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CiteSpace and Bibliometric Analysis of Published Research on Forest Ecosystem Services for the Period 2018–2022

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Abstract: With the development of the social economy, human demand for forest ecosystem service functions is increasing, and at the same time, higher requirements are being put forward for forest ecosystems. Therefore, a more comprehensive and scientific evaluation of forest ecosystem service functions is needed. In order to understand the current status and trends of research on forest ecosystem service functions and value assessment, this study used bibliometric methods and CiteSpace visual analysis to organize and summarize the relevant research. The results show that current research focuses on three aspects: the formulation of forest ecosystem service assessment issues, the classification of ecosystem service functions, and ecosystem service assessment methods. The focus of future research on forest ecosystem services can be summarized as follows: refining the indicators and methods for assessment, extending the research area and scope, analyzing the spatial and temporal dynamics, conducting research on mechanisms of forest ecosystem service functions, and transforming the evaluation results. This study provides an initial insight into the study of forest ecosystem services and a reference for future scholarly research.

Keywords: forests; ecosystem services; CiteSpace; bibliometrics

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1. Introduction

The increasing disruption of ecological balance has led to serious dysfunction in the structure and function of ecosystems, thus affecting human survival and development. The intensification of ecological and environmental problems has become a major threat to global sustainable and socioeconomic development as well as to human living conditions. Ecosystems include forest, wetland, grassland, desert, marine, farmland, and urban ecosystems. Ecosystems are the link between natural systems and human well-being. By maintaining ecological balance, humans can obtain sustainable and stable yield from ecosystems and achieve harmonious development with nature.

Ecosystem services are the environmental conditions and utilities formed and sustained by ecosystems for human survival and development, as reflected by the various benefits that humans derive from them [1,2]. Ecosystem service functions include provision, regulation, cultural, and support services. High-quality ecosystem services can contribute to the smooth and sustainable development of human societies, and accurate assessment of ecosystem services is important for conserving biodiversity, maintaining the stability of the biosphere, improving the ecological environment, carrying out regional planning, and managing remediation. In 1997, Costanza et al. conducted the first global assessment of ecosystem services [2]. This study provoked a strong response from the academic community. Scholars from all over the world have since started to study the functions and value of ecosystem services and how to assess them.

Forest ecosystems are the largest and most important natural ecosystems in the terrestrial ecosystem, and play a decisive role in the global ecosystem. Forests provide enormous material and spiritual wealth for humans and are of great importance to the survival and development of humankind and the maintenance of the earth's environment. Forest ecosystem service functions refers to the natural environmental conditions and utility of forest ecosystems and ecological processes that create and maintain the natural environment on which humans depend [1,2]. Forests provide many types of goods and services to humans, and their impact on and role in the ecological environment are manifested in areas including biodiversity maintenance, forest protection, water conservation, timber supply, climate regulation, soil conservation, carbon sequestration and oxygen release, and recreation. The rise and fall of forests are directly related to the ecological environment, as well as global economic and social development [3–6]. Some countries have introduced the concept of ecosystem services into the field of natural resource management and have incorporated it into forest policy, which is conducive to promoting efficient and orderly forest management, raising people's awareness of environmental protection, and correctly handling the relationship between socioeconomic and ecological development. It is of great importance for ecological restoration, sustainable use of resources, and effective protection [7].

With rapid economic growth and industrialization, human exploitation and intervention in nature is intensifying, seriously affecting global ecosystems and sustainable development. The depletion of natural resources in many ecosystems, the reduction in natural ecological areas, and the impairment of ecosystem services have reduced the capacity of natural systems to contribute to human well-being [8,9]. The study of ecosystem service functions, the valuation of ecosystem services, and their use in guiding ecosystem management and conservation are relevant for promoting global sustainable development.

Bibliometrics is a method of quantitatively analyzing large bodies of literature using statistics. By comprehensively analyzing multiple sources of data through bibliometrics, it is possible to understand the development process and current status of a particular research field. Combining this with relevant information to analyze future trends in the field can provide a reference for future scholarly research. CiteSpace software is a visualization tool for measuring and analyzing literature data, developed by Chaomei Chen of Drexel University, USA, which allows a visual and comprehensive view of developments in fields of research science through knowledge mapping.

Web of Science is among the most important citation databases in the world, covering natural sciences, engineering and technology, social sciences, arts and humanities, and other subject areas. The papers in Web of Science represent the majority of research with complete findings, and have more research value than reports, reviews, and projects available on the Internet. Analyzing the literature over the last 3 to 5 years gives a snapshot of the current state of research in a particular field. To avoid having an overly large scope and unrelated literature, the data in this paper were selected to cover the period 2018–2022. In this study, we searched the Web of Science core database for papers on forest ecosystem services from 2018 to 2022 and obtained 6033 relevant papers. We used CiteSpace 6.1R6 software, Excel charts, and bibliometric analysis to collate and analyze these papers.

