

REVIEW

A Review of Research on Agroecosystem Services Based on Bibliometric Analysis

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ABSTRACT

Agricultural ecosystem is one of the most important ecosystems in the world, which provides multiple ecosystem services such as grain production, climate regulation, water conservation and biodiversity. The degradation of ecosystem services has become an important factor that severely restricts the sustainable development of agriculture. Agroecosystem services have become the core and hot topic of ecological research. In recent years, countries and related institutions have been increasing their research on agricultural ecosystem service. Based on Web of Science(WoS) and China Knowledge Resource Integrated (CNKI) databases, the development characteristics and trends of agroecosystem services research were analyzed by bibliometric methods. The results show that: (1) The number of papers on agroecosystem services is increasing, which shows that the research on it is developing. (2) Developed countries are the main research forces in the field of ecosystem services, and the developed countries in Europe and the United States occupy the absolute leading position; China Agricultural University and the University of California in the United States are the main research institutions. (3) At present, eight research hotspots in this field are the study of ecosystem services mechanism, protection management and sustainability, sustainable development, biodiversity, land use and landscape change, value assessment, climate change, sustainable development of agriculture, ecological compensation. From the overall distribution of research hotspots in each period, the international research focuses more on the interdependence between ecosystem services and ecosystem services and human well-being, while the research in China focuses more on ecosystem services assessment. (4) In recent years, there is a big gap between China and foreign countries in the field of ecosystem services research. It is necessary to strengthen cooperation with research institutions in developed countries in Europe and the United States, and further improve the research content, research vision and research methods.

1. Introduction

Ecosystem services refer to the benefits that human beings obtain from the ecosystem^[1]. The concept of "eco-

system services" has developed from several biological (evolution, environment, conservation) and socio-economic disciplines. In 1997, Daily published "natural ecosystem services of natural ecosystem: social dependence" and

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ecologist Costanza's article entitled "The value of world ecosystem services and natural capital" are often listed by scientists as signs of the emergence of the concept of ecosystem services. The concept of ecosystem services developed from ecology, adopted by conservation biologists, and finally adopted by the political field ^[2].

Agroecosystem is one of the most important ecosystems in the world ^[3]. While providing food supply and other ecological services that can be observed through the market, agroecosystem also provides a series of other ecological services that cannot be observed in the market, such as adjusting climate, conserving water resources ^[4], environmental service value, tourism service value and cultural aesthetic value ^[5]. It has become an important task for scholars in related fields to scientifically evaluate the service value of agroecosystem and correctly guide people's behavior and decision-making.

Since the 1990s, with the reduction of biodiversity, soil degradation and loss, serious water pollution, greenhouse effect, acid rain and other ecological and environmental problems becoming increasingly prominent, the rapid spread of the concept of sustainable development, and the in-depth research on the value of natural capital and ecological services by Costanza R. and Daly H. E, more and more attention has been paid to the function and value of ecological services. Since the mid-1990s, with the introduction of foreign theories, the research on agricultural ecosystem services in China has developed rapidly. Many scholars have made a series of achievements in the research of forest land ^[6,7], grassland ^[8] and farmland ecosystem services ^[9,10], besides discussing the basic theories and methods of ecological service function evaluation. However, the research on agroecosystem services is still in the stage of lopsided reference to the theory of ecosystem services ^[11].

Few scholars analyze the characteristics of agroecosystem services from the practical perspective. Therefore, it is a difficult problem for contemporary ecological research to integrate multi-disciplinary knowledge and promote the temporally and spatially dynamic development of agroecosystem services.

Bibliometrics is a mature method of literature analysis, which has been used in the field of ecosystem and ecosystem services in recent years. For example, Costanza et al ^[12] used Web of Science database as the data source and used bibliometric method to study the author structure system and cooperation relationship in the field of international ecosystem services research; Tancoigne E ^[2] used bibliometric method to analyze the research progress of ecosystem services in agricultural science. Taking agroecosystem services as the theme, this paper analyzes the development status of the research field of agroecosystem services in China and abroad by using

bibliometric method, introduces the relevant information of the main research forces from the level of countries, research institutions, keywords and productive writers, and analyzes the hot topics of the main research countries and well-known institutions. The research hotspots and frontiers in this field in China and abroad are discussed. This will help to grasp the latest development of agroecosystem services research, and provide literature reference for the follow-up research of agroecosystem services.

