

Review Article

Resilient City: A Bibliometric Analysis and Visualization

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Resilient city has attracted global attentions as a new concept for cities to deal with risks and challenges in recent years. Numerous researchers have successively conducted in-depth studies on the resilient city from different perspectives. To acquire an overview of resilient city and grasp the current research hotspots, a bibliometric analysis and visualization of the past decade of research on the resilient city was made. The data were collected from 1249 articles published in the Web of Science database from 2010 to 2019. As the widely used bibliometric analysis tools, CiteSpace and VOSviewer were adopted in this study. The temporal distribution of resilient city research, including annual publication outputs and high-cited papers, was symmetrically analyzed. Then, the spatial distribution of resilient city research, including countries, categories, institutions, co-citation journals, author collaboration network, and author co-citation network, was investigated. Hot topics and evolution trends of resilient city were revealed. The results show that the research of resilient city experienced three periods, namely, germination, rapid diffusion, and reflection and innovation periods. Current research focuses on four aspects, including psychological resilience at the microcommunity and group levels, assessment of urban disaster resilience, multiple theoretical frameworks of urban resilience, and urban resilience promotion strategy. Therefore, this study helps scholars and practitioners to gain a comprehensive understanding of the current research progress and evolution trends of the resilient city field.

1. Introduction

As a large and complex socio-ecological system, cities are characterized by concentration, mobility, integrity, and activity. City labels, e.g., low carbon city, eco city, green city, resilient city, and sustainable city, were used to briefly express essential features of urban development and construction goals. Cities are increasingly vulnerable to natural or artificial disasters due to large population, numerous building, and complicated social network. Resilient city construction has become an important issue during the global urbanization process. Research on the resilient city has attracted wide attentions from the academia and society. There have been abundant theoretical and practical studies in the world. Therefore, a clear and systematic overview can help scholars form a comprehensive understanding of the resilient city research.

Resilience originated from physics and was used to describe the ability of an object to recover from deformation

under an external force. Then, resilience was introduced into ecosystems. Ecological resilience emphasizes the ability to adapt to external shocks and control interactive changes [1, 2]. Subsequently, the concept of resilience was extended to the engineering technology and socio-economic fields. Engineering resilience focuses on the stability of the physical system, emphasizing its ability to recover to the predisruption state [3–5]. In the social economy domain, psychological resilience [6], organizational resilience [7], and industrial resilience [8] were proposed from the perspective of the system level.

Due to complex internal factors and multiple external disturbances, cities have been suffering from a series of challenges, e.g., climate change, natural disasters [9], environmental pollution, disease transmission [10], and terrorist attacks [11]. Since 2002, the concept of urban resilience was presented at the American Annual Conference on Ecology [12]. The representative one, which was defined by the Rockefeller Foundation, refers to the capacity of individuals,

communities, institutions, businesses, and systems within a city to survive, adapt, and grow regardless of chronic or acute shocks they experience [13]. Current research on city resilience mainly focuses on the system characteristics [14–16], construction [17–19], evaluation index system [20, 21], and policy [22–24]. Although current studies are of great importance, the comprehensive overview on resilient cities' research is still lacking. The resilient city is a significant interdisciplinary research field, covering ecological environment, engineering technology, computer science, economics, social science, etc. To comprehensively understand the research progress and hotspots of the resilient city, it is necessary to conduct a bibliometric analysis.

Bibliometric analysis is a popular tool for scientific and technological text mining, which can quantitatively analyze the literature published in a specific field [25, 26]. Mapping knowledge domain is a kind of graph that shows the relationship between the development process and structure of scientific knowledge. It can be used to grasp hotspots and frontiers of research in a certain field and make a panoramic representation by using its unique visualizations. Recently, bibliometric analysis tools, e.g., CiteSpace and VOSviewer, have been widely applied in various fields. CiteSpace can analyze node structure and characteristics, which usually works as an effective tool for researchers to extract network relations [27]. VOSviewer can provide detailed information about the literature, such as hot topics [28].

The objective of this study is to present a bibliometric analysis and visualization of the past decade of resilient city research. This paper is organized as follows. The first section describes the data source and methods. The second section shows the results of bibliometric analysis from six main aspects, namely, publication, subject category, country, institution, journal, and author. Finally, the hot research topics and emerging trends in the field are summarized.

Using the bibliometric analysis approach, this study explores the following research questions (RQ):

RQ1: what is the overall publication trend and discipline distribution of resilient city research?

RQ2: which authors, articles, journals, institutions, and countries have been most influential in resilient city research?

RQ3: what are the hotspots and emerging trends in the study of the resilient city?

RQ4: what recommendations or guidelines can be drawn for researchers of the resilient city field in the future?

2. Data Acquisition and Method

2.1. Data Acquisition. To obtain comprehensive and abundant literatures in terms of resilient city, Web of Science (WoS) was used as the data source. The Web of Science (WoS) online database contains almost all the important research papers, which also provides built-in analytical tools to generate representative data [29]. Detailed information,

including publication year, country, author, institution, and journal source, was exported from WoS. The retrieval conditions were "resilience and urban," "resilience and city," "resilient and urban," and "resilient and city" to explore relevant theories and research contents in this field. The retrieval type was mainly keyword, and the time span was from 2010 to 2019 because the literatures on the resilient city were few before 2010. In total, 1249 valid literatures were obtained.

2.2. Methodology. Developed by Professor Chaomei Chen of Drexel University in the United States, CiteSpace software is used to map and visualize co-occurrence networks and clustering in the research field, identify the coupling relationship between different nodes, and discover the knowledge characteristics in a specific period [30]. In this paper, CiteSpace was adopted to generate knowledge maps, including country, institution, author, journal, and references citation bursts (Section 3). VOSviewer, which was developed by Eck and Waltman, is an effective visualization tool that can be used to construct keyword mappings based on co-occurrence data [31]. VOSviewer was used to implement topic clustering (Section 4) in this study. The writing framework of this paper is shown in Figure 1. After the data were collected (Stage 1), visualization of research was made from temporal and spatial distributions (Stage 2). To be specific, temporal distribution analysis contains publication output and high-cited references. The spatial distribution analysis includes five aspects, i.e., country, category, institution, co-citation journal, and author collaboration network. Subsequently, hot topics and evolution trends were analyzed by the clustering and sequential analysis methods (Stage 3). Finally, conclusions and recommendations were presented (Stage 4).

3. Temporal and Spatial Distribution of Resilient City Research

3.1. Temporal Distribution of Resilient City Research

3.1.1. Distribution of Annual Publication Outputs. The amount of publications can visually present the research interest of a certain research topic in a specific period. The trend of publication outputs can provide an overall grasp of the research progress of the topic and play a strong guiding role in the development of future research. Through the retrieval of articles in the field of resilient cities from 2010 to 2019, a distribution map of the publication output of resilient cities was drawn in Figure 2. Annual publication output in the resilient city field was 24 in 2010, and there was an overall upward trend from 2010 to 2019. The number of annual publications remarkably increased, and the maximum difference was 249 articles. Specifically, from 2010 to 2014, the number of publications on the resilient city grew slowly with an average annual publication volume of only 58. After 2015, with the acceleration of global urbanization and the surge of various natural and artificial disasters, the vulnerability of cities has become increasingly obvious.

