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Bibliometric Analysis of the Research (2000–2020) on Land-Use Carbon Emissions Based on CiteSpace

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Abstract: Carbon emissions are critical to climate change, and land-use change is an essential source of growth in carbon emissions. Research on land-use carbon emissions has become one of the hotspots in academic research. To explore the research hotspots and development trends of land-use carbon emissions in the last 20 years, CiteSpace software was used to conduct a quantitative analysis of relevant literature. This paper was based on the China National Knowledge Infrastructure (CNKI) and Web of Science (WoS) database literature on land-use carbon emissions from 2001 to 2020. The scientific research cooperation network CiteSpace software, with keyword co-occurrence, clustering, and burst word detection, was used to systematically analyze the main research strengths, hotspots and frontiers and clarify the research progress. The research results are as follows: (1) the amount of literature and the depth of research on land-use carbon emissions have increased yearly. However, there is little cooperation between research institutions and scholars, and there is still a lack of large-scale and stable research teams. (2) At the research hotspot level, the English literature focuses on building models and theoretical frameworks to study the internal mechanisms and driving factors of carbon emissions and climate change. The Chinese literature focuses on achieving regional carbon emissions reductions and carbon cycle goals and optimizing a low-carbon economy, transportation and land-use structure. (3) Research frontiers and trends show that the English literature first explored carbon sequestration, organic carbon, and carbon accounting. In China, the research frontiers are gradually becoming focused on influencing factors, decoupling analysis, and the built environment. The study will strengthen the intensity and depth of global carbon emission research and provide a reference for improving global climate change, protecting ecology and balancing economic development.

Keywords: land use; carbon emissions; bibliometric; research hotspot; research frontiers; cluster analysis; CiteSpace

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1. Introduction

Since the 21st century, global warming has become increasingly significant, and natural disasters such as rising sea levels, melting glaciers and permafrost, and high-temperature drought have occurred frequently [1]. One of the crucial factors leading to climate warming and the greenhouse effect is the continuous increase in carbon dioxide emissions caused by human activities [2–4]. In this context, "Carbon peak" and "Carbon neutrality" have gradually attracted widespread attention. Countries worldwide have reduced greenhouse gas emissions through global agreements, and most developed countries have successively pledged to achieve carbon neutrality goals by 2050.

A survey confirmed that about 45% of the carbon pollution in the atmosphere comes from land-use changes and fossil energy combustion [5–7]. A large amount of energy carbon emissions generated by human activities leads to ecosystem imbalance, which has a massive impact on human production and life [8–10]. Reasonable utilization and development of fossil energy and the improvement of land-use efficiency are effective ways to reduce carbon emissions and mitigate climate change.

The study of carbon emissions has become an important topic of academic research, and a large amount of related literature has emerged [11–13]. Research on land-use carbon emissions from the literature published in English is earlier and more in-depth, and the research model is more extensive than in the Chinese research literature [14]. Although the related research in the Chinese research literature has also formed a certain theoretical basis and research framework, there is still a significant gap in the number and growth rate of literature reports, which needs to be further explored [15–17]. A systematic review of the existing relevant literature will help to grasp the development context and cutting-edge trends in research on carbon emissions and accelerate the realization of sustainable development goals for people and ecosystems. Based on the literature database of Web of Science (WoS) and China National Knowledge Infrastructure (CNKI), bibliometric analysis and qualitative classification of the core literature data from 2001 to 2020 was carried out by CiteSpace (version5.8.R3) [18]. In this paper, trend changes, research countries, research institutions, researchers' cooperative relations, and the co-occurrence and clustering of hot research keywords are compared and analyzed to systematically show the research status of land-use carbon emissions over the past 20 years.

Therefore, the main purpose of this paper is to use quantitative analysis methods to explore the research focus of land-use carbon emissions and to point out the existing problems to enrich the results of this research. At the same time, this paper also aims to provide a valuable reference for scholars to further explore the optimization of land use, energy conservation and emissions reduction.

2. Data Acquisition and Methods

2.1. Data Collection and Processing

The English literature analysis was based on the core collection of the scientific citation database, Web of Science (WoS); the search subject was set to "land use AND carbon emissions", the time span was "2001–2020", the language was "English", and the document type was "Article". The preliminary search yielded 7877 pieces of literature. CiteSpace data processing was used for screening to remove duplicates or documents of low relevance, and 7409 valid documents were obtained.

The Chinese literature analysis was based on the China National Knowledge Infrastructure (CNKI) literature database. The search topics were set as "land use" and "carbon emissions," and the search time was set as "2001–2020" through the advanced search function of CNKI; invalid documents such as conference documents, government documents, news, and notices were screened out. Results were exported in "Refworks" format and saved as plain text files; 1259 valid documents were obtained through CiteSpace data conversion.

2.2. Scientometric Method of Analysis

Bibliometric analysis is widely used in literature research in certain fields. Among a series of visual analysis tools, the CiteSpace (v.5.8.R3) software developed by Professor Chen is one of the most influential JAVA applications [19]. The internal relationship between documents can be intuitively displayed through constructing a knowledge map, which helps enhance the abstract cognition of the relevant research status.

Using CiteSpace software, the number of published papers on the use of carbon emissions in the WoS and CNKI databases from 2001 to 2020 was plotted to analyze and summarize its change-related trends. The research cooperation network was analyzed for the main research countries, institutions, and researchers to summarize the frequency and intensity of cooperation between countries, institutions, and scholars. Keyword co-occurrence analysis is a method to determine how research domains are based on high-frequency keywords. Co-occurrence and cluster analysis of high-frequency keywords can summarize the focus and core issues of discussions in this domain. The burst detection function can clarify the research trends and frontiers and predict future research development directions.

3. Results

3.1. Analysis of Research Trend

The trend in changes in the number of published papers, including the number and the growth rate, reflects the relationship between the number of published papers and changes over time; it is an important indicator for measuring the attention of scholars to a particular research field. It also reflects the overall progress of research in this domain. Comparing the WoS and CNKI database literature, it was found that from 2001 to 2020, there were 8668 papers were published in Chinese and English. Among them, 1259 papers were in Chinese, accounting for 15% of the total, and the average annual publication volume was 63; 7409 papers were in English, accounting for 85%, and the average annual publication volume was 370. There are more papers on the topic of land-use carbon emissions in English than in Chinese.

As shown in Figure 1, in terms of the growth rate of publications, the annual publication volume of English literature increased steadily from 2001 to 2020. Although the increase was not obvious, the research was conducted earlier, and the base of the publication volume was relatively large. In 2005, the publication volume exceeded 100. Since then, more and more scholars have conducted scientific research on land-use carbon emissions and have achieved more research results. In contrast, the literature research on land-use carbon emissions in the CNKI database started relatively late. As shown in Table 1, from 2001 to 2009, the research literature was still in its infancy, with only 28 papers published. The year 2010 was a period of rapid development of research on land-use carbon emissions in Chinese literature. Since 2012, more than 100 papers have been published each year. From 2011 to 2020, the number of published papers tended to be stable, ranging from 77 to 139. Based on the overall number of papers published, there is still a definite gap between the Chinese and English literature.

