A Review of Ecosystem Services Based on Bibliometric Analysis: Progress, Challenges, and Future Directions

Xiaoyu Li 1,2, Shudan Gong 1,2, Qingdong Shi 1,2,* and Yuan Fang 1,2

1 College of Ecology and Environment, Xinjiang University, Urumqi 830017, China; lixiaoyu19880527@163.com (X.L.); gshudan0@163.com (S.G.); y_fang@stu.xju.edu.cn (Y.F.)
2 Key Laboratory of Oasis Ecology of Education Ministry, Xinjiang University, Urumqi 830017, China
* Correspondence: shiqd@xju.edu.cn; Tel.: +86-18999130011

Abstract: Assessing the value of ecosystem services (ESV) can promote coordinated economic and ecological development. This study aimed to systematically review ecosystem services (ES) research history and research methodology and used the CiteSpace software to analyze 4063 papers in the field of service value in the ecosystem and visually analyze the developments in ES assessment; a conceptual framework combined with landscape genetics for evaluating ES was then constructed. The results showed that, first, the number of articles in the Web of Science (WoS) and China National Knowledge Infrastructure (CNKI) databases has been increasing annually. Moreover, Ecosystem Services, Sustainability, Ecological Indicators, Science of The Total Environment and Journal of Cleaner Production are the top five journals publishing the greatest number of studies. Second, ES research has seeped into life cycles and landscapes. Lastly, valuation of ES under the impacts of climate change and land use is the current research hotspot. The landscape genetics conceptual framework proposed in this study is a classification system based on the nature of ecological processes and can provide new ideas and methods for ES assessment.

Keywords: ecosystem service assessment methods; value assessment; quality assessment; research progress; landscape genetics; method

1. Introduction

The term “ecosystem services” (ES) first appeared in the article “Extinction, Substitution, and Ecosystem Services” by Ehrlich et al. [1] in 1983. Daily believed that ES are formed by ecosystems and ecological processes and are the natural environmental conditions that sustain human existence and their utility [2,3]. Costanza et al. defined ES as the various products and benefits humans obtain directly or indirectly from ecosystems [4]. Regardless of how domestic and foreign scholars have defined ES, the core definition remains unchanged: ecosystem products and services are all directly or indirectly provided by the material [5], energy, and information flows of natural capital that serve human well-being. Natural ecosystems influence urban social systems to improve human well-being. The assessment of ES can promote the balanced development of people’s production, living standards, and ES capacity; in other words, promote the coordinated development of economy and ecology, which in turn can raise awareness of conservation and increase scientific understanding of the contradiction between ecosystem use and conservation and attention to sustainable use.

Daily, Costanza, Xie, and other domestic and foreign scholars have proposed a close relationship between ES and human well-being [2,4,6–8]. Human welfare is obtained through ES; however, the value of ES cannot be reflected directly in monetary terms [3]. Ecosystems and their ecological processes continuously provide us with ecosystem goods and services. These irreplaceable natural resources and assets become the environmental conditions and material basis for human survival, improvement of human well-being, and achievement of
personal needs and values based on a good quality of life [9]. For example, the wetland ecosystem, known as the “kidney of the earth”, regulates climate and reduces pollution, maintaining water resources, preventing drought, and maintaining biodiversity [10,11]. However, these ecosystem goods and services are not given monetary value, and human beings lack awareness of the importance of ES. They regard ES as inexhaustible free public services. Human activities, such as agricultural and animal husbandry development, water resources development, engineering construction and environmental pollution [12–14], have been associated with several problems, such as wetland shrinkage, desertification, and water environment degradation. Overconsumption of ES leads to their gradual scarcity and degradation of their functions, which in turn affect human well-being in the long term [15,16]. Ecosystems play a role in carrying or constraining human well-being through supply, regulation, culture, and support services. Humans promote or coerce ES and their functions through economic, social, and environmental needs. In summary, human activities affect the operation of ecosystems, and vice versa. The two form a two-way correlation and feedback effect [17,18].

Therefore, an increasing number of scholars are studying the ESV. The evaluation of ESV has always been a research hotspot, and evaluation methods are constantly improving and developing towards diversification [19,20]. They can be roughly divided into two categories: value and quality assessment. The value assessment method is the most common; however, using the same set of evaluation systems for different areas can overestimate or underestimate the value of ES, e.g., using the method proposed by Xie Heights for ES assessment in China can underestimate the value of some ES in arid zones, such as forest ecosystems. In addition, owing to factors such as the spatial and temporal heterogeneity of ecosystems and limitations in the human perception of their characteristics, scholars with different professional backgrounds usually select only the core services they consider most important or establish evaluation systems that are unsuitable for the study area when conducting ESV, resulting in inaccurate assessments.

