Research on Land Use in China under the Background of Carbon Emission Based on WOS Database

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Abstract. Under the global climate change and the synergistic advancement of the dual-carbon strategy, research on carbon effects of land use and its regulatory pathways has emerged as a core scientific proposition for achieving carbon neutrality. This study systematically analyzes 396 publications related to land use and carbon emissions in China from 2011 to 2024 through knowledge mapping analysis using Citespace bibliometric tools based on the Web of Science Core Collection. Key findings reveal: (1) Distinct stage characteristics in research evolution, progressing through initial, steady, adjustment, and rapid expansion phases; (2) A monocentric polarization pattern in scientific collaboration networks; (3) Significant spatiotemporal dimensions and multidisciplinary integration in research themes. The study highlights critical needs for enhancing dynamic monitoring and long-term effect evaluation, strengthening analysis of driving pathways for land system carbon reduction, and advancing policy synergy and innovation to provide theoretical support for territorial spatial planning optimization.

Keywords: Land Use, Carbon Effects, Bibliometrics, Research Hotspots.

1. Introduction

Greenhouse gas emissions in the atmosphere and its potential impact on the global climate have become an important concern all over the world, especially carbon dioxide (CO_2) emissions account for more than half of greenhouse gas emissions [1-2]. From the published articles and research, CO2 emission is the most serious challenge facing human beings, and reducing its emission has become a worldwide concern [3-4]. In recent years, China government has taken a series of positive measures to reduce CO2 emissions, and set short-term and long-term emission reduction targets [5-6]. As an important resource for human survival and development, land has an important impact on carbon emissions and carbon storage. How to promote the coordinated development of land and carbon emissions has become an important challenge for China's current development [7].

The research on land use in China under the background of carbon emissions has always been the focus of many scholars, and the related research mainly focuses on the spatial and temporal differentiation characteristics, driving factors and spatial correlation of carbon emissions from land use. By constructing a grid of land use carbon emissions, Rong et al. found that land use carbon emissions increased with the improvement of urbanization level, and showed a trend of high in the northeast-low in the southwest [8]. Wang et al. found that the spatial distribution and emission of CO2 are negatively correlated with land use efficiency, and economic growth, technical input and energy intensity are the core factors that affect the carbon emission of regional land use [9]. Liu et al. calculated the carbon emissions of land use in China county by using the data of night light, land use and energy consumption, and found that the carbon emissions of land use had obvious spatial heterogeneity and agglomeration [10]. Under the dual-carbon policy in China, it is of far-reaching significance to the rational use of land, but there is a lack of comprehensive research on the visualization and quantification of carbon emissions from land use in this field.

Based on bibliometrics theory, this study constructs a network map of land use field under the background of carbon emissions, summarizes its research hotspots and development trends, objectively and comprehensively grasps the research content and core of this field, and provides guidance and reference for the coordinated development of land use and carbon emissions in China.

2. Research methods and data sources

2.1. Research methods

This study uses the theory and method of bibliometrics to discuss the present situation and development trend of land use research under the background of carbon emission in China. This study mainly uses Citespace to visually analyze the literature: (1) Bibliometric analysis. By drawing cluster diagram and keyword mutation diagram, the basic situation, core concepts and development hotspots of land use in China under the background of carbon emission are sorted out by using the methods of scholar analysis, research institution analysis and keyword co-occurrence analysis. (2) Content analysis method. Based on the results of literature co-citation analysis and cluster analysis, this paper finds the hot topics in this field, and then expounds the contributions made by different researchers in this field. Based on the above research methods, this study will make an in-depth analysis of the relevant literature in the field of land use research under the background of carbon emissions in China, and show the relationship between the various fields of land use research.

