Postprint: Valuation of Ecosystem Services of the Gaotianyan Nature Reserve, Jiangxi

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Abstract

Gaotianyan Nature Reserve, located in Lianhua County, Jiangxi Province, provides multiple ecosystem service functions for local communities. According to the characteristics of the ecological and socio-economic systems of Gaotianyan Nature Reserve, an indicator system for valuing ecosystem service functions was constructed, and based on 2014 data, quantitative analysis methods including cost replacement, market value, shadow engineering, afforestation cost, benefit parameter, and travel cost were comprehensively applied to evaluate the economic value of its ecosystem. The results indicate that in 2014, the total economic value of ecosystem services of Gaotianyan Nature Reserve was 7.20$×10^{8}$ yuan, wherein the economic values of soil conservation and carbon sequestration and oxygen release ranked first and second, respectively, at 4.39$×10^{8}$ yuan and 1.16$×10^{8}$ yuan, accounting for 60.89% and 16.11% of the total service economic value. The nine service indicators are ranked by evaluated economic value as follows: soil conservation > carbon sequestration and oxygen release > product provision > biodiversity conservation > environmental purification > climate regulation > tourism and recreation > flood regulation and water storage > social security. These quantified economic values reflect the important contribution of the Gaotianyan Nature Reserve ecosystem to human society, which on one hand enhances awareness among managers and the public regarding the conservation of Gaotianyan Nature Reserve, and on the other hand provides data support for government formulation of ecological compensation standards for Gaotianyan Nature Reserve.

Full Text

Preamble

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Evaluating the Ecosystem Services of Gaotianyan Nature Reserve in Lianhua County, Jiangxi Province

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Abstract

Gaotianyan Nature Reserve, a provincial-level natural conservation area located in Lianhua County, Jiangxi Province, provides numerous ecosystem services for local communities. Economic valuation of the reserve' s main ecosystem services can help us better understand its direct contribution to Lianhua County and ensure that government authorities comprehensively consider the importance of protecting this natural ecosystem when formulating economic development strategies. In this study, we established an evaluation index system for the ecosystem service functions of Gaotianyan Nature Reserve based on its ecological and socio-economic characteristics. Using 2014 data, we conducted a comprehensive economic assessment employing quantitative methods including replacement cost, market value, shadow engineering, afforestation cost, reference parameters, and travel cost analysis.

The results show that: (1) The total economic value of ecosystem services provided by Gaotianyan Nature Reserve in 2014 was estimated at 7.16×10^8 Yuan, with soil conservation (4.39×10^8 Yuan) and carbon fixation with oxygen release (1.16×10^8 Yuan) ranking as the top two services, accounting for 60.89% and 16.11% of the total value, respectively. (2) Primary production represents a major direct economic benefit; however, its value contributed only 10.75% of the total ecosystem service value, indicating that relying solely on primary production would seriously underestimate the reserve' s total ecosystem service value. (3) The economic values of the nine ecosystem service indicators, ranked by magnitude, are: soil conservation, carbon fixation and oxygen release, primary production, biodiversity protection, environmental purification, climate regulation, tourism and recreation, flood control and water storage, and social security. These direct economic figures demonstrate the vital importance of Gaotianyan Nature Reserve' s ecosystem to human society. This valuation not only helps strengthen awareness among managers and the public regarding conservation efforts but also provides data support for the government to establish ecological compensation standards for the reserve.

Keywords: nature reserve; ecosystem service function; forest ecosystem; evaluation; economic value

Introduction

Nature reserves are complex and unique ecosystems with distinctive ecological functions and economic values. They continuously provide humans with food and raw materials, offer recreational spaces, and serve as critical habitats for biodiversity protection and ecological conservation, thereby demonstrating comprehensive benefits and supporting sustainable development. However, the ecological services provided by nature reserves act indirectly on human economic life in non-physical forms, often leading to unsustainable resource exploitation, ecological damage, and structural changes in ecosystems that reduce the welfare benefits these reserves provide.

Ecosystem services refer to the environmental conditions and utilities formed and maintained by ecosystems and ecological processes that humans depend on for survival. Since Costanza et al. published their global ecosystem service valuation results in 1997, international research on ecosystem services has surged, focusing primarily on common theories regarding assessment indicators, validity, and necessity, as well as economic valuations of typical ecosystems such as rice paddies, forests, grasslands, wetlands, and lakes. Research on the mechanisms and economic values of nature reserve ecosystem services remains in continuous development.

