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Review

A Review of Urban Planning Research for Climate Change

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Abstract: This paper identified the research focus and development tendency of urban planning and climate change research from 1990 to 2016 using CiteSpace, which is based on the Web of Science database. Through cluster analysis and a document sorting method, the research direction of city planning and climate change were mainly divided into four academic groupings, 15 clusters with homogenous themes representing the current research focus direction at the sub-level. The detailed study on the framework presented three mainstream developing directions: (1) The index assessment and spatial simulation on the impact of urban spatial systems for climate change have become important methods to identify and improve the adaptability of urban space. (2) Adaptive governance as a bottom-up strategy giving priority to institutional adaptation policy and collaborative polices for responding to climate change has become the hot direction in recent years. (3) The policies of urban public health-related urban equity, vulnerability, and environmental sustainability were addressed especially during the period from 2007 to 2009. Dynamic evolution trends of the research field were discussed: (1) The total numbers of papers in this field increased distinctly between 2005 and 2008, research focus shifted from single-dimension to multi-dimension comprehensive studies, and the humanism tendency was obvious. (2) After 2010, research on multi-level governance and spatial adaptation strategies became the key issues, and a bottom-up level adaptation policies were addressed. Finally, the critical influence of the important literature and the forefront issues of the research field were put forward.

Keywords: urban planning; climate change; knowledge map; CiteSpace; collaborative planning; city level

1. Introduction

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the most comprehensive report on climate assessment in history, referred to city regions as the main areas that must respond to climate change risks. Climate change research on urban scales has become an important topic. The international literature has already demonstrated the importance of cities in coping with climate change [1–3]. A series of issues has been raised by the rapid development of urbanization, such as the large numbers of greenhouse gas emissions of urban systems, the sprawling layout of urban spaces, and the disordered use of land, leading some to take climate issues more seriously. Therefore, urban systems need to respond to the major challenges of climate change. In recent years, corresponding research on urban spatial planning, combined with climate factors, has been given increasing attention, and the urban space system has become one of the main entry points in coping with climate change [4].

Due to the frequent occurrence of extreme climate events, increasing attention has been placed on the study of such events. Consideration of the climate adaptability of cities has been suggested. IPCC's definition of adaptation of the urban climate is the process of adjustment in human systems to the actual or expected climate and its effects to moderate harm or exploit opportunities. This showed that international institutions and governments in many countries have designated climate change problems and strategies of city regions as key areas of global climate change research and have actively promoted "city climate change act planning". "Climate act planning for Chicago" from the Chicago Ministry of Environment (2008) proposed adaptive strategies, including mitigating urban heat islands, implementing city-based innovations, improving air pollution management, managing rainstorms, establishing green design, protecting trees, and providing an incentive to the public and enterprises to actively respond to climate change [5]. The framework of climate change risk assessment is established in urban areas of the United Kingdom based on the GIS method, and it is integrated with the local development framework, becoming an important strategy for urban environment adaptation to climate change [6]. The United Kingdom and the United States have, as expected, lead in areas of research that have formed a certain reference framework and have implemented many planning practices in policymaking, public participation, and implementation feedback for climate adaptation.

After the IPCC 2007 report had suggested that climate change research at the city level was becoming an important issue, studies on urban planning for climate change have been moving from analyses of the dynamic relationship of urbanization patterns to research on the internal systems of urban space systems and micro-scale unit area climate effects. More studies on multiple spatial scales were proceeding on urban planning for climate change. Discussion of the topic of the rational cooperative development method and the rational path of this field is key, and mainstream research in this area should be summarized and analyzed to promote future planning efforts that are integrated with current outlying theories and methods.

A scientific knowledge map is an image of a knowledge domain that shows the relationship between the development process and the structure of scientific knowledge. It has the characteristics of both "map" and "spectrum", e.g., it is visual and graphic knowledge as well as serialized knowledge, showing many implied complex relationships between knowledge units or the knowledge group and is composed of networks, inter-structures, interactions, evolution and a generative status. This complex knowledge produces a large amount of new knowledge. Based on the Web of Science database (WOS) by the scientific map tool CiteSpace, combined with a later traditional literature analysis method, this paper makes generalizations about the research status of urban planning and climate change, clarifies the hotspots and frontier areas, identify potential development tendencies, and promote the effective implementation of urban space planning and a sustainable development path for climate adaptability. The content and progress of the research system would be developed in accordance with the planning development process via a mainline framework of "drive and impact analysis-prediction simulation-policy response".

2. Methods and Data Sources

Scientific knowledge maps reveal the internal relations of subject knowledge, development context and evolution law, and an implication of a new development direction [7]. Scientometric mapping, or bibliometric mapping, is a visual technique in informatics that quantitatively displays structural and dynamic aspects of scientific research [8–10]. Professor Chaomei Chen from Drexel University in the US developed CiteSpace based on the theory of co-citation and the pathfinder algorithm, among others, for Java-based networks, bibliometrics, and the domain specific literature to identify critical path field evolution and its knowledge inflection point. Chen also illustrated a series of visualization map relationships that focus on the detection and analysis of the trends and interdisciplinary relationship between the frontier and knowledge bases and the internal relations among the different research frontiers [11]. The map result by CiteSpace includes a variety of modes, such as a clustering map, timeline map and time zone map. Several visualization maps can be formed by CiteSpace analysis, such as document clustering visualization maps, national and regional cooperation networks, and a cooperation network, timeline and time zone map, etc. This software offers a significant amount of visualization information, clear interface settings and a simple, user-friendly interpretation. High citation frequency nodes are easily identified through a visualization of different colors, node locations, and node sizes. Dark pink and red are used to represent the explosion frequencies or the frontier areas of the literature. Specifically, visualization maps by CiteSpace combines emergent monitoring algorithms and intermediate metric rule algorithms to generate better visualization effects (such as cluster diagrams and time series charts), which provide a good foundation for in-depth analyses of user profiles. It also further enhances the strengths in capturing scientific frontiers, hotspots, and trends in bibliometric analyses with CiteSpace.

CiteSpace now has a wide range of applications and is basically accepted by users in discipline development scales. The reliability of the results have been shown to be high. Bibliographic coupling techniques for mapping researchers have been explored for the development of urban studies in the context of related academic studies [9,10,12–14]. Numerous scientific mapping analysis tools exist, although CiteSpace has been extensively used [7,15]. This approach focuses on collaborative network maps by co-citation analysis and community (cluster) detection [16–18]. CiteSpace tools convert large amounts of literature data into visualized maps through an econometric analysis based on a map structure analysis. The tools for visualization are used to easily and intuitively identify potential trends in citation data.

This study will regard the WOS Core Collection as a data collection platform according to the data sources required in CiteSpace. Our research included 2442 articles based on the retrieval of the following data from the WOS on 15 February 2017: the retrieval model "TS = (urban plan* or city plan*) and (*climate*change*)", the time span = 1990–2016, literature type = (article or review), and language = English. We ultimately selected 1903 documents by removing irrelevant documents and merging synonyms. Our pool of articles contains data for each article, including the author, title, source publications, research direction and references. We can form a preliminary understanding concerning urban planning and climate change research after an annual analysis (Figure 1) and publication source analysis (Figure 2) of the literature. In the latter part of the paper, the main research contents of urban planning for climate change are summarized and analyzed, and the overall development trend and forecasting front are discussed.

