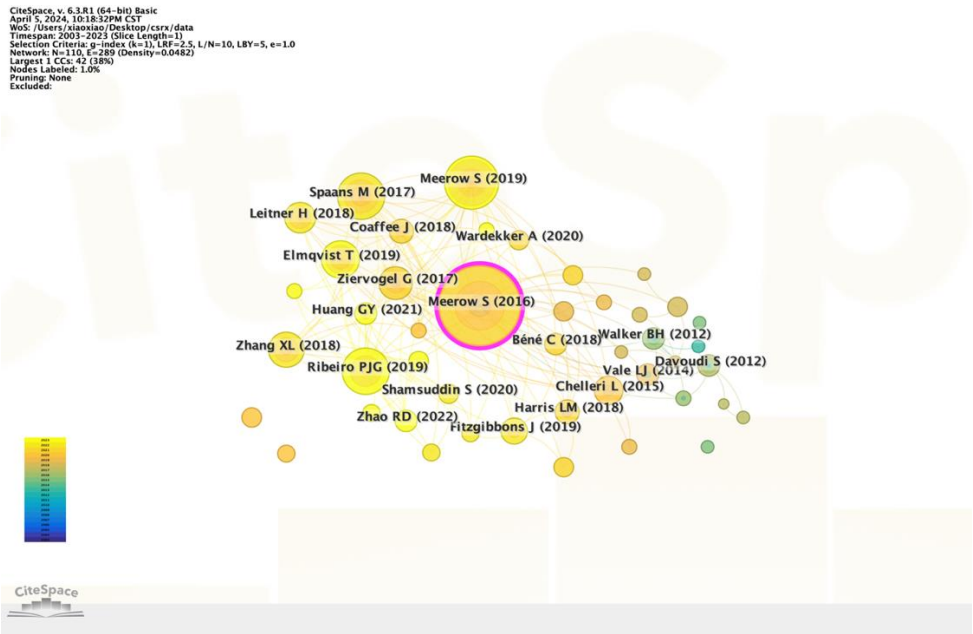

Fig. 6 Most frequently co-cited references

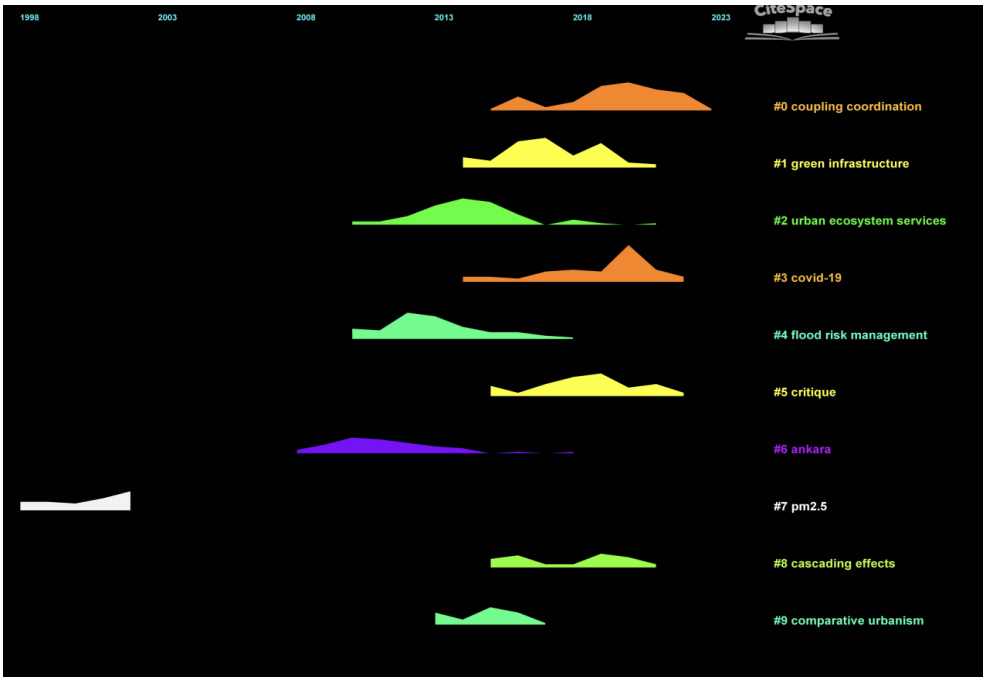

Fig. 7 Clustering of co-cited documents

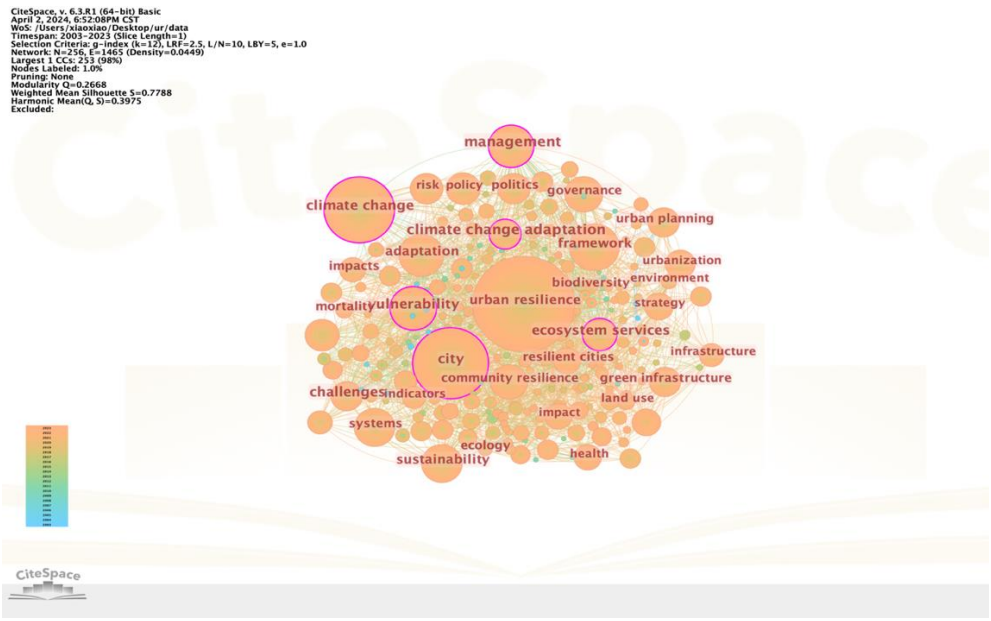

Fig. 8 Co-occurring keywords network

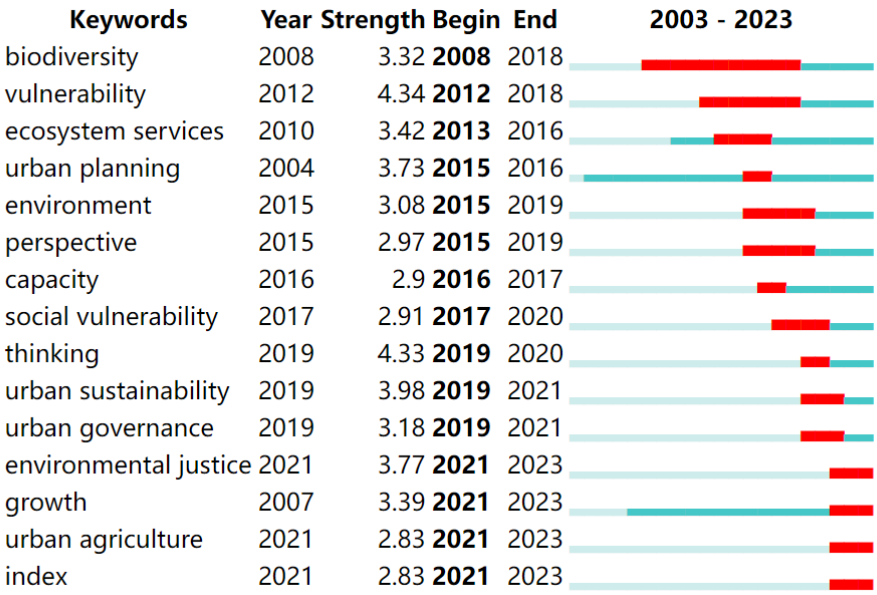

Fig. 9 Keywords Burst Map

Tables

Table 1 Top 15 publications and their respective countries

Institutions	Count	Centrality	Country
University of Melbourne	21	0.11	Australia
Delft University of Technology	17	0.09	Netherlands
University of London	17	0.07	England
State University System of Florida	17	0.05	America
Arizona State University	16	0.04	America
Arizona State University-Tempe	15	0.03	America
Stockholm University	15	0.27	Sweden
Autonomous University of Barcelona	15	0.08	Spain
Chinese Academy of Sciences	13	0.12	China
Utrecht University	12	0.05	Netherlands
National University of Singapore	11	0	Singapore
University of California System	11	0.05	America
Sapienza University Rome	10	0.02	Italy
University of British Columbia	10	0.02	Canada
Polytechnic University of Turin	10	0	Italy