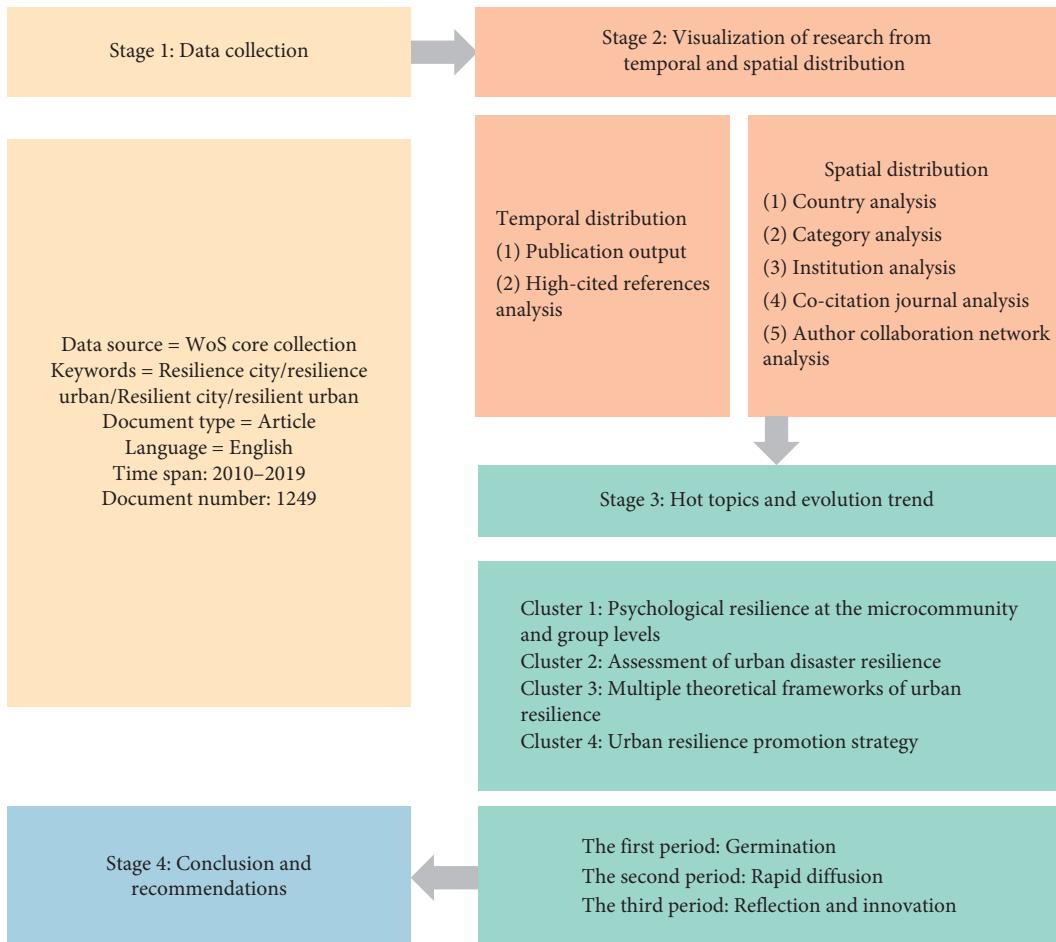


FIGURE 1: Bibliometric analysis framework of this paper.

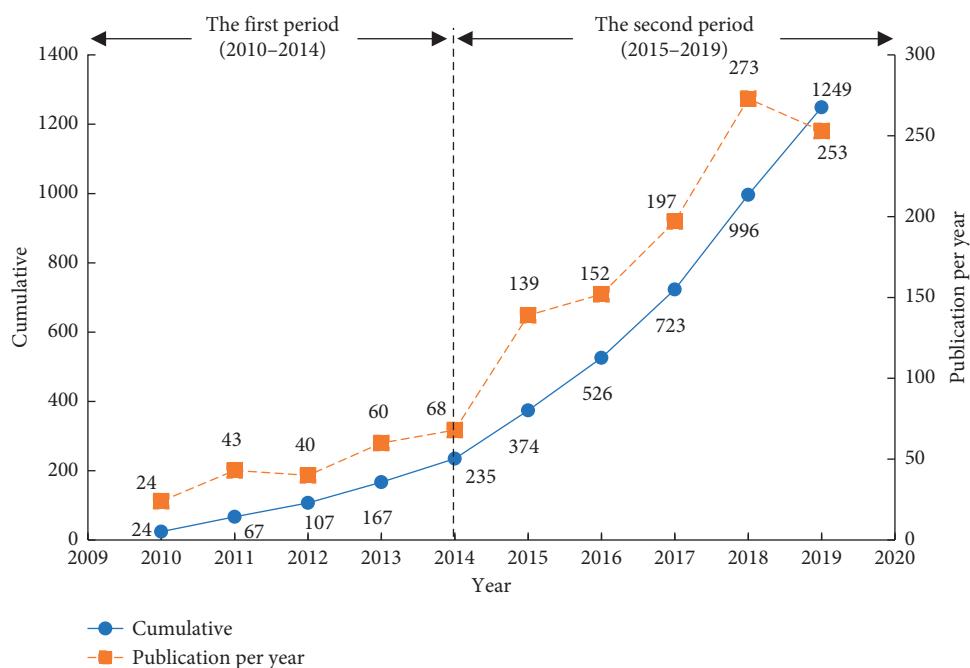


FIGURE 2: Distribution of annual publication outputs in the resilient city field from 2010 to 2019.

Therefore, exploring the construction of the resilient city has become a significant path to achieve sustainable urban development. In 2015, the number of related papers began to grow substantially, exceeding 100 for the first time. In 2018, publication outputs reached the peak in the past decade, at 273. The average increase in the number of articles published in 2015–2019 was 45, which was 4 times that of 2010–2014. The quantity of publications issued in 2019 declined slightly, but it remained at a relatively high level. Obviously, the boom in resilient city research has formed in the past decade.

3.1.2. Distribution of High-Cited References. The chronological distribution of articles is a time-series presentation in the dimension of research quantity, while the distribution of high-cited papers can be regarded as a time-series analysis in the dimension of research quality. The citation frequency of an article can reveal the influence and intelligence value of the article to some extent. Highly cited papers refer to academic papers that are cited frequently and have a long citation cycle. Papers with high citation frequency are usually regarded as authoritative and high-quality literature resources in this field.

This study used CiteSpace to count the top ten most frequently cited papers in Web of Science, which was ranked according to the frequency of citations, as shown in Table 1. The first highly cited document is “Defining urban resilience: a review” written by Meerow Sara, published in “Landscape and Urban Planning” in 2016 and was cited 101 times. Based on a systematic review of the definition of the resilient city, this article summarized and put forward the connotation, extension, and characteristics of the resilient city and deeply revealed the nature and characteristics of the resilient city. This article has become an important reference for multidisciplinary research on the resilient city [12]. The second high-cited article is a collection of essays on resilience research, which contains six subpapers. The authors explained resilience from different perspectives. Simin Davoudi discussed the significance of resilience and Keith Shaw raised questions about the politics of resilience; the third and fourth papers were published by L. Jamila Haider, Allyson E. Quinlan, Garry D. Peterson, and Cathy Wilkinson, both described the experience of integrating resilience into planning practice using examples from rural northern Afghanistan and urban northern Sweden; Hartmut Fünfegld and Darryn McEvoy discussed the main disaster management methods in climate change adaptation strategies and how to use resilience to change this situation; Libby Porter and Simin Davoudi raised some key questions about planning resilience [32]. “From fail-safe to safe-to-fail: sustainability and resilience in the new urban world” is the third highly cited article. It focused on the engineering field of urban resilience and proposed a set of strategies intended to build urban resilience capacity, including multifunction, redundancy and modularity, diversity (biological and social), multiscale network and connectivity, and adaptive planning and design to enhance the sustainability of urban development [33]. The fourth highly cited document “Planning the resilient city: concepts and strategies for

coping with climate change and environmental risk” constructed an innovative conceptual framework: the resilient city planning framework (RCPF), which included the four related concepts of urban vulnerability matrix analysis, uncertainty-oriented planning, urban governance, and prevention. It also solved a key question of what cities and their communities should do to move towards a more resilient country in the future, which provides a comprehensive understanding of urban resilience [34]. From Table 1, the output of high-quality publications on the resilient city field was concentrated in 2010–2014, which indicates that the theoretical construction in the early stage provides a solid foundation for subsequent multidisciplinary research on the resilient city.

Burst detection is an effective tool to detect emergencies or major information within a certain period [35]. Figure 3 shows the top 25 strongest citations detected by CiteSpace from 2010 to 2019. The blue line represents the time interval, and the red part of this line means the time interval when the citation occurred. The largest citation burst strength was 13.7683, which started in 2010 and ended in 2014. This article is titled “Resilience: The emergence of a perspective for social-ecological systems analysis” by Carl Folke. It integrated the concept of resilience into the study of socio-ecological dynamic systems, focusing on the sustainability of resilience in terms of governance capabilities such as renewal, restructuring, and development [36]. Norris et al. published the article “Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness” in 2008. Its citation burst intensity was 8.8638, which ranked second in burst intensity, starting in 2013 and ending in 2016. This article proposed the theory of community resilience to provide strategies for disaster prevention from a microscopic perspective. The theory is based on four main sets of adaptive capacities, including economic development, social capital, information and communication, and community capacity [37]. In addition, it can be seen from citation cycle analysis that the longest citation cycle of the 25 highly cited references was 6 years, while the shortest citation cycle was only 2 years.

3.2. Spatial Distribution of Resilient City Research

3.2.1. Distribution of Countries. Using the national network analysis function in CiteSpace, the node type was set as “country” and the visualization map was optimized to generate a country distribution network map, as shown in Figure 4. The larger the circle, the more the number of publications. The thickness of the outer pink circle represents the size of centrality. The greater the centrality, the closer the connection with other countries and the more obvious the bridge function. The top 10 countries according to publication output are shown in Table 2. In general, there is a large gap in the research on the resilient city across countries. The United States is the first country to carry out research on the resilient city with the most studies of 284 (22.74% of the total). The United Kingdom followed behind with 149 (11.93% of the total). The average number of

TABLE 1: Top 10 cited references in the resilient city field from 2010 to 2019.