Gaotianyan Nature Reserve is situated between Guanshan National Nature Reserve in the Jiuling Mountains and Jinggangshan National Nature Reserve in the Luoxiao Mountains, serving as an ecological corridor connecting these two national reserves. The reserve features complex and varied topography, providing a favorable foundation for rich vegetation types. However, located in remote mountainous areas with underdeveloped surrounding communities, some residents have engaged in illegal logging of precious tree species and poaching of rare wildlife to improve their livelihoods, severely damaging the ecosystem structure and significantly reducing biodiversity. In recent years, the protection and management of Gaotianyan Nature Reserve have gradually attracted attention from management departments and social organizations. Protecting its ecosystem structure and function is crucial for conserving biodiversity and maintaining ecological balance between the two national reserves. Establishing an appropriate ecosystem service assessment index system and conducting valuation studies will help people better understand the reserve' s direct contributions to society, promote strengthened conservation efforts, and provide solid data support for integrating the reserve into government economic benefit trade-off decision-making processes.

1. Study Area Overview

Gaotianyan Provincial Nature Reserve was established in [year not specified] in northeastern Lianhua County, western Jiangxi Province. The reserve covers a total area of 4,780 hm^2, with 4,750 hm^2 of forest land and 30 hm^2 of non-forestry land. Forest coverage reaches 99.37% (4,780 hm^2). The forest composition

includes: coniferous-broadleaf mixed forest (4,250 hm^2, 89.47%), bamboo forest (260 hm^2, 5.47%), shrubland (235 hm^2, 4.93%), and non-stocked forest land (44 hm^2, 0.93%). The region has a subtropical monsoon humid climate with an average annual temperature of 14.1°C (maximum 37.1°C, minimum -7°C) and average annual precipitation of 1,673.0 mm. The frost-free period lasts 278 days, and the average growing season spans 1526.4 hours. The reserve's growing stock volume totals 18×10^4 m^3.

2. Data Sources and Interpretation

This study covers the entire nature reserve. Data sources primarily include: field surveys conducted in Lianhua County in July 2014, the *Lianhua County Statistical Abstract*, the *Gaotianyan Nature Reserve Master Plan*, and selected research results from other studies. To ensure timeliness, 2014 prices were used for all service function valuations. Fertilizer prices adopted unified quotations from Jiangxi Province, while social security standards applied the minimum living standard guarantee from Pingxiang City. For service functions lacking market prices, such as gas regulation and flood storage, we adjusted values using the ratio of consumer price index for residents between the base year (2014) and the original data publication year. If the original publication year was unclear, we used the earliest reference year that cited the data. Moso bamboo prices used the average 2014 selling price in Lianhua County.

3. Research Methods

Ecosystem final services represent the direct contributions of ecosystems to human well-being. Based on the connotation of Gaotianyan Nature Reserve' s ecosystem and its regional socio-economic characteristics, we established a final service value assessment index system comprising nine functional indicators (Table 1) and employed different evaluation methods for comprehensive economic assessment. During the research process, model parameters were adjusted according to the actual conditions of Gaotianyan Nature Reserve.

3.1 Social Security Value

Gaotianyan Nature Reserve provides employment opportunities for local laborers, offering certain social security functions. Without the reserve' s establishment, these workers would require minimum living security payments. Based on this principle, the social security economic value of the study area was estimated at 115.44×10^4 Yuan.

3.2 Product Supply Value

Using calculation methods [equations (3) and (4)], the total economic value of product supply from Gaotianyan Nature Reserve was determined to be 7,691.39 $\times 10^4$ Yuan.

3.3 Carbon Fixation and Oxygen Release Value

The net primary productivity (NPP) and carbon fixation capacity of various forest ecosystem types in Gaotianyan Nature Reserve were calculated [equation (6)]. The results for carbon fixation, oxygen release, and their economic values are presented in Table 2.

3.4 Climate Regulation Value

The economic value of climate regulation primarily refers to the total economic value of forest transpiration and ground water evaporation. The ratio of ground water evaporation to precipitation in subtropical forests typically ranges from 40% to 80%. Using this relationship [equation (2)], the water vapor transpiration was calculated, yielding an economic value of 1,171.64 $\times$ 10^4 Yuan for the gas regulation function of Gaotianyan Nature Reserve.

3.5 Flood Control and Water Storage Value

Forest ecosystems play a significant role in flood control and water storage. Using the shadow engineering method [equations (7)-(9) and (10)], the material quantity of average flood control and water storage was assessed, and the economic value of this ecosystem service was estimated.

3.6 Environmental Purification Value

Forests can absorb SO_2, NO , HF, and reduce dust, playing a crucial role in improving air quality. However, forest ecosystems absorb fluoride and nitrogen oxides at much lower rates than SO_2 and dust. Therefore, this study only examined the reserve' s capacity to absorb SO_2 and reduce dust [equation (11)], yielding an economic value for environmental purification of 1,817.19 $\times$ 10^4 Yuan.

