land

Review

# Review of Valuation of Forest Ecosystem Services and Realization Approaches in China

**Shiliang Liu [1,*], Yuhong Dong [2], Hua Liu [1], Fangfang Wang [1] and Lu Yu [1]**

[1] State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, China
[2] Research Institute of Forestry, Chinese Academy of Forestry, Beijing 100091, China
* Correspondence: shiliangliu@bnu.edu.cn

**Abstract:** Forests are essential for the provision of water, financial resources, food, and carbon, and offer immense ecosystem service values. The accurate, quantitative, and objective evaluation of forest ecosystem service (FES) values can help uncover methods for realizing ecological product value, which in turn supports forest conservation and ecological benefit enhancement. In China, FES valuation methods are diverse and tailored to specific objectives, encompassing matter quantity assessment, value quantity assessment, energy value analysis, and landscape ecological modeling methods. The "Forest Ecosystem Service Function Assessment Specification" guideline plays a crucial role in fostering standardized valuation. Carbon-related ecosystem services have been increasingly studied in China; however, valuation challenges remain, including data accuracy, the double counting of ecosystem services, methodological limitations, and the incomplete assessment of non-use values. Regarding value realization, the development of payment for ecosystem services (PES), ecological product benefit trading (EPBT), ecological premiums, and ecological industries has seen gradual progresses in recent years. However, realization approaches still depend on government support, and the establishment of market-oriented strategies requires further reinforcement. Enhancing FES valuation necessitates the integration of interdisciplinary and multi-method approaches, as well as the creation of an accounting and assessment mechanism. Realization approaches must not only be continuously expanded but also consistently innovated over time. It is essential to consider the impact of market development on FES valuation; establish robust realization approaches; reinforce promotional and guarantee mechanisms; and increase the efficacy of policy management.

**Keywords:** forest ecological product; value realization of ecosystem service; ecological premium; ecosystem service; China



**Citation:** Liu, S.; Dong, Y.; Liu, H.; Wang, F.; Yu, L. Review of Valuation of Forest Ecosystem Services and Realization Approaches in China. *Land* **2023**, *12*, 1102. https://doi.org/10.3390/land12051102

Academic Editors: Guillermo J. Martinez-Pastur, Javier Martínez-López, Robert Baldwin, Diane Pearson and Alejandro Rescia

Received: 29 March 2023
Revised: 15 May 2023
Accepted: 19 May 2023
Published: 21 May 2023



## 1. Introduction

Forests, as major components of terrestrial ecosystems, account for over 60% of the total biomass and more than 50% of carbon stocks, serving an indispensable function in regulating regional climates and maintaining the global carbon balance [1]. Additionally, they also provide a wealth of products, including timber and non-timber products and food, and are essential for maintaining regional ecological functions and the equilibrium of Earth's life system [2,3]. Due to economic development and population growth, forest resources in some regions are being depleted, resulting in ecological challenges and prompting increased attention towards forest conservation. In China, issues such as soil erosion, land desertification, and biodiversity decline persist, while the significance of forests in maintaining regional ecological security has not yet been fully realized [4].

FES is defined as the goods, services, and benefits that forest ecosystems contribute to human economy and society through ecological structures, processes, and functions, including carbon storage, biodiversity conservation, timber and non-timber forest products, water regulation, soil conservation, recreation and tourism, and cultural and spiritual values [5,6]. In China, the specificity of FESs lies in the critical role that forests play in not only sustaining human well-being but also achieving ecological restoration and carbon neutrality goals [2,4]. The complexity of and spatio-temporal variation in forest ecosystem processes present rich research content for investigating ecosystem services. Currently, most studies in China still categorize FESs into four groups according to the Millennium Ecosystem Assessment (MA) approach: provisioning services, regulating services, cultural services, and supporting services [7]. As ecosystem services research progresses, scholars have increasingly concentrated on ecological economics, and the relationship between ecosystem services and human well-being [8].

An objective, dynamic, scientific, and comprehensive evaluation of FES value is of great practical significance to promote and strengthen the leading position of forestry in the national economic development system and improve the management level of forests [9]. At the same time, it facilitates the integration of forest value into the national economic accounting system and helps to balance forest ecological protection with economic development [10]. Accounting for FES is conducive to defining the forest asset ownership relationships, realizing compensation for resource utilization, laying the foundation for the capitalization and market-oriented operation of ecological assets, and promoting sustainable development [11].

Various methodologies have been developed to evaluate ecosystem services, with the goal of supporting decision making and management from both biophysical and economic perspectives [12]. The most crucial aspect in policymaking is the reliance on trustworthy outcomes [13]. Numerous studies have endeavored to quantify and map ecosystem services across diverse scales, scopes, and procedures. Effective decision making and enhanced policy implementation are crucial from both biophysical and economic perspectives [14,15].

In China, the protection and construction of forest ecosystems has further advanced the concept that "lucid waters and lush mountains are invaluable assets". Amid China's high-quality development context, the construction of an ecological civilization, the coordinated management of mountains, waters, forests, farmland, lakes, and grassland and the assessment of FESs have become increasingly important [16]. Reports indicate that the forest ecological construction during the ninth national forest resources inventory has been effective and further elevated the level of FESs nationwide. Recent data indicate that China's forest ecological construction efforts have been effective, with the value of ecosystem services provided by forests reaching CNY 15.88 trillion in 2018, a 25.24% increase from 2013 [17,18].

Constructing pathways for realizing the value of FESs is an effective measure to promote the transition of traditional forestry to modern forestry, and an important means to establish a sound FES management mechanism in China [19]. The realization of FES value and the development of forest ecological benefits are mutually complementary. The establishment of pathways needs to be supplemented and improved continuously, and be innovated to keep pace with the times. Achievements in China must rely on government support, taking into account the influence of market trends on FES values and establishing a sound realization pathway from a market-oriented perspective. However, in China, the approaches for realizing the value of FES have not been comprehensively examined in China, thus indicating the need for further research and analysis.

China has made notable progress in FES assessment, which is of great significance for comprehensively understanding and objectively evaluating the status and role of forests. Despite the progress made, there remain several key issues in accurately assessing FESs during practical application. Moreover, FES valuation serves as the foundation for corresponding realization approaches and related policies, such as enhancing ecological benefit compensation mechanisms and promoting forest resource conservation [18,19]. Therefore, it is imperative to review FES assessment for a better understanding of value realization. Additionally, building on the FES valuation review, the value realization approaches in China could be further organized and explored. Thus, in this study, we provide an overview of FES valuation methods and trends in China, with a further focus on exploring value realization approaches. Our findings have the potential to offer valuable insights for promoting regional sustainable development in other regions of the world. Furthermore, our study may objectively reflect the contribution of China's forests to the global carbon cycle and to mitigating global climate change, and accelerate the internationalization process of forest carbon cycle research.

## 2. Bibliometric Analysis of FES Valuation in China

In this study, the research progresses in FES valuation were visually represented by the widely used bibliometric analysis software VOSviewer 1.6.18 [20]. We used the keywords "forest ecosystem service", "valuation", and "China" to search for studies in the main databases of Web of Science (WOS) and China National Knowledge Infrastructure (CNKI) from 2014 to 2023. We read the article titles and some abstracts to make sure that the retrieved papers were all closely related to the research topic. Finally, we obtained a total of 1350 publications from the CNKI database and 876 papers from the WOS database. To determine the state of the science and the future research direction, the distribution of keywords in the literature were examined.

The bibliometric mapping's keyword co-occurrence network is shown in Figure 1. It is clearly demonstrated that the topics about FES valuation have gradually changed during the past 10 years. For WOS, keywords such as ecosystem service valuation, habitat quality, management, and land use change became hotspots in recent years, which reflect more socio-economic aspects of FESs. Additionally, it is clearer in CNKI results that compensation, asset, benefit, and product are hotspots. To summarize, the research progress on forest ecosystem value assessment focuses on nine aspects, including ecosystem service mapping, cultural ecosystem services, ecosystem values, forest landscape restoration, protected areas, mountain forests, cropland abandonment (land use change), land sharing disputes, and social feedback. In terms of research trends, keywords such as "forest ecosystem", "ecosystem service", "value assessment", "ecological service function", "ecological compensation", "ecological service value", "assessment", "value volume", and "InVEST model" have a high frequency [19].