Rank	Citations	Year	Title	Source	Author
1	101	2016	Defining urban resilience: a review	Landscape and urban planning	Meerow Sara
2	91	2012	Resilience: a bridging concept or a dead end?	Planning theory & practice	Simin Davoudi et al.
3	75	2011	From fail-safe to safe-to-fail: sustainability and resilience in the new urban world	Landscape and urban planning	Ahern Jack
4	59	2011	Planning the resilient city: concepts and strategies for coping with climate change and environmental risk	Cities	Jabareen Yosef
5	59	2013	Climate change and urban resilience	Current opinion in environmental Sustainability	Leichenko Robin
6	51	2012	A framework for urban climate resilience	Climate and development	Tyler Stephen
7	40	2013	Designing, planning, and managing resilient cities: a conceptual framework	Cities	Desouza Kevin C.
8	39	2010	Urban transitions: on urban resilience and human-dominated ecosystems	AMBIO	Ernstson Henrik
9	37	2010	The politics of resilient cities: whose resilience and whose city?	Building research and information	Vale Lawrence J.
10	37	2014	Resilience thinking: integrating resilience, adaptability and transformability	Ecology and society	Folke Carl

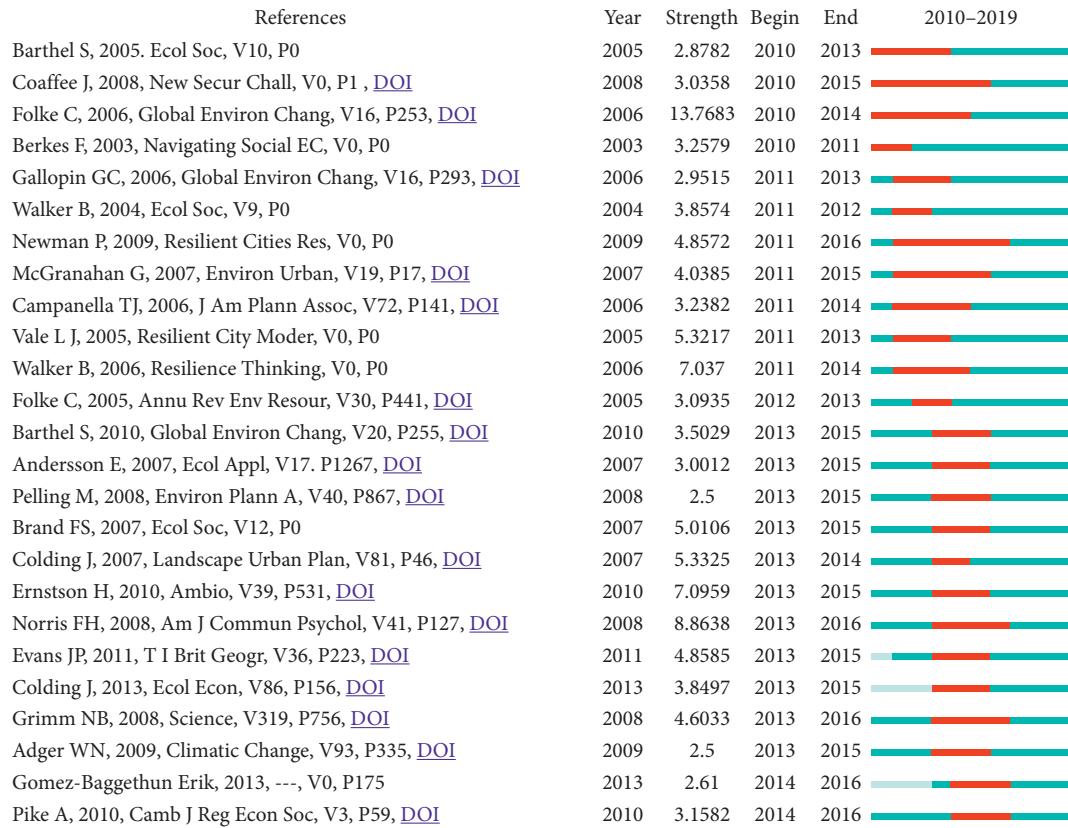


FIGURE 3: Top 25 references with strongest citation burst.

citations issued by the two countries is about 18, which is also at a relatively high level. This shows that they are two major countries in the field of resilient city research. The Dutch centrality is 0.7, and the average number of citations of published articles is about 24.75, indicating that the Netherland plays an important role in the overall research and acts as a knowledge intermediary and information flow controller.

3.2.2. Distribution of Categories. In CiteSpace, “category” was taken as the network node and the time slice was set as 1 year. The co-occurrence map of the category network is shown in Figure 5. The larger the circle, the more the number of articles, and the thicker the connecting line, the closer the correlation. The complex connections established by multiple nodes indicate that the resilient city is a research field with significant interdisciplinary attributes.

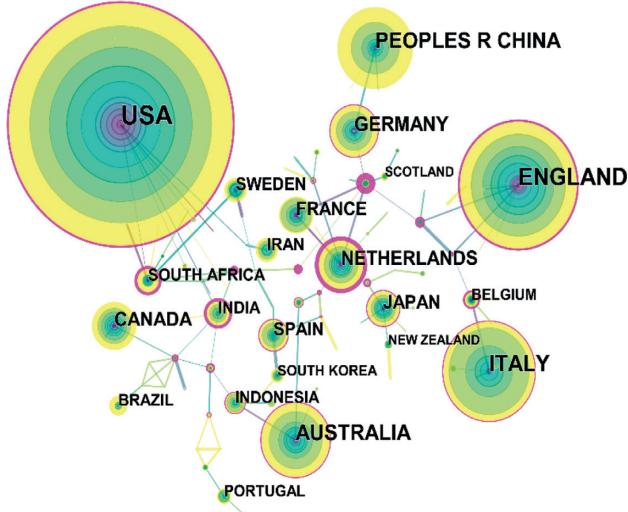


FIGURE 4: Visualization map of main countries in resilient city research from 2010 to 2019.

To further visualize the co-occurrence network map of categories, the annual distribution trend of the top 6 subject categories is shown in Figure 6. Among them, the most closely related category is environmental sciences and ecology with 412 articles published, accounting for 32.99%. The second-ranked category is urban studies with 262 articles, which accounts for 20.98% of the total. The engineering field is the third category of resilient city research. A total of 216 articles have been published, accounting for 17.29%. The top 6 categories also include other topics of science and technology, water resources, and public administration. It can be clearly seen from Figure 6 that, in the first stage of resilient city research (2010–2014), the resilient city study in various disciplines was in a groping stage and the number of publications fluctuated slightly on a relatively small basis. The resilient city research grew rapidly after 2015. The number of papers issued by the environmental sciences and ecology rose gradually and reached the peak in 2019. There was an upward trend in other disciplines despite of the largest fluctuations in the engineering field. It should be noted that the attention of other disciplines in the field of resilient cities greatly weakened except the environmental sciences and ecology in 2019.

3.2.3. Distribution of Institutions. The cooperation network of institutions was analyzed through setting the node type as “institution” in CiteSpace. Figure 7 shows the visualization map of institution in resilient city research. It is found that the connection between various institutions is loose. The cooperative networks have remarkable small group characteristics, e.g., King’s College London and Arizona State University. However, single-line cooperation networks existed between most institutions. Divergent academic cooperation is still lacking in the resilient city field. Therefore, it is necessary to strengthen the partnership between cross-regional institutions and build a multicenter cooperation network. Top 10 productive institutions in resilient city

research are shown in Table 3. The institution with the largest number of articles is the University of Naples Federico II in Italy, with 20 papers. Institutions with more than 15 articles published include Arizona State University in the United States and the University of Melbourne in Australia. Seven universities, including the University of Exeter in the UK, Stockholm University in Sweden, the University of British Columbia in Canada, King’s College London in the UK, Columbia University in the USA, the University of Cape Town in South Africa, and RMIT University in Australia have published more than 9 papers.