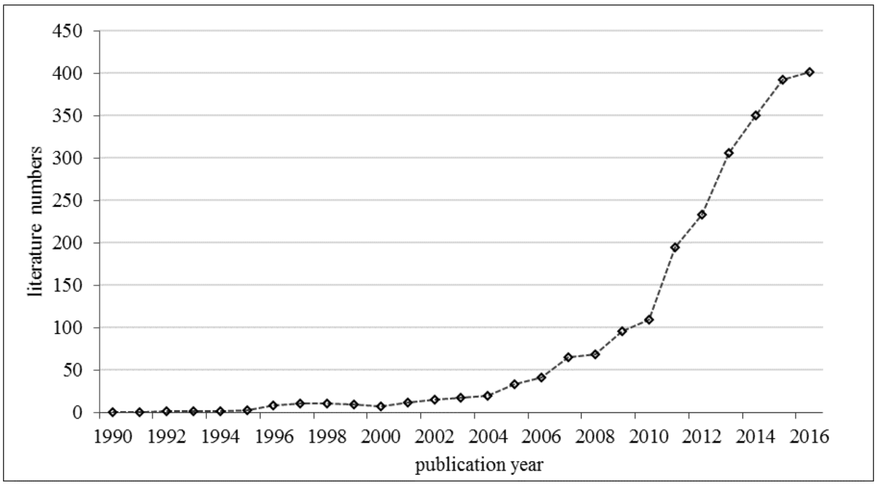

Figure 1. Annual variations of literature numbers on urban planning for climate change from 1990 to 2016.

We created a statistical summary of all the literature and classify the collected articles by date and number of published articles. From the perspective of the annual distribution of literature data (Figure 1), research on urban planning and climate change is rare before the year 2000, indicating a lack of understanding about the relationship between urban planning and climate change. The amount of literature increased steadily from 2001 to 2007, showing a gradual increase in this research area. After 2007, the literature increased suddenly. According to the literature publication sources, the top 15 journals mostly focused on landscape planning, ecological energy, environmental management and urban sustainable development, reflecting that the subject of urban planning had become an important implementation platform to cope with climate change.

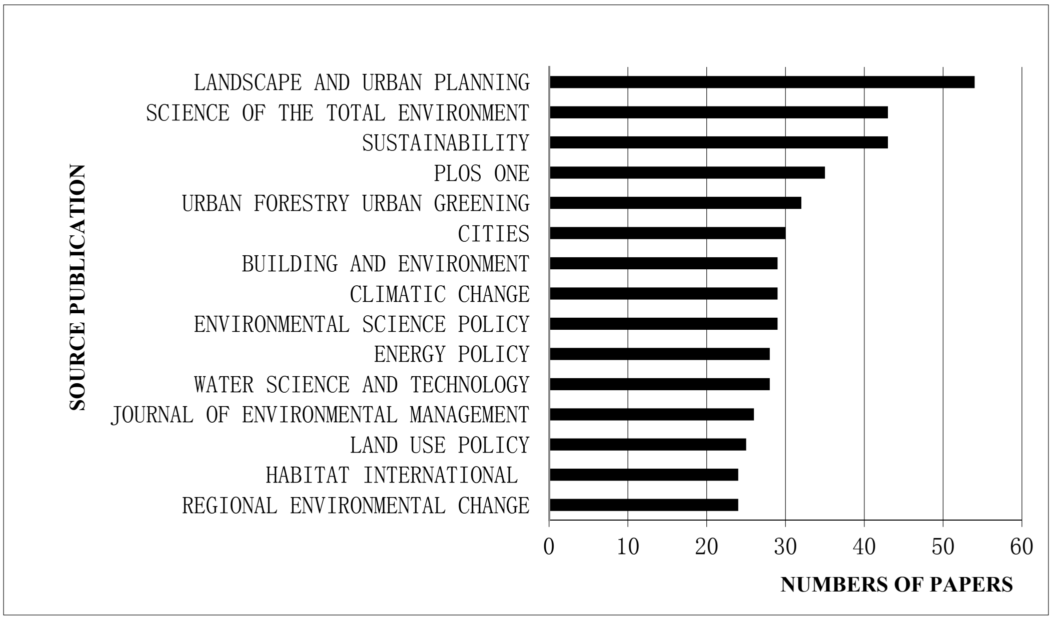

Figure 2. Top fifteen journals of literature sources in the research field of urban planning for climate change.

3. Research Direction and Regional Distribution

3.1. Research Direction

By using the co-occurrence analysis function of CiteSpace, the literature contribution map of the research area was formed, which could reveal the relationship between the main subjects and disciplines in the field. According to Figure 3, the research area mainly consists of two fields. One is the direction of Environmental Studies as the research center, including environmental sciences and ecology, environmental sciences, urban studies, public administration, and other related areas that include the theoretical framework of urban planning for climate change, climate change effects on mechanisms, low-carbon ecological space planning, and climate change risk assessments. The other field includes a direction based on geography, focusing on the mechanism of climate change effects on a regional scale or mesoscale. Figure 3 also shows that public administration is strongly emerging in environmental studies, which reveals that collaborative institutions are particularly active in the relevant research areas.