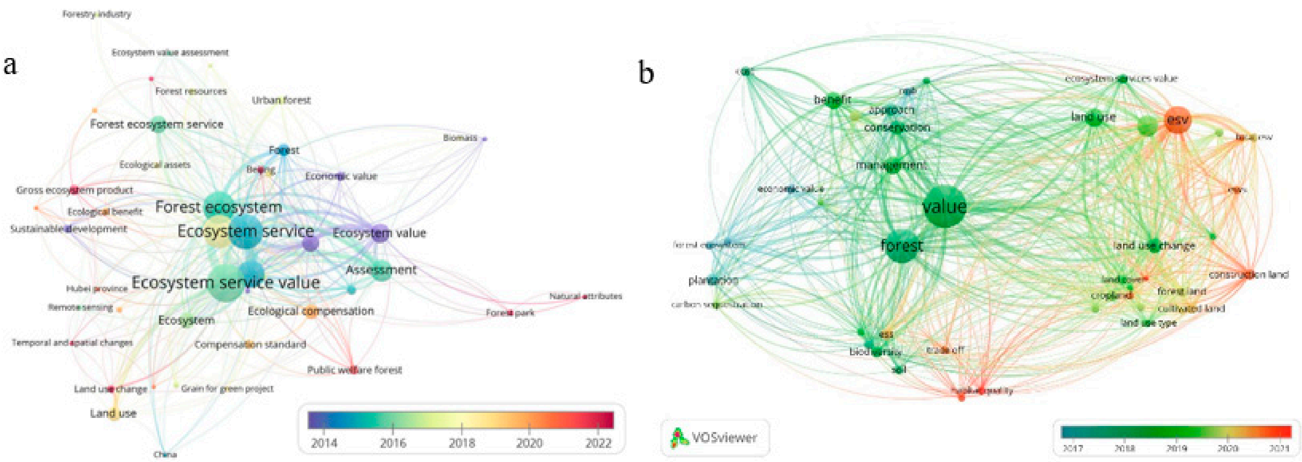


**Figure 1.** The occurrence network map of keywords of forest ecological services ((**a**): CNKI database; (**b**): Web of Science) (Drawn by authors).

## 3. Approaches to FES Valuation in China

Advancements in computer technology have significantly facilitated the study of FES, enabling the continuous collection of forest resource inventory data. The assessment of FES necessitates certain principles and processes, including (1) defining a clear study boundary to determine the scope of assessment; (2) holistically determining ecosystem services under an FES classification system; (3) identifying forest ecological functions and selecting functional indices to clarify assessment methods; and (4) conducting scientific evaluations to obtain specific ecosystem service values [21]. The application scenarios to which different methods or models apply vary widely, the objects to be evaluated vary, and the processes and steps of evaluation also vary widely. For the FES valuation, the corresponding methods need to be selected based on the characteristics of the study area, the reliability of data sources, etc.

### *3.1. General FES Classification and Valuation System*

In general, the methods for assessing FES are similar to those employed for other ecosystems, such as direct market, alternative market, and hypothetical market assessment methods. At present, the FES value assessment in China primarily follows the guidelines of the "Forest Ecosystem Service Function Assessment Specification" (GB/T 38582-2020) of the National Forestry Administration. The guidelines integrate theoretical bases and methods, including ecology, soil and water conservation, and economics, aided by tools such as remote sensing technology, GIS technology, and process mechanism models. The specification combines the remote sensing and field measurement methods, and extrapolates from point analysis to area analysis to evaluate the FESs in terms of both physical quantity and value quantities [6,22]. It introduces the sources of forest resource data, continuous inventory data, and public data used in the assessment. In China, the ecosystem service classification primarily follows the Millennium Ecosystem Assessment (MA) methods. A set of quantifiable and describable operational evaluation index systems have been established, encompassing four types of services: supporting, regulating, provisioning, and cultural services. Additionally, there are nine assessment index systems, including soil conservation, forest nutrient fixation, water conservation, atmospheric environment purification, forest protection, carbon sequestration and oxygen release, biodiversity conservation, forest products supply, and forest recreation. The measurement methods of primary measurement unit (administrative division), secondary measurement unit (dominant species group stand type), tertiary measurement unit (forest origin), and quaternary measurement unit (forest age group) are clearly proposed by a distributed approach. The calculation formula and parameters of each index in the index system are provided and explained [17]. Various assessment index systems have been derived from the four FESs. Among these, a more scientific assessment system comprises 6 ecosystem services (water conservation, soil conservation, carbon sequestration and oxygen release, nutrient accumulation, atmospheric environment purification, and biodiversity conservation) and 11 indicators (water regulation, water purification, soil fixation, fertilizer conservation, carbon sequestration, oxygen release, forest nutrient accumulation, negative ion supply, pollutant absorption, dust retention, and species conservation) (Figure 2). The systems and calculation equations are widely used in China [23].

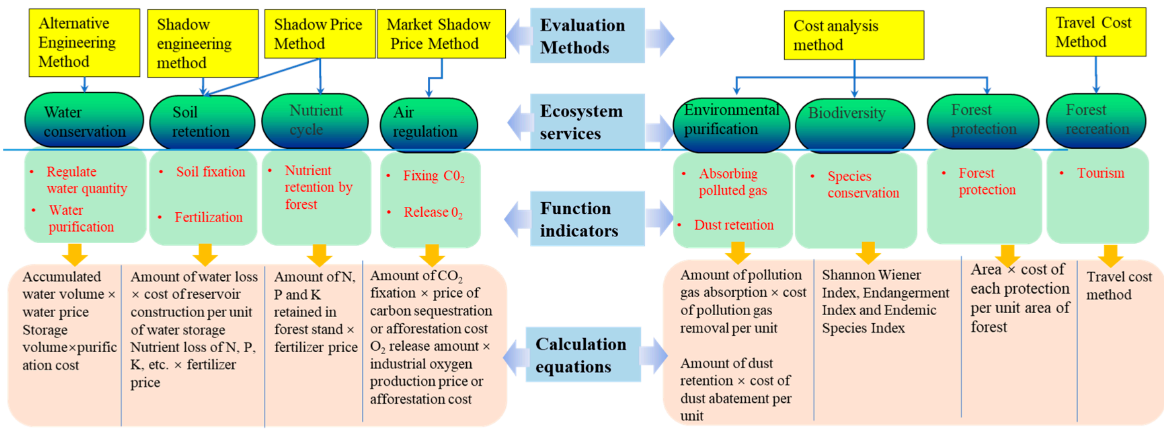


**Figure 2.** Main calculation methods for FES calculations.

### 3.2. Landscape Spatially Explicit Model

The research on FES valuation has achieved fruitful results, particularly in dynamic and accurate service assessments using ecological models. The most applied model at present is the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model, developed by Stanford University, the World Wildlife Fund (WWF), and The Nature Conservancy (TNC), under the auspices of the Natural Capital Project. This model effectively maps and values the goods and services derived from nature that sustain and fulfill human life, especially within forests and watershed ecosystems, including biodiversity, carbon storage, soil conservation, and water purification [24] (Figure 3).