2. Data Sources and Analysis Methods

In this paper, Web of Science(WoS) database is used as the data source to analyze the development trend and research hotspots in the field of international agroecosystem services, and the Chinese literature in China Knowledge Resource Integrated (CNKI) database is used to analyze the development trend and research hotspots in the field of domestic agroecosystem services. In WoS database, the retrieval formula is: subject = ("agricultural ecosystem services" or "agroecosystem service"), and the literature type is "article". In CNKI database, "agroecosystem services" was used as the key word for retrieval. The retrieval time of the two databases was 1949-2018 (deadline was December 31, 2018). According to the information on countries, institutions, journals, keywords and authors in different years, the data were sorted and elaborated in Excel, and the development trend of international and domestic agroecosystem services was analyzed by the number of papers, total citation frequency, average citation frequency and research topics. Using the Cite Space software to analyze the literature information, through the analysis of high-frequency keywords, this paper summarizes the international research hotspots of agroecosystem services, and compares and analyzes the international and domestic research hotspots in different research periods.

3. Results and Discussion

3.1 General Analysis of Literature

Since 1991, relevant literature about ecosystem services has been published in the world. From the whole period of time, there were a few papers on ecosystem services before 2006, and the amount of literature increased rapidly after 2006, especially after the establishment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) proposed by the United Nations Environment Program (UNEP) in 2008. The earliest literature in China was published in 1975, and it was in the period of fluctuation from 1982 to 2002. From 2003 to 2011, it experienced a period of rapid development. Since then, the number of papers further

dropped, and finally reached a stable level of about 18 papers per year. Generally speaking, in the past 20 years, social demand has played a huge role in promoting the development of science and technology, social development, and the free exploration of scientists, which has led to a substantial increase in the number of papers published and a rapid development of the discipline.

3.2 Analysis of Main Research Forces

3.2.1 Analysis of Major International Research Countries

The top 10 countries in terms of the number of articles published were the United States, Germany, Italy, the United Kingdom, Spain, the Netherlands, China, Australia, Sweden and Switzerland.

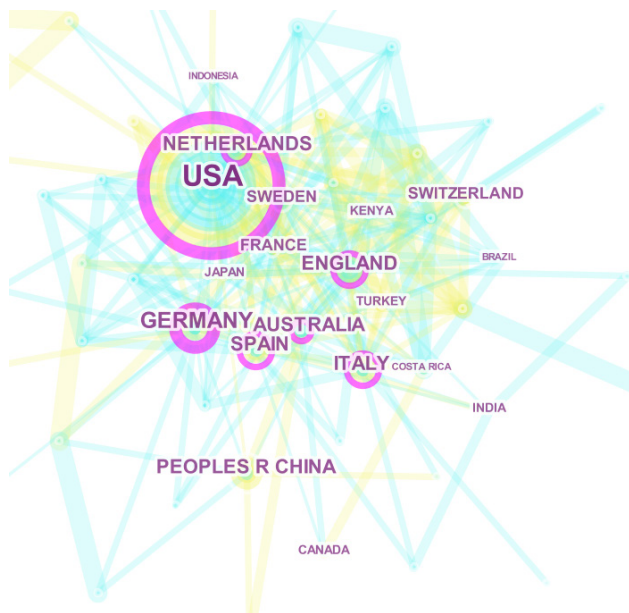


Figure 1. Distribution of main research countries

It can be seen from Figure 1 that: Firstly, the research strength of developed countries in the field of agroecosystem services is obviously stronger than that of developing countries. The number of papers in the United States ranks first in the world and is in a leading position in this research field. Secondly, in terms of the number of papers and citation frequency, the comprehensive influence of papers in the United States, the United Kingdom, the Netherlands and Canada is relatively high, while the quality of papers in China is relatively low, and the scientific influence is relatively low.

3.2.2 Analysis of Major International Research Institutions and Topics

Keywords are a high degree of generalization and re-

finement of the core of the article. By analyzing the keywords in the article, the frequent key words can be regarded as the research hotspot in this field to a certain extent^[13]. With the help of CiteSpace software, the high-frequency keywords are mined and extracted, and the keywords with frequency ≥ 100 are classified to sort out the research hotspots of international ecosystem services (Figure 2).

