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Value Components and Accounting of Ecological Products: Model Comparison and Literature Review

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Abstract:

This article analyzes the constituent elements and accounting methods of the value of ecological products. Through model comparison and literature integration, a comprehensive analysis of the field has been provided. Firstly, the article outlines the definition of ecological products and clarifies the core elements of the value of ecological products. Secondly, different ecological product value accounting models, such as the equivalent factor method, functional value method, and emergy analysis method, were reviewed in detail, and their advantages and disadvantages in practical applications were compared. Research has shown that there are differences in the evaluation methods and application scope of ecological value among various models, but they all emphasize the comprehensive value of ecological services. Finally, this article suggests combining multiple models to achieve more comprehensive ecological value accounting and proposes future research directions, including an in-depth exploration of model improvement and practical application cases. Through these analyses, the article aims to provide valuable insights and tools for policymakers and researchers on the valuation of ecological products.

Keywords: Ecological products; value realization; environmental economic accounting.

1. Introduction

In 2020, During the symposium on comprehensively promoting the development of the Yangtze River Economic Belt, General Secretary Xi Jinping noted that swift action is required to establish a mechanism for realizing the value of ecological products. This will allow for the reasonable return on investment in the protection and restoration of the ecological environment, as well as the payment of corresponding costs for the destruction of the same. The realization of ecological product value is the process of converting the use value of ecological products into exchange value, which requires the establishment of an evaluation system to assess the value. In recent years, there have been numerous methods for evaluating the value of ecological products. Scholars use different measurement methods to evaluate the value of ecological products. The relevant government has also issued evaluation standards for reference. However, these ecological product evaluation systems urgently need to be considered, as they have different usage effects in different regions. Comparing and analyzing these models plays an important role in the transformation results of the ecological product evaluation system.

Ecological products is a concept with Chinese characteristics. Domestic scholars believe that ecological products refer to natural elements that maintain ecological security, ensure ecological regulation functions, and provide a good living environment, including fresh air, clean water sources, and a pleasant climate [1]. Liu Bowen proposed the connotation and institutional framework of the mechanism for realizing the value of ecological products in central documents and practical explorations [2]. Wang Xifeng pointed out the difficulties in realizing the value of ecological products, including “difficulty in quantity, difficulty in collateral, difficulty in trading, and difficulty in monetization”. He proposed to further clarify the “value anchor” for realizing the value of ecological products based on the theory of ecological product value [3].

After the concept of ecological products was proposed, some scholars used various methods such as the functional pricing method, equivalent factor method, “ecological element”, and emergy analysis method to evaluate the value of ecological products [4-6]. The State Forestry Administration has also issued some assessment standards for natural resources such as deserts, wetlands, and forests. The Ministry of Ecology and Environment has issued the “Technical Standards for Accounting the Gross Ecosystem Product of Land Ecosystems” and the Zhejiang Provincial Administration for Market Regulation has issued the “Technical Standards for Accounting the Gross Ecosystem Product (GEP) of Ecosystems” [7]. These documents provide a paradigm for local governments to conduct GEP accounting. However, at present, various statistical and real-time monitoring data of rural ecosystems are incomplete and unsystematic, the distribution of ecological products is fragmented and the homogenization of product types is significant. It is still difficult to carry out value accounting of village-level ecological products [8]. In 2019, Lishui City reasonably calculated its basic economic output value and the value added that its ecological environment advantages could bring, laying the foundation for the marketization of ecological product value, and fully utilizing the pilot advantages to complete the value accounting of Baishanzu National Park [9].

Based on the above background, this article analyzes the cutting-edge achievements of innovative ecological product value evaluation systems at home and abroad and deeply explores the applicability and accounting methods of various innovative ecological product value evaluation systems. Firstly, explore the construction elements of the value evaluation system and the relationships between each element. Secondly, compare the existing value evaluation models with different ecological product value accounting methods, and analyze their characteristics and applicable conditions. Finally, based on the entire text, identify the shortcomings of existing research and propose future research directions.

2. The Constituent Elements of the Ecological Product Value Evaluation System

Ecological products refer to the final products provided and used by ecosystems for economic and other human activities, including supply service products, regulation services, cultural services, etc. Emphasize the ultimate service attributes provided by ecosystems to humans and the attributes ultimately used by humans.

According to the functional value method, the value of ecological products is fundamentally measured by the Gross Ecosystem Product (GEP) accounting technique, which includes the four major service functions of ecosystems - regulation services, supply services, support services, and cultural services. The construction elements of the ecological product value evaluation system are divided into supply product services, regulation services, and cultural services. Its core lies in directly linking various services or products provided by the ecosystem with their corresponding functional values, and then quantitatively evaluating them. The calculation process of the ecological product value presented in monetary form is obtained by using certain mathematical operations. It consists of three parts: the total value of supply products, the total value of regulation services, and the total value of cultural services, which are combined to obtain the total production value of the ecosystem.