2.2. Data sources

Web of Science(WOS) is a comprehensive multi-disciplinary core periodical database and one of the largest databases on the Internet [11]. This study is based on WOS literature database, with "land use" and "carbon dioxide emission" and "China" as search terms, and the retrieval time ranges from 2010 to 2024. In order to scientifically summarize and analyze the research trends and hotspots of intensive land use under the background of carbon emissions in China, marginal information such as meeting minutes, newsletters, interviews and call for papers were manually excluded through preliminary search and reading screening, and articles irrelevant to the research content were removed through extensive reading of article abstracts. A total of 407 research articles were retrieved as basic data sources for analyzing the field of intensive land use under the background of carbon emissions in China. The obtained literature data are stored in text format, converted into Refworks format, and imported into Citespace software. By eliminating the remaining 396 articles, researchers, research institutions, keywords and other topics are selected to draw a knowledge map.

3. Research trend analysis

To explore the changing trend of the historical span of the research topic, this study, based on the visualization analysis of the WOS database, the annual changes in the number of published papers, and the annual changes in research hotspots, has drawn a line chart of the number of published papers from 2011 to 2024, as shown in Figure 1. The research on land use under the background of carbon emissions can be divided into four stages: the initial stage, the stable growth stage, the adjustment and fluctuation stage, and the rapid growth stage.

Initial stage (2011-2013): There were 17 papers in this stage, with an average of 5.6 papers per year, showing a slow growth. In Figure 2, the connections between the keywords in this stage are relatively sparse, and the keywords and clusters have not yet formed. Keywords such as "CO2 emissions" and "land use" have a relatively high frequency of appearance.

Stable growth stage (2014-2017): The total number of papers in this stage was 77, with an average of 19.25 papers per year, which is comparable to the theoretical expected annual number of papers. The number of published papers in this stage increased steadily, with a certain degree of growth each year. The connections between keywords such as "dioxide emissions" and "decomposition analysis" are dense, indicating that this field began to receive more attention, and the research direction gradually highlighted its centrality, with overall development being relatively stable.

Adjustment and fluctuation stage (2018-2021): The total number of papers in this stage was 120, with an average of 30 papers per year. The main keywords were "methane emissions" and "cover change". The number of published papers in this stage fluctuated greatly, and new research keywords such as "stirpat model" and "spatial pattern" emerged. This period was affected by external factors or

internal adjustments and was in the stage of exploring and adjusting the development path, showing a fluctuating upward trend.

Rapid growth stage (2022-2024): The total number of papers in this stage was 179, with an average of 59.67 papers per year. The research keywords in this period included "driving factors" and "carbon neutrality". The growth rate increased significantly, indicating that the development trend of this field is good, and the attention and investment have increased significantly.

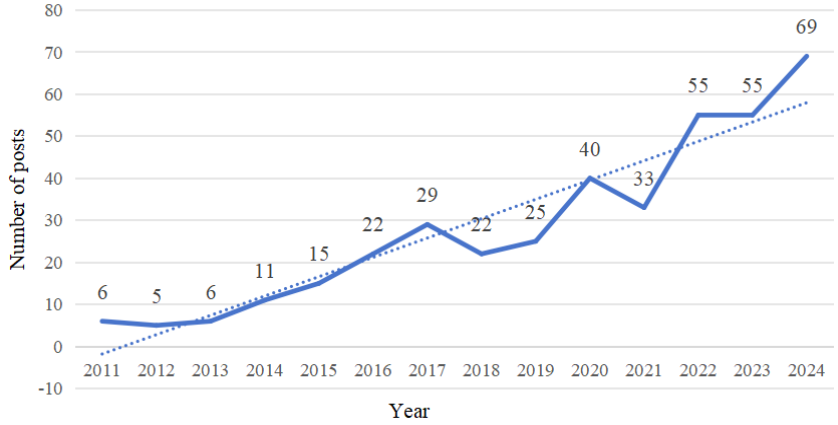

Figure 1. Line chart of the number of papers published in this field from 2010 to 2024

4. Analysis of research status quo

4.1. Analysis of scholars' collaborative network

In the research of land use in China under the background of carbon emissions, the degree of academic cooperation is a key indicator to measure the research progress in this field. With the help of related tools, this study summarizes the top 10 researchers who have published papers, as shown in Table 1.

