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Research progress on agricultural carbon sequestration: bibliometric analysis based on Citespace

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ABSTRACT

To understand the research frontiers and progress of agricultural carbon sequestration, based on the core database of Web of Science, the current research status, research hotspots and trends were analyzed by bibliometric analysis method. The results show that after 2010, the number of papers published on the agricultural carbon sequestration has exploded. From the perspective of discipline distribution, agricultural carbon sequestration research mainly involves environmental ecology, agronomy, atmospheric science and plant science. From the perspective of international cooperation, China and the United States are the countries with a large number of publications, and the research of American scholars is more closely related to that of other countries, thus occupies a core position in this research field. The Chinese Academy of Sciences, the US Department of Agriculture and the Canadian Agri-Food Research Institute are the largest contributors to the agricultural carbon sequestration research field, with institutions in Asia and Europe leading this research field. In terms of influence, LAL, R., SMITH, P., and PAUSTIAN, K. are the top three highly cited scholars. Global Change Biology, Science and Nature are the top three most cited journals. From the research content, the basic principles and measures of agricultural carbon sequestration, the evaluation system of agricultural carbon sequestration and the policy standards of agricultural carbon sequestration are the research hotspots. International research hotspots include "soil carbon sequestration", "soil organic matter" and "crop rotation".

Keywords: agricultural carbon sequestration; agricultural carbon sink; Citespace; bibliometric analysis; research progress

1. INTRODUCTION

Emissions of greenhouse gases (GHGs) are the most important driver of human-induced climate change. In fact, the agricultural, forestry, and fisheries sectors accounted for approximately 4 percent of Japan’s total JFY2018 GHG emissions[1]. 11% of total European GHG emissions derive from agriculture (EU NIR, 2021)[2]. It is recognized that agriculture is the second largest contributor to Australian greenhouse gas (GHG) emissions by 14%[3]. Mitigation in the agricultural sector will be essential to keep the goal of limiting global warming to 1.5 ◦C within reach[4]. For the agricultural sector, the objective is to reduce emissions by 31%–34% relative to emissions in 1990. Since its climate change mitigation potential is derived from both an enhancement of removals of GHGs from the atmosphere, and a reduction of emissions through management of land, crops and livestock[5]. The Land Use, Land Use Change and Forestry (LULUCF) sector is expected to play an even greater role, as these temperature stabilisation targets are unlikely to be met without significant removals ofCO_2 from the atmosphere[6]. In the United States, Greenhouse gas emissions from agriculture come from livestock such as cows, agricultural soils, and rice production account for 10% of 2021, while the land use and forestry was offsets 12% of 2021 greenhouse gas emissions[7]. Specifically, the IPCC's

model pathways that limit global warming to 1.5 ◦C with no or limited overshoot include substantial reductions in agricultural GHG emissions, a reduction from 11% to 30% in CH_4 emissions, and −3% to 21% reduction in N_2O emissions by 2030[8]. Agriculture is both a carbon source and a carbon sink, so based on the carbon sequestration in agriculture, reducing and mitigating/removing agricultural carbon emissions has become a major issue that urgently needs attention and solution. Clearing up the research progress of agricultural carbon sequestration is the prerequisite and basis for determining the future research direction and guiding future agricultural carbon reduction.

Scholars have actively responded to the goal of addressing climate change, and have carried out extensive research around agricultural carbon sequestration. There are five literature review on agricultural carbon sequestration., including forest / agroforestry carbon sequestration[9], global greenhouse gas emissions from aquaculture[10], agricultural soil organic carbon[11], agricultural lands/cropland[12]. A few studies explored climate change and carbon sink[13], influencing factors of agricultural carbon sequestration[14], mechanism of agricultural carbon sequestration[15].The existing literature review presents two characteristics. On the one hand, it is mainly qualitative analysis and content review, which is highly subjective, on the other hand, it mainly focuses on a specific aspect of agricultural carbon sequestration. However, for a comprehensive and systematic review of carbon sequestration in agriculture, a sufficient amount of text is required. Often hundreds, for example, 500 or more, or thousands of papers are necessary. For the traditional qualitative analysis and content review, the systematic analysis of large samples is more difficult. Therefore, this paper intends to use bibliometric analysis and citespace tool to review relevant studies on agricultural carbon sequestration. Citespace software can systematically analyze information such as author, institution and keywords. Compared with traditional methods, citespace has the advantages of more objective results and more comprehensiv content. By using citespace software, this paper intends to visually analyze the status quo, hot spots and trends of global agricultural carbon sequestration, as well as forecast the future research direction to provide reference for subsequent research.