3.2.4. Distribution of Co-citation Journals. The number of publications and the frequency of literature citations are important indicators for measuring journals in a research field. Table 4 shows the top 5 productive journals in the field of resilient city. “Global Environmental Change-Human and Policy Dimension” is the most prolific journal in the field of resilient city research (with 362 publications), followed by “Ecology and Society” (with 305 publications). It is worth noting that the top two journals have a higher total citation frequency at 6311 and 6169, respectively, which indicates that the two journals have higher reference value in the resilient city field than other journals. H-index, as an academic evaluation index, has now become an important criterion for journal assessment. The H-index of “Global Environmental Change-Human and Policy Dimension” ranks first with a value of 147, which indicates that the articles included in this journal play a key role in the study of the resilient city. The average number of citations of a journal can reflect the overall quality of papers published in a certain journal. The articles published in “Ecology and Society” and “Annual Review of Ecology and Systematics” have high-quality characteristics, and the average number of citations of journal articles can reach above 20. The subject classification of five journals shows that the fields of ecology and environmental sciences have received the most attention.

The time-span presentation of cited journals in the field of resilient city research can reflect the outstanding contribution of the high-quality cited journals to the development of resilience urban. According to the time zone view of the co-citation journal in Figure 8 (node type: cited journal), the two journals named “Global Environmental Change-Human and Policy Dimension” and “Ecology and Society” took a leading position in the past decade. By 2011, the journal “Landscape and Urban Planning” received widespread attention and gradually developed into a key journal in the field of resilient city research. In the next few years, “Thesis” and “Sustainability” gradually attracted wide attention in resilient city research.

3.2.5. Distribution of Author Collaboration Network and Author Co-citation Network. Using BICOMB2 software for calculation and analysis, a total of 3186 authors were found to participate in the research on resilient cities from 2010 to 2019. Price [38] defined high-yield authors in his book named “Little Science, Big Science.” He believed “half of the

TABLE 2: Top 10 countries according to publications.

Rank	Country	Publications	Percentage	Centrality	TC	TC/P
1	USA	284	22.74	0.27	5213	18.36
2	England	149	11.93	0.27	2684	18.01
3	Italy	118	9.45	0.12	798	6.69
4	Peoples Republic of China	98	7.85	0.08	1121	11.44
5	Australia	91	7.29	0.13	788	8.66
6	Germany	65	5.20	0.12	574	8.83
7	Canada	61	4.88	0.04	950	15.57
8	Netherlands	61	4.88	0.7	1510	24.75
9	France	46	3.68	0	558	12.13
10	Japan	45	3.60	0.19	416	9.2

Note that the symbols TC and TC/P refer to the total citations and the average number of citations per paper for a country, respectively.

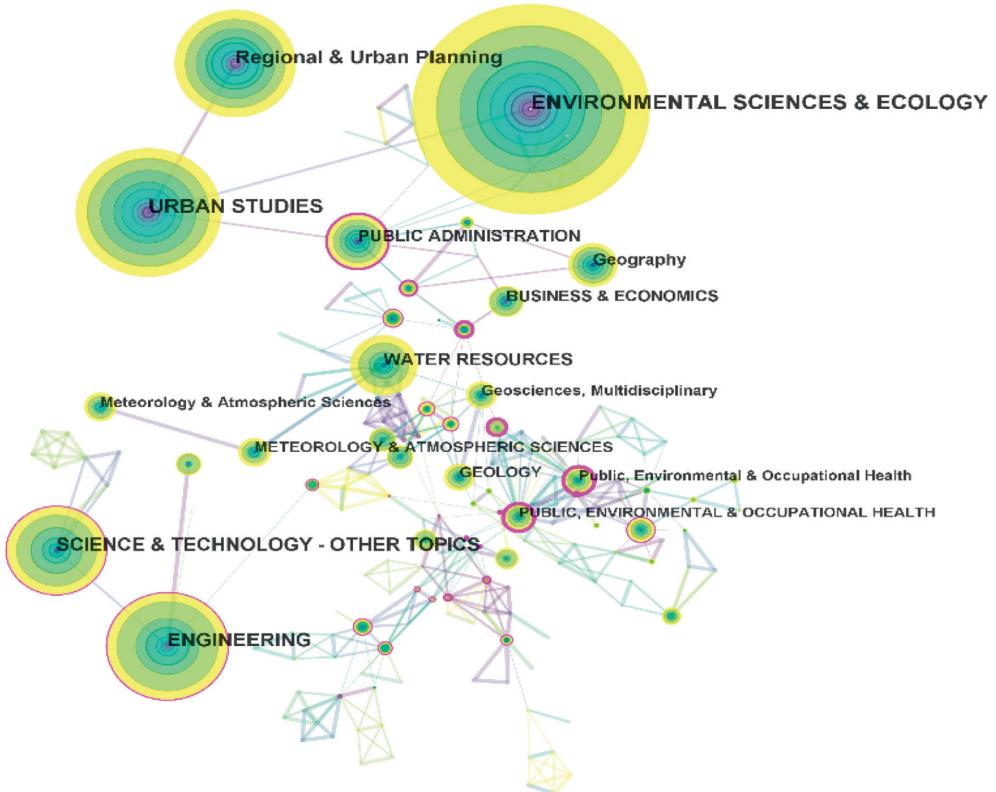


FIGURE 5: Visualization map of subject categories in resilient city research from 2010 to 2019.

papers are written by a group of highly productive authors and the number of author sets is approximately equal to the square root of the total number of authors.” The mathematical quantification of Price’s law is $\sum_{m+1}^i n(x) = \sqrt{N}$, where i represents the number of works published by the most productive author, m is the minimum number of works published by core authors, $n(x)$ refers to the quantity of authors who wrote x works, and N is the total number of authors [38]. After calculation, it is obtained that there are 136 high-yield authors in the resilient city research in the past decade, who published more than 3 papers (including 3).

According to Table 5, David Butler is the author who has published the most papers in the resilient city field, with 9 articles. This scholar is currently a professor in the field of

water conservancy engineering at the University of Exeter in the UK, mainly engaged in water resources management, sustainable and resilient water systems, urban drainage systems, and other fields. The scholar constructed an overall resilience analysis method for urban drainage and supply systems, which can provide a flexible assessment of functional failures caused by unknown risk factors [39,40]. His research achievements have received extensive attention from the academic community. Leire Labaka is a new author in the research field of resilient city, whose most articles were published in the past two years. He mainly focuses on the resilience of urban key infrastructure and proposed a resilience maturity model, which provides an implementation roadmap for urban resilience construction and builds a public-private partnership framework for resilient cities

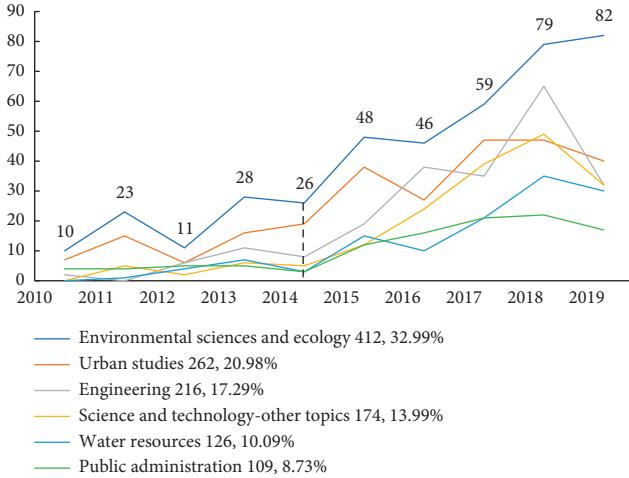


FIGURE 6: Trend of subject categories in the resilient city field with years.

[41, 42]. In addition, the authors who conducted extensive theoretical and practical research in the resilient city field include Josune Hernantes, Mark Pelling, and Eui Hoon Lee, who together constitute the core group of authors in the field of resilient city research.

In Figure 9, the high-yield author's cooperation network map is presented to better display the knowledge cooperation of scholars in the field of resilient city research (node type: author). The nodes in Figure 9 represent authors. The larger the node, the more important the position of the author in the collaborative network and the greater the number of published papers. The lines mean that two authors appear in the paper at the same time, and the thicker the line, the closer the cooperative relationship. From the perspective of the overall cooperation network, the cooperation network density of authors in the field of resilient city research is 0.0044. Obviously, the network density is low, and its overall structure is relatively loose, indicating that the current knowledge and information dissemination and penetration in the field of resilient city research are weak. The breadth and depth of interaction between network nodes need to be further strengthened. The research team, which contains Takefumi Suzuki, Hiroyuki Uchida, Kenichiro Kubo, Masaru Mimura, Yasushi Imasaka, and Kazunari Yoshida, is the most prominent in the author collaboration network. The groups represented by Leire Labaka and David Butler both have a relatively high frequency of cooperation and extensive cooperative relationship. Figure 9 indicates that the academic exchanges between authors in the field of resilient cities need to be deepened. Therefore, the field of resilient city in the future should focus on strengthening more extensive exchanges and communication among scholars.