Researchers who have published three or more papers in this study can be positioned as core researchers in this field. Ciais, Philippe (10 articles), Wang, Shaojian (9 articles), Poulter, Benjamin (8 articles), Sitch, Stephen (7 articles), Kato, Etsushi (6 articles) and Pongratz have published more Tian three articles this time.

Citespace derived the centrality data of scholars. According to this index, the centrality of most researchers is 0, only Ciais, Philippe are 0.04, and a few are 0.01 or 0.02, which indicates that the cooperation between researchers in this research field is low and no centrality scholars have been formed. In terms of academic cooperation, although there is no obvious cooperation network, in 2017, many scholars published research results, which may have some hidden connections. Generally speaking, although there are some high-yielding core scholars in this field, the overall cooperation atmosphere is not strong and a close academic community has not yet formed.

Table.1. Top 10 scholars in this field from 2010 to 2024

Sort	Frequency	Centrality	Age	Author
1	10	0.04	2017	Ciais, Philippe
2	9	0	2015	Wang, Shaojian
3	8	0.01	2017	Poulter, Benjamin
4	7	0.01	2017	Sitch, Stephen
5	6	0.02	2017	Kato, Etsushi
6	6	0.01	2020	Pongratz, Julia
7	6	0	2021	Tian, Hanqin
8	6	0	2022	Yue, Xu
9	5	0	2014	Cai, Bofeng
10	5	0.01	2017	Yue, Chao

4.2. Analysis of cooperative network of research institutions

In the research of land use in China under the background of carbon emissions, research institutions are important platforms for research, and their cooperation has an important impact on the development of this field.

Based on the statistics of the number of documents issued by institutions from 2010 to 2024, Table 2 is obtained by Citespace. According to the table data, the number of papers published by China Academy of Sciences is as high as 121, which is much higher than that of other institutions, occupying a dominant position in this research field, and related achievements have been produced since 2011. In terms of centrality, the University of Chinese Academy of Sciences leads with centrality of 0.21, which plays a key role as a bridge in the institutional cooperation network, indicating that it is closely related to other institutions; However, Tsinghua University, Beijing Normal University and Sun Yat-sen University have zero centrality, which means that they are relatively isolated in the cooperation network.

Judging from the distribution of publication years, many institutions have published results in 2013-2014, indicating that this field is in an active research period. On the whole, the degree of cooperation among research institutions is low, and a wide and close cooperation network has not yet been formed. Only some institutions have certain connections, but the overall academic cooperation is still scattered. In the future, exchanges and cooperation between institutions can be strengthened to promote the in-depth development of research in this field.

Table.2. 10 institutions with the largest number of papers in this field from 2010 to 2024

Sort	Frequency	Centrality	Age	Organization
1	121	0.03	2011	Chinese Academy of Sciences
2	46	0.21	2011	University of Chinese Academy of Sciences
3	28	0.02	2014	Institute of Geographic Sciences & Natural Resources Research
4	23	0.14	2013	Peking University
5	22	0	2018	Tsinghua University
6	22	0	2014	Beijing Normal University
7	19	0.06	2013	Universite Paris Saclay
8	18	0.06	2013	CEA
9	18	0.04	2013	Nanjing University of Information Science & Technology
10	17	0	2017	Sun Yat Sen University

5. Research hotspot analysis

5.1. Keyword co-occurrence analysis

Based on the word frequency statistics function of Citespace, this study systematically extracted the Top20 high-frequency keyword clusters that represent the paradigm of land use research in China under the background of carbon emissions, and accurately identified the discipline evolution mechanism and frontier breakthrough direction in this field, as shown in Table 3. In terms of keyword frequency, the top five keywords with the highest word frequency are CO2 assignments (143 times), dioxides assignments, 92 times, land use”(86 times), energy consumption”(83 times) and carbon dioxide”(63 times). The five keywords with the highest centrality are: "emissions" (0.11), "land use change" (0.11), "CO2 emissions" (0.09), "carbon dioxide emissions" (0.09) and "energy consumption" (0.06), which show obvious centrality characteristics and construct an intermediary mechanism of logical connection among keywords.