Owing to different data sources, evaluation objects, indicators, and parameters, current ESV assessment is diverse in the selection of indicators, functions, and objects, and it is difficult to compare the results of ESV across various regions [21]. Moreover, it is difficult to verify that assessment methods are scientific and effective [22]. Nowadays, the preferred method to classify ecosystems is formed land use, rather than the occurrence process. Occurrence incorporates ecological processes into the classification work, such as climate and environmental factors, and introduces a classification system based on the nature of the processes. It also considers the formation process and formation mechanism of the landscape. The traditional method of assessing the arid zone of Xinjiang will lead to low results, and whether this phenomenon exists for ecosystems with complex structure and function in different regions needs to be explored through the process mechanism of occurrence, because whether their ESVs are overestimated or underestimated cannot be determined. Occurrence is a method to study the preconditions and processes of occurrence, and introducing occurrence into the ES assessment system can effectively address inaccurate assessment results owing to heterogeneity.

Therefore, this study aimed to (1) summarize the research progress on ES assessment, (2) explore the current status of research and research hotspots using a literature search, to sort out the related literature and to conduct relevant analysis, and (3) analyze the research methodology of empirical studies, geographic location, research objects, and service categories to summarize the ecosystem service assessment methods used by authors, to find the shortcomings in them, and to put forward new conceptual frameworks, to improve the accuracy and applicability of the assessment methods. Our paper provides an effective tool for realizing the sustainable development of ecological-social-economic systems.

2. Materials and Methods

First, we read in detail several of the most cited papers in the literature, reviewed the development of ecosystem service assessment, and summarized three important nodes
(Section 3.1). Second, we searched the literature in the field of ESV and used the Citespace software to visualize and analyze the metrics to understand the development trend and research hotspots using quantitative and qualitative analysis (Sections 3.2–3.4). Then, we reviewed the assessment methods of ESV and conducted a summarized content analysis [23]. Finally, we propose several issues and future research directions for ecosystem service evaluation through literature review and visual analysis results (Section 4). The following will provide a detailed introduction to each stage.

2.1. Literature Review

2.1.1. Literature Search

The Science Citation Index Expanded (SCI-EXPANDED) database in the Web of Science (WoS) core collection and China National Knowledge Infrastructure (CNKI) were searched for journal articles from 2016–2023 using the two subject fields in Table 1. A total of 2650 (WoS) and 2236 (CNKI) articles were obtained. To ensure the validity of the data, articles unrelated to the research topic of this study were screened and removed, and 1988 (WoS) and 2075 (CNKI) articles were retained.

Table 1. Field Search Table.

<table>
<thead>
<tr>
<th>TOPIC 1:</th>
<th>“Ecosystem Service Valuation” OR “Ecosystem Services Assessment”</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td>TOPIC 2:</td>
<td>“Ecosystem Service” AND “Value Assessment”</td>
</tr>
<tr>
<td>DATE RANGE</td>
<td>2016–2023</td>
</tr>
</tbody>
</table>

2.1.2. Quantitative Analysis

Publications, source journals, and country publications were quantified, and the search results for relevance across all titles and abstracts were screened. The determination of relevance was based on (i) all articles related to ES assessment published from 2016 to 2023, and (ii) the study was an empirical study of ESV assessment. Only studies that meet the relevance criteria can make final quantitative estimates and be used for subsequent qualitative analysis, and each result was decided by more than two authors to ensure the accuracy of the literature search.

2.1.3. Qualitative Analysis

First, the cooperation between countries in the WoS database was analyzed to map the cooperation. Second, clustering and co-occurrence analysis of co-cited literature and keywords were performed to visualize research hotspots and relevance. Finally, the assessment methods of ES in the literature were summarized by reading and performing a summary content analysis to describe the scope of application and the advantages and disadvantages of different methods.

3. Results

3.1. Ecosystem Service Milestones

Three important nodes are involved in the development of ES (Figure 1). First is accounting for the ESV, a milestone in global ES research. Costanza et al. [4] classified global ecosystems. The natural capital value of the global ecosystem was calculated, and the global ecosystem was divided into 16 categories and 26 subcategories, including ocean, forest, grassland, wetland, water surface, desert, farmland, and city. The ES were divided into 17 services, including gas regulation, climate regulation, and disturbance regulation. When distinguishing between ES and ES functions, where ecosystem functions and processes contribute to ecosystem services, caution should be deployed [4,24]. In the same period, the American scholar Daily published “Nature’s Services: Societal Dependence on Natural Ecosystems” [2]. These two important achievements triggered a research boom in the estimation of the ESV [25], which has laid an important foundation for the establishment
of the classification system of ES and the value estimation method [26] and provided guidelines and references for scholars to conduct assessments of ESV.

![Ecosystem Services Milestones](image)

**Figure 1.** Important nodes of ES research.

The implementation of the United Nations Millennium Ecosystem Assessment (MA) from 2001–2005 was the second most important node, when the concept of ES gained wider attention. It was also the first time that human beings could assess the past, present, and future of global ecosystems. Of the 24 ES assessed, 15 were being degraded [27]. The degradation and loss of ES functions directly affect human health and threaten global ecological security. ES function assessment is a core component of the MA; therefore, MA’s work greatly promoted the study of ES function and promoted studies on the formation mechanism of ES [26], flow, trade-offs and coordination, ES, and human well-being [28]. During this period, the number of published articles on assessment of ESV increased rapidly [29].