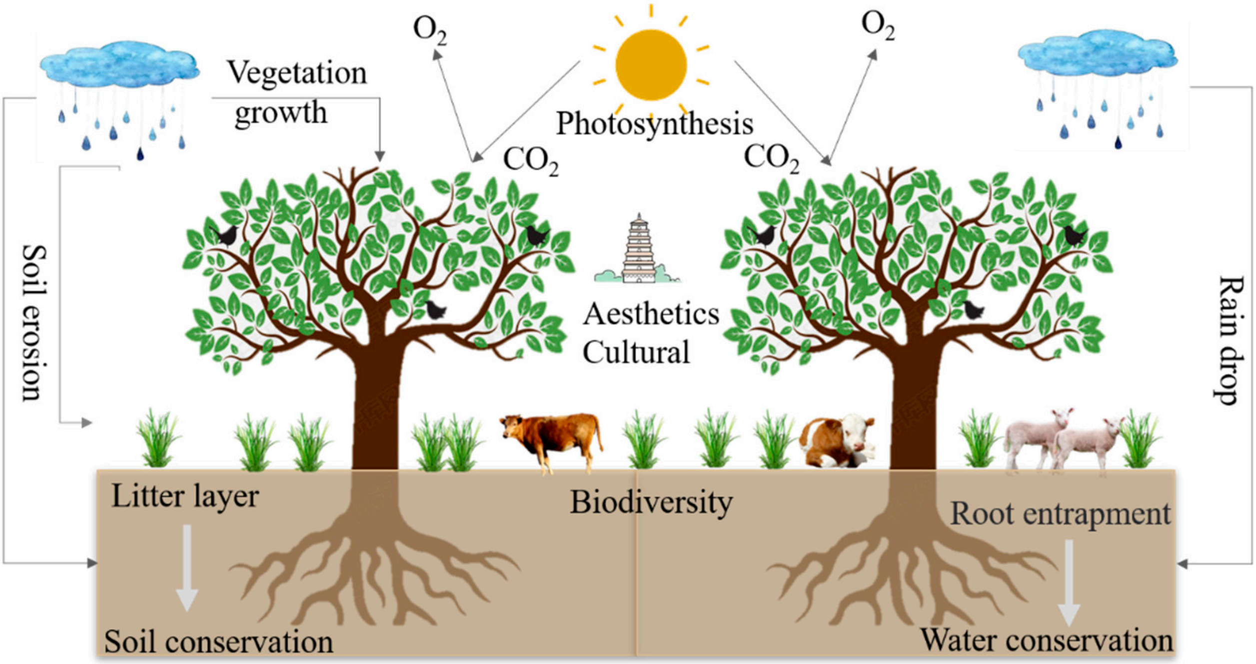


**Figure 3.** FES in InVEST model (drawn by authors).

For instance, the habitat quality and GLOBAL module are commonly employed to represent biodiversity [25]. The carbon module aggregates the amount of carbon stored in four different pools: aboveground biomass (all living plant material above the soil such as trunks and branches), belowground biomass (living root systems), soil organic matter (soil), and dead organic matter (litter and dead wood) [26]. Sediment retention refers to a watershed's ability to retain soil, which improves water quality when soil loss is controlled [27]. Water yield represents the amount of water that runs off the landscape and is useful for the local inhabitants [28]. The model calculates annual water yield using mean annual precipitation, annual reference evapotranspiration, and correction factors for vegetation type, soil depth, and plant-available water content as data inputs [29].

The scenario generator tool can be used to construct different land use and climate change scenarios, such as trends, development, and conservation [27]. In conjunction with FES value analyses, government departments can utilize this model to assist policymakers in considering how the land can be managed to provide the greatest benefit to people or to assist in designing mitigation processes that maintain the social benefits of natural resources to the extent permitted [30]. Environmental organizations can use this model to tailor policies to better improve the quality of people's lives and fulfill their mission of protecting biodiversity [22]. However, the InVEST model, which has been widely used in FESs, is still limited to the assessment of aesthetic and aquaculture.

To evaluate the social values of ecosystem services, some scholars in China have used Social Values for Ecosystem Services (SoLVES), developed jointly by the U.S. Geological Survey Rocky Mountain Geographic Sciences Center (RMGSC) and Colorado State University [31]. This model is mainly used to evaluate and quantify the social value of FESs, such as aesthetics, biodiversity, leisure life, and cultural activities [31]. The evaluation results are obtained by public attitudes and preferences and expressed by the non-monetized value index, which has a high application value [32]. The model has also been applied to the social value assessment of landscapes, parks, and other ecological environments [33]. For example, it has been used to conclude that places with higher aesthetics and biodiversity have higher social value and attract greater attention from tourists in Xi'an wetland park [34]. The closer the leisure area is to the scenic spot, the better the ecological environment, and the greater the attention from tourists, which can help the park personnel to evenly distribute park resources, maintain the ecological environment, and improve the social value of the wetland park [35]. Several models have been developed to evaluate and quantify ecosystem services, including the ARIES (Artificial Intelligence for Ecosystem Services) model, which was developed by the Institute of Ecological Economics, University of Vermont, USA. It is mainly used to evaluate and quantify the ecosystem services flows using artificial intelligence and semantic modeling, combined with ecological spatial data and algorithms, so as to achieve effective applications [36]. It can describe the spatial flow of ecosystem services, including freshwater supply, sediment regulation, flood regulation, recreation, and other ecosystem services [37]. For instance, studies applied to two alternative land use scenarios in South China highlight the potential effects of land use and management decisions on species and functional diversity [38]. However, in practical applications, it is found that the ARIES model is established on the basis of case studies, and its influencing factors are large and its spatial resolution is low [39]. Therefore, it is not suitable for global use, which would lead to a reduction in evaluation accuracy and limit its applications [37]. Other ecological models, such as the GUMBO model and the MIMES model, have application value, but are limited to within certain regions [40].

### *3.3. Emergy Approach for Valuation*

Ecosystem services are the benefits that humans derive directly or indirectly from ecosystem functions [41]. Since the 1990s, various experts have estimated the value of ecosystem services based on ecological, economic, and theoretical perspectives [42,43]. During the same period, international ecologists proposed the theory of emergy analysis for the quantitative analysis of environmental resource values and the complex relationships among ecosystems and economic and social systems [44]. In the past two decades, emergy evaluation has become an important method for ecosystem service valuation methods besides alternative cost, conditional value, market value, and benefit conversion methods [45,46]. The emergy analysis method draws on the advantages of traditional economics and ecology methods, and solves the problem of not being able to account for energy between different service types, while also solving the problem of integrating and accounting for energy, material, and value flows, opening up a new direction for quantitative research on ecological economic systems, and becoming one of the most commonly used methods in ecological capital and ecosystem service value evaluation studies [47]. FESs are of great importance to human well-being, and since 1960, as socio-economic development has continued to destroy ecosystems, many scholars have used energy as a common denominator (Figure 4), accounting for value through a functional relationship between emergy and the value of FESs and monetary conversion rates [48]. A complete and innovative summary of the FES system was developed by researchers in 1997, and subsequent studies built on this to provide the first assessment of the biodiversity and indirect economic value of forest ecosystems in nature reserves [41,49]. Since 2010, various researchers have identified the service value of forest ecosystems in different regions of China from the perspective of "providers", research objects, or functional relationships [50–52].

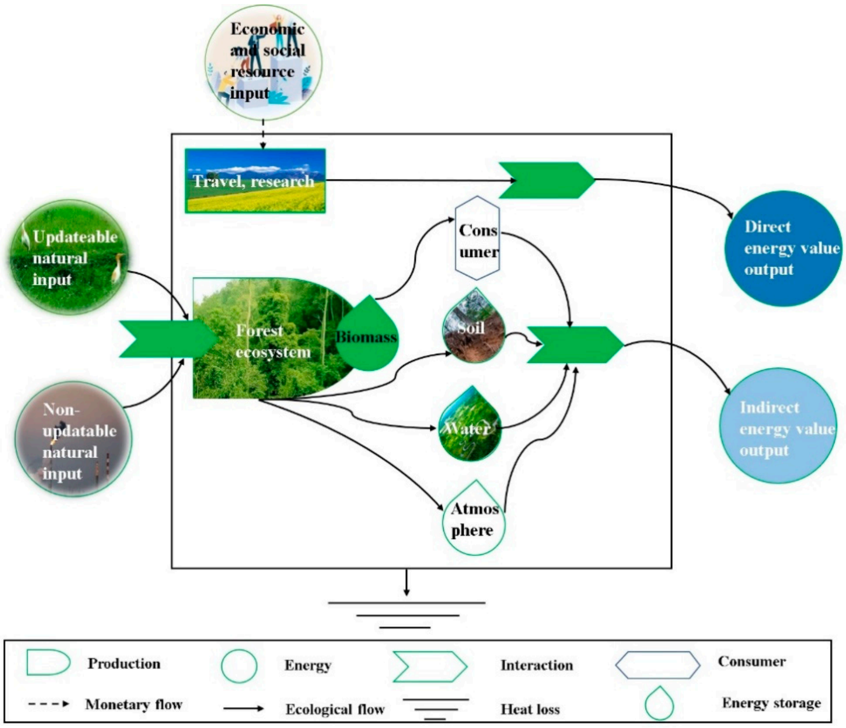


**Figure 4.** Map of the energy structure of forest ecosystem in protected areas. (Drawn by authors.)

### 3.4. Meta-Analysis Value-Transfer Approach

Additionally, the meta-analysis value-transfer approach has been employed in FES valuation [53]. Meta-analysis is considered as a substitute, more practical transfer method, capable of predicting the value of ecosystem services in similar areas [54]. Although a common statistical technique with numerous case studies for constructing meta-regression models of ecosystem service values exists, empirical findings primarily focus on confirming direct linear relationships, with limited attention given to the determinants of transfer efficiency [55]. A notable example is to assess the economic value of ecosystem services per unit area provided by national forest type nature reserves in China. The calculation reveals that the average value per unit area of each ecosystem service, in descending order, is in biodiversity conservation, forest recreation, nutrient accumulation, water conservation, water purification, forest products, carbon sequestration and release, air, forest products, carbon sequestration and oxygen release, and soil conservation (Figure 5). The average value is 70,697.59 CNY·hm$^{-2}$·a$^{-1}$ [53].