With the help of word frequency statistics, a keyword co-occurrence network diagram is drawn, as shown in Figure 2. The keyword co-occurrence network analysis reveals that the research in this field has obvious time-space span characteristics and multidisciplinary cross-attributes, covering multi-dimensional issues such as ecology, economy, climate and land, reflecting the paradigm transformation and connotation expansion of land use research from the perspective of carbon emissions.

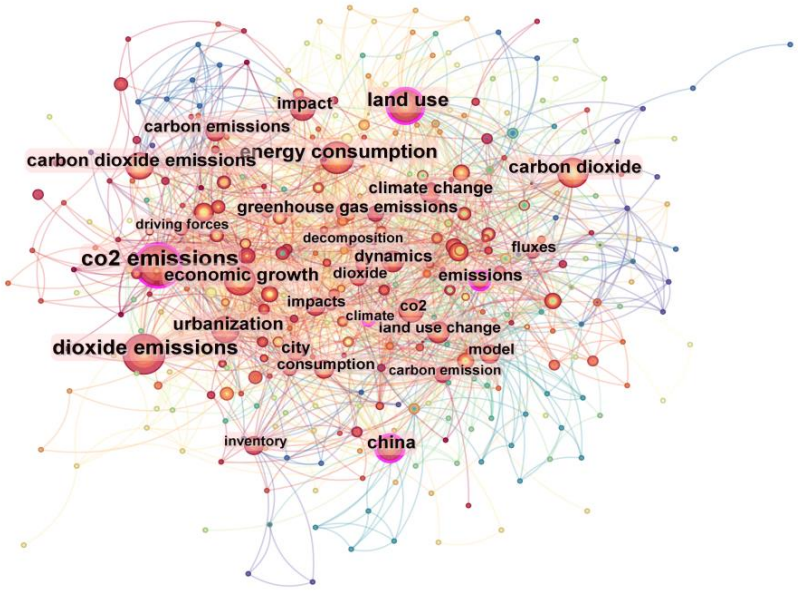

Figure 2. Keywords co-occurrence network diagram

Table.3. Top 20 keywords with co-occurrence times

Sort	Frequency	Centrality	Age	Keyword
1	143	0.09	2011	co2 emissions
2	92	0.05	2015	dioxide emissions
3	86	0.05	2011	land use
4	83	0.06	2014	energy consumption
5	63	0.03	2011	carbon dioxide
6	57	0.09	2012	carbon dioxide emissions
7	54	0.04	2014	economic growth
8	53	0.01	2015	urbanization
9	50	0.03	2013	china
10	45	0.11	2011	emissions
11	44	0.04	2012	climate change
12	44	0.04	2015	impact
13	42	0.03	2015	carbon emissions
14	38	0.03	2014	dynamics
15	38	0.01	2014	greenhouse gas emissions
16	36	0	2015	city
17	34	0.03	2014	impacts
18	33	0	2017	co2
19	33	0.11	2014	land use change
20	30	0.04	2014	consumption

5.2. Keyword cluster analysis

Keyword clustering analysis is a process of simplifying the co-occurrence network relationship of keywords into a relatively small number of clusters through quantitative text mining technology and clustering statistics. By constructing the cluster pedigree of research topics, we can effectively identify the dynamic evolution characteristics of the frontier of disciplines and provide quantifiable theoretical support for the prediction of the development trend of emerging technologies.