The following section is the description of the citecpace methods and the data for analysis in this study. Next, we present the results of the citecpace analysis. Then, following the discuss section with the contents about basic measures and principles of agricultural carbon sequestration, evaluation system and policy standards. Finally, we explain the conclusions and contributions of this research.

2. MATER IALS AND METHODOLOGY

2.1 Bib l iometr ic Analys is Method

Bibliometrics is a method to study literature information, which uses statistics and computer science to quantify and analyze the literature to reveal the characteristics, trends and academic value of the literature. Common analysis tools include endnote, zotero, citespace, etc. This paper uses citespace for bibliometric analysis, which includes the following steps. First, determine the research object, then determine the search terms and search the database, at the same time collect literature data and process the work, on this basis, conduct statistical analysis, and finally write the article.

2.2. Data Acqu is it ion

The database of literature retrieval comes from the core database of Web of Science. By inputting "Agricultural carbon sequestration, Agricultural carbon sink, Agriculture" as the search topic, meanwhile taking Web of Science core collection as the journal source. The language used is "English". The search method is "Highly relevant", and the articles with high citations are screened. By deleting irrelevant literature and merging synonyms, a total of 568 articles from January 1996 to October 2023 were retrieved. The samples were published in 221 journals and cited 32,406 times, mainly in the fields of Environmental Science Ecology, Agriculture, Meteorology Atmospheric Sciences and Plant Sciences. The 2,971 authors are from 1,943 institutions in 243 countries.

3. THE ACADEMIC FRONT IERS OF AGR ICU LTURA L CARBON SEQUESTRAT ION

3.1 Pub l icat ion Quantity Analys is

The number of articles on agricultural carbon sequestration increased only slightly between 1996 and 2009, according to publication statistics available at Web of Science. But after 2010, there was an explosion of the relevant research and reached its peak in 2022. This shows that the study of agricultural carbon sequestration has gradually become a hot issue. The changes in the number of studies are shown in Figure 1.

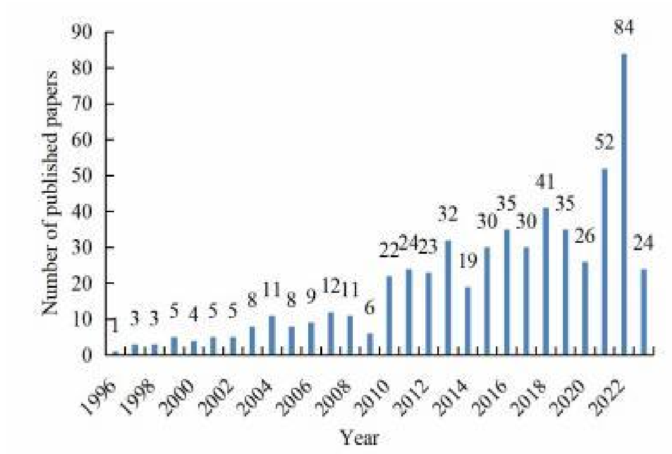

Fig. 1 Distribution of publications

3.2 Cooperat ive Re lat ionsh ip Ana lys is of Agr icu ltura l Carbon Sequestrat ion

3.2.1 Network of Co-authors' Countries

The top 10 countries with the highest number of agricultural carbon sequestration publications and their centrality and starting years showed in Table 1. The United States, Canada, the United Kingdom and Sweden are the early countries in agricultural carbon sequestration research, and their relatively high centrality indicates that these countries are leading the research in this field. The countries with the largest number of articles are China and the United States, with 172 and 155 articles respectively. The centrality of the United States is much higher than that of China, at 0.33 and 0.19 respectively. This shows that the research of American scholars is more closely related to that of other countries and occupies a core position in this field.