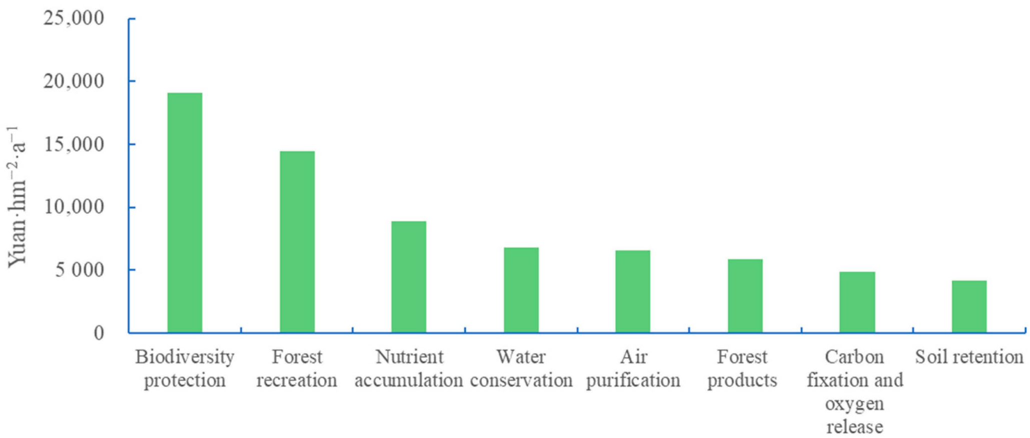


**Figure 5.** Economic value of ecosystem services per unit area provided by national forest nature reserves in China (numerical data from [24]).

Furthermore, Xie et al. proposed a universal and straightforward method called the value-equivalent method for different land uses in China [23]. The value represents the potential ability of the indicator to produce the relative size of the contribution of the ecosystem service in the whole ecosystem production process, defined as an indicator of the economic value of the annual natural production of basic farmland with an average yield per square kilometer of Chinese production [56]. Consequently, the land use table can be converted into a table of ecosystem service values in the study area for that year in the calculation, and the value of each ecosystem service can be determined after a comprehensive analysis and comparative confirmation [57].

## 4. Research Trends and Key issues of FES Valuation in China

### *4.1. The Importance of Forest Carbon Valuation in FES Valuation*

In the context of carbon neutrality in China, carbon sequestration and oxygen release services attract lots of attention. The carbon sequestration of forests and its value accounting are important for carbon trade, and thus have received attention from society. At present, the estimation methods of the amount of carbon fixed by forests mainly include the chemical reaction equation method, the biomass method, the forest volume method, the biomass inventory method, the eddy correlation method, the eddy covariance method, and the remote sensing method [58]. Forest soil carbon models in InVEST have been widely used due to the spatial heterogeneity of forests and uncertainty in carbon pool changes. At present, the relevant forest soil carbon models include Century, RothC, Coup-Model, Q-Model, ROMUL, and DECOMP, and the first two models—Century and RothC—have been more widely used in China [59]. However, the models need extensive input information, which is difficult to obtain. In recent years, the Yasso07 forest soil carbon decomposition model has also been used in related research in China due to its easy operation and reliability. This model assumes that four types of organic compounds in litter are converted between different pools [60]. Until now, forestry growth simulators such as Silva, Sibyla, and Efiscen were seldom used in China, while the models based on remote sensing data have been widely applied and some advanced statistical approaches (PLSR and deep learning) have been adopted [60]. Uncertainties still exist in the forest carbon sinks in China, and the estimation methods used and the parameter values chosen for the estimation of forest carbon sequestration varied greatly and generated different results [61]. According to the seventh forest inventory report of China in 2009, the area of planted forests in China reached 0.69 billion ha, ranking first in the world, maintaining a high and continuous growth rate. Among the national carbon sinks, the role of plantation forests in carbon sequestration has become one of the key contributors. Due to the large differences in climatic and geographic conditions, it is important to accurately assess FES value at a fine scale [62].

Methods for assessing the carbon fixed and stored in forests are controversial, and the main methods include carbon tax, the afforestation cost method, the average value of carbon tax and afforestation cost method, the industrial oxygen production method, the willingness to pay method, the greenhouse effect loss method, the artificial fixed carbon dioxide cost method, and the cost–benefit method [63]. Among these methods, the carbon tax method and the afforestation cost method are more widely used. According to the System of Integrated Environmental and Economic Accounting (SEEA) on resource measurement, different methods are used to measure the carbon of different tree species in terms of carbon stock and carbon flow, respectively. The physical quantities of carbon assets and carbon services of forest ecosystems can then be calculated and used as the basis for assessing their monetary value in combination with carbon prices [64].

For carbon sequestration, the productivity estimation method is one of the most widely used methods. Although each light energy utilization model considers light, temperature, and moisture, there are large differences in the parameters used for the environmental constraints in different models. Many scholars and forestry researchers have estimated primary or plantation forests, such as fir forests, broadleaf red pine forests, and eucalyptus forests, based on light utilization models with high accuracy. However, for regions with large spatial variations in climate conditions, the ecological parameters of the models are also affected and different types of vegetation under different climate conditions should be taken into account for validating the parameters [63]. The carbon sink capacity of forest ecosystems in China is often underestimated and the reason for this is that the woody source biomass method used to calculate forest carbon sinks is based on the increment in forest stock, and some forest carbon resources are not counted [62,63].

### *4.2. Uncertainties and Challenges of FES Valuation*

At present, there are many large-scale studies (watershed, regional, and global) in China, and although the technical methods are improving, the level of infrastructure for the long-term monitoring of regional ecosystems is relatively insufficient and data acquisition is not comprehensive, which directly affects the accuracy of assessment results. In China, the China Forest Ecosystem Service Function (CFESF) project used the national indicator system, the national forest inventory data, and the data measured by the national forest ecological stations, and a dynamic and accurate value assessment was achieved based on distributed algorithms [65].

There are many viewpoints challenging the valuation of ecosystem services, and some argue that prices should not be placed on the valuation of natural resources [43]. However, the quantitative approach is helpful to understand the dynamics of ecosystem services more conveniently despite the current constraints of scientific and technological conditions and data acquisition and processing. The future development trend of FES valuation will involve the integration, dynamism, spatial explicitness, and participation of model applications. Data obtained through the continuous monitoring and inventory of forest resources and remote sensing will be important sources required for models [66].

Currently, remote sensing technology is widely applied in assessing ecosystem services, particularly demonstrating significant advantages in obtaining spatial distribution and temporal change information. For example, the hybrid image model based on the image unit of vegetation cover provides an effective method to measure vegetation information over a large area, which meets the needs of modeling ecosystem services at large scales; however, the time of remote sensing image selection, as well as the conscientiousness of forest surveys, can affect the accuracy of data modeling. It is necessary to further study the temporal and spatial resolution of remote sensing and the suitable parameters of the study area to establish a more suitable assessment model [19].

Compared with studies worldwide, most studies in China face the following problems: (1) Most of the assessments lack in-depth research on the relationship between ecosystem structure, ecosystem processes, and ecosystem service, thus the studies lack a reliable ecological foundation [4]. (2) Research methods are mainly market value methods and alternative market methods, such as the alternative engineering method, the opportunity cost method, the travel cost method, etc., while the virtual market method is not sufficiently applied. (3) There are few case studies on non-use values, such as optional values, heritage values, existence values, etc. [14,19]. (4) Despite the vast number of studies in China, the proposed methodologies lack the necessary data to be directly applied to national or regional biodiversity-related policymaking.