By setting the "cited author" node, the co-cited author network graph is shown in Figure 10. The node represents the author, and the size of the node represents the frequency of citations. The thickness of the connection between the nodes represents how often the author is cited. The top 10 authors who are frequently cited are listed in Table 6. Holling

C. S. is the most cited author (frequency 242 and centrality 0.29). As an expert in the ecology field, he first proposed the concept of resilience. Holling believed that ecosystems have two attributes, including resilience and stability, and specifically divided resilience into engineering resilience and ecology resilience, which promoted resilience research gradually from the field of natural ecology to the field of human ecology [43]. As one of the top 10 highly cited authors, the centrality of Holling C. S. is also particularly remarkable, which indicates that the author has laid a very important knowledge foundation for this research field and made outstanding contributions to knowledge dissemination. Ranked second is Carl Folke (frequency 237 and centrality 0.02), who systematically sorted out the evolution of the resilience perspective and gradually developed from the branch of ecology to social-ecosystem resilience [36]. The third place is Adger (frequency 173 and centrality 0.06), who comprehensively reviewed the fragility tradition and its evolution process. It is believed that vulnerability, adaptation, and resilience of the social-ecological system have common goals and foundations [44]. The author analyzed the significant correlation between ecological resilience and social resilience, which has attracted widespread attention from scholars in resilience urban research [45]. Others of the top 10 highly cited authors are Walker B., Cutter S. L., Meerow S., Davoudi S., Pelling M., Ahern J., and Berkes F.

4. Analysis on Hot Topics and Evolution Trends of the Resilient City

4.1. Analysis of Hot Topics in Resilient City Research. Keywords are the refinement and summary of the content of the article, and thus, the frequency analysis of keywords is usually used to reveal the research hotspots of a specific domain. In the case of numerous literatures and various keyword categories, the keyword co-occurrence map drawn by VOSviewer has the advantages of clear clustering, strong readability, and hard label overlap [31]. Therefore, VOSviewer was utilized in this study to draw a keyword co-occurrence analysis map to present the distribution of hot topics in the resilient city research. In the VOSviewer, the threshold of word frequency statistics was set as 10. The first 120 keywords were selected to conduct keyword co-occurrence analysis of resilient city research in the paper, as shown in Figure 11. The size of the circle represents the frequency of keyword occurrence, the lines between each circle node represent the co-occurrence relationship, and the nodes with the same color represent the same clustering attribute. From the holistic perspective, "practice," "assessment," "measure," and "sustainability" appear frequently, which are hot topics in the field of resilient city. The hot topics of the resilient city can be divided into the following four categories:

Cluster #1 (Yellow): Study on Psychological Resilience at the Micro Community and Group Levels. The keywords are African American, group, child, family, factors, residents, relationships, community resilience, education, violence, etc. Research on specific groups in the

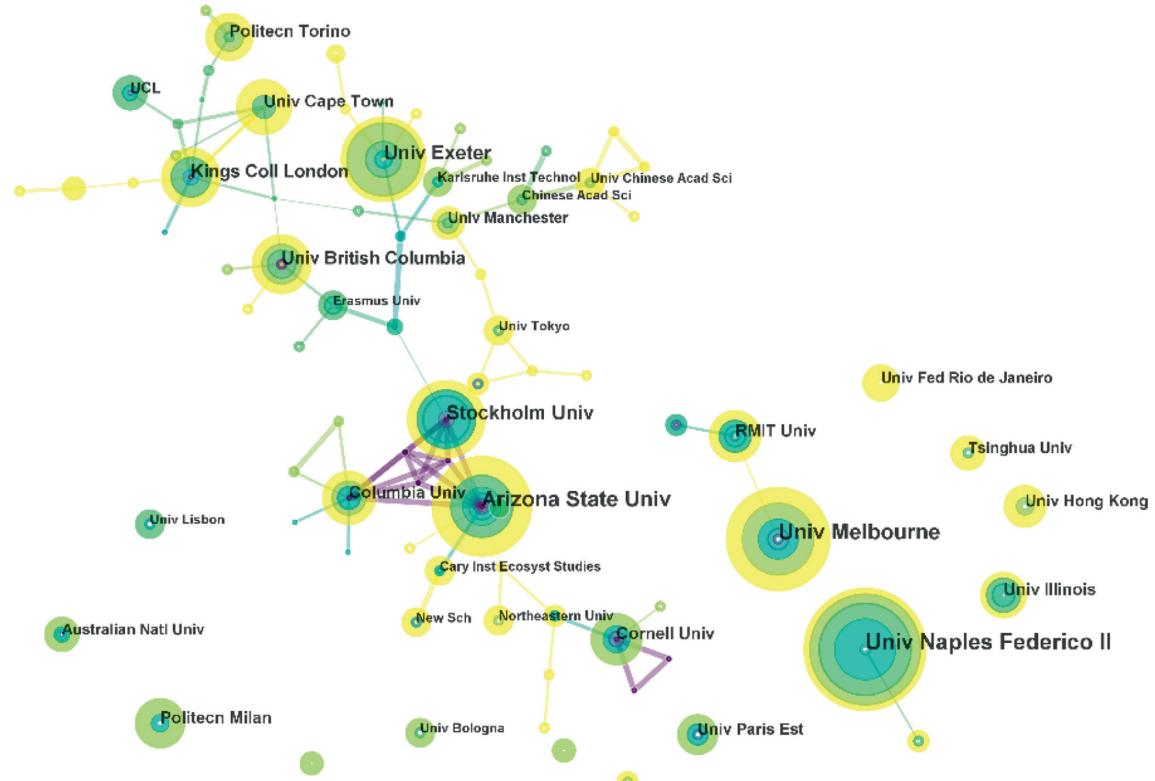


FIGURE 7: Visualization map of institution in resilient city research from 2010 to 2019.

TABLE 3: Top 10 productive institutions according to publications.

Rank	Institution	Publications	Centrality	Country
1	University of Naples Federico II	20	0	Italy
2	Arizona State University	17	0.03	USA
3	The University of Melbourne	17	0	Australia
4	University of Exeter	14	0.01	England
5	Stockholm University	13	0.04	Sweden
6	University of British Columbia	10	0.03	Canada
7	King's College London	10	0.02	England
8	Columbia University	9	0.01	USA
9	The University of Cape Town	9	0	South Africa
10	RMIT University	9	0	Australia

TABLE 4: Top 5 productive journals in the resilient city field during the period of 2010 to 2019.

Journal	Pa	Percentage (%)	TCb	TC/ Pc	H- Index	IF	Subject
Global environmental change-human and policy dimension	362	28.98	6311	17.43	147	10.47	Environmental sciences
Ecology and society	305	24.42	6169	20.23	119	3.89	Ecology
Landscape and urban planning	291	23.30	4478	15.39	132	5.44	Ecology, geography, and physical
Cities	212	16.97	2854	13.46	51	4.80	City planning and urban design
Annual review of ecology and systematics	202	16.17	4109	20.34	N/A	6.15	Evolutionary biology and ecology

Note that the symbols Pa, TCb, TC/Pc, and IF represent the total publications, the total citations, average number of citations per paper, and impact factor of a journal in the latest year, respectively.

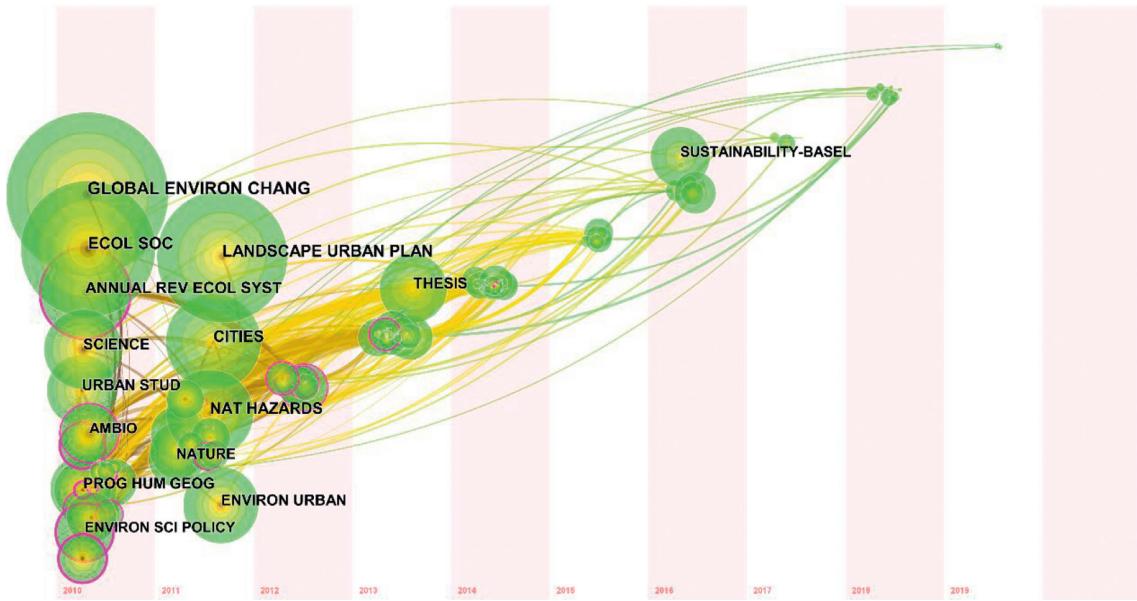


FIGURE 8: Time zone view of the co-citation journal network in resilient city research from 2010 to 2019.