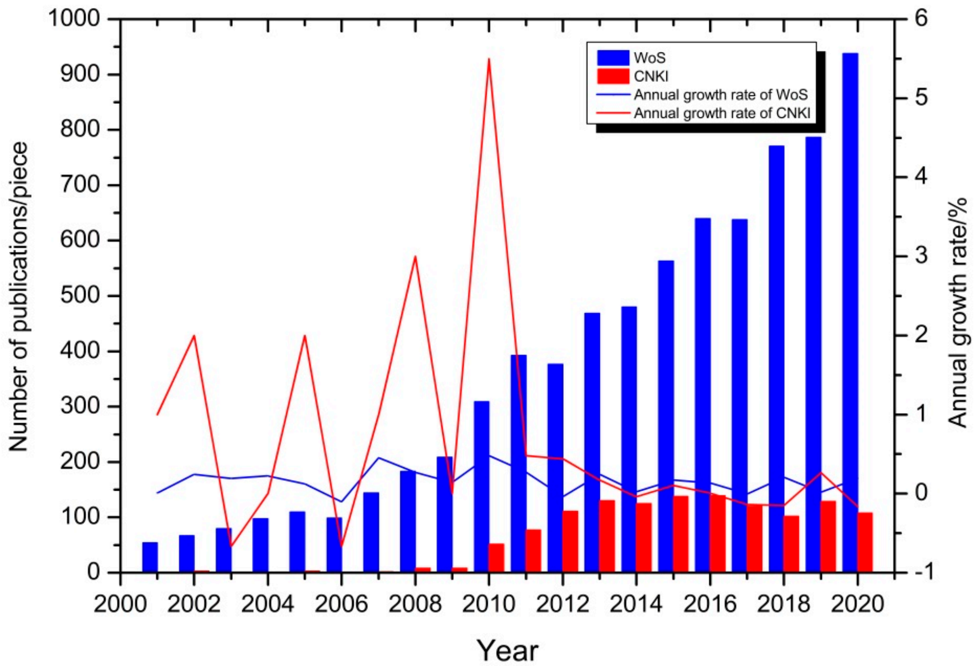

Figure 1. Annual publication volume and growth rate in 2001−2020.

Table 1. Annual publication volume in 2001−2020.

Year	WoS (Piece)	CNKI (Piece)	Year	WoS (Piece)	CNKI (Piece)
2001	54	1	2011	393	77
2002	67	3	2012	377	111
2003	80	1	2013	469	130
2004	98	1	2014	480	125
2005	110	3	2015	563	138
2006	99	1	2016	640	139
2007	144	2	2017	638	120
2008	183	8	2018	771	102
2009	209	8	2019	787	129
2010	309	52	2020	938	108

3.2. Analysis of Research Cooperation Network

3.2.1. Analysis of Research Countries

The analysis of the national cooperation network provides a new perspective for assessing the academic impact of countries in the research on land-use carbon emissions. For analyzing the WoS literature data, the time slice was set to 1 year, and the node type was selected as a country. Owing to the large amount of literature data selected, the PathFinder tool was used to prune and merge documents. Then, CiteSpace was run to obtain a national cooperative relationship map with a network density of 0.013, including 206 nodes and 275 lines. In Figure 2, the size of the node indicates the number of papers issued by a country or region, the number of lines indicates the number of cooperative interactions between countries or regions, the thickness of the line indicates the strength of cooperation, the color of the node and the line indicates the length of time, the color transition from grey-blue to orange-red represents the time span from 2001 to 2020. The betweenness centrality is the importance of a node in the entire network graph; the size of the betweenness centrality value indicates the global influence of a country or region on the research.

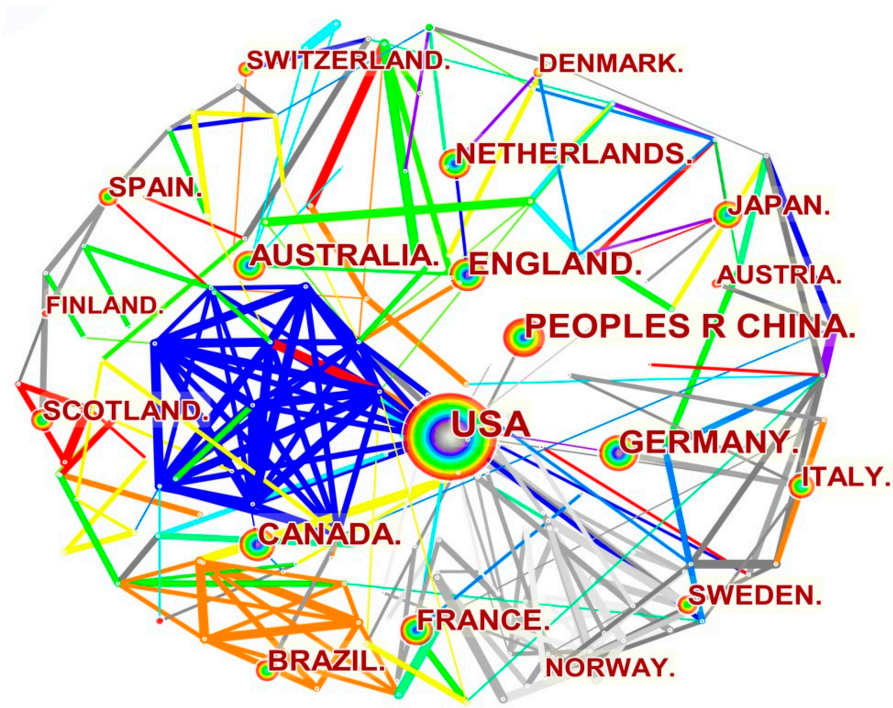

Figure 2. Visualization map of nations for carbon emissions research in the WoS database.

As shown in Figure 2, from 2001 to 2020, 206 countries or regions researched land-use carbon emissions. A high-density value and degree of correlation indicate that the research cooperation network is fairly extensive and mature, and the international cooperation is relatively close. The top five countries in terms of publication volume are the United States, with 2516 papers, China with 1235 papers, England with 783 papers, Germany with 777 papers, and Australia, with 539 papers. The top five countries in terms of betweenness centrality are France (0.65), Romania (0.65), the United States (0.64), Brazil (0.59), and Hungary (0.56). Regarding the number of publications and centrality, the United States has outstanding research results in land-use carbon emissions that involve the active participation of and cooperation with other countries or regions, far exceeding that of other countries. Although the number of papers published in France and Romania is relatively small, both have a high research influence. China has an increased number of publications in the WoS database, indicating rapid research progress has been made in recent years. However, the centrality of China is low (0.06), and there are few research partners. The global academic influence of China needs to be improved, and international cooperation in related domains needs to be further strengthened.

3.2.2. Analysis of Major Research Institutions

The publication volume and cooperation network of research institutions are essential indicators that directly reflect the academic attention and comprehensive strength of research institutions. The time slice was set to 1 year, 'institution' was selected as the node type, the Pathfinder tool was used for pruning and merging, then CiteSpace was run, and an institution partnership graph with a network density of 0.0048 was obtained. As shown in Figure 3, 542 nodes and 703 lines were obtained. The overall connection was relatively close, indicating that 542 research institutions have frequent exchanges and cooperation. Among them, the institution with the largest number of publications was the Chinese Academy of Sciences, with 501 papers and a centrality of 0.03, followed by the Chinese Academy of Sciences University, with 144 papers and a centrality of 0.01. It can be seen that although the volume of publications is relatively large, most of them are independent studies and lack cooperation with other institutions. The National Aeronautics and Space Administration published 128 papers, with a high centrality of 0.13. The denser connection indicates that the National Aeronautics and Space Administration has more active research cooperation. The University of Maryland follows the National Aeronautics and Space Administration with 127 papers, the University of Exeter with 118 papers, and the University of Aberdeen with 118 papers. The color of the connections shows that these three universities carried out cooperative research relatively early, as far back as 2005 and 2010. However, continued cooperation with other institutions after 2010 remains inadequate.