In 2012, *Ecosystem Services*, founded by Elsevier, was launched, and the establishment of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) was officially started. This is the third node of the ES assessment research process. The IPBES is the second global program in the environmental field, with more than 130 participating countries. The main research areas included ES assessment [30–32] and the role of human well-being [33–37] and biodiversity [24,31,38,39]. *Ecosystem Services* has become the largest publishing platform for scientific research related to ES; in the publication ‘One Earth’, ES also emerged as an important topic. The key project of the Earth Science Department of the Natural Science Foundation of China, “Surface Environment Change Processes and Their Effects”, also includes funding for ecosystem process and service assessment research. ES assessment research occupies an increasingly important position in the academic field, both in China and abroad [40].

### 3.2. Visual Analysis of Published Literature

A total of 4063 research papers were published between 2016 and 2023. The number of articles in the WoS and CNKI databases has been increasing annually (Figure 2), indicating that current domestic and international research on ES assessment remains a hotspot.
3.2. Visual Analysis of Published Literature

A total of 4063 research papers were published between 2016 and 2023. The number of articles in the WoS and CNKI databases has been increasing annually (Figure 2), indicating that current domestic and international research on ES assessment remains a hotspot.

Figure 2. Volume of literature published in the field of ES assessment, 2016–2023.

The top five source journals with the most published research results (Table 2) were *Ecosystem Services* with 180 articles (9.05%), *Sustainability* with 163 (8.20%), *Ecological Indicators* with 147 (7.39%), *Science of The Total Environment* with 100 (5.03%), and *Journal of Cleaner Production* with 56 (2.82%), indicating that these journals are authoritative in the field of ES assessment.

Table 2. Statistics of the top five journals in terms of literature sources.

<table>
<thead>
<tr>
<th>Journal</th>
<th>Number/Article</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ecosystem Services</em></td>
<td>180</td>
<td>1</td>
</tr>
<tr>
<td><em>Sustainability</em></td>
<td>163</td>
<td>2</td>
</tr>
<tr>
<td><em>Ecological Indicators</em></td>
<td>147</td>
<td>3</td>
</tr>
<tr>
<td><em>Science of The Total Environment</em></td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td><em>Journal of Cleaner Production</em></td>
<td>56</td>
<td>5</td>
</tr>
</tbody>
</table>

A cooperation network map of countries in the WoS database was constructed (Figure 3). The top five countries in terms of publication volume were China (21.78%), the United States (20.02%), Germany (11.32%), the United Kingdom (10.92%), and Italy (9.31%). The number of studies conducted in these countries is increasing, and they occupy a dominant position in the field of ecosystem service assessment research. The United States has cooperated with 32 countries, including China, Germany, the United Kingdom, and Australia, but has not cooperated with Italy in the past six years. Although China published the first largest number of articles, it only cooperated with seven countries: the United States,
Australia, Japan, Vietnam, Uruguay, Pakistan, and Kazakhstan. Germany cooperated with 44 countries, including the United Kingdom, the United States, and Italy; while Italy cooperated with 39 countries, including China, the Netherlands, and Scotland.

Figure 3. Top 10 countries in terms of number of articles published in the field of ES assessment research.

3.3. Literature Cluster Analysis

Cluster analysis of the literature identified 15 categories (Figure 4): (1) ecosystem services, (2) planetary perspective, (3) remote responsibility, (4) life cycle assessment, (5) cluster analysis, (6) seawater desalination, (7) cost-effectiveness metrics, (8) latent class mixed logit, (9) wqi, (10) marine and freshwater, (11) value of information, (12) landscape metrics, (13) sampling-based rarefaction, (14) land degradation, and (15) forest degradation. The module value was 0.7957, and the average contour value was 0.9763. According to the evaluation criteria [41], the community structure was significant, and the clustering was efficient and convincing. From these results, the field of ecosystem service values focuses on the study of forest and marine ecosystems and has penetrated life cycles and landscapes.

Figure 4. Literature cluster analysis mapping.
We summarized the top five most cited papers (Table 3). The article by Costanza et al. in *Global Environmental Change* was the most frequently cited, followed by an article in *Ecosystem Services* and that by Diaz in *Science*.

**Table 3.** Statistics of high-frequency cited literature in the field of ecosystem service assessment research.

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Year</th>
<th>Journal</th>
<th>Journal Impact Factor (5 years)</th>
<th>Citation Volume (WoS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twenty years of ecosystem services: How far have we come and how far do we still need to go? [24]</td>
<td>Costanza, R. et al.</td>
<td>2017</td>
<td><em>Ecosystem Services</em></td>
<td>8.6</td>
<td>1360</td>
</tr>
<tr>
<td>Assessing nature's contributions to people [43]</td>
<td>Diaz, S. et al.</td>
<td>2018</td>
<td><em>Science</em></td>
<td>54.5</td>
<td>1301</td>
</tr>
<tr>
<td>Valuing nature's contributions to people: the IPBES approach [44]</td>
<td>Pascual, U. et al.</td>
<td>2017</td>
<td><em>Current Opinion in Environmental Sustainability</em></td>
<td>8.5</td>
<td>876</td>
</tr>
</tbody>
</table>

