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REVIEW

Visual Analysis of Crop Rotation Fallow Patterns in Recent 5 Years Based on CiteSpace

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ABSTRACT

Based on the "Web of Science Core Collection" (SCIE database), this article used the visualization software CiteSpace to visualize and analyze the crop rotation fallow patterns in the past five years. It analyzed the countries, institutions, keywords and hot topics of related literature to explore their research characteristics and development, and to provide reference for crop rotation fallow research and practice. The research shows that: 1) developed countries are the main research force in the field of crop rotation and fallowing, and the connection between the research of each country and each institution is not close; 2) research hotspots can be mainly summarized as: crop growth and yield, greenhouse gas emissions and soil health analysis, and the research in this field is constantly refined, combining macro and micro; 3) In recent years, there is a big gap between China and foreign countries in the field of crop rotation and fallow research. It is necessary to strengthen the cooperation with research institutions in developed countries in Europe and the United States, and to carry out cross-regional and interdisciplinary research cooperation to improve the quality of papers and scientific research level.

1. Introduction

The world is generally facing coexisting problems of overcapacity, undersupply of food and degradation of arable land, which directly threaten the sustainable development of human beings [1]. In the past decades, human beings have adopted a large number of monoculture or continuous cropping patterns in agricultural fields, which led to problems such as sloppy agricultural inputs, depletion of soil nutrient production [2,3], promotion of pathogenic microorganisms and reduced biodiversity [4-7], ultimately affecting crop production and the sustainability of the soil environment. Current domestic and foreign research indicates that crop rotation fallow programs are an important means to conserve land resources, improve soil fertility and protect farmland [8], which can not only effectively alleviate crop succession barriers, but also reduce agricultural costs, protect the ecological environment and ensure crop yields [9].

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Therefore, crop rotation fallow policies are commonly implemented not only in China but also in many countries and regions such as the United States [10], Canada [11], Germany [12], Nigeria [13], Japan [14], and Australia [15].

The agricultural models of major countries in the world can be divided into the European and American models represented by Europe, the United States, Australia and Canada, etc. The European and American models are mainly characterized by large-scale, mechanized, high-tech professional farms, with medium and small family farms as auxiliaries. The East Asian model, represented by Japan and South Korea, is mainly characterized by small-scale, small mechanized, high-tech part-time farmers, supported by professional farmers [16]. The United States adopted a fallow land conservation reserve program authorized by the Food Security Act as early as 1985, with the aim of restoring soil quality on agricultural lands and improving the ecological environment [17]. The EU (European Union) first proposed a five-year voluntary fallow program in 1988 to address the problem of declining farmer incomes and surplus agricultural products [18]. Japan implemented the Rice paddy-aside program in 1970. In 1993, Japan first included fallowing as a list of targets to protect the ecological environment of farmland, and there are three main types of farmland fallowing, divided into rotational fallowing, management fallowing and permanent fallowing, of which the total fallowing area accounts for 64.6% of the total farmland area [19]. Both the European and American models and the East Asian model are shaped by economic and geographical conditions. However, in China's vast territory, the climatic and terrain conditions are complex, making the cultivation structure and agricultural patterns diverse. Crop rotation and fallowing were recorded in China as early as 2000 years ago in the Book of Songs and Rites of the Zhou, but most of the crop rotation and fallowing in the historical period belonged to spontaneous and scattered individual farmers' behavior [20,21]. However, China in 2014 for the first time proposed "agricultural resources restoration pilot" work. The crop rotation fallow was first established as a farming system in 2015. In July 2016, the Ministry of Agriculture, together with the Central Agricultural Office, jointly issued the "Pilot Program for Exploring the Implementation of Cultivated Land Rotation and Fallowing System", officially implementing a pilot program of cultivated land rotation and fallowing in some areas. The pilot areas of crop rotation fallow in China from 2016 to 2020 are 41.07 million ha, 80 million ha, 160 million ha, 166.67 million ha and 333.33 million ha [22], which shows that the pilot areas of crop rotation fallow in China keep increasing year by year and take the road of intensive agriculture.