A synthesis of current domestic and foreign research progress shows that research on forest ecosystem services focuses on different dimensions, but there are shortcomings in the scope of research, theoretical studies, assessment methods, and the application of assessment results. The objectives of this study were as follows: (1) to provide an overview of forest ecosystem services in terms of countries, institutions, and author collaborations; (2) to reveal the current status and hotspots of research on forest ecosystem services based on keyword co-occurrence and clustering analysis; (3) to discuss the research frontiers based on keyword emergence analysis; and (4) to point out future trends in forest ecosystem services.

2. Materials and Methods

2.1. Data Sources

In this paper, we used the Web of Science (WoS) database as the data source, and through advanced search we obtained 6033 papers, among which 500 papers with high relevance were selected as the sample data. Figure 1 shows the number of papers published in the field of forest ecosystem services in the past 5 years.

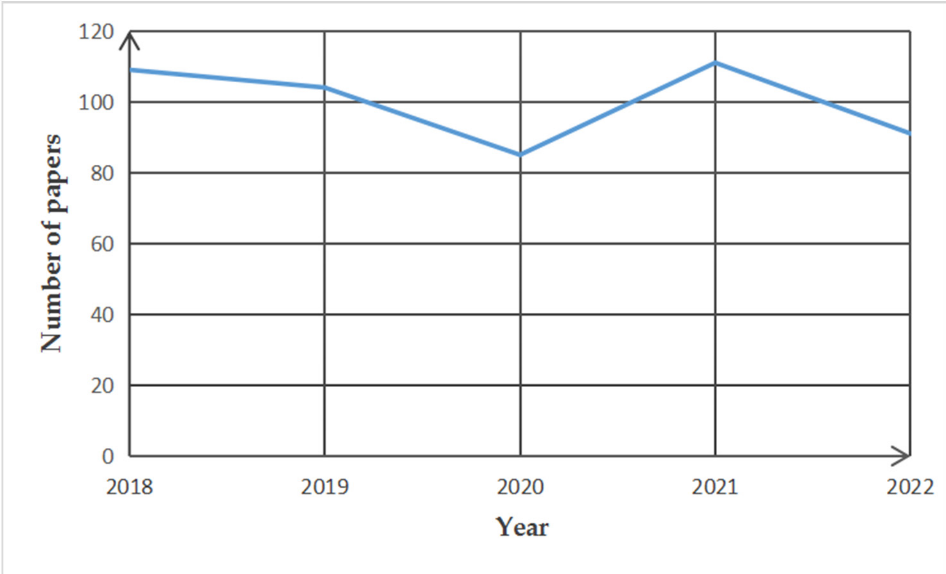


Figure 1. Number of papers published in the field of forest ecosystem services from 2018 to 2022.

2.2. Research Methodology

We used Web of Science Advanced Search to search the literature, with the following search method: Web of Science Core Collection, search formula "TS = (forest) AND (ecosystem service OR ecosystem services) AND (assess OR assessment OR value OR valuation OR evaluate OR evaluation)"; the publication dates were from 2018–2022.

We used bibliometric methods, CiteSpace 6.1R6 software, and Excel charts to visually analyze the number of publications, authors, and research hotspots in the field of ecosystem services, and to produce visual charts of countries, institutions, author collaboration networks, keyword co-occurrence, keyword clustering, and keyword emergence. Using knowledge mapping and Excel charts, we analyzed the current status and trends of ecosystem services research over the past 5 years.

3. Results

3.1. Analysis of Cooperation between Countries, Institutions, and Authors

Collaboration between countries, institutions, and authors is more likely to lead to progress in related research areas. A collaborative network analysis using CiteSpace shows that 84 countries have conducted research and published papers on forest ecosystem services. Of these, the highest number of papers were from China, with 124, followed by the USA, with 73, and Australia, Italy, and Germany, with more papers and collaborations between them (Figure 2).

The Chinese Academy of Sciences, Beijing Normal University, the University of Chinese Academy of Sciences, and the US Forest Service are relatively active in research efforts, but there is a lack of cooperation between domestic and international institutions (Figure 3).

The largest number of publications is by Baral Himlal, followed by Robin R. Sears, Jan E. Vermaat, Ram Prasad Acharya, and others, but there is not much exchange and collaboration between scholars (Figure 4).