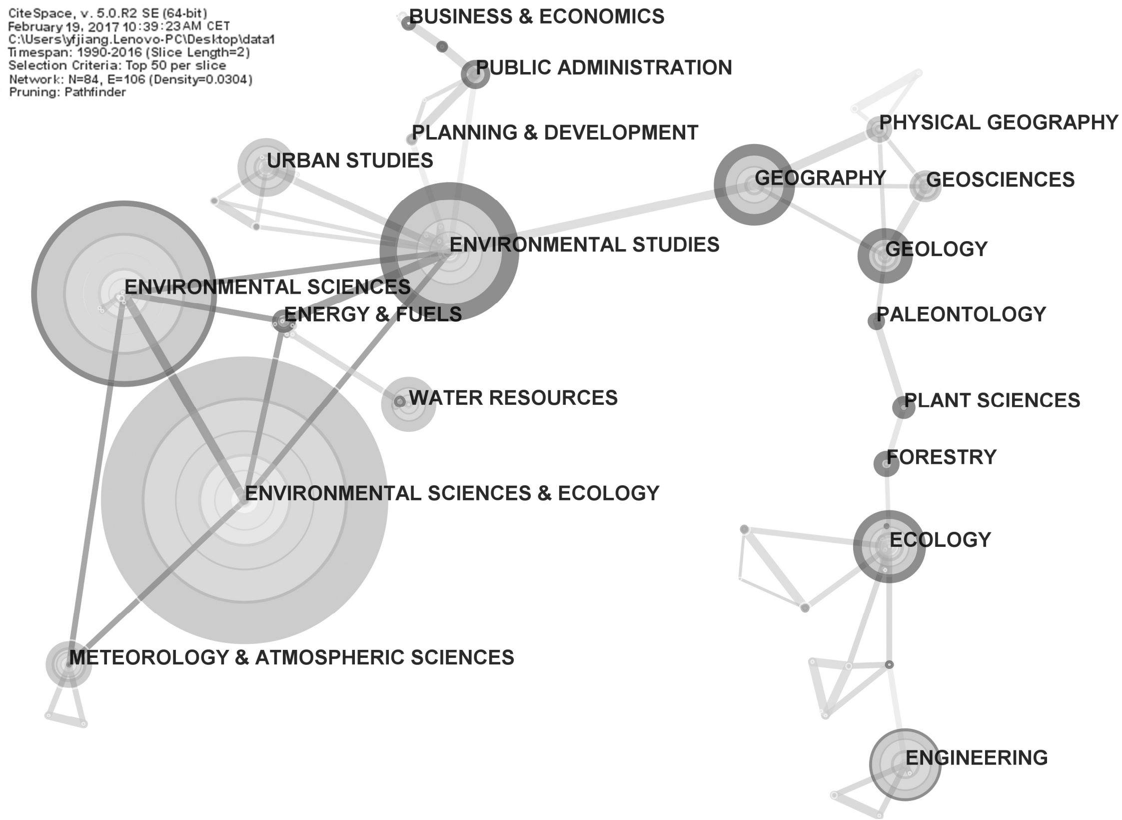

Figure 3. Map of co-occurring subject categories for research direction.

3.2. Regional Distribution

An analysis of the co-occurrence graph of countries and regions in Figure 4 shows the distribution of countries in the research areas and international cooperation relationships. The countries and regions' distributions across the research area showed multi-polar development tendencies that are mainly concentrated in North America, Europe, Australia, and East Asia. Furthermore, academic cooperation between countries was not in equilibrium. The literature frequency of each node showed that the literature contribution rate of the United States is the highest, followed by Australia, Britain, China, Germany, and Canada. Australian and Chinese research is situated at the edges of the graph and showed minimal cooperation and interactions with other countries. The centrality of each node showed that Canada has the highest degree of centrality (centrality = 0.4), which had an intermediary role and strong influence for research in the network structure. The degree of centrality for China was 0.03, which clearly showed that authority and influence were insufficient and showed less cooperation and interaction with other countries in the field.

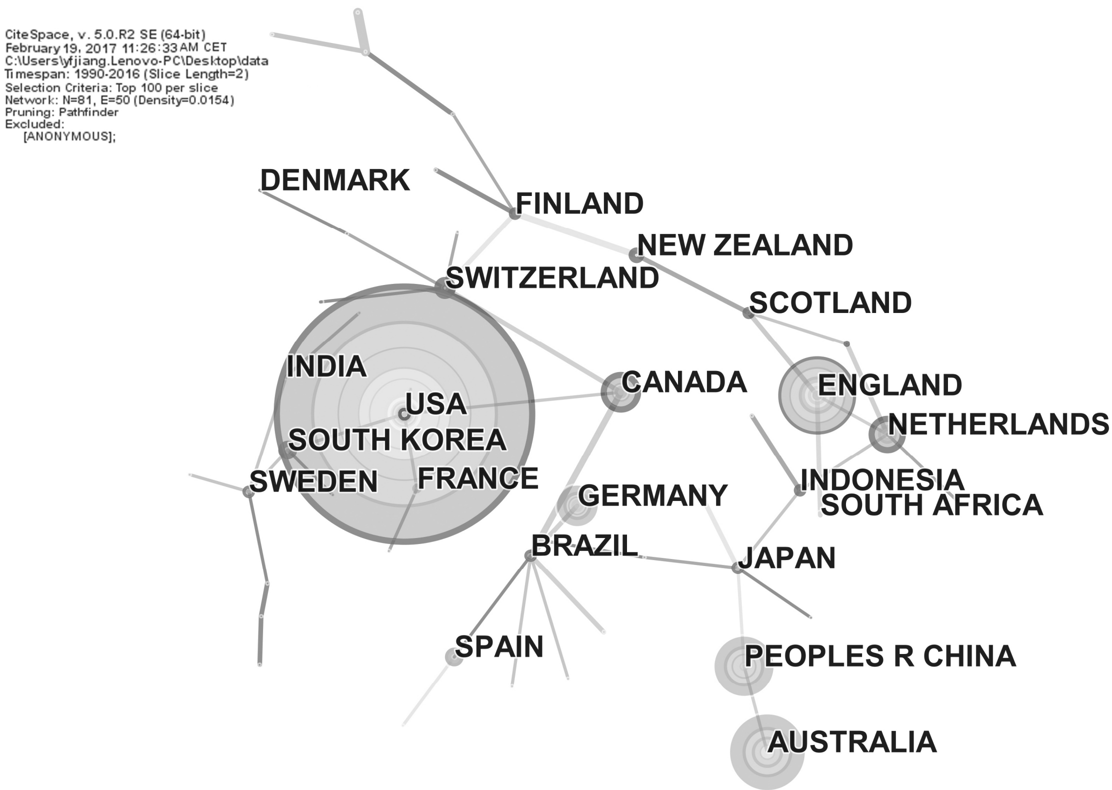

Figure 4. Map of multiple occurring co-author's countries.

4. Research Focus and Academic Groupings

4.1. Research Focus Analysis

The keywords in the literature can reveal the main research content, and literature citation frequency can reflect the research heat. In Figures 5 and 6, the magnitude of the radiation range of the circle indicates the frequency of the literature: the larger the concentric circles are, the higher the frequency of the corresponding keywords appeared. The map (Figure 5) shows that "climate change" and "city" are high-frequency words and have centricity among all the research keywords. Higher frequency and centric keywords identified the research content, research direction and research methods concerning the impact of climate change on cities. Frequently appearing research content includes the following: (1) the climate effects of global warming, urban heat islands and extreme climate; (2) the interactive mechanism between climate change and city systems—with "urban" and "urbanization" as the central topic—and include city carbon emissions, human emissions activities, building energy use, the impact of "urbanization" on climate change, "land use" and climate effects; (3) "adaptation" and "mitigation" as the centricity, including adaptation and mitigation strategies on land use and landscape factors in addition to adaptation and mitigation strategy impact and management, within which urban "vulnerability" assessments, "scenarios", and "simulation" include the highest numbers of research methods in this research area; and (4) City "governance" methods used to cope with urban climate change and urban planning as an important means of governance methods are highlighted here; however, the other part of the controlling methods—the action of urban governance on social ecological systems with resilience and adaptation policymaking for climate change—has become important in this research direction. Urban planning and climate change research has turned from urban climate effects and mechanisms of urban systems and climate change to research on urban space assessments and the development strategies and management policies for coping with climate change.