## **5. Exploring the Value Realization Approaches of Forest Ecological Products in China**

In China, the value realization of forest ecological products has long received widespread attention [33]. Ecological value realization refers to the manifestation and monetization of ecological benefits, which implies the spillover of ecosystem services, the transformation of resources into ecological assets, the transformation of ecological assets into ecological capital, and the development, production, and marketing of ecological products [67]. Ecological asset valuation can be quantified from both stock and flow perspectives, and the assessment methods include physical and value accounting. The stock of ecological assets refers to the ecosystem itself, and can be quantified using indicators such as area, species composition, and forest volume. Ecological asset flows refer to the sustained ecosystem outputs or effects as a result of their existence, i.e., the provisioning, regulating, and cultural services of ecosystem services, which are quantified by the production or service per unit of time [33]. Ecological capital is an ecological asset used for investment and thus profit. Ecological products refer to tangible or intangible products that are produced by ecosystems and enter the market [68]. Thus, the process of providing ecological goods from ecosystems to society through the economy is a pathway of trading ecological products by creating markets or quasi-markets and establishing trading rules to link supply and demand sides in a contractual manner [62] (Figure 6).

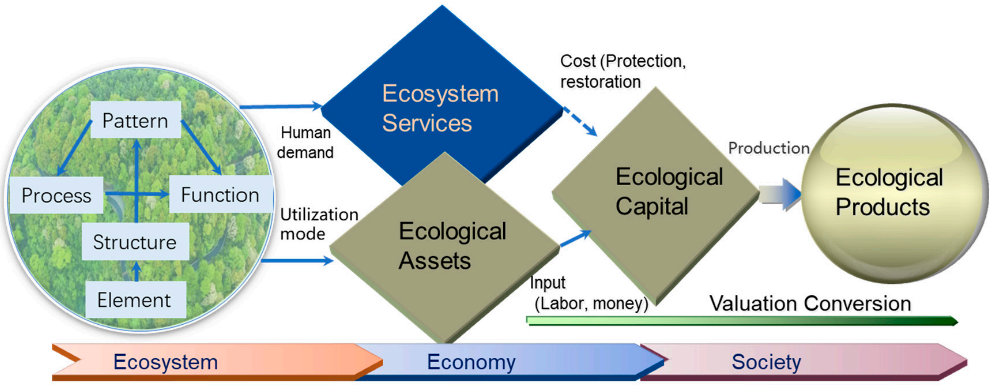


**Figure 6.** The value realization of forest ecological products (drawn by authors).

In 2021, China issued the "Guidance on the establishment of a sound mechanism for realizing the value of ecological products", which called for the promotion of industrialization of ecosystems and industrialized ecological development [69]. This guidance proposed a series of measures, including ecological product surveys and monitoring, value evaluation, operation and development, protection and compensation, value realization guarantees, and promotion mechanisms.

Overall, the paths of value realization in China mainly include six aspects as follows: implementing and innovating diversified ecological compensation, strengthening ecological product rights trading, promoting ecological resource property rights circulation, promoting ecological product premiums, guiding ecological industry integration development, and strengthening the value realization guarantee mechanisms [20,64] (Figure 7).

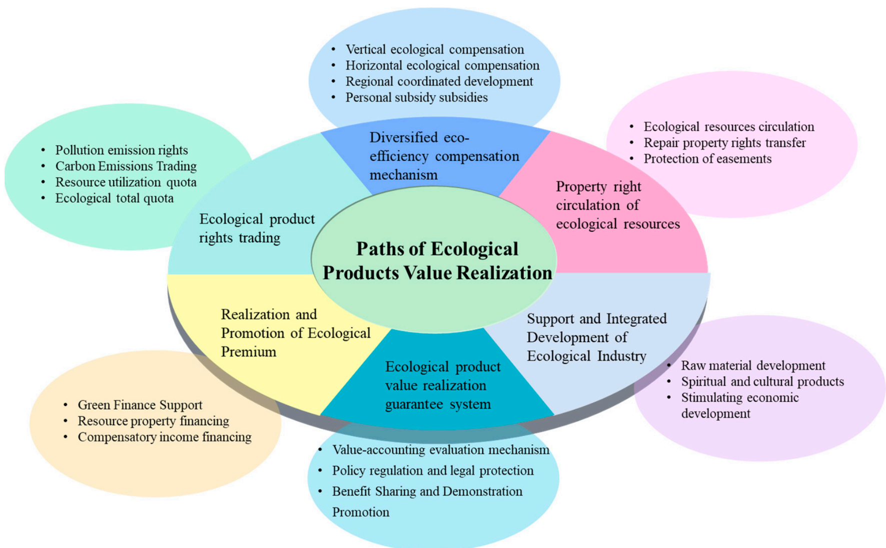


**Figure 7.** Paths of forest ecological products value realization in China (drawn by authors).

### 5.1. Implementation and Innovation of Diversified Ecological Benefit Compensation

China has carried out a lot of exploration in ecological compensation mechanisms. In 2016, the General Office of the State Council issued the "Opinions on Improving Ecological Protection Compensation Mechanism" and the central government issued "Opinions on deepening the reform of ecological protection compensation system" and the "Opinions on establishing a sound mechanism for realizing the value of ecological products" [33]. At present, the scope of ecological compensation in China is small with low standards and a single source of funding lacking market-based mechanisms. In general, payment for ecosystem services (PES) has gradually become an important measure to promote the supply of ecosystem services and is still considered one of the most effective ways to improve ecosystems and realize the value of ecosystem services. PES is a market-based mechanism that involves compensating FES providers for maintaining or enhancing clean water, carbon sequestration, and biodiversity conservation, for example. It can incentivize landowners or resource managers to adopt sustainable land use practices and contribute to the conservation of forest resources. At present, it is necessary to further promote the combination of vertical compensation and horizontal compensation to form a "government-led, enterprise and social participation, market-oriented operation and sustainable ecological protection compensation mechanism" [70]. The main contents include the following aspects: (1) To guarantee the ecological compensation directly subsidized by the central government, increase financial transfer payments, and gradually expand the scope, mainly including subsidies for key forestry projects, compensation for public welfare forests, and an "exit compensation mechanism" for local residents of nature reserves; (2) To promote special compensation or transfer payments from provincial governments to localities. For example, some regions have explored and proposed horizontal ecological compensation mechanisms for forest cover, taking forest cover as a binding indicator, forming a trading demand between areas with differentiated forest covers; (3) To strengthen diversified ecological compensation modes, employing ecological forest rangers to participate in forest resource protection so that local people can gain more economic benefits from ecological protection and restoration [4].

### 5.2. Enhance Trading of Ecological Product Benefits

For public goods or quasi-public goods provided by ecosystems, they can be transformed into private goods through benefits, and then traded by market-based means to realize their economic value [71]. In the context of the "dual carbon" strategy which is used to describe China's goal of achieving both carbon peak and carbon neutrality with climate change mitigation efforts, forestry carbon sinks have potential for realizing the value of forest ecological benefits. The government or a third-party organization establishes the platform and rules for trading forest ecological products, and the market generally determines the supply and demand relationship between the parties. Farmers and other forest land managers can include their forest land in forestry carbon sink projects to increase the carbon sequestration capacity of forest through afforestation and forest management, and then trade and obtain carbon sink revenues on the trading platforms. In recent years, China has carried out some exploration in carbon trading, and the general framework of the carbon sink market has been initially formed, but it is still necessary to promote the integration of forestry carbon sinks into the national carbon emission trading system.

The establishment of carbon sink trading and emission rights trading should be accelerated. The potential of forestry carbon sinks should be accurately assessed for policymaking [40]. Carbon sink trading and carbon credits enable value to be realized, and revenues from trading are further used to prevent soil erosion, mitigate land degradation, and restore endangered wildlife habitats. In addition, the system of paid use of state-owned natural resources assets should be improved, the scope of forest assets should be categorized, the distribution of benefits should be clarified, and multiple forms of distribution policies should be explored [72].