Through the analysis of the CNKI literature data, the institutional cooperation relationship graph with 381 nodes and 295 lines was obtained (Figure 4). The network density was 0.0041, and the overall network shape was relatively loose. It can be seen that Huazhong Agricultural University (40 papers) and Nanjing University (38 papers) are far ahead of other universities in the number of published papers. In terms of node color, the research results of Huazhong Agricultural University were relatively new and were mainly published from 2015 to 2020. Nanjing University published papers intensively from 2010 to 2015. Although the College of Geography and Environmental Science of Northwest Normal University (21 papers) and the School of Land Management of Huazhong Agricultural University (16 papers) have published more than 15 papers, from the number of connections in the figure, it is obvious that most of them are independent studies. This means they need to strengthen exchanges with other institutions and increase their international academic influence.

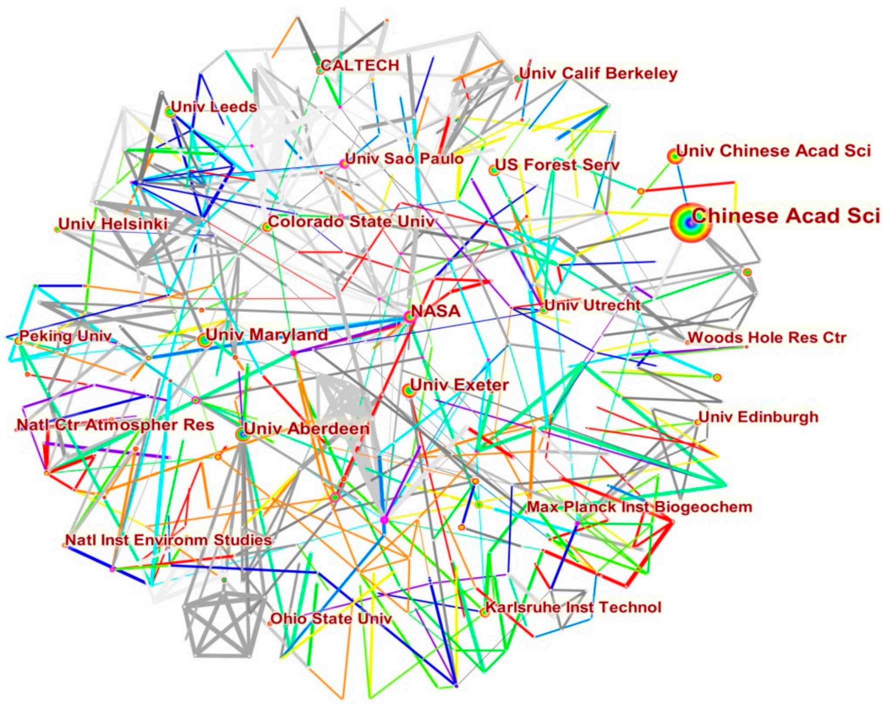

Figure 3. The cooperative network of carbon emissions research institutions based on the WoS database.

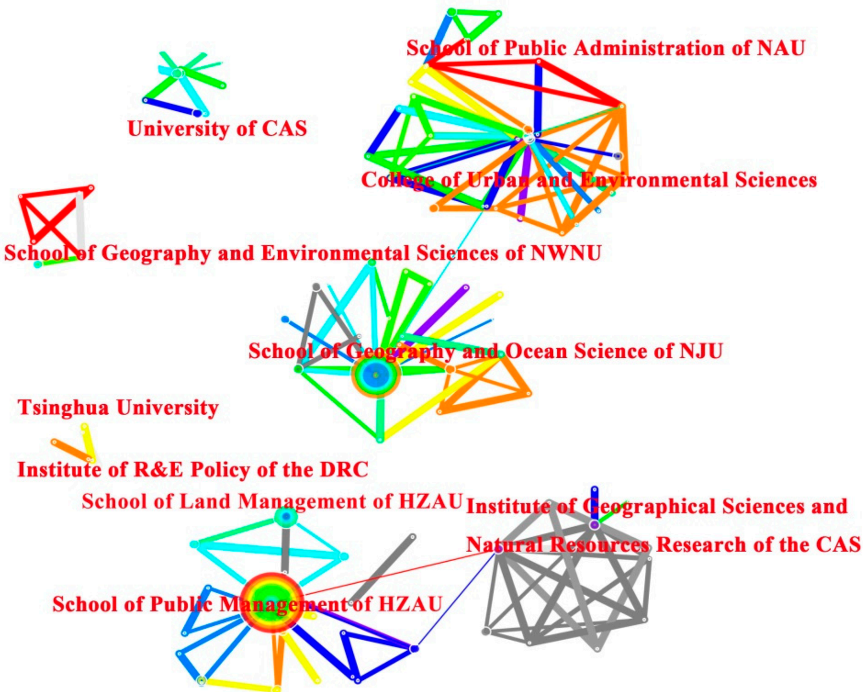

Figure 4. The cooperative network of carbon emissions research institutions based on the CNKI database.

3.2.3. Analysis of Researchers

The number of published papers and cooperation networks reflects the research ability, cooperation intensity, and overall academic influence of the researchers in the research on land-use carbon emissions. The node type was set as 'author', and the author cooperation relationship graph was obtained with 929 nodes and 1233 connections. As shown in Figure 5, the graph network density was 0.0029. It can be seen that the overall cooperation between authors is infrequent, the transnational exchanges between authors were generally lacking, and there were few representative large-scale cooperation networks. There are significant author nodes in the figure, namely Philippe Ciais with 99 papers, Pete Smith with 80 papers, and Rattan Lal with 51 papers; the median values were 0.15, 0.05, and 0.01, respectively. The largest network is the carbon cycle and transformation research team led by Philippe Ciais, an academician of the French Academy of Sciences. He founded the French Greenhouse Gas Observation Network (ICOS) and is a leader in biogeochemical cycles and climate change research. Next are the networks of biologist Pete Smith of the University of Aberdeen, Professor Pierre Friedlingstein of the University of Exeter, and the scientific research team led by Professor Tian Hanqin of Auburn University. Although Professor Benjamin Poulter of Montana State University's Department of Ecology, Professor Rattan Lal of Ohio State University, and Almut Arneth have published a large number of papers on global climate change, carbon management and greenhouse gas effects, their frequency of cooperation is not high from the perspective of centrality and node connection.

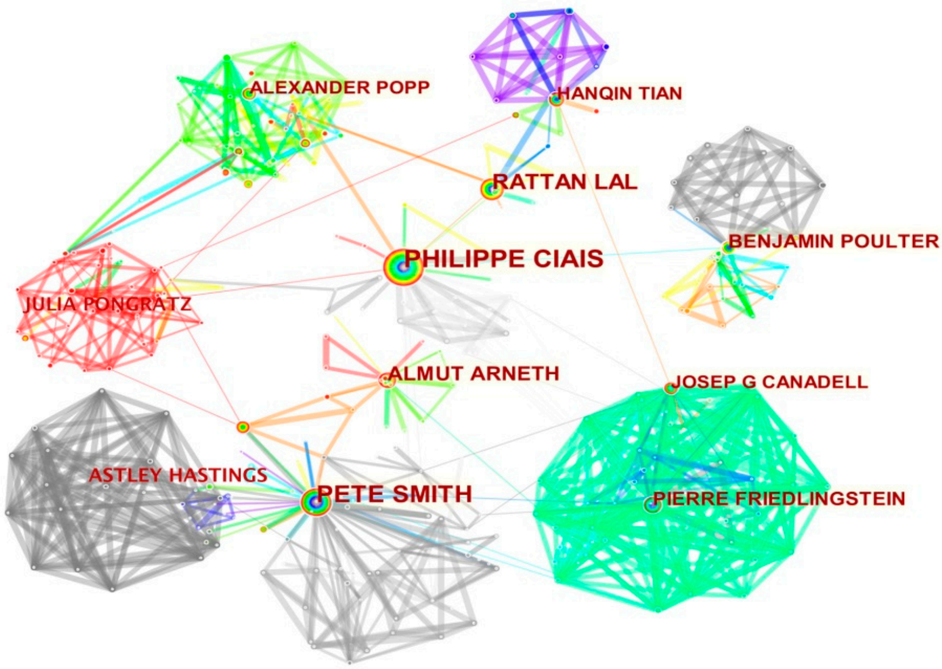

Figure 5. The collaborative network of authors for carbon emissions research in the WoS database.