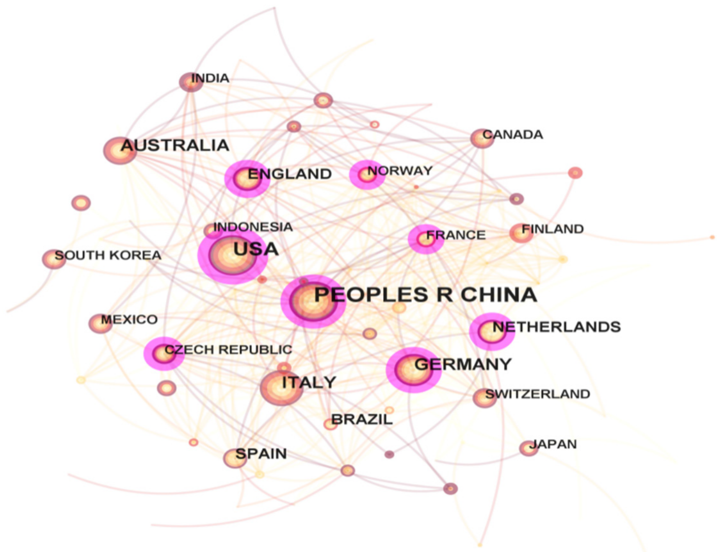


Figure 2. National cooperation in research on forest ecosystem services.

Figure 3. Institutional cooperation in research on forest ecosystem services among countries.

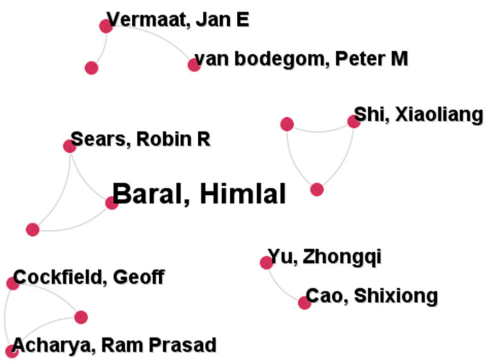


Figure 4. Author cooperation in research on forest ecosystem services among countries.

3.2. Analysis of Research Hotspots

In a CiteSpace keyword co-occurrence network, larger nodes indicate more frequent keyword appearance (Figure 5). The keywords "ecosystem service", "management", "evaluation", "biodiversity", "conservation", and "forest" were all found more than 70 times, and have been hotspots of research in the last 5 years (Table 1).

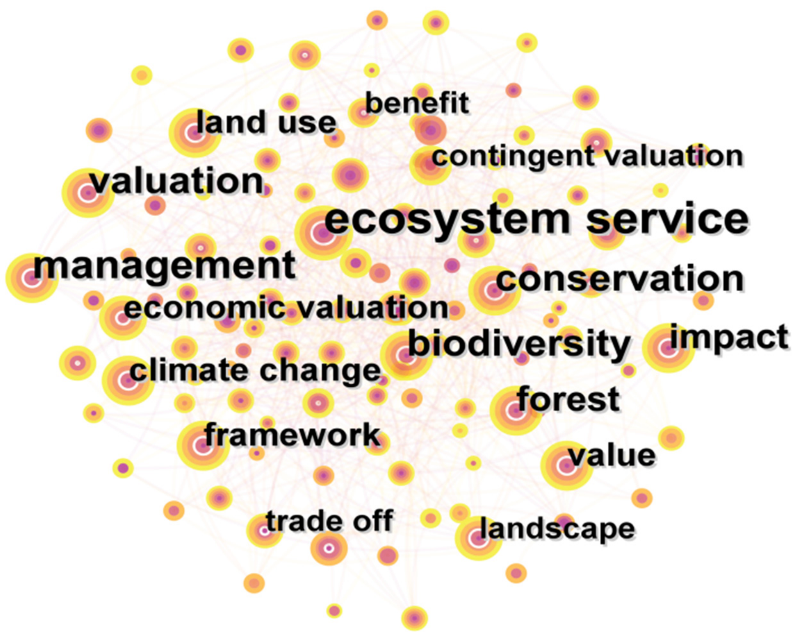


Figure 5. Keyword co-occurrence network.

Table 1. Keyword frequency statistics.

Keywords	Frequency	Centrality
ecosystem service	245	0.02
management	127	0.02
valuation	107	0.02
biodiversity	97	0.04
conservation	95	0.05
forest	75	0.02
impact	68	0.03
framework	64	0.02
climate change	63	0.05
economic valuation	62	0.03
land use	62	0.05
value	60	0.01
landscape	46	0.02
contingent	36	0.05
trade off	36	0.05
benefit	34	0.05
area	33	0.02
indicator	32	0.04
dynamics	30	0.01
economic value	30	0.02

Cluster analysis of high-frequency keywords shows that current academic research on forest ecosystem services focuses on "contingent valuation", "cultural ecosystem services", "climate change", "Turkey", "land use change", "natural capital", "ecosystem services", and "forest systems" (Figure 6). With regard to the relevant literature, the research themes can be summarized into three main areas: the formulation of forest ecosystem service assessment issues, the classification of ecosystem services, and ecosystem service assessment methods.