Moreover, the most frequently cited article, “Changes in the global value of ecosystem services”, updated the estimates of the global ESV based on new data from the Economics of Ecosystems and Biodiversity study, compared these results with the estimation methodology proposed in 1997 [4] and alternative methods [46], provided some answers to some objections to the estimation of the total ESV [47], and emphasized that the valuation of ES (in whatever units) is not equivalent to commodification or privatization [42]. The second most cited paper, “Twenty years of ecosystem services: how far have we come and how far do we still need to go?”, summarized the lessons learned from 1997 to 2000 and provided future recommendations. It pointed out the weaknesses of mainstream economic approaches, such as valuation, and the overriding need to broaden public discourse and engagement to integrate ES and natural capital into mainstream economic policy as the centerpiece of the fundamental changes needed in economic theory and practice to achieve a societal transition to a sustainable and desirable future [24]. The third most frequently cited document was “Assessing nature’s contributions to people”, published in *Science*. It described nature’s contributions to people (NCP) as defined and practiced in the IPBES as different in several important ways from earlier work. It suggested that making the IPBES process and outcomes more equitable is crucial to help overcome existing power asymmetries at the science–policy interface between Western science and local indigenous knowledge and between different disciplines within Western science. Moreover, NCPs are more likely to be incorporated into policy and practice by proposing better and more legitimate products [43].

### 3.4. Keyword Co-Occurrence Analysis

Keywords are the extraction and summary of an article [48]. Keyword co-occurrence maps can intuitively reveal hot spots in the research field of ES assessment through keyword occurrence frequency [49], and correlations in the field of ES assessment research can be intuitively seen through the relationships between keywords [50]. A co-occurrence map of keywords in the field of ES assessment is shown in Figure 5. The top 10 keywords were “ecosystem service”, “management”, “biodiversity”, “conservation”, “valuation”, “framework”, “climate change”, “values”, “land use”, “impacts”, “indicator”, “model”, “cultural ecosystem services”, “landscape”, and “trade offs” were all more than 100. It can be inferred that the hotspot in this field is the ESV under the influence of climate change and land use, focusing on the assessment of biodiversity. The top five keywords for the latest publication year were “contingent valuation method”, “basin”, “cultural services”, “driving factors”, and “expansion”, suggesting that the hotspots are assessment of the ESV
and identification of the drivers, e.g., population, urban sprawl impacts on ES, as well as watersheds.

Figure 5. Keyword co-occurrence map of ES assessment research areas.

3.5. Ecosystem Services Assessment Methods

We reviewed the literature and analyzed the applicability of these methods. There are two methods: quantitative evaluation from the perspective of quality and quantitative evaluation from the perspective of value.

3.5.1. Quality Assessment of ES

Quality assessment is suitable for studying the service capacity provided by the same ecosystem in different time periods or the same service capacity of different ecosystems. Quality assessments can objectively reflect the ecological processes of the ecosystem [3], understand the mechanisms of ES, and reflect the sustainability of the ecosystem. The evaluation results are intuitive and unaffected by market price fluctuations. Evaluation methods include the energy value and model methods.

1. Energy value method

Based on energy system theory, Odum proposed the energy value method, which refers to the total amount of solar joules directly or indirectly consumed in the formation of a product or service provided by an ecosystem. The energy conversion rate is used to calculate the final energy value of the ecosystem [51]. Based on field research and experimental analysis data, with the Tianbaoyan National Natural Reserve in Yong’an, Fujian Province as the research object, Yan Yutong et al. built a peat swamp ESV evaluation system and estimated the value of 16 ES functions of different types of Tianbaoyan peat swamp ecosystems, including net primary productivity increase, peat savings, carbon sequestration, and oxygen release. Their results provide theoretical support for ecological compensation and protection of peat bog wetland [52].

Consequently, the energy value method can be used to quantitatively analyze ecosystem and human social values, as well as the relationships among various systems. Considering the various forms of energy, materials, human labor, and economic services, the energy flow and utilization rate of ES can be better explained. This method is typically used to describe large-scale regional differences, urban ecosystems, and artificial park ecosystems.

2. Model method
In recent years, the model method has played an increasingly important role in assessing the ESV. Supported by remote sensing and socioeconomic and economic data, it has been widely used to study the coupling relationship, trade-off, and synergy of various ES. InVEST, ARIES, SolVES, RUSLE, SWAT, and other models have been widely applied. Table 4 lists their specific applications.

The InVEST model includes terrestrial, freshwater, and marine ecosystem models applicable to energy supply, regulation, and cultural supply services at basin, region, city, regional, and global scales. It can also predict changes in ES functions. Data are easy to obtain, and the results are visible; however, there is an algorithm simplification component, and information flow between some factors cannot be obtained [53]. In addition, the InVEST model can be widely applied on an urban scale [54–56].

The ARIES model is suitable for regional studies and can simultaneously evaluate all supply and demand services (supply, regulation, and cultural services) with high accuracy. However, it has high data requirements, mainly adopts high-resolution spatial data, and has a limited application scope. Mainly used in the United States, the ARIES model cannot fully consider social and economic influencing factors. ARIES dynamically evaluates ES flows through three factors: source, sink, and user. It can also reflect the spatial flow of ES, including freshwater supply, sediment regulation, fisheries, flood regulation, recreation, and other ES [57].