Based on the CNKI database, the authors' cooperation network graph with a network density of 0.0032, a node number of 417, and a connection number of 281 were obtained. According to Figure 6, the cooperation team centered on Huang Xianjin of Nanjing University (23 papers) and Zhao Rongqin of the North China University of Water Resources and Electric Power (20 papers) are closely connected. They form a core force in land-use carbon emissions research. From 2010 to 2015, Chen Yinrong of Huazhong Agricultural University (21 papers), Zhang Miao of Shandong Normal University (13 papers), Yuan Kaihua (6 papers) and others cooperated closely. Yang Xuhong of the Zhongnan University of Economics and Law (16 papers) and Jin Xiaobin (16 papers) and Zhou Yinkang (16 papers), both of Nanjing University, began working together in 2005, and there may be a continuous output of cooperative works in the future. Although Zhou Shenglu and Xu Kang, from Nanjing University, and Yu Guirui, Han Bin and others were not very productive, they formed a close cooperation team from 2000 to 2005. Currently, more authors are working independently than collaborating.

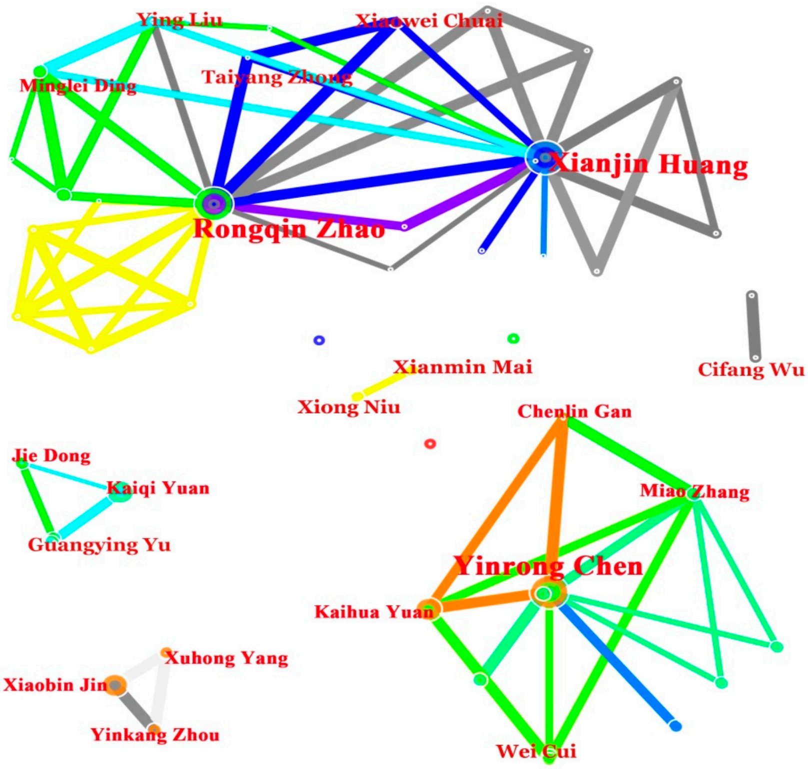

Figure 6. The collaborative network of authors for carbon emissions research in the CNKI database.

3.3. Research Hotspots and Frontiers

The keywords represent the research topics, contents, theories, methods, viewpoints, and other characteristics of the papers. High-frequency keywords can be effectively extracted through the analysis function of CiteSpace, and co-occurrence, clustering, and emerging word detection can be performed. The research field can then obtain topic clustering and its distribution, scope, and sub-clustering [20]. The content of the literature is summarized and refined through keyword analysis in order to comprehensively and scientifically grasp the research hotspots and frontier trends.

3.3.1. Co-Occurrence Analysis of Keywords

The WoS core database and CNKI database literature data were imported into CiteSpace, the node type was set to 'keyword', and the time slice was set to 1 year. As shown in Figures 7 and 8, the knowledge graphs of WoS and CNKI contain 817 and 468 nodes (a moderate number of nodes were selected and labeled) and 1159 and 589 lines, respectively. The network densities were 0.0035 and 0.0054, respectively, with relatively significant high-frequency keyword nodes. There were many connections between nodes, and the network was rather tight. Considering the number of keywords, the frequency of occurrence, and the betweenness centrality, five main research hotspots in this domain were screened out from 817 keywords: 'land use', 'climate change', 'greenhouse gases', 'carbon', and 'impact'. By analyzing the CNKI literature data, it was concluded that the main research hotspots in this domain are carbon emission, land use, carbon cycle, climate change, and low-carbon economy. From 2001 to 2020, the structure of land use, including cultivated land, construction land, pastureland, forest land, and water area, has constantly been changing with the progress of the social economy. The relationship between land use and climate change has also become a research hotspot. As the global climate warms, the need to control greenhouse gas and carbon emissions is imminent. The concepts of the carbon cycle and low-carbon economy have been put forward successively by the research of scholars from all over the world, and they are becoming more and more popular among the public.

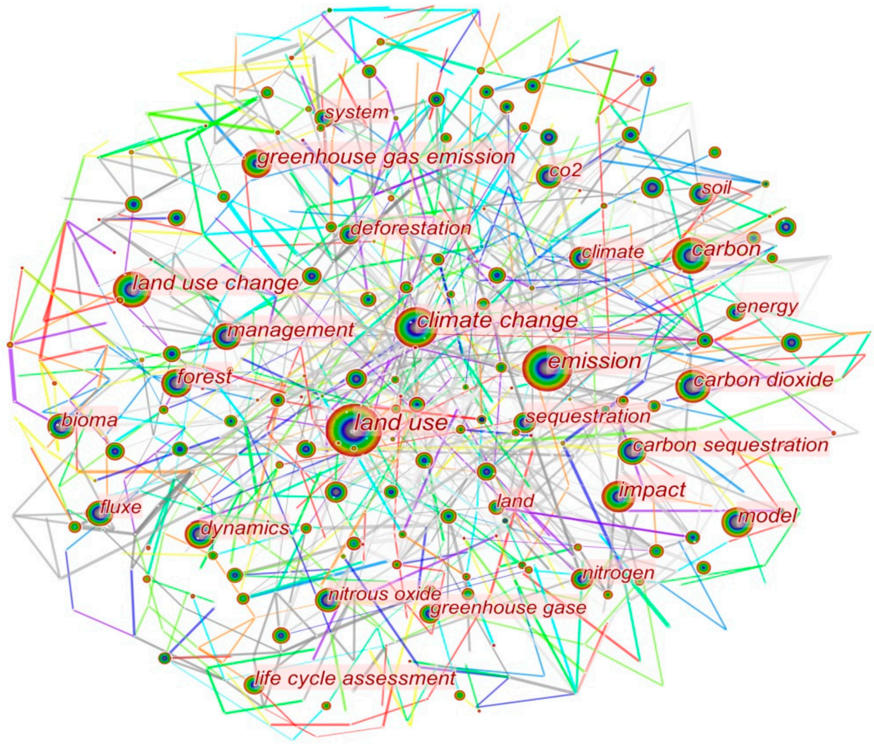

Figure 7. Co-occurrence graph of keywords for carbon emissions research in the WoS database.