Keywords Co-occurrence network view (Figure 3) covers a large area, and the interwoven network highlights the characteristics of its extensive research. There are 9 categories of keywords, which are in descending order: carbon emission, method, dioxides, carbon budget, spatial pattern, ensemble, carbon dioxides removal, air polarization, carbon dioxides emission and carbon sequestration.

Cluster words such as carbon emission, method, carbon budget and air polarization indicate that greenhouse gas control, carbon emission measurement, environmental management and energy conservation and emission reduction are the core research directions of the neighborhood, and "spatial pattern" and "carbon sequestration" highlight the research attention to the spatial pattern of land use and carbon sequestration technology. In addition, "ensemble" reflects the trend of model integration, and the high-frequency word "carbon dioxide removal" indicates that negative emission technology is an important direction for the development of emerging technologies in the future. The wide coverage and interweaving of keyword co-occurrence network reflects that the research covers environmental science, geography and economics, and embodies the interdisciplinary characteristics.

Based on the background of carbon emissions, the literature contents and key words of land use in China are shown in Figure 3, and the hot topic is determined as "Analysis of Spatial Effects of Land Use under the Constraints of Carbon Emissions". The purpose of this study is to promote the practical exploration of low-carbon land use model through the collaborative optimization of spatial planning and emission reduction technology, and provide quantitative basis for policy makers.

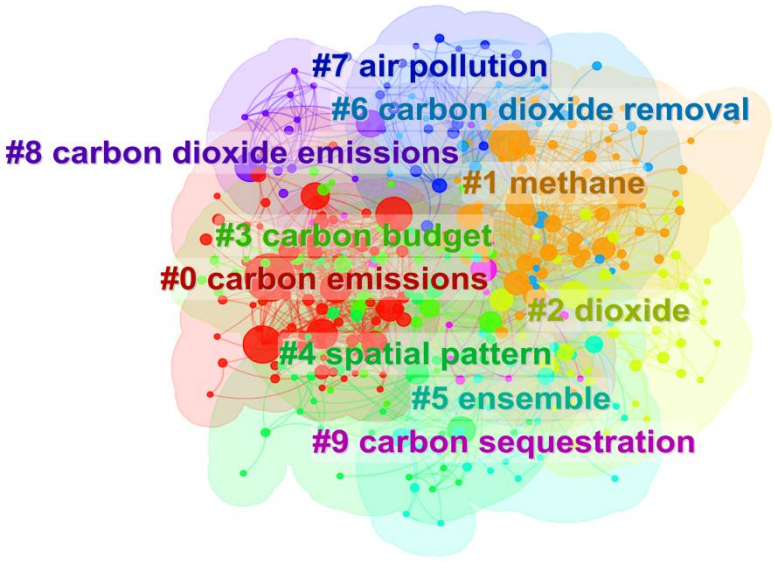

Figure 3. Keywords co-occurrence clustering network diagram

5.3. Analysis of emergent words

Emerging terms refer to the discipline-specific keywords that show a significant growth trend within a specific time window. Their frequent appearance can effectively represent the academic frontier dynamics and evolution trends of a certain research field during a specific period, and can be used as an important indicator for quantitatively analyzing the development context and research hotspots of a discipline. Twelve emerging terms in the field of land use from 2011 to 2024 were extracted in Citespace. By combining their intensity and duration, the research focus and policy-driven effects in the field of carbon emissions and land use can be revealed (Table 4). The top five

keywords in descending order of prominence are: "temperature", "energy consumption", "respiration", "economic growth", and "panel data analysis". During the corresponding time periods, they constitute the core concerns and focus issues in the field of land use research. According to the time dimension, the evolution of emerging term hotspots can be divided into three stages: (1) The period dominated by natural processes (2011-2016): with "temperature" and "respiration vegetation" as the core, the focus was on the regulatory mechanism of land use types (such as farmland and forest) on the carbon cycle. (2) The period driven by social and economic factors (2017-2019): "energy consumption" and "economic growth" showed significant prominence, reflecting the contradiction between the expansion of construction land and industrial carbon emissions caused by rapid urbanization, and focusing on the collaborative emission reduction path of land intensive use and industrial upgrading. (3) The period of deepening policy response (2020-2024): "CO2 emission" and "driving factors" became new hotspots, directly responding to the "Action Plan for Carbon Peaking Before 2030" (2021), and the "National Spatial Planning Outline (2021-2035)" emphasized the supporting role of optimizing national spatial planning for carbon neutrality, reflecting the trend of multi-disciplinary cross-research under the "dual carbon" goals.