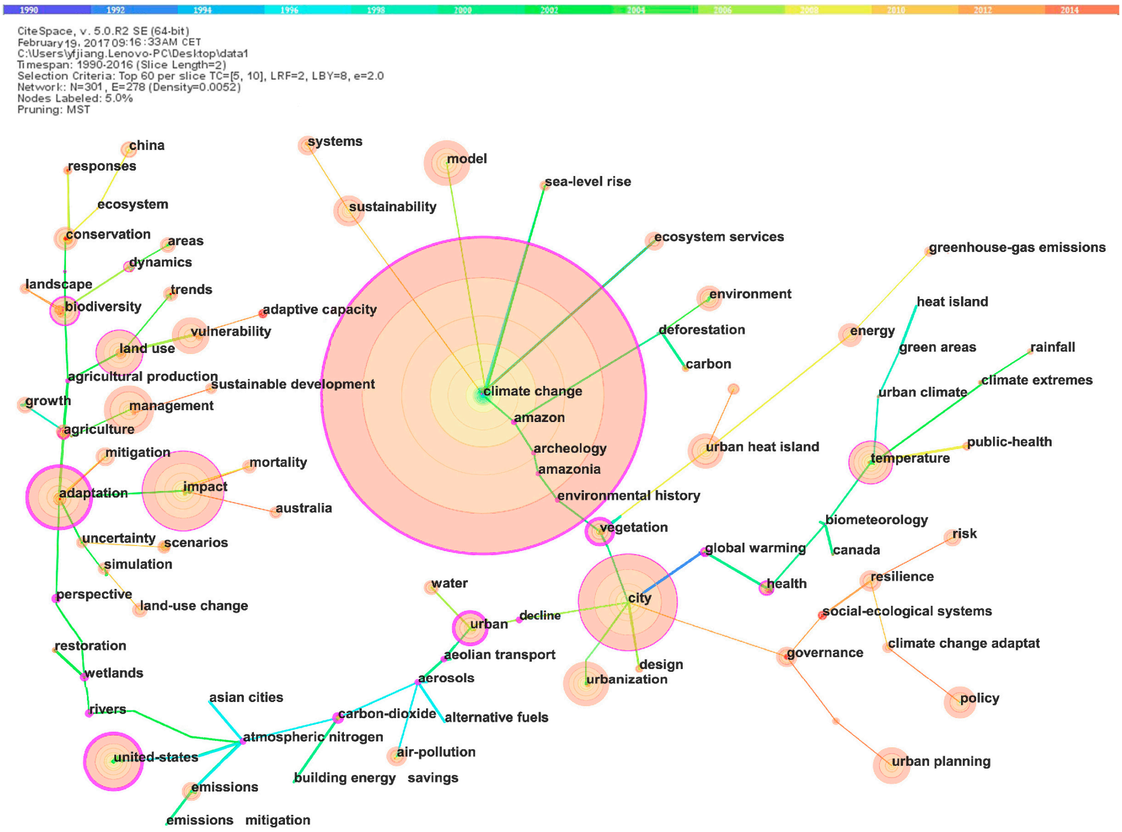

Figure 5. Map of co-occurring keywords on urban planning for climate change.

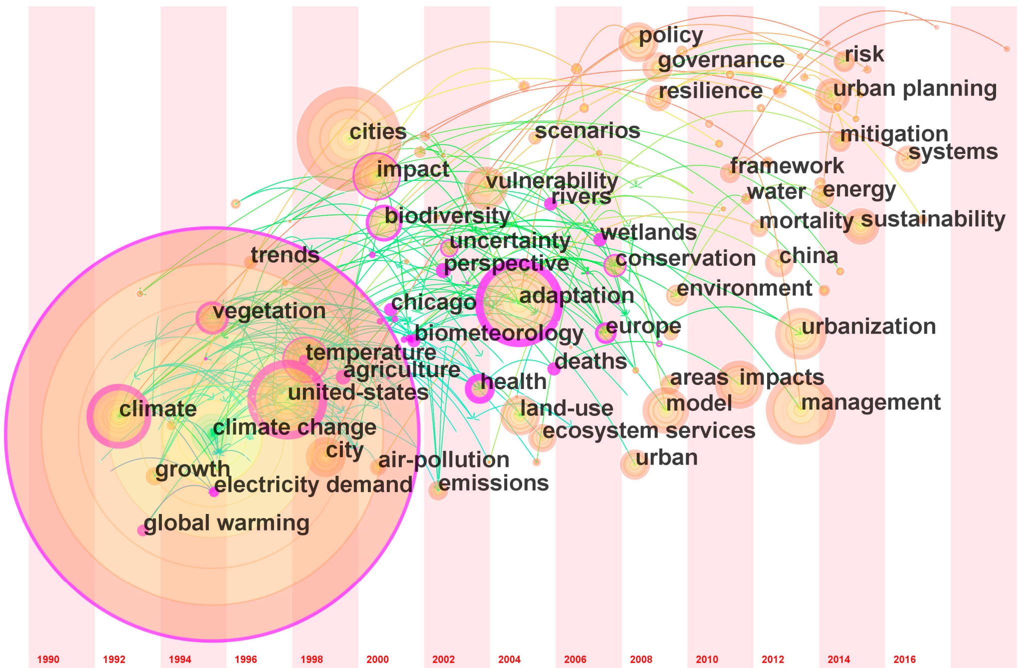

Figure 6. Annual variations of co-occurring keywords on urban planning for climate change.

In terms of time (Figure 6), the research direction of "climate change" shifts from single climate effects to using a "model" simulation to assist in decision-making. "City" is a key battleground and a fragile area in terms of responding to climate change. "Urban planning" scholars proposed the concept of a "resilient" city based on urban system vulnerability. Meanwhile, "adaptation" strategies have also received attention, such as in urban "management", urban "sustainability", urban planning and green infrastructure planning, etc., for the mitigation of the "urban heat island" effect. With quantitative research methods such as numerical simulation and new technology tool development, research perspectives and methods have diversified. The research level of urban climate effects includes multi-spatial scales from urban regions to neighborhood scales, and the focus shifts from an initial single ecosystem to the study of the interaction of the "ecology-society-human" complex ecosystem.

4.2. Academic Groupings

Using the clustering function of CiteSpace and the document sorting method, a total of 15 clusters of co-cited references were identified. As shown in Figure 7, a framework of co-operative references was summarized in two levels and 15 clusters in detail groupings. The research system of urban planning is integrated into climate change, and grouping and clustering in the literature is done in accordance with the planning development process with a mainline of the forming mechanism as urban analysis, spatial planning patterns, and urban development policies and strategy. According to the four academic groupings, 15 clusters with homogenous themes representing the current research focus direction were suggested at the sub-level (explained by Figure 8).