From the perspective of research topics concerned by various countries, the mechanism, protection, management and the assessment of ecosystem services, the relationship between land use and ecosystem services, and sustainable development under the background of global climate change are generally concerned by various countries, but the degree of concern is different. Foreign countries pay more attention to biodiversity and ecosystem services, ecosystem management and protection, climate change, farmland carbon emissions and farmland ecological landscape, while China pays more attention to the assessment of agricultural ecosystem services, land use, ecological compensation, ecological service function and agricultural sustainability. The different concerns of different countries reflect the regional differences of ecosystem services research to a certain extent.

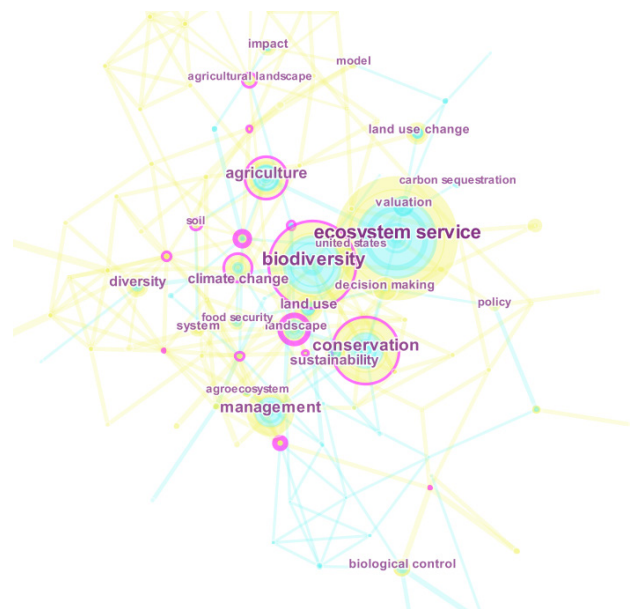


Figure 2. Major international ecological research topics from 1949 to 2018

3.2.3 Analysis of Major International Research Institutions

The top 10 international research institutions are: Michigan State University, Amsterdam University, Wageningen University, Santa Ana University of Higher Technology in Pisa, Cambridge University, Gottingen University, Stock-

holm University, Lund University, Wisconsin University and Swedish University of Agricultural Sciences. These institutions are all from developed countries. The Netherlands and the United States each hold two seats, and Sweden has as many as three. Institutions in the United States, Sweden and the Netherlands are far more than other institutions in terms of the number of papers and citation frequency, which shows the strong strength and influence of scientific research institutions in these three countries in ecosystem services research.



Figure 3. Major international research institutions

3.2.4 Analysis of Major Domestic Research Institutions

China Agricultural University is in a leading position in ecosystem services research. Secondly, Lanzhou University, Northwest University of Agriculture and Forestry Science and Technology, Central South University of Economics and Law, South China Agricultural University and Institute of Geography and Resources of Chinese Academy of Sciences have strong research strength. The main research areas of each institution are different, and the topics concerned are also different. Generally speaking, the research on the function of agroecosystem services, value assessment, the impact of land use change on ecosystem services, ecological compensation, ecological restoration, landscape pattern and ecological process, ecological effect, regional sustainable development and other aspects are the hot topics concerned by various institutions, and also the research hotspot in China.

3.3 Analysis of Disciplines, Source Journals and Authors

From the perspective of discipline, the retrieved literature of agroecosystem services involves many disciplines, and the existing research mainly focuses on the field of natural science, while the content of social science is relatively lacking. The main disciplines in China are ecology, agricultural resources and environment, environmental science, economics, herbalism, biology, forestry, geography. The main subjects in foreign countries are: environmental and

ecological sciences, agronomy, business economics, biodiversity conservation, engineering, geography, computer science and public management. The main related disciplines of ecosystem services research are shown in Table 1.