Table1 Top 10 countries in agricultural carbon sequestration research

Rank	Country	Count	Centrality	Starting year
1	PEOPLES R CHINA	172	0.19	1998
2	USA	155	0.33	1997
3	CANADA	59	0.09	1997
4	AUSTRALIA	54	0. 14	2001
5	ITALY	38	0. 12	2004
6	SPAIN	36	0.07	2007
7	INDIA	36	0.02	2002
8	ENGLAND	30	0.13	1997
9	SWEDEN	30	0. 1	1997
10	GERMANY	29	0.09	2001

3.2.2 Network of Co-authors' Institutions

The top 10 institutions in agricultural carbon sequestration research publications showed in Table 2. Chinese Academy of Sciences (China) is ranked 1 in the agricultural carbon sequestration area (with 59 publications and 0.22 centrality). The subsequent institutions are United States Department of Agriculture (The United States) and Agriculture & Agri Food Canada (Canada), with the 25 and 22 publications, and 0.19 and 0.18 centrality respectively. From Table 4 we can see, institutions in the China still occupy the leading role, while institutions in Russia are also improving. The amount of influential institutions located in Asia and Europe both are 4, while the amount of influential institutions located in North America is 2. This reflects institutions located in Asia and Europe take the leading position in this field.

Table 2 Top 10 institutions in agricultural carbon sequestration research field

Rank	Institution	Count	Centrality	Starting year
1	Chinese Academy of Sciences	59	0.22	1998
2	United States Department of Agriculture	25	0.19	1999
3	Swedish University of Agricultural Sciences	24	0.06	1997
4	Chinese Academy of Agricultural Sciences	23	0.05	2002
5	Agriculture & Agri Food Canada	22	0.18	1997
6	University System of Ohio	21	0.13	1997

7	Ohio State University	19	0.06	1997
8	Ministry of Agriculture & Rural Affairs	18	0.06	2008
9	Indian Council of Agricultural Research	16	0.06	2006
10	Commonwealth Scientific & Industrial Research Organization	15	0.09	2008

3.3 Co-Citat ion Analys is of Agr icu ltural Carbon Sequestrat ion Research

3.3.1 Author Co-Citation Analysis

To detect influential authors in the research field, the top 10 cited authors in the agricultural carbon sequestration area are listed in Table 3. As can be seen, LAL, R., ranked first with 243 citations, followed by SMITH, P., with 138 citations. They are among the most representative of the pioneers of carbon sequestration in agriculture. Lal, R., & Kimble, J. M. (1997) pointed out that an important goal of sustainable management of soil resources is to increase soil organic carbon (SOC) pool by increasing passive or unstable components, and soil surface management, soil and water conservation management and soil fertility regulation are important aspects of soil carbon sequestration. Therefore, the importance of carbon sequestration should be assessed based on SOC content in soil quality evaluation[16]. SMITH, P., & POWLSON, D. S. (2000) proposed that other by-products from animal husbandry and human life, such as manure and sewage sludge from production and life, could be used toincrease soil organic matter (SOM) levels, thereby improving the efficiency of carbon sequestration. Their views challenge Schlesinger's comments that the application of organic fertilizer is not useful for net carbon sequestration. Other highly cited authors include PAUSTIAN, K. (81 articles), SIX, J. (78 articles), HOUGHTON, R. A. (74 articles), POST, W. M. (65 articles), WEST, T. O. (64 articles), SCHLESINGER, W. H. (59 essays), BATJES, N. H. (48 essays) and DAVIDSON, E. A. (43 essays). Through comparison of centrality, it can be found that HOUGHTON, R. A. (0. 13) and BATJES, N. H. (0. 13) are relatively high, indicating that their research has a greater influence in this field. Among them, HOUGHTON, R. A. in an early representative article “Terrestrial carbon storage: global lessons for Amazonian research” comprehensively summarizes and compares five methods for determining net carbon exchange between terrestrial ecosystems and the atmosphere[17] . BATJES in the article "Mitigation of atmospheric CO_2 concentrations by increased carbon sequestration in the soil" proposes various options for the sustainable sequestration of soil carbon through adaptive management of land resources, i.e. the conversion of atmospheric CO_2 into stable humus sequestration in soil[18].