We study the research hotspots and frontiers of crop rotation fallow at home and abroad, which is helpful to grasp the latest research progress of crop rotation fallow and provide literature reference for future research in related aspects. This paper uses the scient metric method CiteSpace to visualize the scientific knowledge map, and analyze the current development and research frontiers in the field of crop rotation and fallowing models at home and abroad in the past five years, using "crop rotation and fallowing" as the theme word. We present information about the main studies at the level of the number of articles published in the study countries, research institutions, and keywords, and read the literature for an in-depth analysis of research hotspots.

2. Data Sources and Analysis Methods

In this article, data in the field of crop rotation fallow were obtained from the web of science database, Analysis of international trends and research hotspots in the field of crop rotation fallow research in the WoS database, using the topic "crop rotation fallow" and the time frame "last five years ", with the search formula: topic= ("crop rotation fallow"). Type of document is "Article", after searching and screening conference proceedings, book chapters, etc., 621 valid documents were obtained (search date of November 19, 2021). Based on the information of countries, institutions and keywords in different years, we derived visual analysis mapping, and organized and elaborated the data in Excel to analyze the development trend of international and domestic crop rotation fallow models in terms of the number of papers and research topics.

3. Results

3.1 Analysis of Major International Research Countries

We obtained a web-based mapping of the number of articles published on crop rotation fallow in each country between 2017 and 2021 through a literature search in Citespace software (Figure 1 and Table 1). The circle size and font size indicate the number of articles published by each country in the field of crop rotation and fallow, and the larger the circle and font size indicate which country published the most. According to the statistics, 72 countries have published articles on "crop rotation", and the countries with the largest number of articles are USA and China, with 212 and 102 articles. The top ten countries in terms of number of articles published are USA, China, Australia, Brazil, Canada, Russia, France,

Spain, India and Germany. The results of the data show that the countries with a high number of published articles are those with predominantly tropical, temperate and subtropical climates and more economically developed countries, so that climatic conditions and national economic development have some influence on crop rotation fallow systems. Secondly, except for China, Brazil, Russia and India, all other countries are developed countries, indicating that the research strength of developed countries in the field of crop rotation and fallow is obviously stronger than that of developing countries, and the number of papers in the United States is the first in the world, indicating that the United States is in the leading position in this research field.

3.2 Analysis of Research Institutions

Based on citespace software, we obtained a collaborative mapping of institutions publishing in the field of "crop rotation fallow" from 2017-2021 (Figure 2). The size of the circles and the font size indicate the number of articles published by each research institution in the field of crop rotation, with larger circles and fonts indicating which institution has published the most articles. The top ten institutions in this field are USDA ARS (United States Department of Agriculture Agricultural Research Service), Aar & Agri Food Canada (Agriculture and Agri-Food Canada), Washington State University, Chinese Acad Sci (Chinese Academy of

Table 1. Number of published articles and climate zones in the top ten countries studied

Countries	Longitude and Latitude		Main climate zone types	Number of articles published
USA	NL25° ~ 49°	WL70° ~ 130°	temperate and subtropical climate	212
China	NL3° ~ 53°	EL73° ~135°	temperate and subtropical climate	102
Australia	SL10° ~ 43°	EL112°~ 154°	tropical climate	48
Brazil	NL5° ~ SL34°	WL35° ~ 75°	tropical climate	47
Canada	NL41° ~ 83°	WL52° ~ 141°	temperate climate	41
Russia	NL41° ~ 82°	EL26° ~ 170°	temperate climate	35
France	NL43° ~ 51°	WL5° ~ EL9°	temperate climate	31
Spain	NL36° ~ 43°	WL9° ~ EL3°	etesian climate	25
India	NL8° ~ 37°	EL68°~ 97°	tropical climate	21
Germany	NL47° ~ 55°	EL5°~ 15°	temperate climate	19