The first grouping was composed of four clusters: urbanization and climate effects, urban ecosystem service, emission and energy balance, and hydrology impact. Urbanization has a series of effects on temperature, precipitation and other climatic factors. In the process of urbanization, ecosystems decrease as urban building areas increase, and changes in anthropogenic heat emission expansion and energy balance affect the urban climate [19,20]. Although urbanization is impacting biodiversity and ecosystems at various scales and is modifying existing ecosystems, urban ecosystems can still provide valuable ecosystem services [21]. Studies of carbon emissions based on urban land use will help explain the human impact mechanism of the carbon cycle in city regions; guide the development of low carbon urban patterns in land use planning, industrial structure adjustment and city transformation policy making; and fundamentally provide a solution for urban heat island effect mitigation [22,23]. Urbanization also has an impact on hydrological effects. UHI acts primarily to enhance rainfall and affect precipitation patterns because of increased condensation nuclei and surface convergence associated with increased roughness. The rain island effect showed a significant precipitation increase in urban areas [24,25]. On the other hand, Urban Heat Islands (UHIs) lead to sea level rise, which resulted in a focus on wetlands; biodiversity conversations are likely to have an impact on urbanization patterns [26]. From the initial focus on the single climate and environmental effects of the city, the focus turns to the integrated climate impact of urban land use change as being urbanization induced in recent years.

The second grouping was composed of three clusters, which are vulnerability assessment, risk assessment, and resilience and sustainability index. The impact of climate change on urban spatial systems has become increasingly prominent. The index method is used to assess the impact of climate change on urban spatial systems and has become an important way to identify and improve the adaptability of urban space, including vulnerability assessments and risk index assessments. The role of a city climate change vulnerability assessment of a city system is mainly to evaluate the external environment, such as climate change leading to high temperatures, and the flood disaster response capacity, through the establishment of an index system of a city in each subsystem, is used to determine the degree of vulnerability of the city [27]. The field began to focus on city residents and the vulnerability assessment of extreme climate events in cities in recent years [28] as part of a humanism trend. Disaster risk index assessment is directly related to vulnerability in terms of evaluating the direct impact of urban development as the climate has changed [29]. The Analytical Hierarchy

Process (AHP) method is centered on a conceptual framework and is the diverse application of the comprehensive index method, spatial analysis methods via a geographic information system (GIS), and the social analysis methods of natural survey and expert investigation. This method is increasing in urban resilience assessments and sustainability index analyses, which have been addressed in these indicators from a social-ecological systems perspective. This index evaluation method will continue to be used in the research to analyze development strategies at the urban macro-level.

The third grouping was composed by four clusters: land use change and planning, urban space adaptation, ecosystem-based adaptation, and Temperature Equivalent Perception (TEP)/bio-thermal simulation. The interaction between urban land use and climate change elements produces a synergistic effect; for example, land use patterns affect the relationship between various air pollution coordination functions, city water circulation and the heat environment, and the role of collaborative climate change and ecological effects [30,31]. Urban land use intensity and the effects of climate change will also impact biodiversity [32,33] in that urban sprawl and unsustainable land use change cause local climate changes [34]. The research on urban space adaptation planning spans a large scale from macro to micro spatial pattern. A numerical simulation emphasizes that the model and setting parameters are established to simulate the process and effects of urban climate factors, and it is an important assisting method for urban planning and decision making. On the urban macro level, research on the relationship between urban spatial growth and the climate system in addition to development strategies of urban spatial growth patterns for climate change has already become a focus [34–36]. On the urban mesoscale level, the simulation study on urban space patterns, reasonable street aspect ratios, comprehensive land development, and ventilation corridor greenbelt layouts have been widely used as analysis tools for providing effective adaptation strategies on the urban spatial level. A climate-based classification of the city was developed as a method for urban heat island investigation [37,38]. Recent studies have combined the LCZs partition method, and a certain number of climate correlation analyses and scenario simulation prediction analyses have been carried out at the city macro level [39]. On the urban microscale level, research has focused on the effects influenced by building layouts and spatial structures. Based on the research of an interaction mechanism between ecological space and climate change in the 1990s, the research on adaptation planning of ecological space has begun to be addressed [40–44]. Concerning individuals' perception and comfort, thermal comfort and Physiological micro Equivalent Temperature (TEP) research and adaptation planning strategy have become an important cluster in the grouping of spatial simulation and adaptation planning [45–48].

The fourth grouping was composed by four clusters—resilience governance, institutional and collaborative polices, mitigation and adaptation governance, and public health response—which have all been addressed in the local implementation of action plan strategies, management responses to climate change and urban governance. Resilience governance has explored institutional resilience and integrated community participation for building a resident-based city [49,50]. Adaptive governance methods mainly include physical adaptation and infrastructure improvements to mainly use scientific innovation methods of technical adaptation and to give priority to institutional adaptation policy legislation. Institutional and collaborative polices identified differences in the response capacity across local governments and emphasized the need to ensure that climate change remains a key objective across localized governance structures and to formulate a series of adaptive public participation measures to respond to climate change based on a bottom-to-top strategy [51–54]. Urban mitigation and adaptation governance mainly focus on adaptive policy implementation. Urban adaptability mainly relates to the rise in the sea level as applicable to urbanization and climate change given the impact of the heat island effect and extreme weather conditions. Adaptive strategies of local action planning and adaptation planning are also discussed [55–57]. In addition to policies and practices, the recent scientific literature has shown growing interest in assessing ecosystem-based adaptation measures and implementation action plans [44]. The policies of urban public health-related urban equity, vulnerability, and environmental sustainability prompted a series of studies on policies and actions to improve the city planning for environmental health protection and communicating the risks of climate change to the public, especially as seen in the clustering from 2007 to 2009 [58–66].

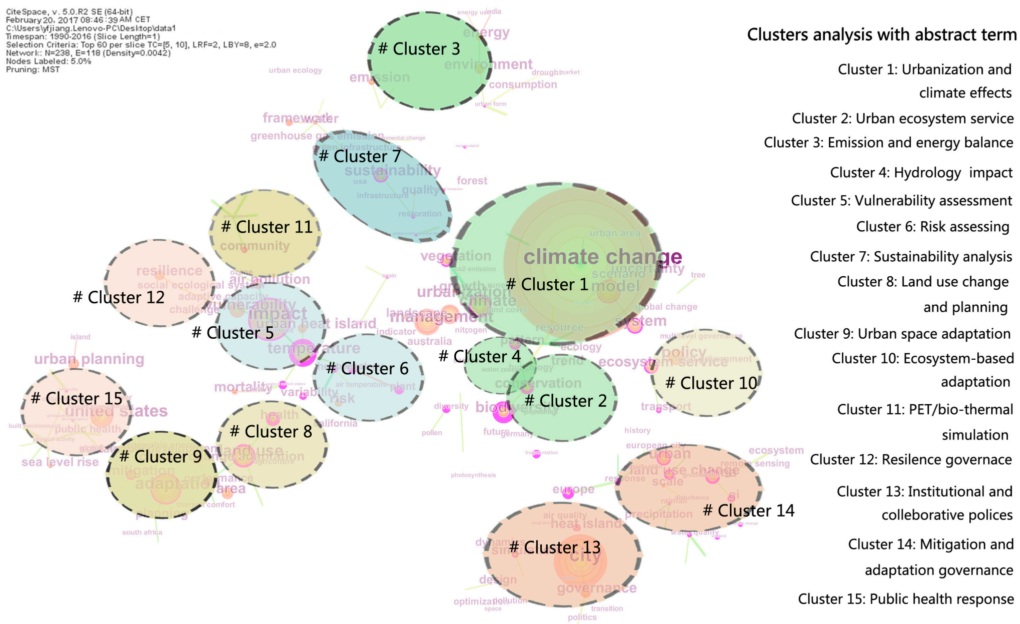

Figure 7. Clustering analysis of co-cited references on urban planning for climate change.