Table 3 Top 10 frequently cited authors in agricultural carbon sequestration research field

Rank	Author	Citation	Centrality	Starting year
1	LAL, R.	243	0.24	1997
2	SMITH, P.	138	0.18	2000
3	PAUSTIAN, K.	81	0. 12	2000
4	SIX, J.	78	0.10	2006
5	HOUGHTON, R. A.	74	0.13	1997
6	POST, W. M.	65	0.05	1997
7	WEST, T. O.	64	0.05	2005
8	SCHLESINGER, W. H.	59	0.05	2000
9	BATJES, N. H.	48	0.13	1998
10	DAVIDSON, E. A.	43	0.06	2001

3.3.2 Journal Co-Citation Analysis

Table 4 lists the 10 most popular journals in agricultural carbon sequestration area from 1996 to 2023 by total citations. The top 3 citations are Global Change Biology, Science and Nature, with 359, 311 and 277 citations, respectively. However, in terms of centrality, Agriculture Ecosystems & Environment topped the list at 0.06, the second is Soil & Tillage Research, which is 0.04. Science and Global Biogeochemical Cycles ranked third, both at 0.03. In terms of publication time, Agricultural Ecosystems & Environment published the earliest studies on carbon sequestration in agriculture in1996, and followed by the Science, Nature, Soil Science Society of America Journal and Soil & Tillage Research. Second in 1997.

Table4 Top 10 frequently cited journals in agricultural carbon sequestration research field

Rank	Journal	Citation	Centrality	Starting year
1	Global Change Biology	359	0.02	1999
2	Science	311	0.03	1997
3	Nature	277	0.02	1997
4	Agriculture Ecosystems & Environment	271	0.06	1996
5	Soil Science Society of America Journal	245	0.01	1997
6	Geoderma	242	0.02	2001
7	Plant And Soil	201	0.01	1997

8	Soil & Tillage Research	200	0.04	1997
9	Soil Biology & Biochemistry	193	0.02	2002
10	Global Biogeochemical Cycles	180	0.03	2000

3.4 Cluster Ana lys is of the Keywords

The sorting algorithm Log-likelihood ratio (LLR) was used to extract words from literature titles as clustering identifiers. Cluster identification is automatically generated, which can objectively reflect the research hotspot in the field of agricultural carbon sequestration, but often presents obvious concrete characteristics, which is difficult to directly reflect the research hotspot. Therefore, according to the clustering results of citespace 6.2 and the topics involved in the clustering literature, this paper selects clusters with more than 20 cluster literatures (Figure 2) and summarizes the following three research hotspots.