The SolVES model is applicable to small-scale studies on wetlands and forest parks. It mainly focuses on the evaluation of cultural and social supply services such as recreation, cultural services, and social values. It has a high accuracy but requires a large number of field and questionnaire surveys. There are also disputes over landscape parameters, and some differences between regions have been ignored.

The RUSLE model is applicable to regional, urban, and watershed studies and can reveal the mechanisms of ecological processes. Although its spatial scale is wide, the required data are large and complex to obtain. Lastly, the SWAT model is suitable for watershed research. Data are easy to obtain; however, digital elevation model data require high accuracy, and the model parameters contain regional differences and uncertainties. In addition, the model can be used to simulate ES flow [58,59] and study the heterogeneity of ES trade-offs and synergies [60–63].

Table 4. Ecosystem Object Quality Assessment Methods.

<table>
<thead>
<tr>
<th>Evaluation Method</th>
<th>Research Area</th>
<th>Evaluation Content</th>
<th>Auxiliary Data</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>InVEST model</td>
<td>Yangtze River delta region, China</td>
<td>Statistical habitat quality indicators, classification of habitat degradation degree</td>
<td>Land use status map</td>
<td>Xueru, Z. [64]</td>
</tr>
<tr>
<td>ARIES model</td>
<td>Santa Isabel National Forest, United States</td>
<td>Twelve values including aesthetics, biodiversity, and life support</td>
<td>Questionnaire survey, biodiversity data</td>
<td>Bagstad et al. [65]</td>
</tr>
<tr>
<td>SolVES model</td>
<td>Pudacuo National Park, China and Santa Isabel Pike National Forest, United States</td>
<td>Twelve social values, including aesthetics, biodiversity, recreation, culture, economy, and education, and their relationship with environmental variables</td>
<td>Questionnaire survey, road, water distance, elevation, and other data</td>
<td>Jianfeng, P. et al. [66]</td>
</tr>
<tr>
<td>RUSLE-GIS model</td>
<td>Sierra de Manantlan Biosphere Reserve, Mexico</td>
<td>Models soil erosion potential and provides powerful soil conservation planning tools that other land managers can use</td>
<td>Elevation, precipitation, soil, and land cover data</td>
<td>Millward et al. [67]</td>
</tr>
<tr>
<td>SWAT model and alternative engineering approaches</td>
<td>Luoyang area, China</td>
<td>Evaluates the value of water resource protection and its service and analyzes the reasons for temporal and spatial changes</td>
<td>Elevation, remote sensing, land use, soil type data</td>
<td>Zhang et al. [68]</td>
</tr>
</tbody>
</table>
3.5.2. Valuation Assessment of ES

Value evaluation is a quantitative evaluation of ES from the perspective of monetary value and is the function value method based on unit service function quantity price and divided into the equivalent factor method based on unit area value [64–66,69–71].

3. Functional value method

The most significant difference between the functional value method and equivalent factor method is that, in the former, the calculation process is complex, and the data input is large [20]. Moreover, it can be divided into actual, alternative, and virtual market methods. (For specific applications, refer to Table 5.) Alternative market methods include alternative cost, opportunity cost, and travel expense methods, which are commonly used to evaluate regulation and cultural services. The virtual market method uses a payment intention survey method and the contingent valuation method. In the evaluation process, subjective factors can easily affect evaluation results.

Table 5. Ecosystem Service Value Volume Assessment Methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>Research Area</th>
<th>Evaluation Content</th>
<th>Auxiliary Data</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent factor, CVM, travel cost, and benefit transfer methods</td>
<td>Xixi National Wetland Park, Hangzhou</td>
<td>ESV, net value of ecosystem services (NES), service cost, and entertainment value</td>
<td>Questionnaires, park basic data, and related literature</td>
<td>Zhang et al. [72]</td>
</tr>
<tr>
<td>Market valuation, cost-based and benefit transfer methods</td>
<td>The forest ES in Taiwan</td>
<td>Biodiversity, soil loss prevention, air purification, forest recreation/environmental education, forest water conservation, forest carbon sequestration</td>
<td>Reference to projects and methods in China, Japan, Korea, etc.</td>
<td>Lin et al. [73]</td>
</tr>
<tr>
<td>Market value, shadow engineering, Swedish carbon tax law, alternative cost, and other monetary value evaluation methods</td>
<td>The wetland ES value of Yellow River Delta (YRD)</td>
<td>Twelve ES functions such as climate regulation, flood regulation aquatic products, and soil protection</td>
<td>Remote sensing, economic Data</td>
<td>Zhang et al. [74]</td>
</tr>
</tbody>
</table>

In general, the value assessment method is suitable for assessing ES supply. It is easy to operate and demands less data, and the assessment results are easy to understand. However, it has some shortcomings, such as strong subjectivity and poor comparability, large spatial heterogeneity, and relatively weak interpretation of the service formation mechanism. The quality assessment method can better reflect the formation mechanisms of ESs, evaluate large-scale complex ecosystems, and eliminate shortcomings due to spatial heterogeneity. However, it involves complex input data, complicated calculations, and high requirements for technical knowledge [75].