Figure 1. Co-presentation map of major research countries in the past five years

Sciences), Northwest A&F Univ (Northwest Agriculture and Forestry University of Science and Technology), Kansas State University, ARS (Agricultural Research Service), Colorado State University, Montana State Univ, and Oregon State Univ. The institution with the highest number of publications is USDA ARS, with 67 publications, this indicates that there are many researches in the field of crop rotation fallow. Moreover, we found that the literature in the field of "crop rotation" is mainly published in foreign institutions compared to other countries. Moreover, we also found that the literature on "crop rotation fallowing" is mainly published in foreign institutions. In addition, according to the network mapping of cooperative institutions in this field (Figure 2), it is known that there are 208 nodes with 219 connections and a density of 0.0102, which indicates that the institutions are not closely connected with each other in the field of crop rotation and fallowing, and it is necessary to strengthen the cooperation between institutions to promote the development of crop rotation and fallowing. The analysis of the results shows that the institution with the largest number of publications in the field of "crop rotation and fallowing" is USDA ARS; compared with foreign countries, the number of publications in the field of "crop rotation and fallowing" by relevant institutions in China is low; the cooperation among institutions in the field of "crop rotation and fallowing" is not close enough.

3.3 Keyword Analysis

We used Citespace to build two maps in the field of "crop rotation and fallowing", which are keyword co-occurrence mapping study and keyword timeline co-occurrence clustering map. From the keyword co-occurrence mapping (Figure 3). The size of the circle and the font size indicate the frequency of keywords in the field of crop rotation and fallow. The larger the circle and font, the more frequent the keyword research. The top ten keywords appearing in this research area were yield, system, soil, tillage, rotation, nitrogen, wheat, no till, organic matter, and carbon in the order of 97, 83, 83, 74, 71, 67, 55, 49, 49 and 46. We can see after the keyword Timeline co-occurrence clustering profile (Figure 4) that the clustering module value (Q value) is 0.4793, which is greater than 0.3, indicating that this clustering result is significant, and the Mean Silhouette: clustering average profile value (S value) is 0.7554, which is greater than 0.7, implying that this clustering has credibility. This clustering resulted in nine keyword clustering research hotspots, namely #0 Cultivation, #1 Dryland wheat, #2 Conservation agriculture, #3 Yield, #4 N_2O emission, #5 Rice, #6 Availability, #7 Grain sorghum, #8 Particulate organic, and #9 Soil Indicators. The results show that yield, system, soil and gas emissions are the key topics that have been constant and continuously studied in crop