To specifically measure the total value of various services, the first step is to determine the accounting geographical scope, clarify the distribution of ecosystems within the geographical scope, compile an ecological product list, continuously collect data and supplement investigations, calculate the functional quantity of ecological products, determine corresponding prices, and finally use appropriate methods to calculate the monetary value, and finally determine the range of ecological product value.

2.1 Supply Product Service Elements

Supply products are mainly divided into direct utilization supply products and conversion utilization supply products. Among them, the output of agricultural, forestry, animal husbandry, fishery, and other products excluding industrialized livestock products can be directly utilized, including food such as grains, vegetables, fruits, meat, eggs, milk, aquatic products, as well as raw materials such as medicinal herbs, wood, fiber, freshwater, genetic material, etc. The production or usage of renewable energy such as hydropower and straw power generation belongs to the supply products of conversion and utilization, excluding photovoltaic, wind power, geothermal energy, and garbage power generation. The accounting indicators for both are the added value of their products or renewable energy, mainly calculated using the market value method. In the market, according to the classification system of the statistical department, the output of the same type of products and various types of renewable energy is summed up. The product output can be calculated based on the physical quantity, and the product price can be obtained from the statistical department or based on market pricing.

2.2 Adjusting Service Elements

The secondary indicators for regulating service elements mainly include water source conservation, soil conservation, windbreak and sand fixation, coastal zone protection, flood regulation and storage, carbon fixation, oxygen supply, air purification, water quality purification, climate regulation, and species conservation.

In terms of physical quantity accounting, the accounting quantity of water conservation is calculated through the water balance method and water supply method. The soil conservation can be calculated by the Revised Universal Soil Loss Equation (RUSLE). The sand fixation amount for wind prevention and sand fixation is also calculated using the Revised Wind Erosion Equation (REWQ). The protection area of the coastal zone is determined through statistical surveys. For the calculation of flood regulation and storage, a water storage model needs to be established to separately calculate the adjustable storage capacity of lakes, flood control capacity of reservoirs, and stagnant water capacity of swamps. For the accounting of carbon fixation, the carbon fixation mechanism model is applied, and the fixed carbon dioxide amount is selected as the evaluation indicator. The carbon fixation amount of the ecosystem is the total amount of carbon fixation in terrestrial ecosystems and karst ecosystems. The carbon sequestration rate method or Net Ecosystem Productivity (NEP) method can be used to calculate the carbon sequestration function of terrestrial ecosystems. Oxygen supply can be calculated based on the oxygen release mechanism model to determine the quality of oxygen released by ecosystems. Air purification uses pollutant purification models to calculate different methods based on whether the concentration of pollutants exceeds the quality standards of environmental air functional zones. The application of pollutant purification models for water quality purification services mainly relies on monitoring data to select appropriate indicators for quantitative accounting based on the composition and concentration changes of pollutants in the aquatic ecosystem. The accounting of climate regulation services uses evapotranspiration models, which account for the actual temperature difference between the inside and outside of the ecosystem, the solar energy consumed by the ecosystem, and the total evapotranspiration of the ecosystem. The actual measurement method is preferred, followed by the solar energy consumed by the ecosystem or the total evapotranspiration of the ecosystem for accounting based on data availability. The conservation value of species can be calculated by the Shannon Weiner index method or the protected area protection method to determine the number of rare and endangered species and the area of protected areas.

In terms of value calculation, the value of water conservation, soil conservation to reduce sediment deposition and non-point source pollution, as well as the loss value of coastal protection projects due to reduced protection, are all measured by the substitution cost method. The value of windbreak and sand fixation projects needs to be measured by restoration costs, while the value of flood regulation and storage needs to be calculated by the shadow engineering method. The carbon sequestration value of ecosystems can be calculated by the substitution cost method (afforestation cost method, industrial emission reduction cost) and market value method (carbon trading price). The value of oxygen supply can be calculated by the market value method (i.e. oxygen production price). The value of air purification is calculated by the substitution cost method (industrial treatment of air pollutants cost), and the value of water purification is calculated by the substitution cost method, The value of ecosystem transpiration regulating temperature or humidity and the value of water surface evaporation regulating temperature or humidity are calculated using the alternative cost method (the amount of electricity required for manual temperature and humidity regulation), and the value of species conservation services is calculated using the unit area conservation cost.