4. Equivalent factor method

The equivalent factor method was proposed by scholars such as Xie [17], who calculated the unit area value of different types of ES by multiplying the area of different land-use types by the original equivalent factor or a modified equivalent factor [76,77]. Liu et al. combined meteorologic, vegetation, and land-use social and economic data and used the average value of wetlands, rivers, and lakes as the water area value equivalent factor, selected desert value as the unused land value equivalent factor, revised the ESV coefficient and model, and quantified the Xinjiang ESV from 1990–2020 according to Xinjiang grain production and price in 2020. A Bayesian network model was used to simulate the difference in ESV under different scenarios in Xinjiang [78], and the revised equivalent factor table was more subjective. Yang et al. adopted the equivalent factor and geospatial exploration method, introduced the elastic coefficient, and explored the response of ESV change to land use change, based on land use and cover data from 1990 to
2020 [79]. Huang et al. used the equivalence factor method to estimate ESV in the Beibu Gulf region, explained the contribution of different drivers to ESV changes and established a link between changes in geographical patterns and ESV changes [80]. Scholars, including Liu et al. and Yang et al. [78,79,81,82], made corrections based on the table of biomass factors or grain price correction equivalent factors or used an average value [74,83–85], which was highly subjective and could not accurately reflect the characteristics of their study areas.

Therefore, the equivalent factor method requires little data, is simple to operate, can quickly obtain results, and provides intuitive evaluation results. Its core is determining the unit area value of various ESs. However, ES are heterogeneous in terms of time and space, indicating that a specific evaluation index system for ESV cannot be used to measure the actual value of ES in each region [77]. Most studies have used the unit value method proposed by Costanza et al. and Xie et al., which is simple to calculate but does not consider the spatial–temporal heterogeneity of the ES supply, which may lead to high or low assessment results. For example, Liu et al. [78] chose desert as unused land and subjectively did not give it a function; however, desert has functions, such as cultural tourism in Xinjiang. Moreover, the functions of forests in Xinjiang are different from those of the mountains and plains, and not differentiating them will lead to high or low assessment results.

4. Discussion
4.1. Debates and Challenges

The results of the combing and visual analysis revealed the following problems.

4.1.1. Applicability of ES Assessment Criteria

In recent years, research evaluating ESV has increased. However, in many cases, the evaluation system and method imitate domestic and foreign evaluation standards and even appear to be used in multiple regions without considering the regional differentiation law. The most important aspect of studying ESV is the determination of equivalent factors [86]. The method should be modified according to the characteristics of the ecosystem in the study area, and the classification system of the China Multi-period Land Use Remote Sensing Monitoring Dataset should not be widely used [87]. Daily et al. evaluated ESV from the perspective of ecology [70], and Costanza et al. evaluated ESV from the perspective of economics. However, the classification of ecosystems based on land use did not consider the regional differentiation law and the differences among study areas. For example, Xie et al. believed that the value of deserts in China is very small, while in Xinjiang, the arid desert, saline-alkali land, and marshland have functional value. Deserts also have recreational and other service functions. Therefore, such mistakes should be avoided, and the applicable criteria for assessing ES should be explored in different study areas.

4.1.2. Assessments Ignore Ecological Factors such as Long-Term Climate Change

Previous studies have paid little attention to long-term climate change, which affects eco-system support service functions not only through precipitation and temperature, but also indirectly through the intensity of land and other resource use, thus affecting ecosystem provision, regulation, and cultural services. Domestic and foreign scholars classify land use according to the changes in land use caused by human activities but do not fully consider ecological indicators, such as light, temperature, water, and soil. Different scholars have conducted research in different research areas, and according to their research purposes, there are some imperfect situations, such as assessments of agricultural and watershed ecosystems based on landscape classification lists of land use/land cover, which did not fully consider the relationship between landscape formation and development and solar radiation, sea and land distribution, changes in terrain height, and the role of human activities. As far as Xinjiang is concerned, owing to the influence of the zonal arid environment, there is no relatively standardized and quantitative equivalent factor for
arid areas. Therefore, it is classified according to the reasons for landscape formation and related to influencing factors, such as climate, heat, terrain, moisture, and human activities in natural processes [88]. The table of equivalent factors was determined by classifying ecosystems based on vegetation and land use types.

4.1.3. Ignoring the Temporal and Spatial Heterogeneity of ES

The temporal and spatial heterogeneity of ES was not considered in typical research methods [3], which makes the equivalent factor table based on land use classification or ecosystem type non-universal, resulting in inaccurate assessment results. For example, trees in all forest ecosystems are widely believed to have water conservation functions, but they play different roles because of various factors, such as the location and structure of trees. For example, forests in arid mountainous areas have water conservation function value, whereas those in plains areas have water and soil conservation function values. This issue is often ignored without considering the spatiotemporal heterogeneity of ES. Although it is possible to assess the value of ES as a whole, the assessment results are affected, and spatiotemporal variation in ES and functions remains unknown.