### *5.3. Promote the Circulation of Ecological Resource Property Rights*

Resource property rights circulation refers to the process of realizing the value of ecological products through the circulation of ecological resources with clear property rights, such as ownership, use, management and income rights. Ecological resources are the production carriers of ecological products, and ecological resources with clear and explicit property rights can facilitate the value realization of ecological products with relatively ambiguous property rights. In some regions, the "land ticket" mechanism reclaims idle rural residential land into arable land, forest land, grassland, and other ecological land, and the reduced construction land index becomes a tradable land ticket after certification, thus realizing the value exchange of ecological products [72]. For forest land, on the basis of clarifying the contractual management rights and ownership of collective forests, the management and ownership rights are circulated through subcontracting, leasing, transferring, exchanging, and taking shares to obtain the benefits of transfer. In South China, the forest ticket and forest eco-banking system have centralized the reserve of fragmented and fragmented forest resources to the eco-bank, realizing the transformation of forest resources into assets. The exploration of easement modes needs to be strengthened. The conservation easement system is a way to achieve a unified management of land without changing ownership. The government signs an easement contract with local residents on behalf of the right holder, defining the positive and negative activity of forest conservation and dynamic compensation mechanisms. If the local residents meet the obligation standards agreed in the easement contract, they will be compensated, and at the same time, the rights holders can have a variety of rights, such as priority for developing ecological agriculture and ecological recreation projects [73].

### *5.4. Promote Eco-Product Premiums*

The essence of the eco-product premium is to transfer the positive externalities of reducing pollution or enhancing ecosystem services to consumers in the form of a premium for product labelling or certification, thus encouraging manufacturers to conduct production activities in a more green and sustainable way. In developed countries, a variety of measurements and mechanisms have been applied to enhance the value of eco-products. The eco-product premiums for forests in China are still at a low level and the modes are relatively inadequate, so there is a need to explore diversified mechanisms for realizing eco-product premiums [66]. Forest certification can enhance the status of forest products in international trade, increase the added value of ecological products, and increase the revenue of forest ecological product suppliers. China should step up efforts to promote forest certification, establish and standardize ecological product certification evaluation standards, and build a forest ecological product certification system with Chinese characteristics [74]. China launched forest certification in 2001 and now has eight types of forest management certification. In the regions with excellent forest ecological conditions, agricultural and forest products that meet ecological and green standards could be entitled to create green ecological brands. Additionally, it is good to combine ecological restoration with related industries to promote the premium of land and related industrial development by ecosystem restoration and landscape quality improvement [74].

### *5.5. Guide the Integrated Development of Ecological Industries*

In recent years, China has strengthened the development of forest-related ecological industries, such as accelerating the development of the under-forest economy, the development of the specialty economic forestry industry, and the development of the forest recreation industry. Driven by industrial policies, industries such as sustainable timber utilization, bamboo processing, characteristic economic forests, forest economy, ecotourism, and forest recreation have achieved integrated development, making the ecological industries the main actors in achieving forest ecological product value [38]. China should promote key projects such as natural forest protection and reserve forest construction to increase the forest resource quantity, continuously optimizing the forest harvesting system and developing industrial raw material forests and large-diameter and rare species timber forests. In terms of characteristic economic forests, it is necessary to develop characteristic economic forests, seedlings, and flowers and other characteristic economic forest industries, and build a number of special product processing and service bases [15]. As for the under-forest economy industry, China should promote its intensive and specialized operation, explore the establishment of the forest economy standard system, and strengthen the quality and brand building. Under the forest, the land resources should be fully utilized to carry out the compound production and operation of the agriculture, animal husbandry, grass, and medicine sectors. In the forest products manufacturing and processing industry, it is important to accelerate industrial transformation and upgrading, increase industry scale, improve industry competitiveness, and develop new industries. In terms of ecological tourism with forest recreation, local governments should integrate and upgrade ecotourism with forest recreation, ecological culture, nature education, leisure and vacation, and mountain sports in order to create quality products. In general, China's forest eco-industry development level still lags behind with an extensive development mode, an incomplete industrial chain, a low added value of products, a lack of regional characteristics, and weak scientific support; thus, it is necessary to adjust the forest eco-industry's development mode [75].

### *5.6. Strengthen the Mechanism for Guaranteeing the Realization of Ecological Product Value*

In addition to optimizing various value realization paths, China needs to further strengthen the mechanism for guaranteeing the realization of ecological product value [76]. There are four aspects that need to be addressed: (1) It is crucial to establish forest ecological product value accounting and assessment systems to provide a scientific basis for policymaking, such as ecological compensation, ecological and environmental damage compensation, and ecological product rights trading. In addition, forest resource accounting studies lay an important foundation for compiling forest resource balance sheets and exploring value realization mechanisms [77]. (2) Special financial input mechanisms, policy control mechanisms, and legal safeguard mechanisms need to be developed to guarantee the value realization's long-term effectiveness. The government should promote the comprehensive regulation of the scale and speed of different value realization paths on the premise of asset appreciation, strengthen the supervision and law enforcement of forest ecological product markets, and reduce the transaction costs of ecological products [19]. (3) Benefit sharing mechanisms and demonstration mechanisms need to be further improved. This includes forestry industrialization consortia construction, perfecting the value of the industrial chain, enhancing the capacity of professional cooperation, strengthening the supply capacity of ecological products, strengthening the mutual assistance and benefit sharing systems, and promoting the construction of value realization demonstrations in regions, counties, townships, and villages [40].

## 6. Conclusions

In this study, we have examined the current advancements in FES methodologies and their ecosystem service value realization pathways in China. We have analyzed the primary models and methods employed in the country for FES assessment, including the InVEST model, ARIES model, emergy analysis, and value-transfer approach. Further, a bibliometric analysis of FESs in China exhibited the research trends that have gained more and more importance for value realization in socio-economic-related studies. We identified several challenges and offered suggestions. Additionally, the importance of forest carbon valuation and the uncertainties and challenges of FES valuation were presented. Despite the diversification of ecological product value realization pathways in recent years, many domestic forest ecological product value realization pathways are still in the pilot and investigation stages due to various restrictions. Consequently, there is a limited pool of experiences to learn from, promote, and replicate, leading to under-realized ecological product value. As a result, in order to promote ecological product value realization for

China's forest ecological products, it still needs to be improved from the mechanism design perspective. To improve the effectiveness of policy management, future research should prioritize interdisciplinary and multi-method integration and the fine assessment of FES values at small and medium scales to improve the effectiveness of policy management. By doing so, we can better understand the complex relationships among ecosystems and economic and social systems, and identify effective strategies for promoting FES value in China.

In conclusion, our study highlights the importance of FES value assessment in promoting sustainable forest management and ecosystem services in China. By addressing the challenges associated with FES value assessment and identifying effective value realization pathways, we can promote the sustainable use and management of forest ecosystems, and improve the well-being of both human societies and ecosystems.

**Author Contributions:** S.L.: research design, review and editing; Y.D.: drafting the article and revising; F.W. and H.L.: methods; L.Y.: references. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was supported by National Key Research and Development Project (No. 2022YFF1303204) and National Natural Sciences Fund Project (No. 42271097).

**Institutional Review Board Statement:** This article does not contain any studies with human or animal subjects performed by any of the authors.