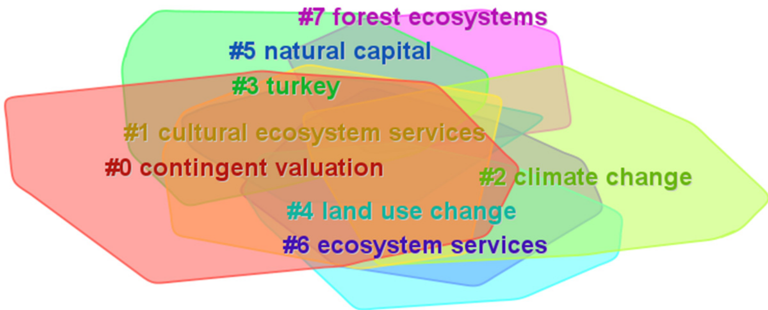


Figure 6. Keyword clustering analysis network.

3.2.1. Formulation of Forest Ecosystem Service Assessment Issues

Forests are the largest and most important land ecosystems. Apart from their production function, forests are also important in maintaining the life support system of the Earth through their ecological service functions. Scholars have carried out comprehensive research on forest ecosystem processes, service functions, and economic value, and have made significant achievements in enriching the meaning of forest ecosystem service functions and further exploring techniques and methods for assessing them.

The concept of ecosystem services was originally described by Holdren as the services that natural ecosystems provide to humans, and he explored the human influence on the functioning of ecosystem services [10]. De Groot noted that ecosystem services have the ability to provide goods and services that directly or indirectly meet human needs through natural processes and constituent structures [11,12]. According to Daily, ecosystem services are the ecological processes and environmental conditions that are provided for human survival from the disciplinary perspective of ecology [1]. Costanza et al. described ecosystem services as the products of ecosystems and ecosystem functions that contribute to human survival and studied their development from the perspective of social and management sciences [2]. Building on the research of Daily and Costanza et al., a Millennium Ecosystem Assessment report describes ecosystem service functions as the various benefits and advantages that people derive directly or indirectly from ecosystems [13]. In summary, some authors and others define ecosystem services more from an economic perspective, i.e., in terms of the benefits that people can derive, while others propose a definition more from an ecological perspective, i.e., in terms of the processes by which such services are provided [12].

Current research on ecosystem services in China is based on existing research in foreign countries. Domestic scholars such as Zhiyun et al., Xie et al., Fu et al., and Tongqian et al. have continued Daily and Costanza et al.'s view on ecosystem services as the natural environmental conditions and functions formed and maintained by ecosystems and ecological processes for human survival [3,14–17]. Tongqian and Zhiyun established an evaluation index based on a classification of forest ecosystem service functions and explored methods for assessing the economic value of ecosystem services [16]. Fu et al. explored the interactions between the services of different ecosystems such as forests, grasslands, and wetlands, and further studied methods and model systems for evaluating ecosystem service functions at the national scale [15].

In summary, forest ecosystem service functions refers to the natural environmental conditions and utilities of forest ecosystems and ecological processes that form and maintain the natural environment on which human beings depend [1,2]. Assessing the value of forest ecosystem services focusing on the benefits that they provide to humans and society has broad social significance and is conducive to enhancing our comprehensive understanding of them, better formulating scientific and rational forest management and conservation policies, and enhancing human well-being.

3.2.2. Classification of Ecosystem Service Functions

Research on ecosystem service functions in foreign countries began earlier and has made remarkable progress. Daily discussed the definition of ecosystem services and their value attributes and relationship to biodiversity, and listed 13 essential functions of life support systems, including biodiversity maintenance, climate regulation, and environmental purification [1]. Costanza et al., in their global assessment of ecosystem service value, classified ecosystem functions into 17 categories, including atmospheric regulation, water regulation, and water supply [2]. The current internationally accepted classification system was proposed by the UN Millennium Ecosystem Assessment Working Group, which classifies ecosystem services into four broad categories of support services, provision services, regulation services, and cultural services, with 21 sub-categories [13]. Provision services refers to the primary and secondary products that ecosystems produce that provide direct benefits to people, including food, timber, and fresh water [18]. Cultural services refers to the non-material benefits that humans derive from ecosystems through spiritual satisfaction, the development of cognition, reflection, recreation, and the experience of beauty, mainly in the areas of cultural diversity, recreation and ecotourism, and aesthetic value [19]. Ecosystem regulation services ensure long-term functioning by maintaining ecosystem characteristics within a stable range, including water and air purification, atmospheric regulation, and biological control. Ecosystem support services are the underlying functions that enable other services to work properly; they include primary production (plant photosynthesis), biodiversity maintenance, soil formation, and nutrient cycling [20]. Based on the MEA classification system, TEEB classifies ecosystem services into four broad categories: provision services, regulation services, cultural services, and habitat services [21]. The Common International Classification of Ecosystem Services (CICES) uses three main categories: provision services, regulation and support services, and cultural services [22]. A comparison of the four main ecosystem service classification systems used worldwide and a list of their differences and similarities are given in Table 2 [23].