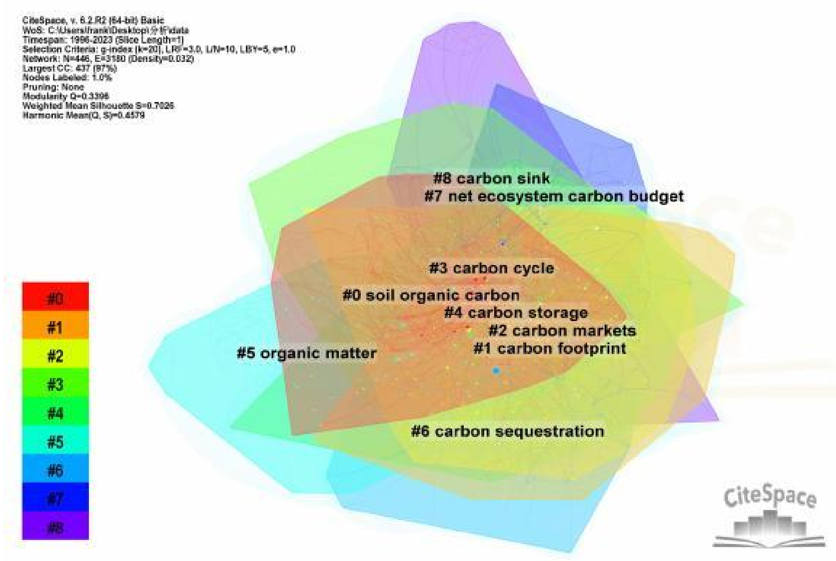

Fig.2 Cluster of keywords in agricultural carbon sequestration research

3.4.1 The Research of Principles and Measures of Agricultural Carbon Sequestration

The clusters related to this area include clusters #3 carbon cycle, #4 carbon storage, #6 carbon sequestration, and #8 carbon sink. cluster #3 carbon cycle has 48 members with a silhouette value of 0.729. The basic principles of carbon cycling in different crops and agricultural practices are discussed from the perspectives of decomposition, stabilization, conservation agriculture, carbon budget, forest management, crop management, climate extremes, carbon saturation and carbon neutrality[19] . The common approach is science-based computer simulation[20] .

Cluster #4 carbon storage has 41 members with a silhouette value of 0.788. This cluster highlights the importance of future soil carbon sequestration for sustainable agriculture and climate change from the biomass, climate change mitigation, land management, sustainable development, environmental impacts, climate-smart agriculture, climate policy and vegetation carbon stocks perspective[21] . Previous studies highlight the contribution of land management and climate-smart agricultural practices in effectively reducing carbon emissions from agricultural processes and increasing carbon storage in agricultural systems. At the same time, some studies believe that forest area, storage volume and coverage rate, as the decisive factors of forest carbon sink, are also a huge source of carbon sink. Therefore, agricultural carbon sinks should be combined with forestry carbon sinks, a measure that will further improve the efficiency of carbon sinks[22].

Clusters #6 carbon sequestration and #8 carbon sink have 29 and 23 members, respectively. Their silhouette values were 0.805 and 0.889, respectively. These two clusters further discuss the basic principles and measures of agricultural carbon sequestration. Cluster #6 carbon sequestration based on food security, cultural land, land-use change, soil properties, geographical distribution, biological activity and carbon-uptake costs emphasize the principle of biochemical processes that naturally remove carbon from the atmosphere through soil and plants. Carbon sequestration through the humus of biosolids and crop residues added to the soil and the dissolution of CO_2 to form secondary carbonates [15], as well as through the accumulation of humus on the surface of the soil (usually 0.5 to 1 m deep), or artificially sequestered in soils through land use change or through recommended Management Practices (RMPs) in agricultural, livestock or forest ecosystems[23] .

Cluster #8 carbon sink covers a much broader scope of discussion. The occluded carbon, biological control, agricultural ecosystem, conservation reserve program, as well as forest-agriculture trade-offs further explain the principle of biochemical carbon sequestration, and emphasize the methods and means of innovating land use patterns and planning.

3.4.2 Agricultural Carbon Sequestration Evaluation System

Cluster #0 soil organic carbon, #1 carbon footprint and #5 organic matter indicate the evaluation system of agricultural carbon sequestration. Cluster #0 soil organic carbon has 84 members with a silhouette value of 0.609. The cluster proposes strategies to improve soil carbon capture and storage from dimensions of soil carbon sequestration, storage, management, soil organic carbon, dynamics, organic carbon, stocks, land use change, accumulation, crop rotation, cropping systems, conservation tillage. These strategies include fertilization, conservation tillage (minimal tillage, no-till/no-till), carbon capture, carbon utilization and storage, crop residue management, mulch planting, application of inorganic fertilizers, rotational grazing, perennial tillage systems, management practices, etc. [24],which provide the basis for systems to assess organic carbon sinks.

Cluster #1 carbon footprint has 69 members and a silhouette value of 0.578. This cluster presents methods and indicators to measure the carbon footprint of crop production from perspectives of greenhouse gases, ecosystem services, terrestrial ecosystems, cropping system, global warming, temperature, plant diversity, biomass production, environmental impact[25] . Life cycle assessment method is commonly used in this field[26] .