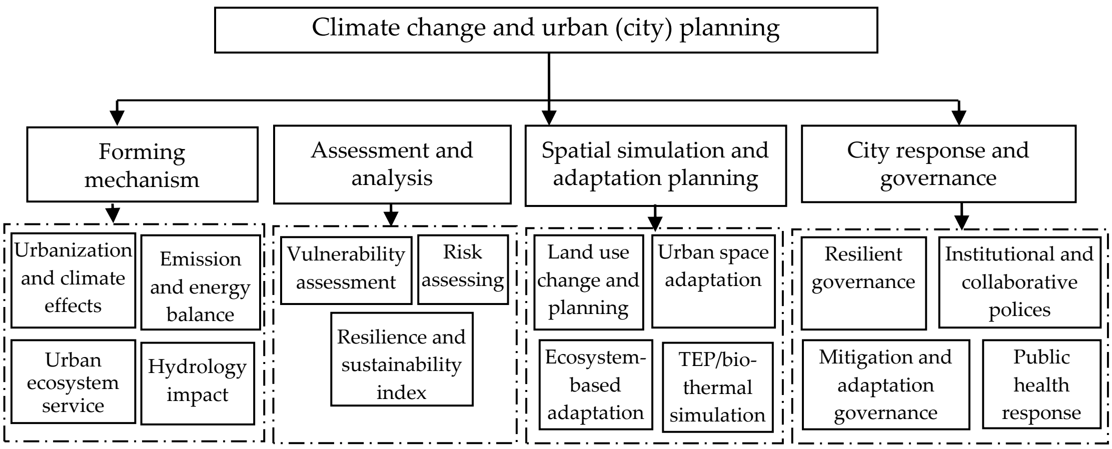

Figure 8. The framework of co-cited references on urban planning for climate change.

4.3. Landmark References

An analysis of co-cited references can effectively identify the paradigm. From the co-cited reference network based on the CiteSpace analysis, the top 20 cited references from 1990 to 2016 were obtained as a list in Table 1. In the top 20 most-cited reference lists, most of the research content from the literature belongs to clusters 1–6, which is the literature from the 1990s and early 2000s; this basically reflects the forming mechanism of urban climate, and the impact assessment was the domain and long-term research area. The most-cited article, "Adaptive governance of social-ecological systems" by Folke et al., represented new challenges for governance and management in relation to interdependent social ecological systems and ecosystem services [67]. "Global Change and the Ecology of Cities" by Grimm et al. showed a framework in which urban ecology integrates natural and social sciences to study radically altered local environments and their regional and global effects [3]. The two papers drove rational urban system development of ecosystem-based adaptation and governance in cities under the influence of climate change. "Adaptation, adaptive capacity and vulnerability" by Smit and Wandel (2008) outlined the distinctive feature of adaptation and described the interaction between participatory vulnerability assessments and other adaptation analyses [68]. "Local Government and the Governing of Climate Change in Germany and the UK" by Bulkeley and Kern (2006) [69] and "Rethinking Sustainable Cities: Multilevel Governance and the 'Urban' Politics of Climate Change" by Bulkeley and Betsill (2005) [51] argued that the "urban" governance of climate protection involves relations between different levels of the state and new network spheres of authority. "State and Municipal Climate Change Plans: The First Generation" by Wheeler (2008) analyzed this first generation of climate change plans in the U.S. to assess the goals that were implemented [70]. These three papers showed that institutional and collaborative policy making is a unitary part to form an urban planning system for climate change adaptation. "Resilient cities: meaning, models, and metaphor for integrating the ecological, socio-economic, and planning realms" by Pickett (2004) examined a promising new tool for promoting the metaphor of cities of resilience, which pursued the integration concept to forming resilience development [71]. "Green Cities, Growing Cities, Just Cities? Urban Planning and the Contradictions of Sustainable Development" by Campbell (1996) [72] defined the triangle of conflicting goals for planning toward sustainable development, which is consistent with promoting the adaptation planning process of cities. "Excess hospital admissions during the July 1995 heat wave in Chicago" by Semenza (1999) presents the strategies for promoting public health that adapted to climate change risk [73]. We find that the adaptation policies and institution research are composed of the emphasized content in our discussed research area.

Table 1. The top 20 most-cited references from 1990 to 2016.

Freq.	Author	Title	Source	Year	Cluster ID
1498	Folke, C.; Hahn, T.; Olsson, P.; Norberg, J.	Adaptive governance of social-ecological systems [67]	Annual Review of Environment and Resources	2005	Cluster 14
1331	Smit, B.; Wandel, J.	Adaptation, adaptive capacity and vulnerability [68]	Global Environmental Change	2006	Cluster 5
1289	Grimm, N.B.; Faeth, S.H.; Golubiewski, N.E.; Redman, C.L.; et al.	Global Change and the Ecology of Cities [3]	Science	2008	Cluster 14
1242	Adger, W.N.	Vulnerability [74]	Global Environmental Change	2006	Cluster 5
1114	Mckinney, M.L.	Urbanization, Biodiversity, and Conservation [75]	BioScience	2002	Cluster 1
1049	Seager, R.; Ting, M.; Held, I.; Kushnir, Y.; et al.	Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America [76]	Science	2007	Cluster 4
824	Arnfield, A.J.	Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island [77]	International Journal of Climatology	2003	Cluster 1
712	Rosenfeld, D.	Suppression of Rain and Snow by Urban and Industrial Air Pollution [78]	Science	2000	Cluster 1
656	Fitter, A.H.; Fitter, R.S.	Rapid changes in flowering time in British plants [79]	Science	2002	Cluster 2
636	Voogt, J.A.; Oke, T.R.	Thermal remote sensing of urban climates [80]	Remote Sensing of Environment	2003	Cluster 1
562	Mcgranahan, G.; Balk, D.; Anderson, B.	The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones [81]	Environment and Urbanization	2007	Cluster 6