2.3 Cultural Service Elements

The secondary indicators of cultural service indicators mainly include leisure tourism and landscape value. The physical quantity accounting of leisure tourism adopts the total annual number of tourists visiting the natural landscapes within the region as the physical quantity evaluation index for cultural services. The accounting parameters are the list of natural landscapes, the number of tourists, and the source of tourists. By using the travel expense method, people can calculate the intangible value of experiencing ecosystems and natural landscapes through leisure tourism activities and obtaining knowledge and spiritual pleasure. Mainly obtain tourists' socio-economic characteristics, travel expenses, etc. through social surveys; The physical quantity accounting of landscape value adopts the land and residential area that can directly obtain landscape value from natural ecosystems as the evaluation indicators of landscape value physical quantity, and the accounting parameters are the list and area of beneficiary land and residential area. Value measurement uses the hedonic value method to calculate the value of an ecosystem in providing aesthetic experiences and spiritual pleasure functions for the surrounding population.

When calculating the supporting role of ecosystems in human well-being and economic and social development, the sum of the material product value, regulatory service value, and cultural service value of ecosystems should be accounted for. GEP=EPV+SERV+ECV . In the equation, GEP is the total ecosystem production value. EPV stands for the value of ecosystem material products. The Value of Ecosystem Regulation Services (SERV) is the value of ecosystem regulation services. ECV represents the cultural service value of ecosystems.

3. Valuation Methods for Different Ecological Products

3.1 Method Introduction

The comparable factor approach, functional value method, emerge analysis method, etc. are the several categories of value accounting techniques now in use. Value equivalents for various kinds of ecosystem services are constructed using the equivalent factor technique, which is based on measurable criteria. The economic value of the yearly natural grain production of farmland with a national average yield of one hm2 is referred to as one standard unit of ecosystem product value equivalent factor.

The value of one standard unit of ecosystem service value equivalent factor must be ascertained before applying the equivalent factor approach in terms of accounting stages. The accounting approach involves multiplying the sowing proportion by the net profit per unit area of the principal food crops grown in the area, and then adding the results. The value of one standard unit of ecosystem service value equivalent factor must be ascertained before applying the equivalent factor approach in terms of accounting stages. The accounting approach involves multiplying the sowing proportion by the net profit per unit area of the principal food crops grown in the area, and then adding the results. Based on the revised research area value equivalent and the area of various land use types, the service value of the ecosystem in the research area is calculated using the following formula:

$$VC_i = \sum_{f=1}^{m} EC_f * E_a \tag{1}$$

$$ESV_f = \sum_{i=1}^{n} LA_i * VC_i \tag{2}$$

$$ESV = \sum_{i=1}^{n} LA_i * VC_i \tag{3}$$

In the formula, ECf represents the value equivalent of the f-th item of ecosystem services for a certain land use type, which is obtained based on the revised benchmark unit area ecosystem service value equivalent table. Ea symbolizes the equivalent value of one standard unit of ecosystem service value. The ecosystem service value coefficient of the i-th land use category is denoted by VCi. LAi represents the area of the i-th land use type. Hm2; VCfi represents the coefficient of the i-th land use type in the f-th ecosystem service value, and The ecological value of ecosystem service f is represented by its ESVf. ESV is a measure of the research area's ecosystem service value. The functional value method is based on the classification of the ecological value functions of natural resources, and calculates the total value by multiplying the physical quantity and service quantity provided by the ecosystem with the price based on various monitoring and statistical data. In terms of setting accounting classification standards, the current accounting classification is mainly based on the 2005 United Nations Millennium Ecosystem Assessment (MA) report, which specifically categorizes ecological value accounting into four functional evaluation items: supply, regulation, support, and culture. In addition, there are several sub-service unit indicators under the four major functional services, which specifically quantify the value of the primary system. This classification has been well applied in the research of the Haihe River Basin, Liaoning coastal areas, and other regions in China.

Famous American ecologist H T. Odum's team established the emergy analysis method in the 1980s. This method converts different categories of energy and matter into emergy through the conversion rate of emergy, thereby transforming the problem into a problem that can be quantitatively analyzed using data. Emergy analysis can comprehensively analyze the flow of energy, logistics, currency, population, information, and other aspects of a system, and derive a series of comprehensive emergy indicators to gain a deep understanding of the economic efficiency, environmental carrying capacity, and structure and function of the studied ecosystem. The steps of emergy analysis mainly include drawing energy system diagrams, developing emergy analysis tables, calculating and evaluating emergy, calculating emergy conversion rates and other various emergy indicators, and conducting comprehensive system analysis. The commonly used emergy indicators are shown in table1. According to the different levels evaluated by these indicators, they are divided into four categories.