Cluster #5 organic matter has 35 members with a silhouette value of 0.810. The literature of this cluster mainly focuses on the factors of agricultural soils, cultivation, conventional tillage, mineral soils, grassland management, deforestation. It is mainly divided into natural factors (climate, soil parent material, land cover and/or vegetation and topography) and human factors(land use, management and degradation)[27] . These factors further complement the evaluation index of agricultural carbon sequestration.

3.4.3 Research on Policy of Agricultural Carbon Sequestration

Cluster #2 carbon markets and #7 net ecosystem carbon budget focus on the discussion of policy for carbon sequestration in agriculture. Cluster #2 carbon markets has 65 members with a silhouette value of 0.635. It mainly puts forward the agricultural carbon credit project policy from the perspectives of climate change, soil carbon, eddy covariance, ecosystems, net ecosystem exchange, grassland, carbon balance and dioxide exchange. The policyies including forestry carbon sequestration projects, biogas carbon reduction, wetland carbon sequestration.

Cluster #7 net ecosystem carbon budget has 28 members with a silhouette value of 0.778. It discusses the input and output processes of carbon balance in a state system, the difference of which is net ecosystem productivity from the persperctives of greenhouse gas emissions, fertilization, cropland, water use efficiency, sustainable agriculture, agricultural management practices, agronomic assessment[28] . Land use optimization plays

an important role in realizing regional carbon balance[29]. Compared with natural ecosystems such as grassland and forest, the carbon balance of farmland ecosystem is not only affected by natural factors such as climate and soil properties, but also by human factors such as agricultural management measures[30]. At present, the research on carbon balance of farmland ecosystem mainly focuses on planting patterns[31], tillage practices[32], water and fertilizer management[33], straw turnover[34] .

4. EVOLUT ION TREND ANALYS IS OF AGR ICU LTURA L CARBON SEQUESTRAT ION

4.1 Historical Development Track of Agricultural Carbon Sequestration

The analysis of emergent words can help us understand the change of research hotspot in this field[35] . The keyword emergence map (Table 5) has a total of 9 emergent words, including soil organic matter, crop rotation,carbon dioxide, forest, CO2, soil carbon sequestration, forests, stocks and climate change mitigation, which mainly appeared for the first time between 1996 and 2007. Soil carbon sequestration, soil organic matter and crop rotation have relatively high emergent intensity, which indicates that these emergent words are hot topics in a certain period of time. The relatively long duration of the four words carbon dioxide, soil organic matter, crop rotation and soil carbon sequestration indicates that they have received continuous attention from the academic community in a certain period of time. The keywords stocks and climate change mitigation continue until 2023, indicating that agricultural carbon efficiency will remain a hot issue.

Table5 Keywords with stronger citation bursts in different periods

Rank	Keyword	Strength	Begin	End	1996 - 2023
1	soil organic matter	5.99	1996	2007	
2	crop rotation	5.00	1997	2006	
3	carbon dioxide	3.43	1997	2015	
4	forest	3.46	2004	2005	
5	CO2	3.7	2006	2010	
6	soil carbon sequestration	6.09	2007	2014	
7	forests	3.38	2015	2019	
8	stocks	3.94	2020	2023	
9	climate change mitigation	3.38	2021	2023	

4.2 Prospect of Frontier Fields of Agricultural Carbon Sequestration

4.2.1 Bas ic Pr inc ip les and Measures of Agr icu ltura l Carbon Sequestrat ion

The process of soil carbon sequestration involves three basic mechanisms including the formation of soil micro-aggregates, its long-term stability, and improvement in soil structure with the deep placement of SOC in the sub-soil layers[36], These processes are commonly addressed as physical and chemical mechanisms[15] . The illuviation as well as translocation of C into sub-soil layers is another important mechanism. Carbon fixation in the cropland ecosystem is a very complex process, which is affected and restricted by the climate, cropping system, soil properties, farmland management, and other factors. Strategies to improve soil carbon capture and storage include fertilization, conservation agriculture (low till, zero till/no till), crop stubble management, irrigation and fertilization; straw returning, mulch planting, farm manure; apply inorganic fertilizer; crop rotation; rotation grazing; perennial planting system; crop variety improvement[37] .