Table 1. *Cont.*

Freq.	Author	Title	Source	Year	Cluster ID
369	Campbell, S.	Green Cities, Growing Cities, Just Cities?: Urban Planning and the Contradictions of Sustainable Development [72]	Journal of the American Planning Association	1996	Cluster 9
366	Taha, H.	Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat [82]	Energy and Buildings	1997	Cluster 3
253	Bulkeley, H.; Betsill, M.	Rethinking Sustainable Cities: Multilevel Governance and the 'Urban' Politics of Climate Change [51]	Environmental Politics	2005	Cluster 13
250	Semenza, J.C.; Mccullough, J.E.; Flanders, W.D.; Mcgeehin, M.A.; Lumpkin, J.R.	Excess hospital admissions during the July 1995 heat wave in Chicago [73]	American Journal of Preventive Medicine	1999	Cluster 15
172	Pickett, S.T.A.; Cadenasso, M.L.; Grove, J.M.	Resilient cities: meaning, models, and metaphor for integrating the ecological, socio-economic, and planning realms [71]	Landscape & Urban Planning	2004	Cluster 12
179	Bulkeley, H.; Kern, K.	Local Government and the Governing of Climate Change in Germany and the UK [69]	Urban Studies	2006	Cluster 13
169	Brazel, A.; Selover, N.; Vose, R.; Heisler, G.	The tale of two climates-Baltimore and Phoenix urban LTER sites [83]	Climate Research	2000	Cluster 1
166	Whitford, V.; Ennos, A.R.; Handley, J.F.	"City form and natural process"—indicators for the ecological performance of urban areas and their application to Merseyside, UK [84]	Landscape and Urban Planning	2001	Cluster 2
130	Wheeler, S.M.	State and Municipal Climate Change Plans: The First Generation [70]	Journal of the American Planning Association	2008	Cluster 13

5. Intellectual Dynamics

5.1. Timeline Map Analysis

A timeline view of the network of each cluster is arranged on a horizontal timeline. The direction of time moves to the right. This timeline map showed some of the basic movement of the research area. According to the timeline map observed in Figure 9, we can see that the year in which the keyword clustering began to appear was when the clustering results began to increase and the trending of the development of the whole cluster can be seen. In the 1990s and early 2000s, the first and second intergovernmental panel on climate change (IPCC) conferences were held, and the main research remained at the macro-policy research stage. From 2000 to 2005, the research was mainly focused on the rapid development of urbanization and the interaction between climate factors.

The year 2007 is an important node in the history of the research on urban planning for climate change. The fourth IPCC Climate Assessment Conference was held, and the field entered an unprecedentedly prolific period in terms of studies. The fourth Climate Assessment Conference in 2008 and the United Nations Environment Programme (UNEP) had the theme of "promoting transformation to a low-carbon society", and a series of important events promoted the research process. After 2008, the focus shifted from single-dimension to multi-dimension comprehensive studies, and the humanism tendency was obvious. For example, McGranahan et al. (2007) carried out a risk assessment for a coastal area. At the same time, a series of adaptable concepts were promoted, such as ecological cities, low-carbon cities, and green cities [81]. Green infrastructure was evident in the urban cooling effect due to the ecosystem and human health improvements in cities [85–87]. After 2010, multi-level governance research was the mainstream content, and the research on spatial adaptation strategies, especially ecosystem or green infrastructure aspects, became the key issues in urban planning for climate change. At the same time, thermal comfort research at the community level was addressed in depth, and a bottom-up level adaptation framework was considered.

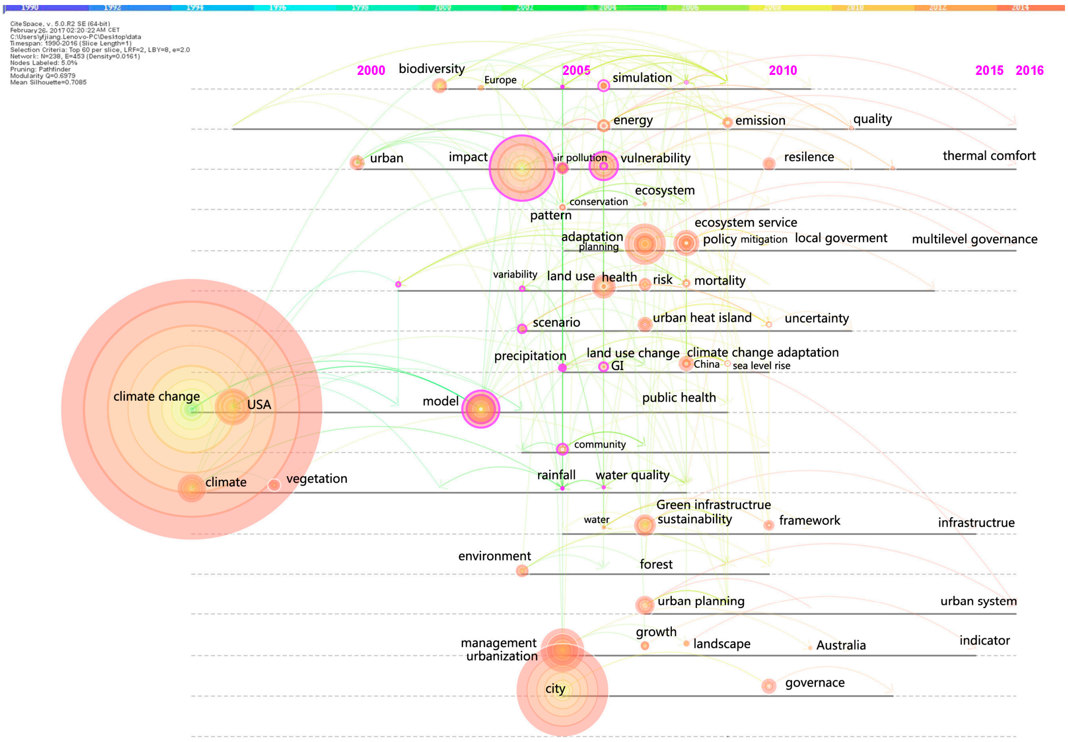

Figure 9. Co-appearance timeline map of bursting cited keywords.

5.2. The Strongest Citation Burst Detection Analysis

Citation bursts are indicators of the most active areas of research and indicate authors who rapidly increased their number of publications. For keywords, the bursts indicate quickly growing topics. A citation burst provides evidence that a particular publication is associated with a surge of citations. In other words, the publication has attracted an extraordinary degree of attention from the scientific community. Furthermore, if a cluster contains numerous nodes with strong citation bursts, then the cluster as a whole captures an active area of research or an emerging trend [11]. According to burst detection on the data of urban planning for climate change, the 150 strongest citation bursts referenced from 1990 to 2016 were selected. Table 2 lists the literature numbers by different frequencies based on the citation burst detection analysis and the representative references in each academic community of the 150 total selected references.

Table 2. The strongest cited references based on a burst dictation analysis during the 1990–2016 period.