Table 2. Comparison of four main ecosystem service classification systems used worldwide and their differences and similarities [23].

	Costanza et al., 1997 [2]	**Millennium Ecosystem Assessment, 2005**	**TEEB, 2010**	**CICES, 2017**
Provision services	Food production	Food	Food	Raw materials
	Water supply	Fresh water	Fresh water	Water
	Raw materials	Fiber, etc.	Raw materials	Biomass: fiber, energy, and other materials
		Ornamental resources	Ornamental resources	
	Genetic resources	Genetic resources	Genetic resources	
		Biochemicals and natural medicinal materials	Medicinal resources	
				Biomass: mechanical energy
Regulation services and habitat	Gas regulation	Air quality regulation	Air purification	Mediation of gas and air flows
	Climate regulation	Climate regulation	Climate regulation	Atmospheric composition and climate regulation
	Disturbance regulation (storm protection and flood control)	Natural hazard regulation	Disturbance prevention or moderation	Mediation of air and liquid flows
	Water regulation (e.g., natural irrigation and drought prevention)	Water regulation	Regulation of water flows	Mediation of liquid flows
	Waste treatment	Water purification and waste treatment	Waste treatment (esp. water) purification)	Mediation of waste, toxics, and other nuisances

Table 2. *Cont.*

	Costanza et al., 1997 [2]	Millennium Ecosystem Assessment, 2005	TEEB, 2010	CICES, 2017
	Erosion control and sediment retention	Erosion regulation	Erosion prevention	Mediation of mass-flows
	Soil formation	Soil formation (support service)	Maintenance of soil fertility	Maintenance of soil formation and composition
	Pollination	Pollination	Pollination	Life cycle maintenance (incl. pollination)
	Biological control	Regulation of pests and human diseases	Biological control	Maintenance of pest and disease control
Support services and habitat	Nutrient cycling	Nutrient cycling and photosynthesis, primary production		
	Refugia (nursery, migration habitat)	Biodiversity	Life cycle maintenance (habitat)	Life cycle maintenance, habitat and gene pool protection
Cultural services	Recreation (incl. ecotourism and outdoor activities)	Recreation and ecotourism	Recreation and ecotourism	Outdoor experience
	Cultural (incl. aesthetic, artistic, spiritual, educational, and scientific)	Aesthetic values	Aesthetic information	
		Cultural diversity	Inspiration for culture, art, and design	
		Spiritual and religious values	Spiritual experience	Spiritual and/or emblematic interactions
		Knowledge systems	Information for cognitive development	Intellectual interactions
		Educational values		

Research in China started late, and relevant scholars have classified ecosystem service functions based on existing research. Ouyang et al. used eight categories: synthesis and production of organic matter, production and maintenance of biodiversity, regulation of climate, renewal and maintenance of soil fertility, environmental purification and degradation of harmful and toxic substances, dispersal of plant pollen and seeds, control of pests, and mitigation of natural disasters [8]. Based on Costanza et al.'s work, Fu et al. classified global ecosystem services into 17 categories and four levels: production (including products and maintenance of biodiversity), basic functions (including pollination, seed dispersal, biological control, and soil formation), and environmental benefits (including improved drought and flood mitigation, climate regulation, air purification, and waste treatment), and recreational value (recreation, entertainment, culture, artistic literacy, ecological aesthetics, etc.) [15]. Tongqian et al. classified forest ecosystem service functions into the categories product provisioning, regulation, culture, and life support, and established an evaluation index consisting of 13 functional indicators: forest products, forest by-products, oxygen release, biodiversity maintenance, climate regulation, photosynthetic C fixation, water conservation, nutrient cycling, soil conservation, wind and sand control, environmental purification, cultural diversity, and recreational tourism [16]. Xie et al. classified ecosystem services into three broad categories: the provision of living and productive materials, the maintenance of life support systems, and the enjoyment of spiritual life [14]. Later, Xie et al. adopted the Millennium Ecosystem Assessment method to divide ecosystem services into four categories: provision services, regulation services, support services, and cultural services, which can be divided into 11 service functions: food production, raw material production, water supply, gas regulation, climate regulation, clean environment, water temperature regulation, soil conservation, nutrient cycle maintenance, biodiversity, and aesthetic landscape [24].