Table 1. Index classification

Assessment level	Emergy indicator
Basic level of agricultural natural environment	Resource emergy density, renewable energy ratio, environmental contribution rate, environmental load rate
Development level of agricultural economy	Emergy input rate, net emergy output rate, emergy density, Y/I
Living standard of farmers	Per capita emergy utilization and per capita emergy output
Sustainable development capability	Sustainable indicators of emergy value

3.2 Characteristics and Applicable Conditions of the Methods

3.2.1 Equivalent factor method

The equivalent factor method is used for value accounting, covering various types of ecological products and applicable to global, national, or regional large-scale ecological product value accounting. The advantages are that the demand for accounting data is low, the operation is relatively simple, the accounting results are comparable, and it is easy to widely apply. The limitation lies in the fact that the equivalent factor table has a certain time delay and strong subjectivity, making it difficult for the accounting results to reflect the real situation.

3.2.2 Functional value approach

The functional value method adopts physical quantity accounting, and the accounting scope is divided into supply services, regulation services, and cultural services. Applicable to administrative regions such as provinces, cities, counties, townships, and villages, as well as other ecological geographic units with relatively complete functions. The advantage is that the accounting results have high accuracy; The disadvantage is that it requires a large amount of data and the accounting process is relatively complex.

3.2.3 Emergy analysis method

The emergy analysis method adopts value-based accounting, where emergy is equal to the energy of various ecological products multiplied by the conversion rate of solar energy. The accounting scope covers various ecological products and is suitable for larger areas. The advantage is that it solves the problem of not being able to analyze and compare the values of different ecological products simultaneously; The disadvantage is that it relies on the accuracy of ecological assets and the certainty of emergy conversion rate, which has great uncertainty and regional variability in emergy conversion rate.

4. Literature Review

The public nature and other attributes of ecological products make their supply and use mostly not realized through market transactions, making value accounting difficult. At present, various scholars use different accounting frameworks and methods for ecological product value accounting, resulting in poor comparability and lack of authority in the accounting results.

The classification standards for ecological products are not yet unified, resulting in significant differences in the scope and content of accounting. At present, the technical specifications for ecological product value accounting released by China generally adopt categories such as supply services, regulation services, and cultural services in the first-level classification, but there are inconsistencies in the second-level classification. Due to the diverse characteristics of ecological products, it is difficult to standardize classification standards, and there are differences in the understanding and definition of classification among different technical specifications. In addition, there are significant differences in the scope and content of accounting for ecological products within the same ecosystem among various studies. On the one hand, existing research lacks a systematic accounting scope and fails to account for nonuse values such as spiritual and aesthetic aspects involved in cultural services, thus failing to fully reveal the economic value of ecological products. On the other hand, some products that should not be included in the accounting are mistakenly included, resulting in overestimation or double calculation of the value of ecological products, such as not stripping away human inputs, including ecological products generated outside the region in the accounting scope, and difficulty in distinguishing between intermediate services and final services.

Secondly, the lack of uniformity in the accounting methods for ecological product value has led to poor comparability of accounting results. This is mainly due to the complexity and diversity of ecological products themselves, as well as the technicality and differences in accounting methods. Due to the diverse characteristics and complex nature of ecological products, the value accounting methods for different ecological products vary, and the technical requirements are high. At present, the accounting of the value of ecological products is not precise enough, and there are problems such as strong subjectivity, low accuracy, and poor repeatability. This has brought great difficulties in practical applications, making it difficult to fully play its role in ecological environment protection and improvement.

5. Conclusion

The value composition of ecological products involves multiple elements, including supply services, regulation services, and cultural services. The characteristics and functions of each service category are crucial for the overall value assessment of ecological products, but the current classification and accounting standards are not unified, which makes it difficult to comprehensively evaluate the value of ecological products.

The existing methods for calculating the value of ecological products have their advantages and limitations. These methods are often limited in their application by the difficulty of data acquisition, the applicability of models, and the degree of consideration for different ecological products, which affects the accuracy and comparability of accounting results.

Due to the strong technicality and inconsistent standards of accounting methods, the value accounting of ecological products often exhibits subjectivity, low accuracy, and poor repeatability of results in practice. This has prevented the full play of the role of ecological products in ecological environment protection and resource management. To improve the accuracy and practicality of ecological product value accounting, it is suggested that future research should focus on unified accounting standards and methods, and combine multiple models to achieve more comprehensive evaluations. In addition, strengthening the accounting of nonuse value of ecological products and improving data collection and analysis techniques are key measures to improve the quality of accounting.

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