3.7 Soil Conservation Value

Using the Universal Soil Loss Equation (USLE) and related parameters [equations (12) and (13)], the material quantity of soil conservation in Gaotianyan Nature Reserve was calculated as 29,854.0 t/hm^2. The economic values for soil retention and fertility maintenance were then determined (Table 3).

3.8 Biodiversity Value

Gaotianyan Nature Reserve is rich in wildlife resources with high biodiversity value. Using appropriate valuation methods [equations (15) and (16)], the economic value of biodiversity protection was calculated as 5,417.84 $\times$ 10^4 Yuan.

3.9 Tourism and Recreation Value

Gaotianyan Nature Reserve connects Guanshan National Nature Reserve and Jinggangshan National Nature Reserve, occupying a unique geographic position. The reserve features serene mountain landscapes and rich wildlife resources, offering excellent tourism and recreation potential. Using the travel cost method [equation (17)], the economic value of the tourism and recreation function was estimated at 187×10^4 Yuan.

4. Total Ecosystem Service Value

The total ecosystem service value of Gaotianyan Nature Reserve represents the sum of all assessed service function indicators (Table 4).

5. Discussion

The social security value accounts for only 0.16% of the total service value, ranking last among all evaluated indicators. This function primarily manifests through employment opportunities in forest management and non-timber forest product development. Rational development of nature reserve resources to provide more employment opportunities represents an effective way to enhance social security value.

Product supply is an important ecosystem service and the cornerstone of human civilization. The economic value of product supply from Gaotianyan Nature Reserve was 7,691.39 $\times$ 10^4 Yuan. Under unified statistical standards, this compares favorably with other reserves: Nankunshan National Nature Reserve (15.07 $\times$ 10^4 Yuan), Kanas Nature Reserve (1.66 $\times$ 10^4 Yuan), and Lushan Nature Reserve (983.52 $\times$ 10^4 Yuan), indicating that Gaotianyan' s product supply function is relatively strong. This is attributed to its high forest coverage rate and large timber volume per unit area, which directly increase the economic benefits of product supply.

Soil conservation and carbon fixation/oxygen release represent the dominant services, accounting for 60.89% and 16.11% of total value respectively. This demonstrates that forest ecosystems provide not only timber and non-timber products but also more important economic value through indirect services such as soil conservation and carbon sequestration. In 2014, Lianhua County' s total GDP was 51.91 $\times$ 10^8 Yuan, while the nature reserve' s annual service value reached 13.87% of the county' s GDP, despite the reserve occupying only 4.46% of the county' s total area. This highlights the reserve' s significant material, environmental, and ecological support to the county' s economic development.

Future planning, management, and protection of Gaotianyan Nature Reserve should establish ecological compensation mechanisms based on ecosystem service values to better promote wildlife conservation and improve the reserve' s facilities, education, and reasonable development. Developing the reserve' s latent ecological functions will enable it to fully realize its economic, social, and

ecological benefits, thereby achieving sustainable development.

This study' s evaluation index system fully considered the social, economic, and ecological benefits of the nature reserve ecosystem, incorporating regional characteristics to comprehensively assess its social contributions. Model parameters were selected with timeliness considerations, and the valuation methods represent improvements over previous studies. However, due to data limitations, only nine functional indicators were evaluated; other functions such as education, research, and negative ion provision were not considered. The actual total service value should therefore be higher.

6. Conclusion

Based on 2014 data, this study evaluated the final service value of Gaotianyan Nature Reserve' s ecosystem functions. The results reveal that the reserve provides approximately 7.20×10^8 Yuan in total ecosystem service value, equivalent to about 342.18×10^3 Yuan per hectare. Among the nine assessed functions, soil conservation ranks first in both material quantity and economic value, accounting for 87.26% of total material quantity and 60.89% of total economic value, indicating that soil conservation is the core service provided by Gaotianyan Nature Reserve.

The economic values of the nine service indicators, in descending order, are: soil conservation, carbon fixation and oxygen release, primary production, biodiversity protection, environmental purification, climate regulation, tourism and recreation, flood control and water storage, and social security. Due to the lack of appropriate measurement methods and reasonable conversion standards, material quantity comparisons were only possible for environmental purification, carbon fixation/oxygen release, and soil conservation, which ranked as: soil conservation > carbon fixation/oxygen release > environmental purification.

Limitations of this study include: (1) evaluation based solely on 2014 data without dynamic modeling to reflect future changes; (2) inability to estimate material quantities for biodiversity protection and cultural functions due to measurement method constraints; (3) potential biases from evaluator preferences and subjectivity in model selection. Establishing reasonable conversion mechanisms to unify measurement standards across services remains important for identifying service priorities. Determining model accuracy and selecting optimal assessment methods warrant further investigation.

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Note: Figure translations are in progress. See original paper for figures.