TABLE 5: Top 10 productive authors in the resilient city field from 2010 to 2019.

Rank	Publications	Author	Institution	Country
1	9	David Butler	University of Exeter	England
2	7	Leire Labaka	University of Navarra	Spain
3	5	Josune Hernantes	University of Navarra	Spain
4	5	Mark Pelling	King's College London	England
5	5	Eui Hoon Lee	Chungbuk National University	South Korea
6	5	Sara Meerow	Arizona State University	USA
7	5	Ayyoob Sharifi	Hiroshima University	Japan
8	5	Domenico Asprone	University of Naples Federico II	Italy
9	4	Youssef Diab	Lab LabUrba	France
10	4	Kenichiro Kubo	Jikei University	Japan

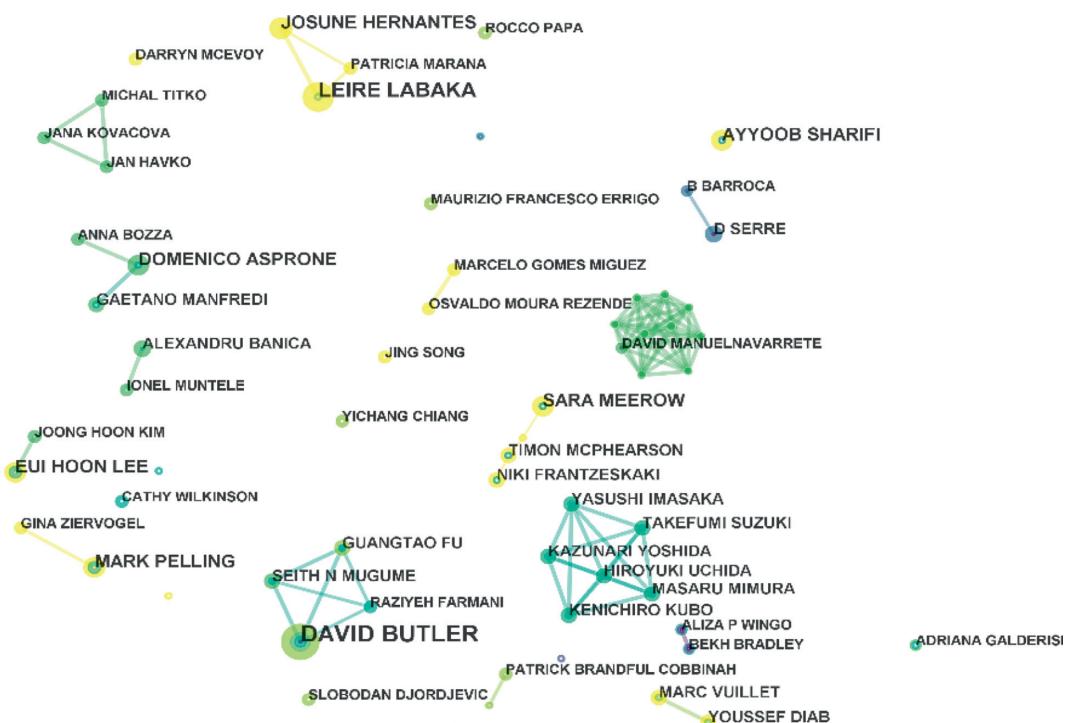


FIGURE 9: Visualization map of the author cooperation network in the resilient city field.

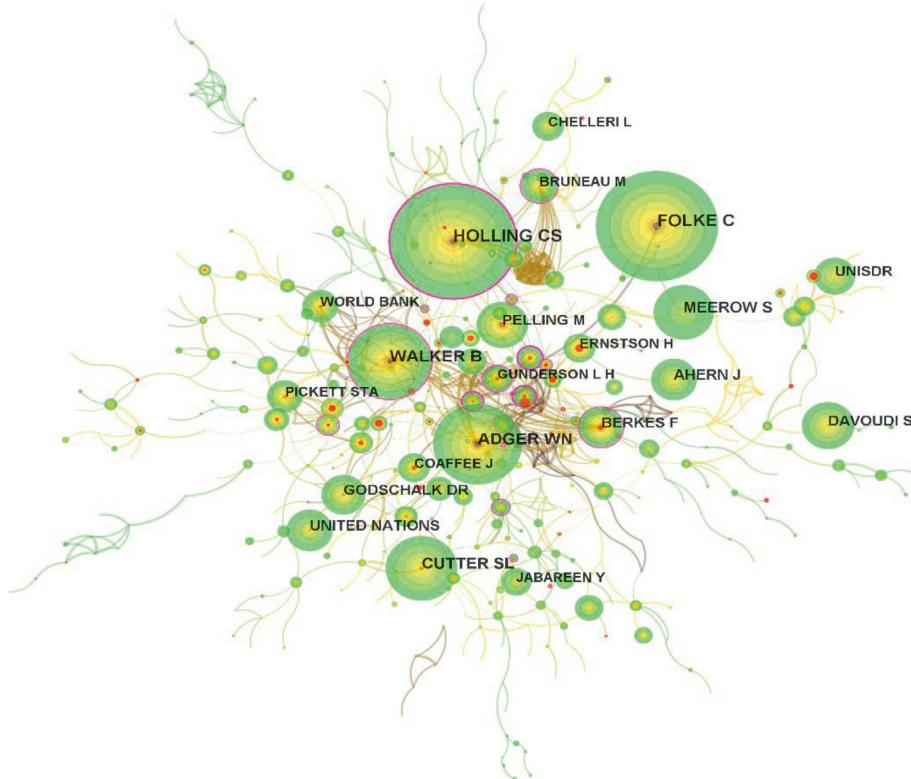


FIGURE 10: Visualization map of the co-cited author in resilient city research.

TABLE 6: Top 10 cited authors in the resilient city field from 2010 to 2019.

Rank	Author	Frequency	Centrality	Year	H-Index	Institution
1	Holling C. S.	242	0.29	2010	37	University of Florida
2	Folke C.	237	0.02	2010	92	Stockholm University
3	Adger W. N.	173	0.06	2010	60	University of Exeter
4	Walker B.	163	0.13	2010	58	Australian National University
5	Cutter S. L.	140	0.02	2011	8	University of South Carolina System
6	Meerow S.	118	0.01	2016	11	Arizona State University
7	Davoudi S.	105	0.02	2013	22	Newcastle University-UK
8	Pelling M.	105	0.02	2011	30	King's College London
9	Ahern J.	94	0	2013	10	University of Massachusetts System
10	Berkes F.	93	0.14	2010	45	University of Manitoba

context of community is an early focus of urban resilience, which embodies the application of the concept of resilience in the psychology field. Community is the main unit of urban construction, and human beings are an important part of the urban system. These studies believed that, in times of adversity, the leadership of individuals, the trust and support of the organization network, and the vision for the future are the significant factors for building urban resilience [46–48]. The high citation articles during this period focused on the psychological resilience and mental health of children or adolescents. Laura Camfield found that children with stronger social abilities were more likely to recover quickly from adverse experiences than children with personal abilities in developing countries based on a long-term follow-up

survey of four adolescents in Ethiopia [49]. Due attention should be paid to developing children's social capacity to enhance psychological resilience. Fergus Stevenson and Zimmerman Marc A. conducted a study on adolescent psychological resilience at risk and discussed three elastic models, including compensation, protection, and challenge [50]. They argued that parental support and personal social networking skills can help youth overcome risks and avoid negative outcomes.