**Data Availability Statement:** The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Dixon, R.K.; Solomon, A.M.; Brown, S.; Houghton, R.A.; Trexier, M.C.; Wisniewski, J. Carbon pools and flux of global forest ecosystems. *Science* **1994**, *263*, 185–190. [CrossRef] [PubMed]
2. Daily, G.C. *Nature Services: Social Dependence on Natural Ecosystems*; Island Press: Washington, DC, USA, 1997; pp. 1–10.
3. Wang, B.; Niu, X.; Song, Q.F. Forest ecosystem service assessment and path design of value-oriented realization in China. *Environ. Prot.* **2020**, *48*, 28–36.
4. Liu, C.; Zhang, M.X. Literature review and comments on forest ecological compensation. *J. Nanjing For. Univ.* **2019**, *43*, 149–155.
5. Ouyang, Z.Y.; Wang, X.K.; Miao, H. A primary study on Chinese terrestrial ecosystem services and their ecological economic values. *Acta Ecol. Sin.* **1999**, *19*, 607–613.
6. *GB/T 38582-2020*; National Forestry and Grassland Administration. Specifications for Assessment of Forest Ecosystem Services. Standards Press of China: Beijing, China, 2020.
7. MA. *The Millennium Ecosystem Assessment*; Island Press: Washington, DC, USA, 2005.
8. Sutherland, I.J.; Gergel, S.E.; Bennett, E.M. Seeing the forest for its multiple ecosystem services: Indicators for cultural services in heterogeneous forests. *Ecol. Indic.* **2016**, *71*, 123–133. [CrossRef]
9. Liu, S.R.; Dai, L.M.; Wen, Y.G.; Wang, H. A review on forest ecosystem management towards ecosystem services: Status, challenges, and future perspectives. *Acta Ecol. Sin.* **2015**, *35*, 1–9.
10. Pan, T.; Wu, S.H.; Dai, E.F.; Liu, Y.-J. Spatiotemporal variation of water source supply service in Three Rivers source area of China based on InVEST model. *Chinese J. Appl. Ecol.* **2013**, *24*, 183–189.
11. Wu, S.; Yan, X.D.; Zhang, L.J. The relationship between forest ecosystem emergy and forest ecosystem service value in China. *J. Geogr. Sci.* **2014**, *69*, 334–342.
12. Liu, X.D.; Zhang, W.Q.; Feng, Y.J.; Zhao, X.Y.; Gan, X.H.; Zhou, Q. Research on water conservation function of forest ecosystem: Progress and prospect. *Chinese J. Ecol.* **2021**, *41*, 1–9.
13. Li, G.Y.; Jiang, C.H.; Cheng, T.; Zhou, Q.; Zhang, H.R. Ecosystem services evaluation based on national geographical state monitoring land cover data: Taking Yichun as an example. *Ecol. Econ.* **2016**, *32*, 126–129.
14. Wang, B.; Ren, X.X.; Hu, W. Assessment of forest ecosystem services value in China. *Sci. Silvae. Sin.* **2011**, *47*, 145–153.
15. Wang, C.; Zhang, Y.X. Implementation pathway and policy system of carbon neutrality vision. *Chinese J. Environ. Manag.* **2020**, *12*, 58–64. [CrossRef] [PubMed]
16. Yang, J.Y.; Wen, B.; Song, S. Domestic research advances in service value appraisal of forest ecosystem. *J. Southwest For. Coll.* **2008**, *28*, 65–69.
17. *GB/T38590—2020*; National Forestry and Grassland Administration. Technical Regulations for Continuous Forest Inventory. Standards Press of China: Beijing, China, 2020.
18. Ouyang, Z.Y.; Wang, R.S.; Zhao, J.Z. Ecosystem services and their economic valuation. *Chinese J. Appl. Ecol.* **1999**, *10*, 635–640.

19. Wang, S.B.; Jiao, X.; Li, D.D.; Li, T.W. Review and prospect of research on ecosystem services: The evolution from functional cognition and value accounting to consumption value realization. *For. Econ.* **2021**, *43*, 49–67.
20. van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *2*, 523–538. [CrossRef] [PubMed]
21. Zhang, L.B.; Yu, H.Y.; Li, D.Q.; Jia, Z.; Wu, F.; Liu, X. Connotation and value implementation mechanism of ecological products. *Trans. Chin. Soc. Agric. Mach.* **2019**, *50*, 173–183.
22. Wang, H.; Wang, W.J.; Liu, Z.; Wang, L.; Zhang, W.; Zou, Y.; Jiang, M. Combined effects of multi-land use decisions and climate change on water-related ecosystem services in Northeast China. *J. Environ. Manag.* **2022**, *315*, 115131. [CrossRef]
23. Xie, G.D.; Zhang, C.X.; Zhang, K.M.; Chen, W.H.; Li, S.M. Improvement of the evaluation method for ecosystem service value based on per unit area. *J. Nat. Resour.* **2015**, *30*, 1243–1254.
24. Sun, X.; Li, F. Spatiotemporal assessment and trade-offs of multiple ecosystem services based on land use changes in Zengcheng, China. *Sci. Total Environ.* **2017**, *609*, 1569–1581. [CrossRef]
25. Schipper, A.M.; Hilbers, J.P.; Meijer, J.R.; Antao, L.H.; Benitez-Lopez, A.; de Jonge, M.M.J.; Leemans, L.H.; Scheper, E.; Alkemade, R.; Doelman, J.C.; et al. Projecting terrestrial biodiversity intactness with GLOBIO 4. *Glob. Change Biol.* **2020**, *26*, 760–771. [CrossRef] [PubMed]
26. Ma, S.; Qiao, Y.P.; Wang, L.J.; Zhang, J.C. Terrain gradient variations in ecosystem services of different vegetation types in mountainous regions: Vegetation resource conservation and sustainable development. *For. Ecol. Manag.* **2021**, *482*, 118856. [CrossRef]
27. Vo, Q.T.; Kuenzer, C.; Vo, Q.M.; Moder, F.; Oppelt, N. Review of valuation methods for mangrove ecosystem services. *Ecol. Indic.* **2012**, *23*, 431–446. [CrossRef]
28. Yohannes, H.; Soromessa, T.; Argaw, M.; Dewan, A. Impact of landscape pattern changes on hydrological ecosystem services in the Beressa watershed of the Blue Nile Basin in Ethiopia. *Sci. Total Environ.* **2021**, *793*, 148559. [CrossRef] [PubMed]
29. Li, J.; Dong, S.; Li, Y.; Wang, Y.; Li, Z.; Li, F. Effects of land use change on ecosystem services in the China–Mongolia–Russia economic corridor. *J. Clean Prod.* **2022**, *360*, 132175. [CrossRef]
30. Zhang, Y.; Zhao, Z.; Fu, B.; Ma, R.; Yang, Y.; Lu, Y.; Wu, X. Identifying ecological security patterns based on the supply, demand and sensitivity of ecosystem service: A case study in the Yellow River Basin, China. *J. Environ. Manag.* **2022**, *315*, 115158. [CrossRef]
31. Arbault, D.; Riviere, M.; Rugani, B.; Benetto, E.; Tiruta-Barna, L. Integrated earth system dynamic modeling for life cycle impact assessment of ecosystem services. *Sci. Total Environ.* **2014**, *472*, 262–272. [CrossRef]
32. Chan, K.M.A.; Satterfield, T.; Goldstein, J. Rethinking ecosystem services to better address and navigate cultural values. *Ecol. Econ.* **2012**, *74*, 8–18. [CrossRef]
33. Brown, G.; Brabyn, L. The extrapolation of social landscape values to a national level in New Zealand using landscape character classification. *Appl. Geogr.* **2012**, *35*, 84–94. [CrossRef]
34. Zhang, L.B.; Yu, H.Y.; Hao, Z.C.; Wang, H. Practice model and path of ecosystem product value realization. *Res. Environ. Sci.* **2021**, *34*, 1407–1416.
35. Brown, G. Relationships between spatial and non-spatial preferences and place-based values in national forests. *Appl. Geogr.* **2013**, *44*, 1–11. [CrossRef]
36. Bagstad, K.J.; Semmens, D.J.; Winthrop, R. Comparing approaches to spatially explicit ecosystem service modeling: A case study from the San Pedro River, Arizona. *Ecosyst. Serv.* **2013**, *5*, 40–50. [CrossRef]
37. Bagstad, K.J.; Johnson, G.W.; Voigt, B.; Villa, F. Spatial dynamics of ecosystem service flows: A comprehensive approach to quantifying actual services. *Ecosyst. Serv.* **2013**, *4*, 117–125. [CrossRef]
38. Cotter, M.; Häuser, I.; Harich FKHe, P.; Sauerborn, J.; Treydte, A.C.; Martin, K.; Cadisch, G. Biodiversity and ecosystem services—A case study for the assessment of multiple species and functional diversity levels in a cultural landscape. *Ecol. Indic.* **2017**, *75*, 111–117. [CrossRef]
39. Niu, Z.; He, H.; Peng, S.; Ren, X.; Zhang, L.; Gu, F.; Zhu, G.; Peng, C.; Li, P.; Wang, J.; et al. A Process-Based Model Integrating Remote Sensing Data for Evaluating Ecosystem Services. *J. Adv. Model. Earth Syst.* **2021**, *13*. [CrossRef]
40. Boumans, R.; Roman, J.; Altman, I.; Kaufman, L. The Multiscale Integrated Model of Ecosystem Services (MIMES): Simulating the interactions of coupled human and natural systems. *Ecosyst. Serv.* **2015**, *12*, 30–41. [CrossRef]
41. Costanza, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; Paruelo, J.; Raskin, R.G.; Sutton, P.; et al. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260. [CrossRef]
42. Pimentel, D.; Harvey, C.; Resosudarmo, P.; Sinclair, K.; Kurz, D.; McNair, M.; Crist, S.; Shpritz, L.; Fitton, L.; Saffouri, R.; et al. Environmental and economic costs of soil erosion and conservation benefits. *Science* **1995**, *267*, 1117. [CrossRef]
43. Costanza, R. Ecosystem services: Multiple classification systems are needed. *Biol. Conserv.* **1999**, *141*, 350–352. [CrossRef]
44. Odum, H.T. The energetic basis for valuation of ecosystem services. *Ecosystems* **2000**, *3*, 25. [CrossRef]
45. Chee, Y.E. An ecological perspective on the valuation of ecosystem services. *Biol. Conserv.* **2004**, *120*, 549–565. [CrossRef]
46. Faber, M.; Winkler, R. Heterogeneity and time: From austrian capital theory to ecological economics. *Am. J. Econ. Sociol.* **2006**, *65*, 803–825. [CrossRef]
47. Huang, S.L.; Chen, Y.H.; Kuo, F.Y.; Wang, S.-H. Emergy-based evaluation of peri-urban ecosystem services. *Ecol. Complex.* **2011**, *8*, 38–50. [CrossRef]