The research on carbon emission from land use in China presents a three-stage evolution of "natural process → social economy → policy optimization", which is deeply coupled with the "double carbon" strategy. It will be a hot research topic to explore the driving factors of land use in China under the background of carbon emission and analyze the driving path of carbon emission reduction in land system.

Table.4. The top 12 keywords with the most frequent citations

Keyword	Year Of First Appearance	Disappearing Year	Intensity
Temperature	2012	2016	5.19
Respiration	2011	2016	3.90
Water content	2011	2016	3.26
Vegetation	2012	2016	2.97
Temperature sensitivity	2012	2016	2.78
Soil respiration	2011	2019	2.71
Greenhouse gas emissions	2014	2016	3.00
Energy consumption	2017	2019	4.70
Economic growth	2017	2019	3.61
Panel data analysis	2017	2019	3.43
CO2 emission	2019	2022	2.75
Driving factors	2022	2024	2.81

6. Conclusion

This study systematically combs the research trends in the field of land use in China under the background of carbon emissions, and reveals the research trends, cooperation networks and hot topics in this field. Overall, the research results of this paper are as follows:

(1) The research trend is remarkable in stages. From 2011 to 2024, the research in this field can be divided into four stages: initial stage, steady growth stage, fluctuation adjustment stage and rapid growth stage.

(2) The academic cooperation network is loose. Although the core scholars such as Ciais Philippe, Wang Shaojian and Chinese Academy of Sciences are highly productive, the degree of cooperation among scholars is low, the centrality is generally close to zero, and the inter-agency cooperation network is not closely related, which restricts knowledge sharing and collaborative innovation.

(3) Research hotspots are interdisciplinary, and keywords such as "land use", "spatial effect", "carbon dioxide emission" and "economic growth" appear in keyword co-occurrence and cluster analysis, which indicates that the research topic covers the spatial effect of land use and the driving mechanism of regional environment under the constraint of carbon emission, and embodies the

characteristics of multi-disciplinary integration such as ecology, economy and geography. The emergent words "vegetation", "economic growth" and "driving factors" further reveal the evolution path of research focus from natural process to socio-economic drive and policy response.

(4) In terms of policy and practical significance, the research results echo the strategic demand of "double carbon" in China, which provides theoretical support for land space optimization, regional coordinated emission reduction and low-carbon land use mode, and also provides reference for policy makers to integrate multidisciplinary achievements and strengthen inter-agency cooperation.

In the future, the following three areas deserve further study and reflection: (1) Deepening interdisciplinary and inter-institutional cooperation. At present, the cooperation network between scholars and institutions is relatively loose. It is suggested that regional research alliances or academic exchange platforms should be established to promote the collaborative cooperation among scholars, universities, research institutes and government departments at home and abroad. (2) Strengthen dynamic monitoring and long-term effect evaluation. A dynamic monitoring system of carbon emission from land use is constructed, and the temporal and spatial evolution of carbon content is tracked by combining remote sensing technology with ground observation data. At the same time, pay attention to the long-term impact of uncertain factors such as extreme climate and population movement on carbon emissions from land use, and improve the forecasting model and risk early warning mechanism. (3) Focus on emerging hot spots and policy responses. Following the strategic orientation of "double carbon", we will focus on the optimization of land space, urban green renewal and other fields, and explore the low-carbon transformation under the framework of "nature-society-policy" to help China achieve the goal of carbon neutrality.

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