4.1.4. Evaluation of Reliability of Model Data Sources

Recently, ES assessment models, supported by socioeconomic data, remote sensing data, and GIS technology, have become increasingly important. It is difficult to establish an empirical and innovative object quality model for ES assessment, especially to develop a model that adapts to regional characteristics and improves model adaptability and effectiveness of results. However, owing to the limitations of scientific and technological conditions, data acquisition, and processing, it is difficult to obtain accurate data, and the lack of continuous monitoring and inventory data limits the establishment of a new model.

4.2. Future Directions for ES Assessment

4.2.1. Conceptual Framework for Improving Value Assessment of ES Based on Landscape Genetics

The genesis method originates from natural science research and is used to study the premise, background, process, and reality of occurrence [89,90]. Landscape is a regional complex formed by the comprehensive action of geological landforms, climate, soil, human activities, and other factors within the region [91]. The current land use classification judges ecosystem classification based on the results that have been formed and does not classify the ecosystem in conjunction with the ecological processes. Landscape genetics incorporates ecological processes into taxonomic work, such as climate and environmental factors. The introduction of the landscape genetics considers the formation process and formation mechanism of the landscape and is a classification system based on the nature of the process. Therefore, the genesis method can be introduced into the assessment method of ESV by analyzing the formation process of the landscape, determining the ES value system of various land cover types at the landscape scale, and reclassifying the ecosystem according to the formation reasons of the ecosystem, combined with the global climate, regional differentiation law, and status quo of the study area. This can provide new ideas and methods for assessing ES.

Figure 6 presents a conceptual framework for improving ES assessment based on landscape genetics. The main influencing factors were selected, and the influence of human factors was considered to classify the overall attributes and characteristics of the landscape. Accordingly, the value of local ES was evaluated. In the classification, the most important heat and moisture climate indices were considered the highest indices to determine the temperature zone, which can reflect the latitudinal zonality and the background of climate change. Using dryness and precipitation as secondary classification indices to divide dry and wet areas can reflect the zonality of longitude. Vertical zonality is reflected in mountains with high elevation, so the landform is used as the three-level classification index, and elevation is used to determine the landform type. In addition to referring to
the classification of the ecosystem, the landscape function, land use mode, and degree of human disturbance should be considered. Land-use and vegetation types should be used to classify ecosystems. Land use reflects the principles of human activity, while vegetation is a representative symbol of an ecosystem. After classification, appropriate equivalent factors were determined to rationalize the table of equivalent factors, effectively evaluate ES function value, and accurately evaluate the ES function of the study area to provide a reliable reference for the government to formulate protection and regulation laws and policies.

Figure 6. A conceptual framework for improving the value assessment of ES based on landscape genetics.

4.2.2. Selecting the Appropriate Time and Space, Evaluation Scale

Based on the characteristics of the study area and surrounding socioeconomic environment, it is important to choose an appropriate evaluation scale and research scope. In the selection of spatial and temporal scales, large-scale assessment studies should not be limited to specific regions but should comprehensively consider the trade-offs and synergies among different ES [29]. Understanding the relationships between social, economic, and ecological factors can provide a scientific basis for monitoring and managing ecosystems. At present, most studies on ESV evaluation have focused on forests, wetlands, and other natural ecosystems and have ignored artificial, semi-artificial, and degraded ecosystems. Each ecosystem has a unique function. For example, forest ecosystems have regulatory functions, such as carbon sequestration, oxygen release, and water conservation. They can also provide cultural services, such as culture and tourism. Therefore, when assessing ecosystems, all types of ES should be considered to better understand the overall well-being of various ecosystems.

4.2.3. Strengthen Cooperation between Domestic and Foreign Institutions and Establish Platforms for Sharing Data and Information

The application of ES valuation models is another future research direction. Owing to limitations in technological conditions, data collection, and processing, which make it difficult to obtain accurate data, data obtained from continuous monitoring and inventory will become an important source. In addition, constructing a data- and information-sharing
platform, which is lacking in China, is essential to establish empirical and innovative quality models for assessing ES. By synthesizing and analyzing a large amount of valid and reliable information, it is possible to select appropriate spatial and temporal scales for assessment and research based on the characteristics of ES in the study area and reduce the possibility of drawing incorrect conclusions [26,69]. Therefore, domestic research institutions should actively strengthen cooperation, break down barriers, and jointly achieve mutual academic benefits.

4.2.4. Broadening the Application of ES Assessment to Contribute to Human Well-Being

Future research should further strengthen social, economic, and management aspects to contribute to the optimization of the decision-making process. For example, although ecosystem service trade-off/synergy analysis is popular, current research is limited to the relationship between the two ES, and future studies should investigate the non-linear relationship between multiple ES. Undertaking research on ES and ecological carrying capacity to promote sustainable urban structure and the balance between supply and demand and urban development and ES can affect human lives and production, and after comprehensive analysis of the costs and benefits involved, the local development intensity threshold can be assessed, which in turn influences urban planning and decision-making. Only with good planning and decision-making by local governments can a closed loop of cities, ecosystems, and humans develop in a healthy and sustainable manner, and ecosystems can provide increasingly valuable goods and services that contribute directly and indirectly to human well-being [5]. Therefore, in future research, the value evaluation of ES should be deeply integrated into society [21], and the relationships between changes in the value of ES and urban planning decisions [92], human survival and development, employment rates, poverty alleviation, and well-being should be studied from the perspective of social ecology.