Academic Communities	The Reference Frequency of Citation Burst ≥2	The Reference Frequency of Citation Burst ≥5	Representative Citation Bursts References (before the Year 2000)	Representative Citation Bursts References (after the Year 2000)
Urbanization and climate effects	3	0	Watson, V., 2009 [88]	Yu, M., 2012 [89]; Debbage, N., 2015 [90]
Urban ecosystem service	9	4		Kong, F.H., 2014a [91]; Kong, F.H., 2014b [92]; Maimaitiyiming, M., 2014 [93]; Cavan, G., 2014 [94]
Emission and energy balance	5	3	Kjellstrom, T., 2007 [58]	Gurney, K.R., 2012 [22]; Liu, Z., 2012 [23]
Hydrology impact	2	1		Wilby, R.L., 2012 [95]; Gober, P., 2010 [96]
Vulnerability assessment	3	0		Sampson, N.R., 2013 [97]; Weber, S., 2015 [98]; Kumar, P., 2016 [99]
Risk assessing	2	1	Gwilliam, J., 2006 [29]	Horton, R.M, 2011 [100]
Sustainability assessment	4	1	Musacchio, L.R., 2009 [101]	Milan, B.F., 2015 [102]; Suarez, M., 2016 [103]; Kotzee, I., 2016 [49]
Land use change and planning	10	3	Roy, M., 2009 [104]	Viegas, C.V., 2013 [31]; Dugord, P.A., 2014 [30]
Urban space adaptation	16	7	Lindley, S.J., 2006 [6]; Blanco, H., 2009a [105]; Blanco, H., 2009b [106]	House-TEPers, L.A., 2011 [107]; Burley, J.G., 2012 [26]; Reyer, C., 2012 [108]; Picketts, I.M., 2014 [109]; Hamin, E.M., 2014 [110]
Ecosystem-based adaptation	5	4		Lafortezza, R., 2013 [40]; Lehmann, I., 2014 [42]; Demuzere, M., 2014 [43]; Geneletti, D., 2016 [44]
TEP/bio-thermal simulation	7	5		Muller, N., 2014 [111]; Abreu-Harbich, L.V., 2014 [112]; Jamei, E., 2016 [113]; Algeciras, J.A.R., 2016a [114]; Algeciras, J.A.R., 2016b [115].
Resilience governance	2	1		Meerow, S., 2016 [116]; Hung, H.C., 2016 [50]
Institutional and collaborative polices	19	1		Ng, M.K., 2012 [52]; Picketts, I.M., 2012 [117]; Reckien, D., 2014 [118]; Reckien, D., 2015 [119]; Wamsler, C., 2015 [120]; Wamsler, C., 2016 [121]
Mitigation and adaptation governance	16	4	McEvoy, D., 2006 [55]	Poyar, K.A., 2010 [56]; Gore, C.D., 2010 [122]; Santamouris, M., 2014 [57]; Santamouris, M., 2015 [123]
Public health response	12	9	Kjellstrom, T., 2007 [58]; Luber, G., 2008 [59]; Jackson, R., 2008 [60]; Campbell-Lendrum, D.C., 2007 [61]; Patz, J., 2008 [62]; Kinney, P.L., 2008 [63]; Younger, M., 2008 [64]; ONeill, M.S., 2009a [65]; ONeill, M.S., 2009b [66]	

Selected total number = 115.

6. Conclusions

With the aid of the knowledge map visualization software CiteSpace, we systematically review research hotspots and academic groupings in this field from 1990 to 2016 based on the development context of urban planning research under the influence of climate change. This paper discusses the main research directions, dynamic developing stages, and the growing topics of urban planning research for climate change in detail.

Most of the review studies in the past focused on specific topic within climate change research and did not analyze the complete research field [124]. Haunschild et al. (2016) used the bibliometric study method to analyze the relevant literature on climate change between 1980 and 2014. The results referred that research papers dealing with adaptation, mitigation, risks, and vulnerability of global warming increased exponentially since 2005. The analysis also shows that "research dealing with the various effects of climate change", and "the high relevance of climate modeling" prominently appeared [124]. The paper written by Haunschild et al. involves a fairly wide area of climate change, title words from bibliographic showed that urban response and model analysis in the related research field quantitatively increased since 2005, although the total numbers of related study are comparatively small. Ng and Ren (2017) critically reviewed adaptation policies to climate change in China and introduced three adaptation planning for climate changes in Chinese cities [125]. This paper attempted to give an overlook of China's climate change action plans from the national to the city and urban level. Strictly speaking, this paper has merely discussed on the current development policies of this subject field in China. Now, this paper focused on the limited research field of urban planning for climate changes, addressed on the research directions, the developing stages and the growing trend. Therefore, more specific analysis outlined the intellectual dynamics of different timeline stages, and hot literature to indicate the increasing research directions under the background of climate change.

From the content system, the integration of climate change and urban planning is currently an international mainstream research area. Through checking the grouping framework on assessment and spatial simulation research aspect, it showed that the interactive index assessment and dynamic simulation prediction among urban spatial factors were becoming the important processes and tools in the field of urban planning for climate change. Climate mitigation and adaptation measures are constantly widening, innovatively advocating the combination of biophysical characteristics and socio-political factors. Urban space system resilience development with a multi-spatial scale interactive analysis provides a new theoretical framework for decision-making and effective implementation management. The research on "Institutional and collaborative polices" and "mitigation and adaptation governance" emphasized on the coordination among the spatial, human social and political decision-making. The research had entered a complex and highly collaborative process in this field.

The climatic effect of land use/cover types is not only to face the impact of global and regional climate change, but also to understand the interactive effects of urban climatic factors, such as temperature, precipitation, evaporation, wind speed, and pollutants. Therefore, the study on the effect mechanism of different land use types in urban planning needs to strengthen the quantitative analyses of the comprehensive effects. The comprehensive interaction assessment methods for analyzing the multi-factors effects should be emphasized, such as the UHI cooling effect with ventilation corridor effect and the carbon emissions effect to promote formation of the low-impact development pattern of an urban space system.

With the dynamic evolution and characteristics relationship analysis between the climate system and the urban spatial system, the interaction between the two systems presents the dynamic development effect process. Thus, urban planning for climate change should include the concept of an "interactive change process" and integrate the interactive effect assessment into the planning process to reflect the dynamic planning method with resilience characteristics. International studies of urban planning for climate change has focused on the simulation analysis method for the prediction of climate model effects and the dynamic simulation of the climate effect field of different urban space pattern, which have been effectively combined on different scales of spatial development and have been used to analyze the impact mechanism of climate effects and the urban space system, eventually generating adaptive planning methods for dynamic collaborative development. At the same time, the effects of the climate environment caused by urban development will have an impact on all stakeholders in the city. The different stakeholders should be involved in the process of urban planning, focus more on the assessment process for urban climate influence due to the effect of human activities, respond to climate change planning efficiency tests and provide feedback regarding supervision policy formulation and implementation processes.

The space comfort and physiological equivalent temperature of research at the micro level has proceeded to the main list content. The dynamic simulation of the effect of carbon emissions on urban land use and other climate effects of urban spatial growth also need to investigate the mode of people's actions, interests and willingness regarding spatial development presetting and scenario model. In the process of decision-making and implementation management, considering cooperative development in social and political factors such as culture, politics and other social and political factors will be conducive to the implementation of adaptive action planning. In conclusion, the importance of public participation and the participation planning process should be given more attention.

Global extreme weather events occur with increasing frequency, and climate change will inevitably become an important challenge for human habitation. The city is the main human settlement space, which encompasses a variety of human needs and functional satisfaction, but also constantly changes and affects the role of global climate change. In facing the most important task of the current time, urban planning should address the effects of climate change today. Based on the rational allocation of urban space for urban climate, optimization space patterns and adaptation strategy research on urban spatial development are being promoted to achieve a balanced development of the climate environment and human settlements. Based on the analysis of the existing international research achievements and the development tendency, deeper and more extensive research should be performed in the future.

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