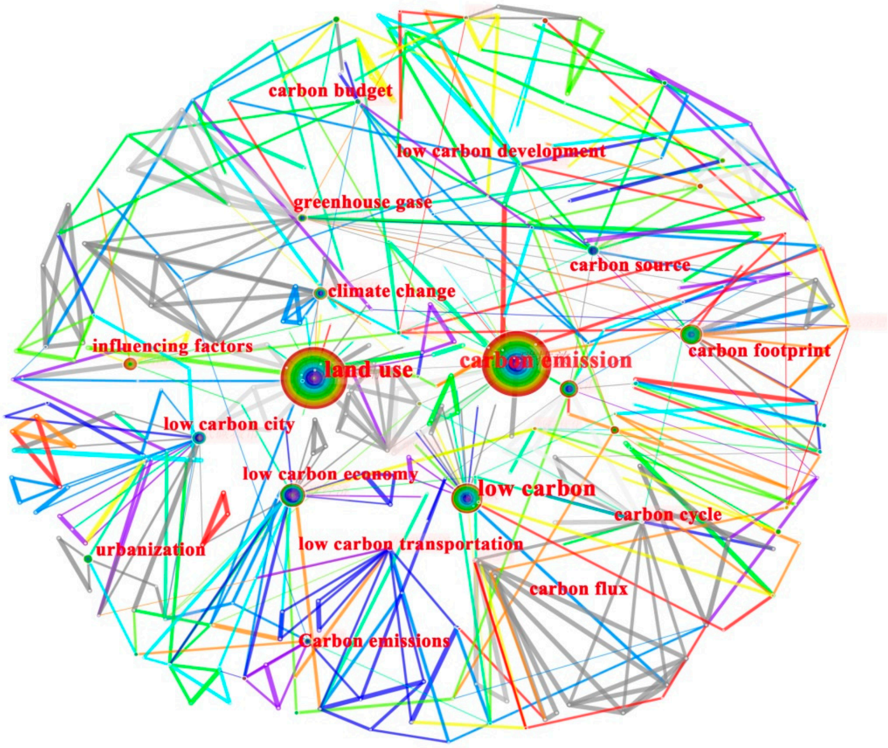

Figure 8. Co-occurrence graph of keywords for carbon emissions research in the CNKI database.

3.3.2. Cluster Analysis of Keywords

Cluster analysis of keywords through CiteSpace can classify hot keywords in a certain research domain and further focus on the core word groups of the research topic. Based on the keyword co-occurrence map for land-use carbon emissions research in the WoS database, the keyword clustering function of CiteSpace was used for analysis, and the LLR logarithmic likelihood algorithm was used to obtain 26 keyword clusters. The top 10 are reserved according to the cluster size. As shown in Figure 9, modularity Q = 0.7807 (>0.3), weighted mean silhouette S = 0.9057 (>0.7), the clusters have high performance and reasonable structure, indicating that the cluster is convincing. The main keywords of each cluster are summarized as: #0—atmospheric CO_2, #1—life cycle assessment, #2—nitrous oxide, #3—deforestation, #4—carbon dioxide, #5—organic carbon, #6—burned area, #7—climate change, #8—transport, and #9—eddy covariance. The contour values of each cluster are higher than 0.8, indicating that each cluster has a high degree of acquaintance, and the research topics are overlapping and concentrated. The publication years of each cluster are distributed around 2010, indicating that the research of land-use carbon emissions was a trendy research domain in the WoS database in 2010, and it is still relatively popular today.

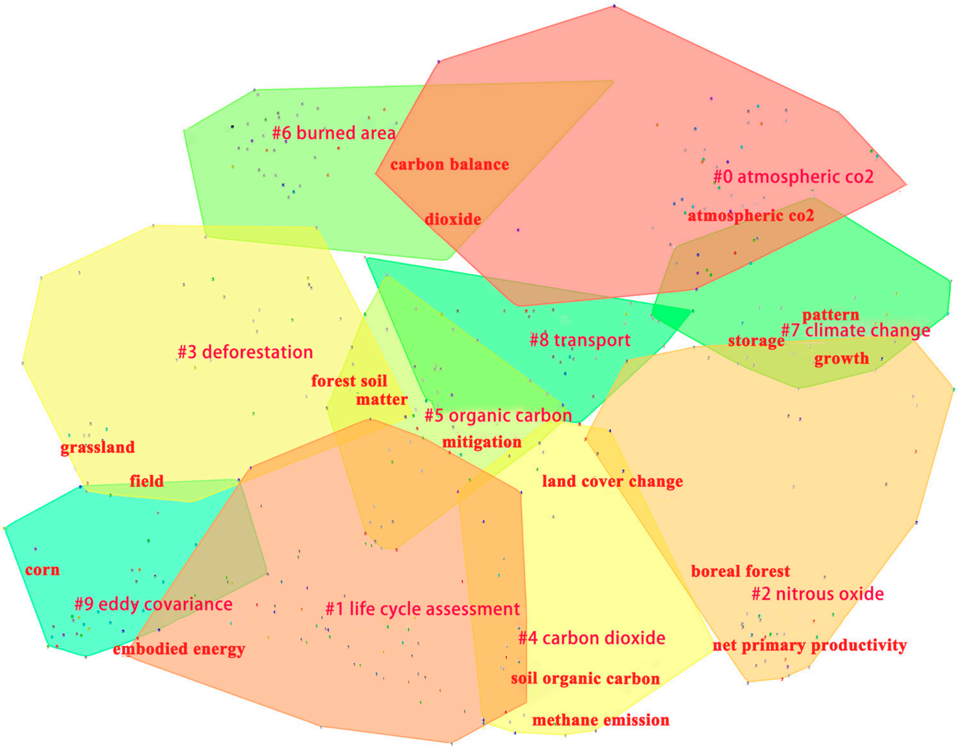

Figure 9. Cluster map of keywords for carbon emissions research in the WoS database.

The first cluster, #0 (with 66 keyword nodes), the fifth cluster, #4 (with 44 keyword nodes), and the sixth cluster, #5 (with 43 keyword nodes), can be merged into carbon dioxide. The research focuses on carbon dioxide, net primary productivity, earth system models, soil organic carbon and methane carbon emissions. Philippe Ciais proposed a new hypothesis that permafrost carbon release contributed to the increase in atmospheric CO_2 during the deglacial period, challenging the traditional view that all atmospheric CO_2 during the deglacial period came from the ocean [21]. Using Earth system model CLIMBER-2, Brovkin found that the relative effect of land cover changes on atmospheric CO_2 in the past 150 years has shown a downward trend [22]. Eddy J Moors explored the factors influencing changes in carbon exchange by estimating net primary crop production and annual climate change in Europe [23]. To explore the future scenario simulation of the Arctic carbon cycle, Yi Yonghong chose Alaska as the study area and proved the seasonal effect of snow cover on soil respiration with the help of satellite-based permafrost carbon model analysis [24]. To better understand the global carbon cycle and to support climate development, Pierre Friedlingstein updated the global carbon budget data in real-time; it was found that, due to the impact of the new crown pneumonia epidemic, global carbon dioxide emissions fell by 7% in 2020 [25]. However, the total amount and the concentration of carbon dioxide in the atmosphere are still increasing.