5. Conclusions

This paper provides a systematic review and econometric analysis of articles in the field of ES valuation. The following conclusions are drawn: (1) The development of ecosystem services has gone through three important points. (2) The number of articles in the WoS and CNKI databases has been increasing annually, with the *Ecosystem Services, Sustainability, Ecological Indicators, Science of The Total Environment* and *Journal of Cleaner Production* as the top three journals publishing the highest number of studies. China, the United States, and Germany are the top three countries in terms of publication volume. (3) Cluster analysis showed that ES research has seeped into life cycles and landscapes, with forest and marine ecosystems and cultural services as the main focus. The most frequently cited article was “Changes in the global value of ecosystem services”, providing a reliable and applicable method for the rapid valuation of ecosystem services. (4) Keyword co-occurrence results showed that the hotspot in the field is the valuation of ES under the impacts of climate change and land use, focusing on the valuation of biodiversity. The hotspot of recent research is the valuation of ES and the identification of drivers. (5) ESV methods include quality assessment (energy value and model method) and valuation assessment (functional value and equivalent factor method). (6) ES assessment criteria may have problems of applicability, ignoring ecological factors, spatiotemporal heterogeneity, and data sources.

This review summarizes EV methods after sorting out the research history of ecosystem service assessment and visualizes the research field of ecosystem service assessment from bibliometric and analytical perspectives using CiteSpace software. Ecosystem service value assessment remains a popular research topic in ecology, ecological economics, and other disciplines. Ecosystem types are rich and diverse and have great economic value. However, because of the complexity, spatiotemporal heterogeneity, and other characteristics of ecosystems, their economic value can only be assessed using existing methods. Problems, such as poor applicability and difficulty in comparing results between regions, were identified during assessment. Therefore, some perspectives and suggestions for the
future development of research in the field of ecosystem services are provided, and a conceptual framework for improving the value assessment of ecosystem services based on landscape genetics was constructed. To provide effective tools for realizing the sustainable development of eco-socio-economic systems, it is also necessary to strengthen international exchange and cooperation to promote better development of ESV assessments.

**Author Contributions:** All authors contributed to the study conception and design. Literature search and data analysis were performed by X.L., S.G. and Y.F. Framework development and supervision by Q.S. The first draft of the manuscript was written by X.L. and all authors commented on previous versions of the manuscript. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was supported by the Third Xinjiang Comprehensive Scientific Investigation Project (2021XJKK110403) Investigation and Assessment of the Impact of Energy and Mineral Resources Development in the Turpan Basin on the Regional Ecological Environment.

**Institutional Review Board Statement:** Not applicable.

**Data Availability Statement:** Data are contained within the article.

**Acknowledgments:** The authors express their sincere thanks to the editor and reviewers for providing valuable comments and suggestions.

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

**References**

50. Yu, Y.; Xu, M.; Ye, Y. A Review of Forests Ecosystem Services Valuation Based on CiteSpace and Bibliometric Analysis. Ecol. Environ. 2020, 29, 421. [CrossRef]
61. Cong, W.; Sun, X.; Guo, H.; Shan, R. Comparison of the SWAT and InVEST Models to Determine Hydrological Ecosystem Service Spatial Patterns, Priorities and Trade-Offs in a Complex Basin. Ecol. Indic. 2020, 112, 106089. [CrossRef]
70. Shoyama, K.; Yamagata, Y. Local Perception of Ecosystem Service Bundles in the Kushiro Watershed, Northern Japan—Application of a Public Participation GIS Tool. Ecosyst. Serv. 2016, 22, 139–149. [CrossRef]

73. Lin, J.-C.; Chiou, C.-R.; Chan, W.-H.; Wu, M.-S. Valuation of Forest Ecosystem Services in Taiwan. *Forests* 2021, 12, 1694. [CrossRef]


78. Liu, Y.; Yuan, X.; Li, J.; Qian, K.; Yan, W.; Yang, X.; Ma, X. Trade-Offs and Synergistic Relationships of Ecosystem Services under Land Use Change in Xinjiang from 1990 to 2020: A Bayesian Network Analysis. *Sci. Total Environ.* 2023, 858, 160015. [CrossRef]


82. Xu, Y.; Xiao, F.; Liao, Y. Assessment of Grassland Ecosystem Service Value in Response to Climate Change in China. *Diversity* 2022, 14, 160. [CrossRef]

83. Cheng, W.; Shen, B.; Xin, X.; Gu, Q.; Guo, T. Spatiotemporal Variations of Grassland Ecosystem Service Value and Its Influencing Factors in Inner Mongolia, China. *Agronomy* 2022, 12, 2090. [CrossRef]


88. Wang, Y.; Lin, N.; Gao, J.; Zou, C.; Xu, D. Impacts of China’s Western Development and Protection Strategy: An Ecosystem Services Perspective of Western China. *Diversity* 2022, 14, 863. [CrossRef]


Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.