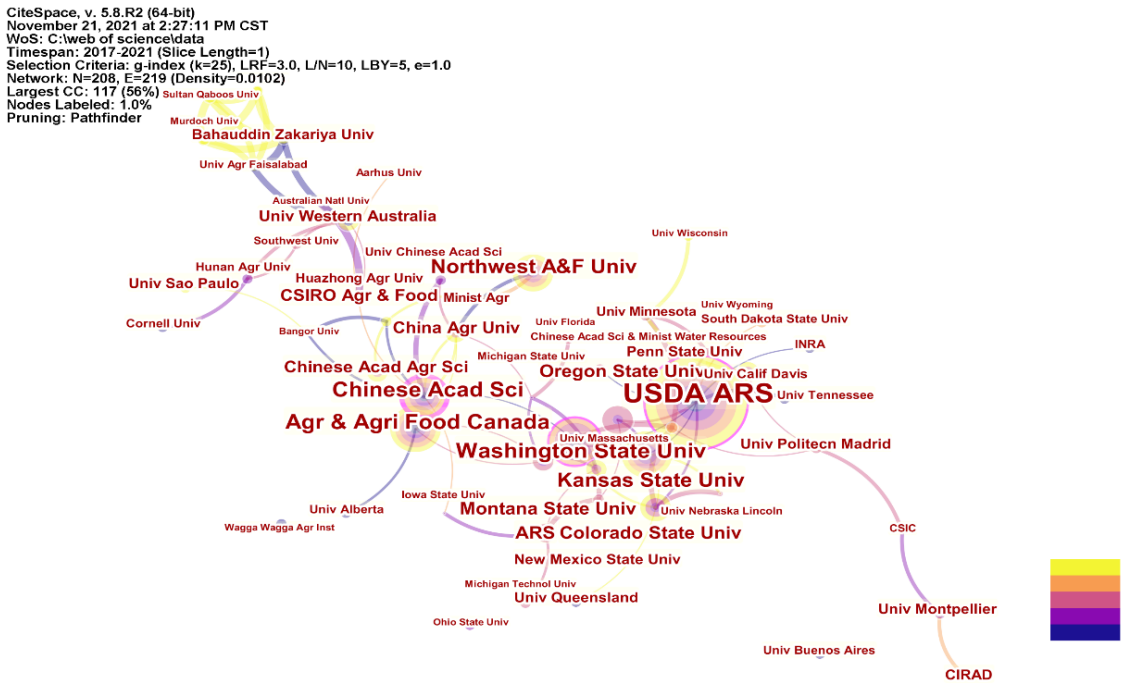

Figure 2. Institutional co-occurrence mapping of major studies in the last five years

rotation fallow. The clusters were organized and analyzed, and the clusters were formed into three major research hot topics, research on crop yield and crop growth from crop rotation fallowing, research on greenhouse gas emissions from crop rotation fallowing, and research on soil health from crop rotation fallowing.

4. Discussion

Hot Topic 1: Research on crop yield and crop growth from crop rotation fallow. This category of hot topics in the figure (Figure 4) includes #0 Cultivation, #1 Dryland wheat, cluster #3 Yield, cluster #5 Rice, etc. The main keywords are yield, grain yield, cropping system, growth, etc. We found that a large number of studies have now shown that crop rotation fallow can not only promote crop growth but also increase crop yield [23]. Xuan, Wang and Linh et al. [23-25] found that rice field crop rotation could induce a significant increase in dry matter accumulation in the aboveground part of rice and promote soil nutrient uptake by rice roots in the belowground part, thus increasing rice yield and improvement in soil health. Wang et al. [26] showed that all rice yields showed some degree of improvement when the single-season rice pattern was changed to a crop rotation pattern. Li et al. [27] found an increase of 23.64% to 55.49% in rice yield under the rotational crop cultivation model compared to the single-season rice model. Therefore, in summary, the study showed that the crop rotation system made to increase the accumulation of dry matter in the above ground part of the crop, thus promoting the crop yield.

Hot Topic 2: Study of crop rotation fallow on greenhouse gas emissions. This category of hot topics in the figure (Figure 4) includes clusters #4 N_2O emission derived from the keywords N_2O emission, CO_2 emission, nitrous oxide emission, emission and nitrous oxide. Tillage patterns have been used in many countries to influence the issue of greenhouse gas emissions from large fields, and Linquist et al. [28] found that CH_4 mainly originated from paddy systems, while N_2O mainly came from dryland systems and rice baking periods, and the conversion of wet and dry in rotational systems from paddy to dryland can significantly reduce methane emissions [29-32], but the alternation of wet and dry soils

Figure 3. Co-occurrence mapping of crop rotation fallow keywords in the past 5 years