Cluster #2 (Green): Study on Assessment of Urban Disaster Resilience. The prime keywords are disaster, flood, earthquake, adaptability, assessment, method, uncertainty, recovery, indicators, etc. Natural disasters are the earliest area of concern for urban resilience. Research contents involve the construction of the

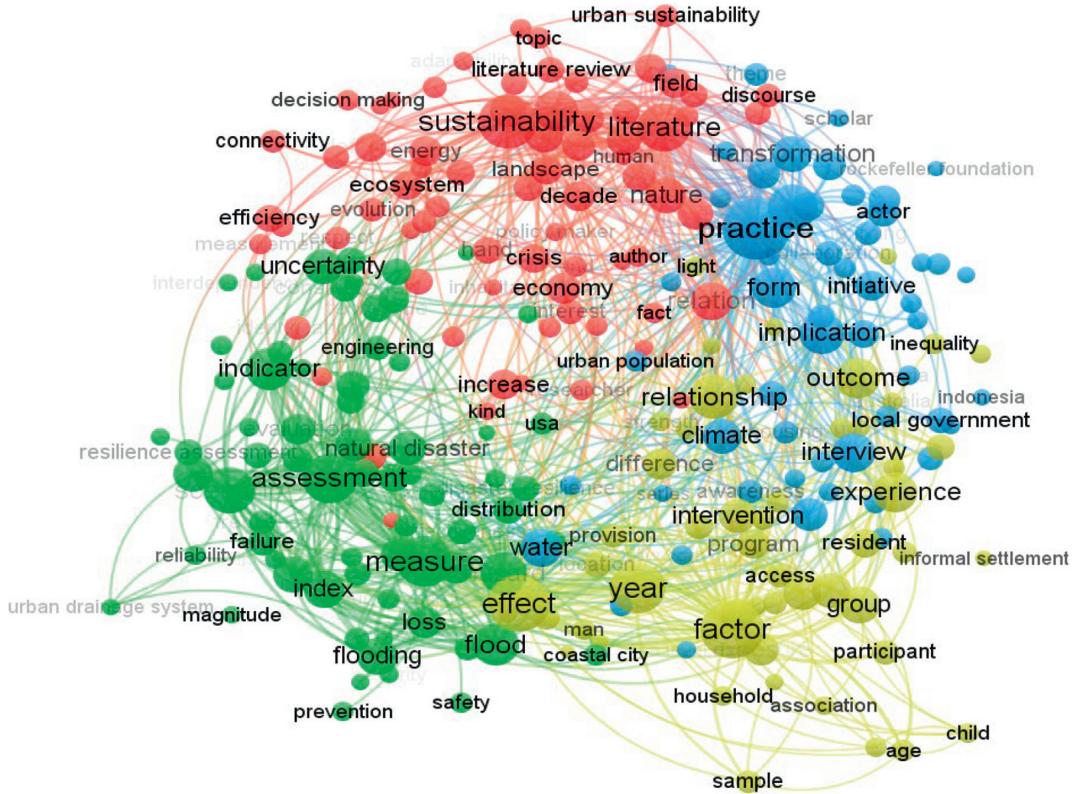


FIGURE 11: Network visualization map of keyword co-occurrence in resilient city research.

resilience capacity index system from the perspective of natural disasters, the experience reference of the resilient city case, and the discussion on the path of resilient cities to cope with natural disasters. The research of this cluster focuses on the capacity of urban infrastructure to withstand disaster risk. Hence, the construction of urban disaster recovery framework mainly pays attention to the features of facility redundancy, resource usefulness, and reflection when cities face risks. In 2003, Godschalk initiatively defined the resilient city from the perspective of urban disaster prevention and mitigation [18]. Additionally, he proposed a comprehensive urban disaster reduction strategy and considered that strengthening cooperation among professional teams and expanding urban systems research are important paths to build the resilient city [18]. Cutter et al. proposed the disaster resilience of place (DROP) model for communities to cope with natural risks, aiming to improve comparative assessments of disaster resilience at the local or community level [51]. León and March argued that the resilience in response to the tsunami can be enhanced by pooling regional urban resources through street networks [52]. Conducting the research on community parks in New York City under the impact of Hurricane Sandy, Chan et al. found that community parks not only strengthen food and ecosystem security but also play a crucial part in fostering community citizens' awareness of greening public spaces and social ecological restoration after disasters [53].

Cluster #3 (Red): Study on the Multiple Theoretical Frameworks of Urban Resilience. The prime keywords are sustainability, landscape, urban systems, economic resilience, ecosystems, transformation, theoretical framework, etc. Resilience Alliance is one of the earliest organizations to conduct research on urban resilience. The alliance believed the research on the resilient city can be divided into four priority areas, namely, infrastructure environment, metabolic flow, regulatory network, and social level. In fact, it emphasized different emphases of the construction of the resilient city from the perspectives of economy, infrastructure, society, and ecology [54]. The Rockefeller Foundation put forward the City Resilience Framework (CRF) in 2014, which believes that a resilient city should include four main dimensions, including health and well-being, infrastructure and environment, economy and society, and leadership and strategy, with three specific driving factors in each dimension [55]. Desouza and Flanery believed that cities are composed of physical and social systems and cities need to resist natural, technological, economic, and human pressures through case studies [14]. Cutter et al. established a multidimensional resilience framework system for cities and communities to carry out resilience planning and evaluation for different subjects [17, 51].

Cluster #4 (Blue): Study on Promotion Strategy for Urban Resilience from the Perspective of Social Governance and Urban Planning. The prime keywords are governance, government, practice, case study, food

safety, green infrastructure, water resources, climate adaptation, housing supply, land use, etc. With the transition from ecological resilience to evolutionary resilience (social ecological resilience), the traditional “security defense” response strategy is no longer effective, and the “security free” strategy is exactly what is advocated in the modern construction of the resilient city [33, 36]. Some scholars provided resilience as the core of the promotion strategy. For example, Ahern offered a suite of strategies intended to build urban resilience capacity, including multifunctionality, redundancy and modularization, diversity (biological and social), multiscale networks and connectivity, and adaptive planning and design [33]. Case study is a commonly used research method from the perspective of social resilience. Through the tsunami event in Chile, León and March believed that the design of the urban space and street layout can improve the resilience of a city to cope with the tsunami and thus summarized the strategy of planning resilience improvement [52]. Wardekker et al. took the specific city of Rotterdam as a case to put forward resilience strategies to deal with climate change and flood risk, aiming to provide a corresponding basis for the city’s decision-making and planning [54, 56].

4.2. Analysis on the Evolution Trend of the Resilient City Theme. CiteSpace was used to present the time zone map and emerging word view of the keywords in resilient city research, as shown in Figure 12 and Table 7, respectively. According to the generated time zone map, the research on the resilient city can be roughly divided into three periods, namely, germination, rapid diffusion, and reflection and innovation periods.

4.2.1. The First Period: Germination Period (2010–2011). In the early years of this period, the theme of resilient city studies involved the psychological resilience of specific groups of human beings, mainly children and adolescents, with high frequency keywords such as adolescent development, community violence, resilience, protection, and African Americans. Meanwhile, with the development of ecological resilience in this field, the academic community has begun to pay extensive attention to the ability of cities to adapt to climate change. From the perspectives of ecology, engineering, and social politics, Kim and Lim presented a conceptual framework for analyzing urban resilience in the context of climate change, aiming to shed light on future urban planning and policies for adapting to climate change [57]. Similarly, Tyler and Moench proposed a framework of resilience to climate change, which includes the characteristics of urban systems, the agents (individuals and organizations) that rely on and manage these systems, the institutions that link systems and agents, and patterns of exposure to climate change [58]. The viability of the framework by the literature [58] was demonstrated through examples from 10 cities across Asia. Although the research literature on psychological resilience and ecological

resilience dominated during this period, the resilience characteristics of urban systems began to attract attention from all sectors of society and generated research topics such as urban resilience planning, governance and transformation, sustainability, and management.

4.2.2. The Second Period: Rapid Diffusion Period (2012–2016). During the rapid diffusion period, resilience was applied to the functional construction of various subsystems of the city. Some themes related to urban resilience emerged, including community resilience, flood control resilience, critical infrastructure resilience, building environment resilience, earthquake mitigation resilience, and water resource resilience. The range of disciplines involved is increasingly wide, including energy, environmental science, engineering, geography, economics, management, and regional planning. Most of the multidisciplinary and multi-dimensional studies in this period focused on the construction of evaluation index system for different urban subsystems and the construction of the systematic comprehensive urban resilience framework. A typical example is the Baseline Resilience Indicators for Communities (BRIC) model proposed by Cutter et al. based on 6 aspects of community capital, society, economy, system, housing and infrastructure, and environment, with 49 indicators [51]. Frazier et al. added two influencing factors, place and time, into the BRIC model and emphasized the important role of the two factors in community resource allocation and measures improvement [59]. Frazier et al. also carried out a specific study and application of community resilience indicators in Sarasota County, Florida.