In fact, the content of studies on ecosystem service functions by domestic and international scholars is the same; there are only differences in the types and names of the functions. According to existing studies, forest ecosystem service functions can be briefly summarized in three aspects: (i) Forests provide physical resources (forest land, timber, forest by-products, etc.) necessary for human survival and development. (ii) Forests have ecological benefits (maintaining biodiversity, regulating climate, containing water, sequestering carbon and releasing oxygen, purifying the environment, preventing wind and sand, etc.). (iii) Forests have social benefits (providing recreational, aesthetic, spiritual, and cultural value of the natural environment, etc.) [25].

3.2.3. Methods for Valuing Ecosystem Services

Domestic and international methods for assessing ecosystem services fall into two broad categories: value assessment and physical assessment [26]. Xie et al. divided current ecosystem service value accounting into two broad categories: approaches based on the functional price per unit of service (functional value methods), including direct, indirect, and simulated market approaches; and methods based on equivalent factors of value per unit area (equivalent factor methods) [24,27,28]. Physical assessment methods are divided into two types, energy value analysis and modeling. Energy value analysis uses energy as the common evaluation criterion to determine the service value of forest ecosystems through the monetary conversion rate of energy values, or the functional relationship between energy values and the value of forest ecological service functions [29]. The use of models is a breakthrough in ecosystem service valuation, with assessment models such as InVEST, ARIES, and SolVES, and InVEST is among the most widely used models. InVEST is a free, open-source model developed jointly by Stanford University, WWF, and the Nature Conservancy, mainly for ecosystem service function assessment, including freshwater and marine, with each module covering specific assessment items [30]. In addition, GIS and remote sensing technologies play important roles in data collection and spatial and temporal analysis and are also used in ecosystem service assessment.

Geng et al. assessed the service functions of forest systems, including biodiversity, water conservation, carbon sequestration, oxygen release, forest nutrients, and soil conservation, through alternative cost, market value, and control cost approaches [6]. Mancini et al. identified two approaches for measuring the value of ecosystem services: a monetary valuation approach based on monetary units and a biophysical accounting approach based on quantitative empirical measurements. They explored biophysical measurements using ecological footprints as a way to valuate ecosystem services and compared the results of economic and ecological footprint assessments [31]. In order to identify and valuate ecosystem services in the Czech Republic, Frélichová et al. developed a geographically specific database of ecosystem service values calculated by entering the biophysical and economic values for 41 biosystem categories [32]. An approach for assessing and weighing the ecological, social, and economic values of ecosystem services proposed in the USA combines multiple perspectives and spatial scales for an integrated assessment to inform national forest decision-making [33]. A meta-analysis-based functional value transfer of ecosystem services can reduce costs and increase efficiency in practice, and is a fast and effective assessment method [34–36]. In recent years, remote sensing technology has been widely used in ecological monitoring and evaluation and is an important source of information, improving the accuracy and timeliness of collected data. Chen et al. evaluated forest ecosystem services in Pudacuo National Park, Shangri-La, China, based on a variety of data, including remote sensing and ground data, and used alternative market, shadow project, and conditional valuation methods, including soil conservation and forest nutrients. However, there was some subjectivity in the selection of data and indicators, and the evaluation results are somewhat controversial [37].

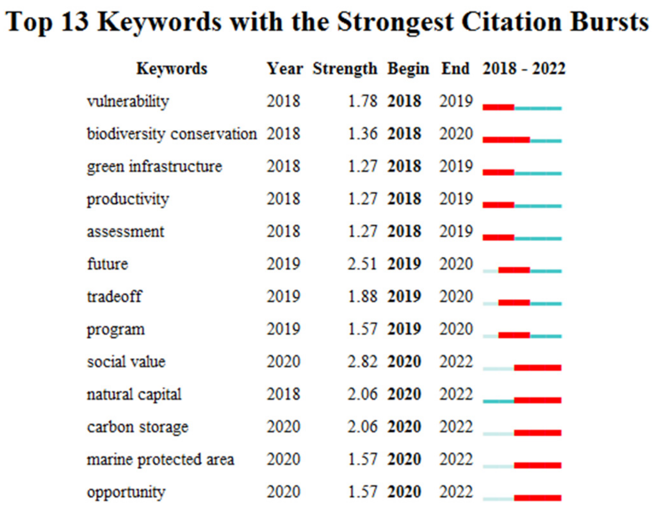
The traditional assessment methods used in domestic and international research on the water conservation function of forest ecosystem services include integrated storage capacity, annual runoff, water balance, and precipitation storage methods, but these have little flexibility and applicability. Choi et al. divided the assessment models for the water conservation function into biogeochemical, hydrological, integrated, and regional models based on this [38]. Wang et al. divided such assessment models into two categories, empirical and physical models; the former include the SCS, TVDI, and soil-based dynamic water storage models, and the latter include the InVEST, Terrain Lab, and SWAT models. They analyzed the characteristics and applicability of the various models [39].