48. Watanabe, M.D.; Ortega, E. Dynamic emergy accounting of water and carbon ecosystem services: A model to simulate the impacts of land-use change. *Ecol. Model.* **2014**, *27*, 113–131. [CrossRef]
49. de Groot, R.S.; Wilson, M.A.; Boumans, R.M.J. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecol. Econ.* **2002**, *41*, 393–408. [CrossRef]
50. Lu, H.; Campbell, E.T.; Campbell, D.E.; Wang, C.; Ren, H. Dynamics of ecosystem services provided by subtropical forests in Southeast China during succession as measured by donor and receiver value. *Ecosyst. Serv.* **2017**, *23*, 248–258. [CrossRef]
51. Nadalini, A.; Kalid, R.; Torres, E.A. Emergy as a tool to evaluate ecosystem services: A systematic review of the literature. *Sustainability* **2021**, *13*, 7102. [CrossRef]
52. Tang, C.W.; Yang, S.S.; Liu, L.J.; Zhang, Z.M.; Xiao, D.N.; Tian, C.D. Ecological services value of forest ecosystem in eastern Qilian mountains based on energy theory. *Chinese J. Ecol.* **2012**, *31*, 433–439.
53. Shu, H.; Zhuang, L.W.; Sun, X.J.; Xing, Y.M.; Sang, W.G. Application of value transfer model in the evaluation of ecosystem services function of forest reserve. *J. Northeast. For. Univ.* **2020**, *48*, 52–57.
54. Zhang, Y.X.; Liu, Y.; Zhu, B.W. Ecosystem service valuation and value transfer of land use types: A comprehensive Meta-analysis of the literature. *Acta Sci. Nat. Univ. Pekin.* **2016**, *52*, 493–504.
55. Siriwardena, S.D.; Boyle, K.J.; Holmes, T.P.; Wiseman, P.E. The implicit value of tree cover in the US: A meta-analysis of hedonic property value studies. *Ecol. Econ.* **2016**, *128*, 68–76. [CrossRef]
56. Xie, G.D.; Zhang, C.X.; Zhang, C.S.; Xiao, Y.; Lu, C.X. The value of ecosystem services in China. *Res. Sci.* **2015**, *37*, 1740–1746.
57. Gao, X.L.; Zhang, Y.K.; Ma, D.C.; Xu, W.H.; Zheng, H.; Ouyang, Z.Y. Research on the path to the key problems of the value realization of ecological products. *Acta Ecol. Sin.* **2022**, *20*, 1–9.
58. Deng, L.; Liu, G.B.; Shanggusn, Z.P. Land-use conversion and changing soil carbon stocks in China's Grain-for-Green Program: A synthesis. *Glob. Change Biol.* **2014**, *20*, 3544–3556. [CrossRef] [PubMed]
59. He, S.J.; Xie, J.S.; Zeng, H.D.; Tian, H.; Zhou, Y.X.; Xu, C.; Lü, M.K.; Yang, Y.S. Dynamic of soil organic carbon pool after restoration of *Pinus massoniana* in eroded red soil area. *Acta Ecol. Sin.* **2013**, *33*, 2964–2973.
60. Luo, C.L.; Hou, L.; Bai, L.L.; Geng, Z.C.; He, W.X. Effects of forest thinning on soil $CO_2$ emissions in a pine-oak mixed stand in the Qinling Mountains based on the Yasso07 model estimate. *Acta Ecol. Sin.* **2017**, *37*, 2894–2903.
61. Deng, D.W. Urban green space construction strategy under the concept of carbon sink. *Prot. Forest Sci. Technol.* **2019**, *5*, 88–90.
62. Wang, J.; Feng, L.; Palmer, P.I.; Yi, L.; Shuangxi, F.; Hartmut, B.; Christopher, W.; Xiaoping, T.; Dongxu, Y.; Lixin, L.; et al. Large Chinese land carbon sink estimated from atmospheric carbon dioxide data. *Nature* **2020**, *586*, 720–723. [CrossRef]
63. Zhang, H.Y.; Zhou, Y.F.; Zhang, Y.; Xu, X.J.; Li, C.; Xu, L. Research progress of international Bamboo forest carbon sequestration in the last 30 years based on biliometric analysis. *J. For. Res.* **2020**, *39*, 13–23.
64. Wang, B.; Niu, X.; Wei, W. National forest ecosystem inventory system of China: Methodology and Applications. *Forests* **2020**, *11*, 732. [CrossRef]
65. Li, T.; Cui, Y.; Liu, A. Spatiotemporal dynamic analysis of forest ecosystem services using "big data": A case study of Anhui province, central-eastern China. *J. Clean Prod.* **2017**, *142*, 589–599. [CrossRef]
66. Zhang, Z.; Zhang, H.; Feng, J.; Wang, Y.; Liu, K. Evaluation of social values for ecosystem services in urban riverfront space based on the SolVES Model: A case study of the Fenghe River, Xi'an, China. *Int. J. Environ. Health.* **2021**, *18*, 2765. [CrossRef] [PubMed]
67. Li, W.M.; Yu, M.; Gu, S.Z. General scheme of developing path and mechanism of realization of the value of China's ecological products. *Dev. Res.* **2020**, *3*, 66–71.
68. Zeng, X.G. The value realization mechanism of ecological products. *Environ. Sustain. Dev.* **2020**, *45*, 89–93.
69. Available online: http://www.gov.cn/gongbao/content/2021/content_5609079.htm (accessed on 1 May 2023).
70. Xie, G.D. Realization mechanism of ecosystem service value. *Environ. Prot.* **2012**, *17*, 16–18.
71. Muradian, R.; Corbera, E.; Pascual, U.; Kosoy, N.; May, P.H. Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services. *Ecol. Econ.* **2010**, *69*, 1202–1208. [CrossRef]
72. Han, Y.; Liu, Y.X.; Liu, X. Research progress on the market-oriented investment in ecological remediation for the realization of ecological product value. *Acta Ecol. Sin.* **2021**, *43*, 1–13.
73. Su, X.; Mou, C.L.; Zhang, Z. A study on the mechanism and realization path of service-oriented. *Macroeconomics* **2021**, *1*, 96–104+130.
74. Gao, Y.N.; Li, D.Q.; Jiang, C.; Wang, W.; Zhang, J.; Ren, X.; Zhang, L. Estimation of substance equivalent of ecosystem services in the Three-River Headwaters region based on emergy. *Res. Environ. Sci.* **2017**, *30*, 101–109.
75. Zhao, Y.H.; Xu, Z.J.; Xin, L.; Wang, Z.K.; Lu, J. Research on the marketization path of ecological product value based on the national EOD model pilot practice. *Ecol. Econ.* **2022**, *38*, 160–166.
76. Huang, Y.C.; Yao, M.X.; Wang, Q.; Su, J.H.; Wang, M. Theoretical research and practical progress on ecological products value realization. *Chinese J. Environ. Manag.* **2022**, *14*, 48–53.
77. Yang, M. Chinese forest ecosystem service value and realization path analysis. *South China Agric.* **2020**, *14*, 194–195.