The second cluster, #1, named 'life cycle assessment', contains 62 keyword nodes and focuses on research on carbon footprint and environmental impact. For example, Hanna Treu quantified the carbon footprint and land use of German traditional and organic diets based on life cycle assessment. She made recommendations to reduce animal-based diets to maintain a balance between the ecological environment and human health [26]. Miguel Brandao used life cycle assessment to quantify the environmental impact of land-use systems [27] and found that different crop types have different degrees of influence, with forest residues being the smallest.

The third cluster, #2, and the eighth cluster, #7, can be combined into climate change, and the central keyword nodes included are soil respiration, greenhouse gas, vegetation, land-use change, etc. The cluster uses a series of scenario experiments to assess the impact of land use, climate change, and vegetation on greenhouse gas emissions. For example, Leemans experimentally analyzed the feedback process of CO_2 concentration accumulation, emphasizing the importance of proper parameterization of the carbon cycle and land use in determining the future state of the climate system [28]. Rattan Lal focused on soil carbon management [29]; he believed that soil carbon sequestration was significant for limiting global warming to 2 °C and proposed soil carbon farming, an emerging technology to reduce anthropogenic carbon dioxide emissions and address climate change.

The fourth cluster, #3, is marked by LLR as deforestation and contains 44 keyword nodes, and the seventh cluster, #6, is the burned land, which includes 41 keyword nodes. The research hotspots of this cluster are remote sensing, conservation, nitrification, biomass burning, land cover, and forest fires. Almut Arneth and Tian Hanqin used the weighted mean method to quantify changes in carbon fluxes from land cover change (LULCC) by geographic region, focusing on deforestation and forest regeneration fluxes [30]. By establishing a probabilistic model, Rafaella Almeida Silvestrini found that the combination of climate change and deforestation increased the incidence of fires outside protected areas [31] while confirming the synergy between deforestation and forest degradation.

The ninth cluster, #8, is labeled 'transport', and includes carbon exchange and the carbon cycle. It is well known that transportation has become a major component of urban greenhouse gas emissions and understanding trends and drivers of terrestrial carbon exchange is critical to combating climate change. Li Xin applied the ARDL and VECM models to analyze the causal relationship between carbon dioxide emissions and transportation in China [32]. He found that expanding domestic road, aviation and waterway infrastructure led to a long-term increase in carbon dioxide emissions. In the long run, railway expansion will reduce carbon dioxide emissions.

The tenth cluster, #9, is called eddy covariance and includes 39 keyword nodes, among which energy consumption, system boundary, net ecosystem exchange, and bioenergy are the main ones. Terenzio Zenone studied agricultural land-use patterns under three different cropping systems based on eddy covariance and ecosystem carbon balance methods. He found that land-use changes in biofuel crops resulted in a large amount of carbon emission [33]. Pete Smith evaluated soil carbon sequestration and biochar negative emission technologies [34] and found that biochar can be implemented with bioenergy for both carbon capture and carbon storage.

Using the keyword clustering function of CiteSpace, the CNKI database was analyzed to obtain a keyword clustering map. As shown in Figure 10, the modular Q value was 0.858 (>0.3), and the weighted average contour value was 0.9652 (>0.7), indicating that the clustering structure is significant and that the clusters are similar. The main keywords of each cluster are summarized below: #0—influencing factors, #1—carbon emissions reduction, #2—land use, #3—carbon cycle, #4—low-carbon transportation, #5—carbon footprint, #6—low-carbon city, #7—climate change, #8—carbon budget, and #9—low-carbon economy. The publication years of each cluster are mainly concentrated after 2010, indicating that land-use carbon emissions research is a relatively new research domain in the CNKI database. The contour values of each cluster are all greater than 0.9, indicating that the degree of acquaintance between clusters is very high, and the research direction of the literature is relatively consistent.

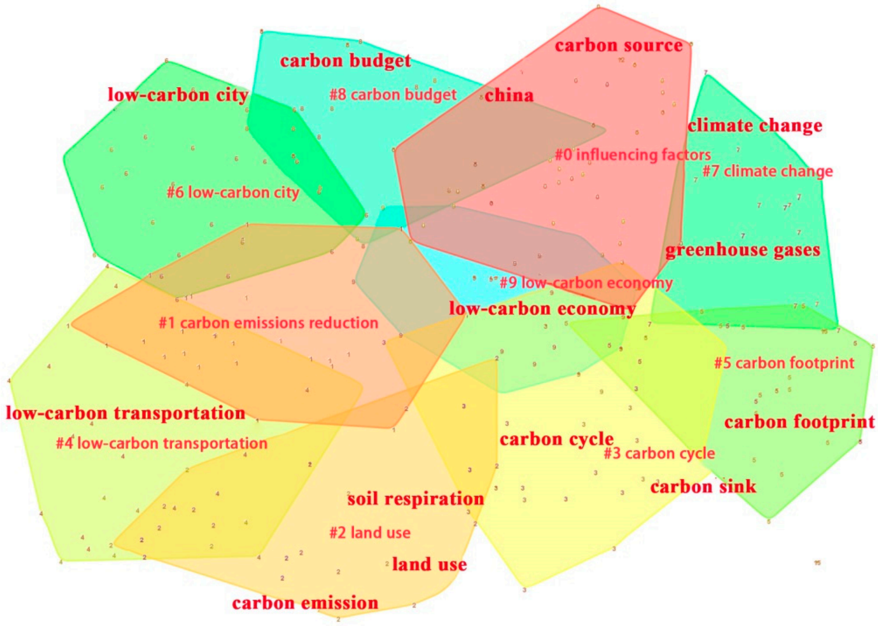

Figure 10. Cluster map of keywords for carbon emissions research in the CNKI database.

The largest cluster, #0, with 30 keyword nodes and a contour value of 0.957, was marked as an influential factor by LLR. Liu Xuerong, Yang Lin and other scholars selected Northeast China, Shaanxi Province, Beijing–Tianjin–Hebei urban agglomeration, and other places as research areas and analyzed the impact of land-use change on carbon emissions in different regions using the STIRPAT model, EKC curve fitting, the LMDI model, and the GIS-GWR model. They provide a reference for promoting the optimization of the land-use structure under low-carbon emissions in various regions [35]. Cui Wei, Zhu Zhiyuan, and other researchers explored the influencing factors of land-use carbon emissions from multi-scale perspectives, such as industrial land, urban non-agricultural land, urbanization, and the ecological footprint of net productivity [36]. Yuan Kaihua, Xu Jie, Zhang Miao, and others, based on LUCC regional carbon emissions effect and spatial pattern research [37,38], promoted regional low-carbon development from the aspects of regional development, industrial structure adjustment, land-use planning, urban layout and urban development patterns.