Carbon storage capacity is an important indicator of terrestrial ecosystem service functions, and the InVEST model can be quickly applied to assess the carbon stored and sequestered by ecosystems in order to monetize the value of this service. Pache et al. used a combination of GIS, ground scanning, and modeling techniques to quickly and efficiently calculate the economic value of the amount of carbon stored and sequestered [40]. Since carbon stocks are related to carbon suitability, Caglayan et al. used digitization and mapping methods to develop a guiding model that could be used to calculate carbon stock and sequestration values and classify carbon stock potential, facilitating the identification and development of areas with carbon storage potential [41]. There have been studies on the monetary valuation of forest carbon storage and sequestration, but they used different methodologies and are not standardized.

There is still no unified method or index system for assessing the value of ecological service functions. At the same time, due to the different assessment systems and evaluation methods, the assessment results for the same forest ecosystem can vary greatly and lack comparability.

3.3. Analysis of Research Frontiers

CiteSpace 6.1R6 software was used to highlight the keywords, and 13 were selected for analysis. Figure 7 shows that the top five keywords with high emergence rates were "social value", "future", "natural capital", "carbon storage", and "trade-off". In terms of duration of emergence, the keywords with longer duration were "social value", "natural capital", "carbon storage", "marine protected area", and "opportunity", which mostly started to appear in 2020, and have become hot spots and frontier directions of ecosystem service research in recent years.



Top 13 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2018 - 2022
vulnerability	2018	1.78	**2018**	2019	
biodiversity conservation	2018	1.36	**2018**	2020	
green infrastructure	2018	1.27	**2018**	2019	
productivity	2018	1.27	**2018**	2019	
assessment	2018	1.27	**2018**	2019	
future	2019	2.51	**2019**	2020	
tradeoff	2019	1.88	**2019**	2020	
program	2019	1.57	**2019**	2020	
social value	2020	2.82	**2020**	2022	
natural capital	2018	2.06	**2020**	2022	
carbon storage	2020	2.06	**2020**	2022	
marine protected area	2020	1.57	**2020**	2022	
opportunity	2020	1.57	**2020**	2022	

Figure 7. Keyword bursts.

3.3.1. Carbon Storage

Carbon sequestration and oxygen release are services that make a significant contribution to value, as plants absorb carbon dioxide and release oxygen through photosynthesis to maintain the balance of carbon in the atmosphere. The amount of carbon sequestered and oxygen released reflects the productivity of the forest ecosystem and its degree of stability. Carbon storage represents carbon stocks (the size of the carbon pool at a given point in time), while carbon sequestration represents carbon flux (the amount of carbon exchanged between the atmosphere and the forest between two points in time) [42,43]. Forests are the most important carbon reservoirs in terrestrial ecosystems and play an important role in the global carbon cycle. Carbon storage and sequestration are among the most important services provided by forest ecosystems and are the most powerful tools for climate change mitigation and adaptation; they also play a key role in human well-being and biodiversity conservation. In the context of a warming climate, quantifying and assessing carbon storage and sequestration are essential to provide effective incentives to combat climate change [40,41,44]. When agricultural land expansion encroaches on ecological lands (e.g., forests, grasslands, and wetlands), the significant loss of forests and wetlands can seriously affect carbon stocks. Therefore, it is also necessary to take into account the loss of carbon stocks due to cropland expansion when implementing land use planning and cropland conservation policies [45].

3.3.2. Social Value

Traditionally, the valuation of ecosystem services has focused on the assessment of economic value and neglected social value. In recent years, the role of human society in ecosystem services has begun to be emphasized, and the social value of ecosystem services has gradually attracted the attention of scholars. There is growing recognition of the social value of ecosystem services. The social value of ecosystem services reflects human attitudes and preferences, including human spiritual needs and the development characteristics of the times, and can be divided into seven areas: aesthetics, recreation, education, cultural heritage, religious spirituality, local identity, and recreational experiences [46–48]. Assessing social value opens up new ideas for assessing ecosystem service value, provides strong support for planning and management related to land, the environment, and ecology, and provides a basis for the formulation and implementation of environmental protection measures. Social Values for Ecosystem Services (SolVES), a tool jointly developed by the USGS and Colorado State University for use in ArcGIS, is a typical method for assessing the social value of ecosystem services and consists of three sub-models: the social value of ecosystem service functions, value mapping, and value conversion. It has good applicability in assessing the social value of ecosystem services at small and medium scales [49–51].