Table 1. Related disciplines of international ecosystem services research

ENVIRONMENTAL SCIENCES ECOLOGY	112	71.338 %	
AGRICULTURE	35	22.293 %	
BUSINESS ECONOMICS	22	14.013 %	
SCIENCE TECHNOLOGY OTHER TOPICS	22	14.013 %	
BIODIVERSITY CONSERVATION	11	7.006 %	
ENGINEERING	9	5.732 %	
PHYSICAL GEOGRAPHY	7	4.459 %	
COMPUTER SCIENCE	4	2.548 %	
GEOGRAPHY	4	2.548 %	
PUBLIC ADMINISTRATION	4	2.548 %	

International journals are mainly sponsored by the Netherlands, the United States, Sweden, Germany and other developed countries. *Ecological Economics* is the journal that publishes the most researches on ecosystem services. The main journals in China include *Acta Ecologica Sinica*, *Chinese Journal of Applied Ecology* and *Journal of Natural Resources*. Most of the foreign productive authors are from the United States, Germany, the United Kingdom and Sweden. Daily G C, Tilman D and Costanza R have high influence in the field of ecosystem services. Most of the productive authors in China are from China Agricultural University and Chinese Academy of Sciences. Among them, Gao Wangsheng published the most Chinese literature, while Fu Bojie and Lv Yihe published the most English literature. The main topics covered in this field are ecosystem service mechanism research, value assessment, biodiversity, social natural ecosystem coupling mechanism, ecosystem management, ecosystem services and human well-being.

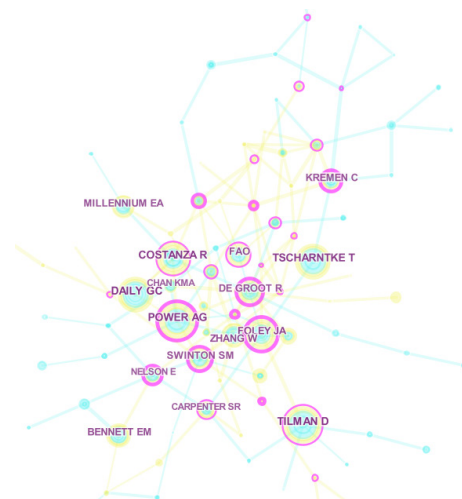


Figure 4. Main productive authors in international ecosystem services

3.4 Analysis of Research Hotspots of Agroecosystem

Keywords are generalization and refinement of the core of the article. To analyze the key words in the article, the frequent key words can be regarded as the research hotspot in this field to a certain extent. With the help of CNKI visualization analysis and cite space software, the high-frequency keywords are mined and extracted, and the research hotspots of foreign agricultural ecosystem services are sorted out, which are briefly summarized as follows.

Firstly, the impact of biodiversity on ecosystem services has been one of the focuses of international ecological research. Scholars in China and abroad have carried out a lot of research on biodiversity, ecosystem services and their relationship. Clarifying the relationship between biodiversity and ecosystem services, further understanding the ecological mechanism of ecosystem services, providing management and decision support for the effective protection and sustainable utilization of biological resources are still key issues to be solved urgently. Therefore, understanding the relationship between biodiversity, ecosystem services and human well-being, clarifying the economic value loss caused by the loss of biodiversity and ecosystem services and its impact on human well-being, and revealing the sensitivity and adaptation mechanism of biodiversity, ecosystem functions and their stability to global change and human activities are the focus of future research.

Secondly, ecosystem services may change due to climate or environmental changes. For example, biodiversity, water supply and carbon storage are the most direct ecosystem services affected by climate change. At present, under the upsurge of global climate change research, scholars are very concerned about the impact of climate change on ecosystem services including biodiversity and the whole social environment. The possible impacts of climate change on regional ecosystem services and their thresholds, the response of regional ecosystem services to global climate change, and the vulnerability and risk assessment of agriculture, water resources, human health and food security to global and regional climate change, the protection, management and sustainable utilization of natural resources in the context of climate change are the current and future key research topics.

Thirdly, the interaction between scientific research and policy is very important, especially for ecological restoration, ecological compensation and maintaining regional ecological security. Through changing the way of agricultural land use and controlling the use of natural resources,

policies directly or indirectly affect the structure and process of agroecosystem, thus changing the services of agroecosystem. Carrying out the research on the response and feedback mechanism of agricultural ecosystem services to policies, revealing the effects of policy changes on the maintenance and conservation of agricultural ecosystems, is more helpful to put forward the decision-making schemes and management strategies for the conservation and sustainable utilization of ecosystem services, so as to better serve human well-being.