The second cluster, #1 (29, 0.987), contains 29 keyword nodes, and cluster, #3 (28, 0.942), contains 28 keyword nodes, mainly focusing on the goals of carbon emissions reduction and the carbon cycle in a low-carbon context. In his review of Dr. Zhao Rongqin's monograph, "Research on Urban System Carbon Cycle and Land Regulation", Huang Xianjin initially constructed a carbon cycle assessment and land regulation method and proposed a low-carbon management strategy based on land structure optimization [39]. Scholars such as Zhao Rongqin, Huang Xianjin, and Gao Shan analyzed the carbon emissions reduction potential of Jiangsu Province and Wuhan. They proposed that based on ensuring the presence of carbon sinks, the structure of industrial land should be optimized, and the tertiary and modern service industries should, on the whole, be encouraged [40]. Zhao Rongqin, Huang Xianjin, Zhong Taiyang, and other scholars analyzed the relationship between land-use change and carbon source or sink at global and regional scales and constructed calculation models for land-use carbon source or sink research. They proposed that a low-carbon land-use regulation mechanism should be established to achieve the optimal land-use layout under the carbon emissions reduction target [41]. Huang Jinbi and Jin Xiaobin established a carbon cycle stress index model to optimize regional carbon management by analyzing carbon sources or sinks in terrestrial ecosystems [42].

The third largest cluster, #2 (28, 0.977), and the eighth largest cluster, #7 (24, 0.969), were labeled as land use and climate change and contained 28 and 24 keyword nodes, respectively. To achieve low-carbon land regulation, Cai Miaomiao, Wu Kaiya, and other authors analyzed the dynamic relationship between the development intensity of construction land and the effect of carbon emissions in different regions based on the VAR model and CLUE-S model simulation [43]. Zhang Miao, Chen Yinrong, and other authors started from the perspective of changing urban land-use methods and used the STIRPAT model, the ANP method, and the obstacle model to find the driving factors of carbon emission intensity in the process of land-intensive use and improve the level of land-intensive use under the low carbon concept [44]. Land use change is a crucial factor linking climate change and human activities. Other scholars, such as Liu Bojie, proposed sustainable development measures to deal with global climate change, including greenhouse gas emissions reduction and net carbon sequestration [45].

The average citation year for clusters #4, #6, and #9 was 2013, and they explored low-carbon development from the aspects of low-carbon transportation, low-carbon cities and low-carbon economy, respectively. Based on the development status of carbon sources and carbon sinks, Li Peiying and Shi Tiemao proposed a low-carbon urban spatial layout of "large dispersion and small aggregation" [46]. Ye Yuyao and Zhang Hongyou proposed from the perspective of urban layout planning that improving the land-use intensity and increasing land diversity is the way to realize low-carbon transportation based on the urban transportation carbon emission and land-use system dynamics model. [47]. Yang Wenyue and Cao Xiaoshu analyzed the relationship between the built environment and residents' low-carbon travel through a multi-level mixed-effect model and a decoupling index model [48]. They found that the built residence environment has a more significant impact on commuting carbon emissions than the work environment.

The sixth cluster, #5 (26, 0.956), and the eighth cluster, #8 (24, 0.932), take carbon footprint and carbon budget as the starting point, and focus on the study of land-use carbon emissions in industrial land, land suitability evaluation, low-carbon issues related to agriculture, carbon balance, and factor decomposition, etc. For example, Bai Cuimei, Mei Yun, and other authors calculated the carbon footprint of Wuhan and its influencing factors by building a carbon footprint model. They found that the carbon emissions potential of construction land is significantly higher than the carbon absorption potential of production land. Therefore, they proposed controlling the expansion of construction land and adjusting the energy consumption structure [49]. To promote the realization of the high practicability of the regional carbon cycle, Feng Yuan and Zhu Jianhua researched and predicted the dynamic changes in the carbon budget in different land-use patterns in Chongqing based on the CLUE-S model [50].

3.3.3. Frontiers and Prospects of Research

Burst word detection is used to determine whether the research hotspot of a certain research domain has changed. Burst word detection of land-use carbon emissions research was carried out based on the keyword co-occurrence and clustering map. By adjusting the mutation detection parameters, invalid keywords are eliminated, and the keyword emergence intensity ranking is generated to get an overview of the changing trend of the themes in this research domain. As shown in Figure 11, in the past two decades, most of the ten outliers in the research on land-use carbon emissions appeared earlier and with high mutation intensity in the WoS database. From 2001 to 2003, there were a lot of burst words, including 'atmosphere', 'Kyoto Protocol', 'carbon sequestration', 'models', etc., which lasted for a long time. Combined with the study of national visualization maps, it can be seen that most of the land-use carbon emissions studies in English are dominated by western developed capitalist countries. As a result of the difference in the degree of industrialization, from 2005, developed countries have assumed the responsibility for energy conservation and emissions reduction, and developing countries have postponed it for seven years. Burst words in recent years have included 'biofuel' in 2009 and 'energy consumption' in 2017. Owing to the positive encouragement of the European Commission, the British and American governments have successively issued plans to promote the healthy development of the biofuel industry and increase the utilization of renewable energy. Data from the International Energy Agency shows that, in 2011, global biofuel production decreased from 1.822 million barrels to 1.819 million barrels per day, reflecting the effectiveness of the global community in responding to the call for energy conservation and consumption reduction.

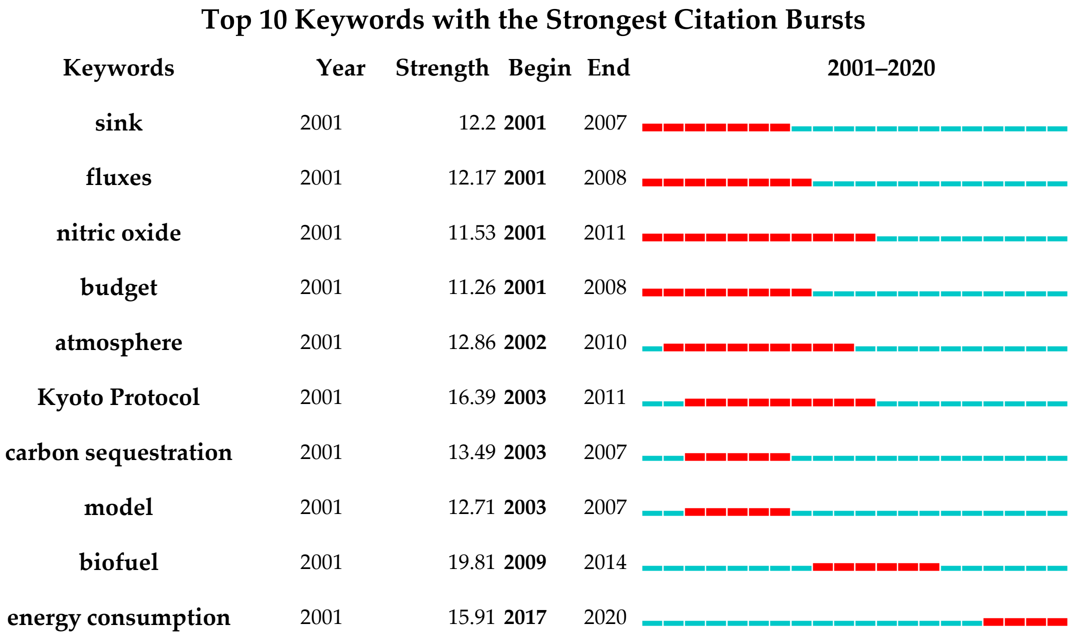

Figure 11. Burst intensity map of keywords for carbon emissions research in the WoS database.