Table 2 Most frequently co-cited references (more than 10 citations)

No	Count	Centr	Author	Title	DOI
1	167	0.15	Meerow S, 2016	Defining urban resilience: A review	10.1016/j.landurbplan.2015.11.011
2	75	0.04	Meerow S, 2019	Urban resilience for whom, what, when, where, and why?	10.1080/02723638.2016.1206395
3	57	0.03	Ribeiro PJG, 2019	Urban resilience: A conceptual framework	10.1016/j.scs.2019.101625
4	53	0.02	Spaans M, 2017	Building up resilience in cities worldwide–Rotterdam as participant in the 100 Resilient Cities Programme	10.1016/j.cities.2016.05.011
5	42	0.01	Elmqvist T, 2019	Sustainability and resilience for transformation in the urban century	10.1038/s41893-019-0250-1
6	34	0.01	Zhang XL,2018	Urban resilience and urban sustainability: What we know and what do not know?	10.1016/j.cities.2017.08.009
7	27	0.00	Leitner H, 2018	Globalizing urban resilience	10.1080/02723638.2018.1446870
8	27	0.01	Ziervogel G, 2017	Inserting rights and justice into urban resilience: a focus on everyday risk	10.1177/0956247816686905
9	21	0.00	Chelleri L,2015	Resilience trade-offs: addressing multiple scales and temporal aspects of urban resilience	10.1177/0956247814550780
10	18	0.00	Fitzgibbons J, 2019	Just urban futures? Exploring equity in “100 Resilient Cities”	10.1016/j.worlddev.2019.06.021
11	17	0.00	Coaffee J, 2018	“Urban Resilience Implementation: A Policy Challenge and Research Agenda for the 21st Century.”	10.1111/1468-5973.12233

12	16	0.01	Harris LM,2018	Negotiated resilience	10.1080/21693293.2017.1353196
13	15	0.01	Vale LJ, 2014	The politics of resilient cities: whose resilience and whose city?	10.1080/09613218.2014.850602
14	14	0.00	Huang GY,2021	Influencing factors and their influencing mechanisms on urban resilience in China	10.1016/j.scs.2021.103210
15	14	0.03	Davoudi S,2012	Resilience: A Bridging Concept or a Dead End?.....	10.1080/14649357.2012.677124
16	14	0.02	Walker BH,2012	Resilience practice: building capacity to absorb disturbance and maintain function	
17	13	0.00	Bene C, 2018	Resilience as a policy narrative: Potentials and limits in the context of urban planning	10.1080/17565529.2017.1301868
18	12	0.00	Zhao RD,2022	The evaluation and obstacle analysis of urban resilience from the multidimensional perspective in Chinese cities	10.1016/j.scs.2022.104160

Table 3 The top 30 keywords on urban resilience research.

Number	Frequency	Centrality	Year	Keywords
1	428	0.08	2012	urban resilience
2	241	0.16	2006	city
3	205	0.14	2007	climate change
4	111	0.06	2014	framework
5	101	0.10	2012	management
6	99	0.07	2012	adaptation
7	96	0.11	2012	vulnerability
8	80	0.07	2015	sustainability
9	74	0.04	2015	systems
10	72	0.03	2014	governance
11	69	0.05	2016	community resilience
12	65	0.11	2010	ecosystem services
13	65	0.02	2014	policy
14	53	0.04	2015	politics
15	53	0.03	2016	risk
16	53	0.01	2015	resilience
17	50	0.11	2010	climate change adaptation
18	49	0.08	2012	challenges
19	47	0.06	2004	urban planning
20	47	0.03	2016	green infrastructure
21	45	0.04	2016	urbanization
22	43	0.08	2006	resilient cities
23	37	0.05	2017	impact
24	36	0.03	2017	strategy
25	35	0.02	2018	model

26	34	0.08	2013	health
27	33	0.06	2011	impacts
28	30	0.03	2016	infrastructure
29	29	0.02	2016	community
30	26	0.03	2018	indicators