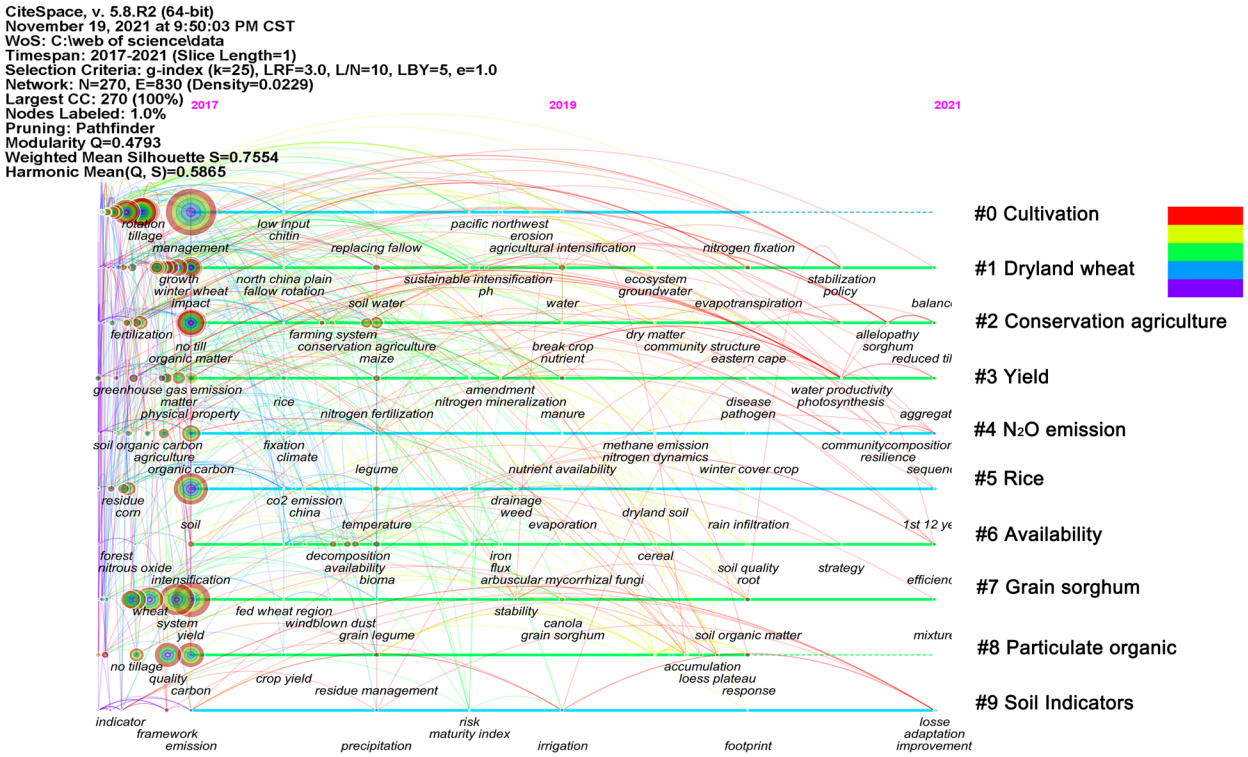

Figure 4. Research keyword Timeline co-occurrence clustering mapping

causes alternating smog and aeration states in the soil, which can accelerate nitrification and denitrification processes in the soil, thus increasing N_2O emissions [33]. Zhong et al. [34] concluded that water-drought rotation significantly increased N_2O emissions and decreased CH_4 emissions through different cropping patterns. Yang et al. [35] found that bean-grass rotation significantly altered soil nitrifying and denitrifying microbial populations. In summary, researchers have improved the nitrogen cycle through agricultural management practices that allow microbially driven denitrification processes to influence changes in soil nitrogen and greenhouse gas emissions from agricultural fields, which can also influence important factors in CH_4 and N_2O emissions from rice fields. At present, there are many researches on greenhouse gas emissions in different crop systems, but there are few studies on the internal connection of crops, greenhouse gases and soil microorganisms.