At present, soil carbon (C) sequestration projects are rare in C markets. One concern surrounding soil C is uncertainty regarding the permanence of newly sequestered soil C. This scientific uncertainty is exacerbated by differences in terminology used by scientists and policymakers, which impedes the integration of new scientific findings regarding soil carbon longevity into evidence-based policies[38] . Additionally, there is much uncertainty and debate, as to the total potential of agricultural soils to store additional carbon, the rate at which soils can accumulate carbon, the permanence of this sink, and how best to monitor changes in SOC stocks. What more, most reported SOC stock increases under CA are overestimates because of errors introduced by inappropriate soil sampling methodology [39]At present, the study on the mechanism of SOC fixation has entered a relatively micro- level of soil particles. However, there are few studies on the existing state, binding form, and the related fixation mechanism of SOC in aggregates. The design of rationally optimized agricultural management measures to achieve maximum carbon sequestration potential remains to be studied further. The future research efforts should also be devoted to develop monitoring and verification protocols for C sequestration which will assist economists and policy makers to assess economic value of soil C and formulate right policies[37] .

4.2.2 Evaluat ion System of Agr icu ltural Carbon Sequestrat ion

The analysis of agricultural soil carbon storage mainly includes field sampling method, model method, micrometeorology method and remote sensing method[40] . Compared with the chemical equation of crop respiration,

the error of calculating agricultural carbon sink is too large. It is a more accurate and widely used method to calculate the carbon sink of different crops by using the net primary productivity formed by crop photosynthesis and combining the indexes such as crop yield, economic coefficient, root shoot ratio, carbon content and water coefficient into the formula[41] . This method is used to calculate agricultural vegetation carbon storage based on main crop types. Although there are insufficient errors caused by incomplete statistics, it still does not affect its important position in the agricultural carbon sink accounting field. Traditional methods of wet digestion and dry combustion (DC) are extensively used for routine laboratory analysis[42] . Spectroscopic techniques can measure SOC stocks in laboratory and in-situ even up to a deeper depth[43] . At the ecosystem level, carbon balance can be estimated directly using the eddy-covariance approach and indirectly by employing agricultural life cycle analysis(LCA)[44] . While, as an emerging method for measurement of C sequestration in soil, accounting soil carbon change using agricultural LCA method needs reliable SOC data in agricultural ecosystems, which can be achieved by using suitable modelling or measurement techniques. These methods could provide the basis for the global soil information system ， whiles many of the methods discussed have their own undisputed advantages.

In fact, agricultural carbon sink accounting is difficult, carbon sink methodology is not perfect. Broad agriculture covers the four major industries of agriculture, forestry, animal husbandry and fishing, and each industry is also subdivided into various crops. At present, the carbon sink accounting system of forest and grassland industry is relatively perfect, while the carbon sink coefficient of other industries is difficult to grasp. Different from forestry, agriculture has a high utilization rate of fertilizers, pesticides and agricultural machinery in the production process, and large carbon emissions in straw recycling, so it is difficult to accurately calculate agricultural net carbon sink[45]. To explore the path of carbon sink marketization, regional/local carbon sink accounting system and methodology have been introduced, but there is a lack of international and national standards. Therefore, it is necessary to establish a unified agricultural carbon sink evaluation system and scientific accounting methods. Developing the accounting methodology of agricultural carbon sink projects in different regions, improving the accounting methodology of planting carbon sink, establishing the accounting methodology applicable to different crops, and determining the baseline situation of different crops, additional sinks, carbon sink measurement methods and monitoring procedures are one of the emphases of agricultural carbon sink development in the future[46] .