Lastly, the service function of agroecosystem has obvious limitation and variability in time and space. The service function of agroecosystem will change with the change of farming system, resource allocation mode, cultivation mode and season. Therefore, the research on spatiotemporal dynamics of agroecosystem and the interaction mechanism between agroecosystem and farming system is also an important content of agroecosystem service research.

4. Conclusions and Prospect

The research on agroecosystem services is a hot topic in the international scientific community and government departments, involving agriculture, resources and environment, economics, biology and other disciplines. Based on Web of Science(WoS) and China Knowledge Resource Integrated (CNKI) databases, this paper searched Chinese and English literature in the field of agroecosystem services, and analyzed their development characteristics, trends and research hotspots by bibliometric methods.

(1) The research on agricultural ecosystem services at home and abroad is carried out under the overall background of ecosystem services, which shows that the research on its development, and some achievements have been made. European and American agricultural developed countries are the main research force in the field of ecosystem services, and Michigan State University is the main research institution. China Agricultural University is one of the major research institutions in the world. However, due to the weak cooperation with the international community, the citation frequency of the papers is low and the international influence is not great.

(2) The productive authors in the field of agroecosystem services are mainly from the United States, the Netherlands and Sweden, and the domestic productive authors are mainly from China Agricultural University.

(3) Eight research hotspots in the field of ecosystem services include: ecosystem mechanism research, conservation management and sustainability, biodiversity, vulnerability, land use and landscape, assessment and model, climate change, policy and decision analysis. From the

overall change of research hotspots in each period, the international research focuses on the mechanism of agroecosystem services and the dependence of agroecosystem services on human well-being, while the domestic research pays more attention to the assessment of agroecosystem services.

(4) In recent years, Chinese scientific research strength in the field of agricultural ecosystem services has been enhanced, and the number of scientific research articles has increased significantly. However, there is still a certain gap between domestic and foreign related research. The quality of papers needs to be improved, and international cooperation needs to be strengthened and improved. But on the whole, there are still some problems worthy of further study and improvement.

From the research content, we need to strengthen the research on the function and value of ecosystem services. For agroecosystem, its service value depends on the type and mode of services provided, and its service depends on the system function, which in turn depends on the system structure. Therefore, in order to strengthen the research of agroecosystem service value, we need to analyze its structure, explore its function, and then outline the composition of ecosystem service value through the setting of index system. Because the understanding of agroecosystem service function is not comprehensive enough, the setting of agroecosystem function and service value index system should be one of the key points of future research. As far as the value structure is concerned, there are some positive services (ES) and some negative services (EDS). Both sides should be considered.

From the perspective of research, agricultural ecosystem is an interdependent system with other ecosystems. On the one hand, it provides ecological services for human beings and other ecosystems. On the other hand, it receives ecological services from other ecosystems. Therefore, further research needs a broader perspective, not only to evaluate the service value provided, but also to evaluate the service value accepted. It is necessary to further study the interaction between agricultural ecosystem and wetland, forest and grassland ecosystem.

From the perspective of research methods, the ecological services provided by agricultural ecosystem change in time and space, and the services provided in different backgrounds will be different. When evaluating its service value, on the one hand, we should pay attention to the small-scale research which can reflect the specific background characteristics, on the other hand, we should introduce the viewpoints and methods of comparative static analysis and dynamic analysis. At the same time, in order to make the decision-making based on the research results

more scientific and operational, the research should distinguish the potential ecological service value from the actual expression of ecological service value, and strengthen the research and application of Contingent Valuation Method (CVM) and other methods.

From the perspective of research technology, the research of agroecosystem service value needs the help of modern information technology including global positioning system (GPS), geographic information system (GIS) and remote sensing system (RS), and the use of genetic engineering, cell engineering and microbial engineering technology to promote the further micro development of agroecosystem service value research.

Finally, it should be pointed out that the research in this field needs the contribution of ecologists and environmentalists, as well as the intervention of economists, so as to provide an economic theoretical basis for the evaluation of agroecosystem service value.

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