4.2.3. The Third Period: Reflection and Innovation Period (2017–2019). During this period, the publications continued to increase. High-frequency keywords in this stage include green infrastructure, economic crisis, economic resilience, social resilience, urban resilience, sustainable development, and flood risk management. In addition to the diversity of research perspectives, there began to be some reflections on urban resilience paths and solutions, as well as the reconstruction of urban resilience indicators and theoretical framework. Kaika made a profound reflection on the construction of resilient cities, arguing that it would be difficult to make substantial progress if the resilient city study continues to adopt old methodological tools, institutional frameworks, and techno-managerial solutions [60]. Zier vogel et al. believed that the practice of resilience may be not consistent due to the difference in the development level between the global North and South, especially African cities, and proposed four entry points for integrating the right and justice into urban resilience [61]. Resilient city research is a dynamic and complex process from the perspective of the development needs of the city. Resilient city construction needs to pay equal attention to theory and practice.

The future trend of resilient city research is to put the research under the multilevel framework of environment, economy, society, and management, construct an operable

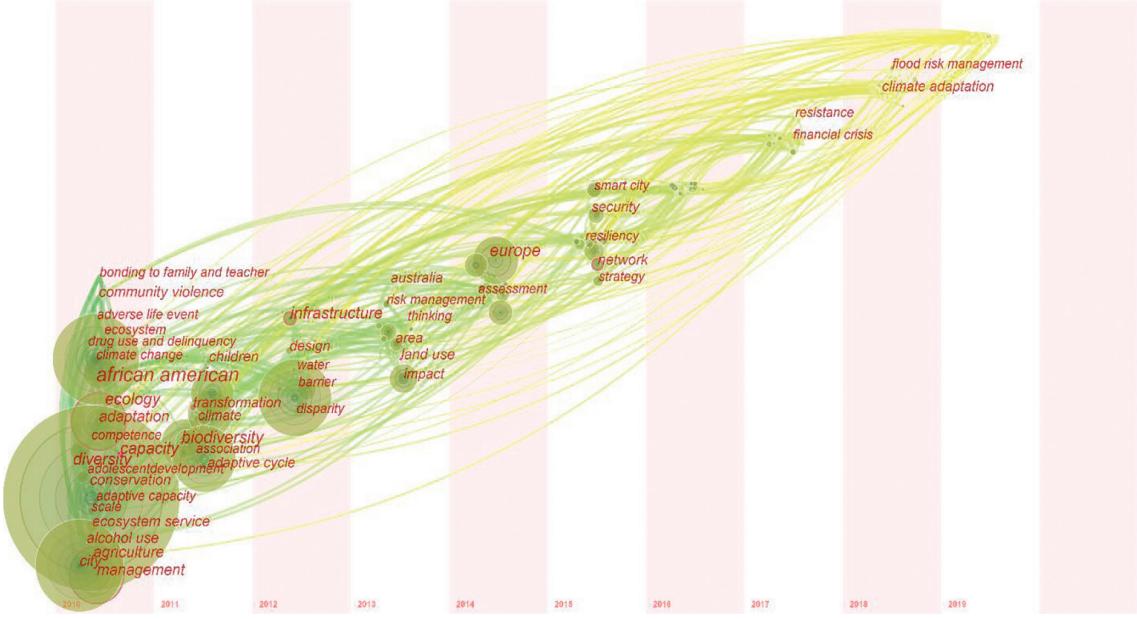


FIGURE 12: Visualization time zone map of keywords in resilient city research from 2010 to 2019.

TABLE 7: Annual high-frequency keywords.

Frequency	Centrality	Years	Keywords
334	0.02	2010	Resilience
170	0.08	2010	City
167	0.05	2010	Climate change
114	0.15	2010	Adaptation
112	0.16	2010	Management
67	0.03	2010	Governance
45	0.05	2010	Disaster
30	0.02	2010	Climate change adaptation
30	0.03	2010	Ecosystem service
124	0.02	2011	Vulnerability
92	0.04	2011	Risk
90	0.07	2011	Sustainability
86	0	2011	System
51	0.05	2011	Urbanization
41	0.07	2011	Urban
32	0.02	2011	Resilient city
30	0.03	2011	Urban planning
138	0.04	2012	Urban resilience
39	0	2012	Challenge
34	0.16	2012	Infrastructure
22	0.08	2012	Design
14	0.06	2012	Built environment
57	0.06	2013	Impact
37	0.06	2013	Health
28	0.03	2013	Lesson
18	0.01	2013	Complexity
17	0.05	2013	Risk management
16	0.01	2013	Landscape
15	0.02	2013	Area
94	0.02	2014	Framework
51	0.01	2014	Policy
44	0	2014	Model
30	0.03	2014	Politics
20	0.04	2014	Mitigation

TABLE 7: Continued.

Frequency	Centrality	Years	Keywords
41	0	2015	Community resilience
33	0.03	2015	Indicator
30	0.05	2015	Smart city
26	0.13	2015	Network
26	0.07	2015	Perspective
25	0.08	2015	Strategy
18	0.01	2015	Flood
16	0	2015	Performance
16	0.04	2015	Security
21	0.01	2016	Hazard
14	0.1	2016	Disaster resilience
13	0.01	2016	Earthquake
13	0.02	2016	Recovery
12	0.02	2016	Social ecological system
11	0.05	2016	Poverty
10	0.01	2016	Climate resilience
16	0.01	2017	Green infrastructure
12	0.03	2017	Flood risk
11	0.02	2017	Economic resilience
7	0	2017	Knowledge
7	0.01	2017	Natural disaster
7	0.01	2017	Social resilience
10	0.03	2018	City resilience
10	0	2018	Sustainable development
9	0.05	2018	Flood risk management
8	0	2018	Regional resilience
8	0.03	2019	Flood resilience
6	0.02	2019	Index
5	0	2019	Flooding
5	0	2019	Justice
5	0	2019	Knowledge system
5	0	2019	Rotterdam

implementation framework, and formulate time-sensitive strategies for resilience improvement. The academic community believes that emerging technologies such as the Internet of Things, big data and cloud computing, artificial intelligence, and blockchain will serve as the development path for the construction of resilient cities. Smart technologies can provide a starting point in enhancing the city's disaster response, prevention capacity, and resilience of postdisaster recovery, which facilitate building a smart, safe, and resilient city. Importantly, smart, safe, and resilient city research is being highly focused, which has become the forefront of resilient city research.

5. Conclusion

Since the 21st century, the concept of resilience has been widely applied to the socio-ecological field and the research on resilient cities has shown a rapid growth trend. In this paper, CiteSpace and VOSviewer bibliometric softwares were used to analyze the temporal and spatial distribution of the research on the resilient city. Moreover, the research hotspots were revealed under the topic clustering of the co-occurrence network based on keywords. Finally, the thematic evolution trend of the resilient city was summarized according to the time zone distribution characteristics of keywords. The following conclusions were drawn:

- (1) The research of the resilient city presents the characteristics of multiscale, multidimensional, and interdisciplinary knowledge systems. In the context of different disciplines, the study of the resilient city has formed four aspects of subject clustering, including psychological resilience at the microcommunity and group levels, assessment of urban disaster resilience, multiple theoretical frameworks of urban resilience, and urban resilience promotion strategy.
- (2) According to the evolution trend of the theme, the research of the resilient city has experienced three periods, namely, germination, rapid diffusion, and reflection and innovation periods. With the adoption and application of the concept of resilience in various fields, the subject of research on resilient cities has become more and more extensive, from psychological resilience and ecological resilience in the early period to diversified research in different dimensions and processes in the social domain. The research issues have also expanded from the early restoration of natural ecology and spiritual level to urban regional planning, infrastructure construction, reconstruction of the built environment, water supply, and other issues. Thus, the theoretical framework and evaluation system for the construction of modern resilient cities have emerged.
- (3) From the perspective of co-authors and institutions, the research teams and institutions are relatively concentrated and the author cooperation network is loose as a whole. Knowledge dissemination and permeability are poor, and research cooperation depth and breadth are insufficient. The cooperation

network shows fragmentation characteristics. In future research, scholars and institutions should break down barriers and explore cross-team, cross-school, and cross-regional collaboration.

- (4) In terms of the characteristics of the literature knowledge structure, the research on the resilient city is on the upsurge. The research methods are mostly theoretical, while the research from positivism is rare. The research focuses more attention on the construction of the theoretical system, and the practical exploration lags behind the theoretical analysis. Future research needs to combine theory with practice and carry out more cases and exploratory analysis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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