According to the ranking map, the burst intensity of land-use carbon emissions research keywords in the generated CNKI database (as shown in Figure 12) can be roughly divided into three stages. In the first stage, the main burst word from 2001 to 2009 was 'carbon cycle', which was the earliest high-frequency emergent word' with an emergent intensity of 3.63, indicating that the research on carbon emissions was in the initial stage of theoretical exploration. The carbon cycle is also the origin of research in this domain, which activity in atmospheric ecosystems, forest ecosystems, marine ecosystems, and human activities. In the second stage, from 2010 to 2016, the emergent words were mainly 'low-carbon economy', 'low-carbon city', and 'carbon source'. In 2010, with the convening of the National People's Congress and the Chinese People's Political Consultative Conference, one of these important topics, "low-carbon", became a hot topic of public concern. Under the call of the "low-carbon economy" and the "energy-saving society", the government took the lead in carrying out demonstration projects, and all sectors of society responded positively to build a low-carbon city. In the third stage, the burst words from 2017 to 2020 were 'influencing factors', 'decoupling analysis' and 'built environment'. At this stage, scholars focused on using a series of models, such as decoupling analysis, on analyzing the factors influencing carbon emissions. They provided the scientific basis for coping with ecological changes from different perspectives, such as land structure optimization, economic growth, and energy efficiency improvement. The "14th Five-Year Plan" in 2020 proposes to continuously improve the environment's quality and comprehensively improve the city's quality. It is essential to fully understand the mechanisms and laws of the influence of the built environment on energy consumption related to production and living. At the same time, optimizing the urban spatial layout and building low-carbon cities against a background concept of low-carbon development may be an important direction for China's future carbon emissions research.

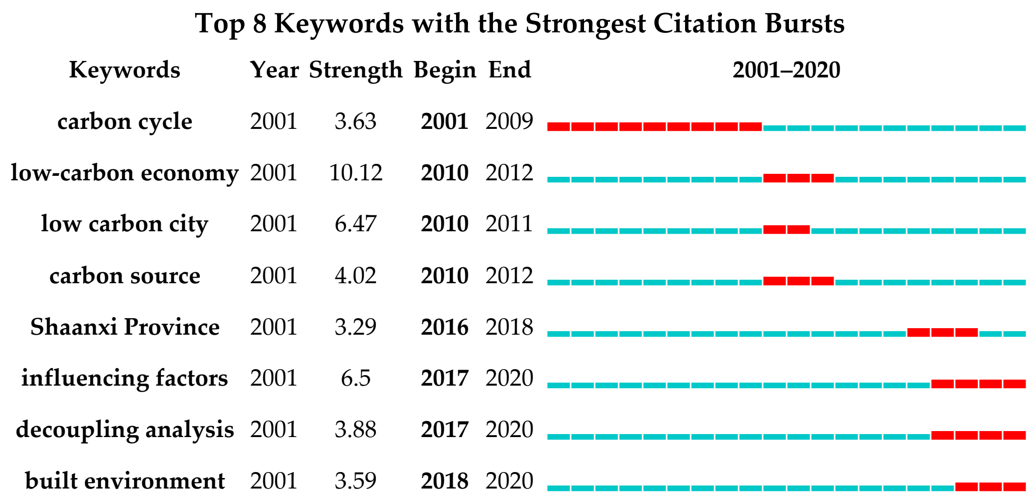

Figure 12. Burst intensity map of keywords for carbon emissions research in the CNKI database.

4. Discussion

An analysis and summary of the existing relevant literature was carried out in this paper. The results show that although the studies on land-use carbon emissions are not the same, they all promote research progress in this domain. At the same time, relevant research on carbon emission measurement and assessment provides theoretical guidance for countries to establish and improve carbon trading systems and speed up the process of improving climate change, energy conservation, and emissions reduction.

4.1. The Practices of Land Use Carbon Emissions in Western Countries

The United States leads the way in both publication volume and academic influence. The US Regional Greenhouse Gas Initiative (RGGI) framework agreement was signed in December 2005, thanks to extensive and intensive research by NASA, the University of Maryland, and numerous other researchers. It aims to reduce carbon dioxide emissions in RGGI member countries in the most economical way. California's carbon cap-and-trade program (CCTP) has succeeded to some extent in reconciling the seemingly contradictory goals of carbon reduction and economic development. England (which officially left the EU on 31 January 2020) and Germany, which ranked second and third in the number of publications, have also made significant achievements in carbon emissions research. The research teams, led by Prof. Philippe Ciais from France, Prof. Pete Smith from the University of Aberdeen and Prof. Pierre Friedlingstein from the University of Exeter, have continuously exported their research results since 2000, promoting the practice of low-carbon emission reduction in the EU. In 2005, the first international emissions trading system in the world, the European Union Emission Trading Scheme (EU-ETS), was established and entered the fourth trading stage (2021–2030). Among the top five countries in betweenness centrality, France, Romania and Hungary all have a high academic influence on carbon emissions research, which enhances communication and cooperation between the EU and other countries. In August 2012, the EU and Australia agreed to dock their carbon emissions trading systems from July 2015.

4.2. The Practices of Land Use Carbon Emissions in China

According to the CNKI database, carbon emissions research in China began to develop after 2010. Although the Chinese Academy of Sciences ranks first in the WoS database, its academic influence is far lower than that of other foreign institutions. This may be one reason why the emissions trading market was set up late in China. The national carbon emissions trading market was launched simultaneously in Beijing, Shanghai and Wuhan on 16 July 2021. The terms "Carbon peak" and "Carbon neutrality" were proposed again during the two sessions in 2021, and related work has been progressing steadily and in an orderly manner. In the context of dual carbon, land-use carbon emissions research will still be a key topic in the academic community in the long term. Given the current research status in China, Chinese scholars should persist in learning from others' strong points and referring to mature empirical theories in other countries. In addition, it is necessary to continuously expand the depth and breadth of research and further improve the overall framework and methodological system of land-use carbon emissions research.

5. Conclusions

By combing the research hotspots of the Chinese and English literature over the past 20 years and comparing the differences between them in relation to land-use carbon emissions, it can be inferred that, due to differences in the level of economic development and environmental factors, the focus of the Chinese and English research literature is somewhat different. This difference is mainly reflected in the following aspects.

(1) In terms of research strength, economically developed countries such as the United States, England, Germany, France, and Australia are regarded as the leading forces. Although China is a late starter in this domain, its research has progressed rapidly and achieved fruitful results. Owing to differences in regions, languages, and cultures, cross-border cooperation is not frequent, on the whole. In terms of research institutions, the Chinese Academy of Sciences is higher than the National Aeronautics and Space Administration in the number of publications. However, it lacks the frequency of cooperation and academic influence. Research institutions in China are more self-directed, whereas institutions in other countries have conducted deeper and broader cooperation. In terms of research teams, although Chinese scholars lag behind other countries in their research progress, they have initially formed several relatively clear fixed cooperation teams, and the cooperation results were mainly distributed around 2015. Scholars from other countries generally publish a higher volume of papers, but the research teams were mainly distributed around 2005, and there has been no significant team cooperation in recent years.

(2) In terms of research hotspots, the English research literature focuses on building models and theoretical frameworks to study the internal mechanisms and driving factors of carbon emissions and climate change, such as greenhouse gases, life cycle assessment, and deforestation. Research in China focuses on regionalized carbon emission reduction, realizing carbon cycle goals, and optimizing a low-carbon economy, transportation, and land-use structure.

(3) In terms of research frontiers, after exploring carbon sequestration, organic carbon, and carbon accounting, the English scientific literature has gradually shifted its focus to biofuels and energy consumption since 2010. To promote the reduction of greenhouse gas emissions, biofuels are promoted all over the world. However, there are certain limitations in the fields of the use and supervision of biofuels. Trying to improve the rate of energy consumption and realize sustainable renewable energy development has become the latest research frontier in foreign countries since 2017. In China, with the gradual advancement of the low-carbon economy, low-carbon transportation, and low-carbon cities, the latest research frontiers are gradually focusing on influencing factors, decoupling analysis, and the construction environment.

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