Hot Topic 3: Rotational fallow on soil health research. This category of hot topics in the figure (Figure 4) includes cluster #9 Soil Indicators and cluster #6 Availability, with keywords such as fertilization, bacterial, carbon sequestration, and soil. It has now been shown that the alternating wet and dry soil environment in crop rotation fallow can improve soil physicochemical properties, eliminate the adverse effects of long-term flooding on soil structure, make the structure and aeration of the soil improved, increase the agglomeration structure of the soil, and effectively prevent soil acidification and soil secondary gleization [36,37]. For example, Murugan et al. [38] showed that microbial populations were significantly higher in soybean-rice rotation fields than in rice monocultures and that the nitrogen activity of soybean rhizobia could reduce nitrogen fertilizer inputs and thus improve nitrogen fertilizer utilization. Chang et al. [39] found that soil bulk weight decreased in all three water-dry rotation patterns, but total soil porosity, capillary porosity and non-capillary porosity increased to some extent, and rice rotation also increased soil pH by 2.48% to 11.46%, which was beneficial to the prevention and control of soil acidification. Bandyopadhyay et al. [40] concluded that the best way to enhance the soil to nourish the land is the long-term fallow model. In terms of soil microorganisms, different crop rotations make crop root secretions and rotational crop residues decompose in the soil, which can affect the availability of nutrients to soil microorganisms, and the amount and type of root secretions vary from crop to crop, with implications for microbial metabolism, growth and development, and diversity [41]. Fenghua et al. [42] found that the changes in soil properties under their rotational cropping pattern led to significant changes in microbial community structure, which was mainly influenced by soil pH and organic matter, through a 20-year long-term crop rotation

experiment. Xuan et al. [23] crop rotation resulted in an increase in soil bacterial community composition, abundance and diversity. In summary, the alternation of wet and dry in the rice field crop rotation fallow produces anaerobic oxygen and aerobic state, as well as the interaction of inter-root secretions of different crops and the residues of different crops, which accelerates the cycle of soil carbon and nitrogen and affects the diversity, abundance and community composition of soil microorganisms, which directly and indirectly affects soil fertility and soil health.

5. Conclusions and Prospect

We used bibliometric methods to analyze the research progress in the field of crop rotation and fallow in the past five years based on the Web of Science (WoS) search of English literature in the field of "crop rotation and fallow", and mainly analyzed their development characteristics, trends and research hotspots. The research results show that: (1) developed countries are the main research force in the field of "crop rotation and fallow", and the US and USDA ARS research institutions have more results and stronger influence. In addition, we found that most of the countries in the field of crop rotation and fallow research belong to the countries with better climatic conditions and more developed economies. In terms of network connectivity, there are weak links between countries and between institutions, and the density of cooperation is poor. (2) From the perspective of research keywords and hotspots, the research perspectives of articles on "crop rotation and fallowing" are diverse. From the analysis of key words and the overall changes of research hotspots in each period, we can see that the research hotspots in the field of "crop rotation and fallowing" are constantly refined and deepened, and the current research hotspots in the field of "crop rotation and fallowing" have the trend of sustainable development and high-quality development. (3) Analysis from research hotspot themes. A total of nine keyword clustering research hotspots were formed through data analysis, namely Cultivation, Dryland wheat, Conservation agriculture, Yield, N_2O emission, Rice, Availability, Grain sorghum, Particulate organic, and Soil Indicators. We found that the overall research hotspots are changing from time to time, but research on crop yield and growth, greenhouse gas emissions, and soil health are constant topics.

Land ecological problems are becoming increasingly serious, and the conflict between food production and soil health is becoming more prominent. In the context of threats to ecological sustainability, it is crucial to objectively evaluate crop rotation fallow models in favor of healthy and sustainable soil development. Using Citespaces software combined with visual analysis of research in the field of "crop rotation fallow", we propose two research perspectives: (1) Developed countries in Europe and the United States occupy a leading position in the field of research on "crop rotation fallowing", although China is a leading country in the field of crop rotation and fallowing, but there is still a gap with developed countries, the quality of papers needs to be improved, international cooperation needs to be strengthened, and at the same time, strengthen the development of cross-regional interdisciplinary research cooperation. (2) Strengthen the research on the linkage of various indicators of crop rotation and fallowing. The research content is becoming more and more detailed in terms of key words, but there is a lack of research on the linkage of each indicator, and there is less research on how the crop rotation fallow system affects the inner linkage between crop growth, greenhouse gas emissions and soil health, and there is a need to dig deeper into the inner linkage.

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