3.3.3. Natural Capital

Capital is the commodity that can lead to surplus value, and in the ecological economic model it is expressed as natural, human, social, and productive capital, among other types. Natural capital, which precedes capital with the attributes of nature, emphasizes the role of nature in supporting economic development and human well-being, and is a sustainable concept [52–54]. Natural capital is defined as natural assets that generate economically valuable ecosystem services, and it is considered that all-natural capital has the potential to generate economic value [55,56]. Natural capital can be used to produce goods and services, as well as ecological services that directly benefit people, and the rational use and optimal allocation of natural capital are important for economic development and human well-being [57,58]. Maseyk et al. described the relationship between natural capital and ecosystem services, recognizing the role of natural capital in the provision of ecosystem services and the importance of managing natural capital stock to maintain the flow of ecosystem services, where material, energy, and information flows generated by natural capital accumulation form ecosystem service functions [59]. Natural capital and ecosystem services functioning together provide human benefits.

4. Discussion

The analysis revealed that there are still some problems and shortcomings in the field of forest ecosystem services research; for example, the scope of research is not comprehensive, theoretical research is insufficient, assessment methods need to be improved, and the assessment results are not applicable. Based on the above analysis, future research on forest ecosystem services should focus on the following areas.

4.1. Refinement of Indicators and Methods for Ecosystem Service Assessment

A unified, standard, and generally accepted indicator system and assessment method has not yet been formed for the assessment of ecosystem service value. Instead, different methods are used in the same area, yielding different results and leading to poor comparability between results [37,60–62]. Selecting accurate representative indicators and data is an important research direction for future forest ecosystem integrity assessment. An interdisciplinary research method should be adopted, combining natural and social science research methods, using methods based on ecology, management, economics, and other areas, and strengthening the application of 3S technology and dynamic assessment models to improve ecosystem service value assessment index systems and methods [29].

4.2. Extended Research Area and Scope

To date, there has been much research on the carbon and oxygen sequestration, water connotation, and soil conservation functions of forest ecosystems, but very little on cultural services such as recreation and tourism, and provision services such as timber and forest by-products [63]. Forest ecosystems are comprehensive systems, and the relationships between the various service functions they provide are intricate and complex. Therefore, research on forest ecosystem services should cover all of the services as well as the relationships between them and their interactions to make the research more comprehensive, deepen people's understanding, and facilitate scientific planning and management of forest ecosystems to enhance human well-being [64].

4.3. Analysis of the Spatial and Temporal Dynamics of Forest Ecosystems

Currently, research on ecosystem service functions mainly involves static analysis of the service function value of a certain region or certain type of forest ecosystem, with little focus on the spatial and temporal differences between forest ecosystems in the same region, and a lack of dynamic monitoring and management of forest resources [65,66]. In fact, there are large differences in the service functions of the same type of forest ecosystem at different times and in different spaces, and of different functions in the same time and space. Therefore, the dynamic evolution of forest ecosystems needs to be analyzed, compared, and assessed temporally and spatially by combining multi-source data, which is the focus and challenge of research on ecosystem service function assessment [67,68].

4.4. Research on Mechanisms of Forest Ecosystem Service Functions

Studies on ecosystem service functions mostly involve quantitative analyses of connotations, functional classifications, assessment methods, and values or the spatial patterns of ecological service flows. Furthermore, much research lacks an assessment of the relationship between ecosystem structure, ecological processes, and ecological service functions, and the research on theories and methods for valuating ecological service functions and natural capital lacks a reliable ecological basis [69]. The performance of ecosystem service functions relies on complex ecological processes, and as the research continues to develop, this will become a hot spot for the analysis of interrelationships between human activities and natural ecosystems and the extent of their influence, as well as interrelationships between multiple ecosystem service processes, starting from the mechanism of value formation.

4.5. Transformation of Evaluation Results

Because the evaluation methods and index system are not perfect, the evaluation results are not highly credible, which hinders their application in practice, and there is a problem of poor application of such results. Many scholars have assessed the functions of ecosystem services, but this research is only at the academic level and the results are not used to guide forest management practices [69]. The ultimate purpose of research on ecosystem services is to serve humans. It is important to promote the transformation of evaluation results into applicable constructs, and carry out research on the application and practice of forest ecosystem service assessment results [70–73]. Based on the evaluation results, the reality of social development, and the ecological and environmental issues, relevant measures are proposed to provide scientific guidance for promoting sustainable development and improve human well-being.

5. Conclusions

This paper presents an analysis of the progress of domestic and international research on forest ecosystem service valuation based on the CiteSpace visualization tool and bibliometrics. First, the proportion of scholars in this field has been increasing, but there is little communication and cooperation between institutions and scholars in different countries. Second, according to the CiteSpace keyword co-occurrence and clustering results, current research hotspots mainly include the formulation of ecosystem service valuation issues, the classification of ecosystem service functions, and ecosystem service valuation methods. Finally, the analysis of CiteSpace keyword emergence shows that social value, natural capital, and carbon storage have gradually become the frontier of research in the field of ecosystem services. In addition, we further point out future trends of forest ecosystem services. This study provides a basic understanding and appreciation of forest ecosystem services research, as well as a reference for future scholars in related research.

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