4.2.3 Pol ic ies for Agr icu ltur ial Carbon Sequestrat ion

Since the beginning of the 21st century, a series of policies and rules have been introduced internationally to encourage soil carbon sequestration. FAO launched the SOC Growth Initiative, which aims to promote sustainable agricultural development and mitigate climate change by increasing SOC content in 2009. The UNFCCC agreed to the Paris Agreement, which includes the goal of mitigating climate change through soil carbon sequestration in

2015. The Article 6 agreement reached at the United Nations Climate Change Conference in 2021 sets out rules for the international sale of credits, thereby stimulating investment in land-based climate mitigation projects. In the European Union, a new round of reform of the Common Agricultural Policy plans to increase subsidies for "carbon farming". In addition, the list of specific agricultural practices published by the EU also includes "conservation agriculture" — no-till farming. Meanwhile, in its Farm-to-Fork strategy, launched in May 2020, the European Commission has identified carbon storage on agricultural land as a "new business model" for farmers. In the United States, moves are underway to provide financial incentives for carbon storage on agricultural land, a "carbon bank" championed by the new Biden administration[47] . In 2021, the U.S. Senate passed the Climate Solutions Act, which aims to help farmers benefit from a market system that incentivizes climate-friendly agricultural practices.

Agricultural carbon sequestration policy is one of the important means to promote the transformation of low- carbon economy, which has been widely practiced and applied in some countries. The EU mainly implements carbon sequestration projects in agriculture and forestry, including areas such as green energy, land use change and forestry. By developing a carbon emission quota trading system, the EU provides carbon trading opportunities for farmers and forestry operators, encourages farmers to participate in carbon sink projects, and achieves carbon reduction and carbon sink increase[48] . The United States mainly implements the agri-climate solutions program, including land management, climate change adaptation, energy conservation and emission reduction measures. The U.S. government provides subsidies and incentives to farmers, encourages farmers to participate in climate solutions programs, and provides economic incentives to farmers, including through carbon trading markets[49] . Japan mainly implements carbon abatement agriculture, including promoting fertilizer free cultivation, increasing vegetation, improving soil. By providing funds and technical guidance, Japan encourages farmers and agricultural enterprises to implement carbon emission reduction agriculture, and promotes the development of agricultural carbon sink projects[1] . China mainly implements this through land use change and forestry carbon sequestration projects, including afforestation and returning farmland to forest and grassland. The Chinese government encourages farmers and forestry enterprises to participate in carbon sequestration projects by issuing carbonemission reduction quotas, incentives and subsidies, and promotes the implementation and development of agricultural carbon sequestration policies[50] .

Due to the complexity, variability and spatial heterogeneity of agricultural carbon sequestration, the policies and research of countries are mainly carried out at the regional, national and regional levels, and there is a lack of international unified policy standards. In addition, the number of climate mitigation policies in the agriculture sector is less compared to the energy, transport and buildings sectors[51] . Therefore, to achieve the goal of agricultural carbon sequestration to mitigate climate change, future policymakers and researchers should focus on the two aspects. first, to develop more strategies and plans related to agricultural carbon sequestration, as well as legal and regulatory tools; The second is to establish a larger scale, even global agricultural carbon sequestration standards, and accelerate the realization of global agricultural carbon sink credit transactions, so as to accelerate the transformation of the global low-carbon economy and promote sustainable economic development.

5. Conclus ion

Based on the description and statistics of agricultural carbon sequestration literature on Web of Science, it is found that the research on agricultural carbon sequestration shows an increasing trend year by year and has become a highly concerned research field. The research direction of relevant literature is mainly ecological environmental science and agricultural science, showing the interdisciplinary characteristics of agricultural carbon emission research.

Citespace co-citation network cluster analysis shows that the academic frontier in the field of agricultural carbon sequestration mainly focuses on the basic measures and principles of agricultural carbon sequestration, the evaluation system of agricultural carbon sequestration, and the policy standards of agricultural carbon sequestration.

Meanwhile, citespace's key literature analysis and emergent word analysis show that the frontier evolution of agricultural carbon sequestration has obvious context to follow. The research on farmland/soil carbon sequestration has developed from experimental research and situational research to meta-analysis based on existing measured data or existing knowledge, and then modeling research based on process models, and the research content has gradually expanded from a single study on carbon emission flux/potential and its influencing factors to carbon sequestration effects and other carbon sequestration measures. At the same time, carbon sequestration and climate change mitigation have become the focus of current research in agricultural carbon sequestration.

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