Key Drivers of Ecosystem Cultural Service Value: Insights from Zhalong Nature Reserve

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Abstract

Recent advancements in the field of ecosystem service valuation have emerged from deepening research in ecosystem functions. Nonetheless, the study of ecosystem cultural services has predominantly concentrated on qualitative aspects. A substantive need exists for further exploration into their quantitative assessment through multidimensional analysis. This emphasizes the critical significance of identifying and understanding the factors that influence the valuation of ecosystem cultural services. Using the Zhalong Nature Reserve as a case study, this research categorizes influencing factors and explores their interrelationships. A path model was developed to examine the effect of geographical environment, resource endowment, government intervention, development level, and market demand. The findings reveal that these factors not only interact among themselves but also collectively enhance the value of ecosystem cultural services. This research contributes valuable insights for augmenting the value of ecosystem cultural services, provides a robust scientific framework, and serves as a reference for future studies.

In recent years, the intensification of global environmental challenges has heightened the demand for ecological security, increasingly recognized as an essential element of national security. This recognition has become especially prominent in contemporary development discourses. Concurrently, the concept of new-quality productivity has surfaced, underscoring the imperative for sustainable ecosystem development. Anchored in green technological innovations, new-quality productivity advocates for efficient resource use and minimized environmental impacts, thereby catalyzing a comprehensive green transformation across economic and social systems. The interconnection between new-quality productivity and the value of ecological and cultural services is profound, with each concept mutually reinforcing the other.

New-quality productivity prioritizes green development, aligning closely with the core values of ecological and cultural services, which focus on the synergy between ecological conservation and economic growth (Lin et al. 2025). Regarding value creation, innovative technologies from new productive forces unlock enhanced possibilities for ecological and cultural services. These services, in turn, guide the principles of green consumption, fostering market demand and developmental momentum for new-quality productivity. Together, they play a pivotal role in sustainable development, promoting enduring economic and social progress. Additionally, their collaborative efforts in industrial integration help establish comprehensive industrial chains and foster coordinated industrial advancement. In practice, these elements are complementary, jointly advancing the sustainable development of the economy and society (Li et al. 2024).

Cultural ecosystem services, a crucial subset of ecosystem services, bolster public cultural identification with natural environments and cultivate a sense of place attachment, which in turn motivates efforts to protect ecosystems. Research indicates that the sensory dimensions of urban green spaces significantly affect the provision of cultural

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ecosystem services. Strategically designing green spaces to align with public preferences can substantially enhance the supply of cultural services, thus supporting ecosystem sustainability (Chen et al., 2023). Furthermore, cultural ecosystem services are instrumental in regional sustainable development. The natural landscape plays a vital role in actualizing the value of cultural services, and optimizing infrastructure development alongside ecotourism strategies can significantly improve the efficiency of cultural service realization, which supports ecosystem sustainability (Lin et al. 2025). In studies focused on the Yellow River Basin, the coordination among cultural, ecological, and economic systems has been identified as a central pathway to sustainable development, highlighting the pivotal role of cultural services in augmenting ecosystem functions and enhancing community well-being, especially in terms of improving overall ecosystem value and functionality (Yu et al. 2024). Consequently, cultural ecosystem services are indispensable in driving ecological sustainability.

Subsequent research demonstrates that ecological restoration markedly enhances the values of cultural services. The provision of high-quality cultural services satisfies the public's aesthetic, leisure, and spiritual needs concerning natural landscapes, thereby augmenting public satisfaction. This satisfaction, in turn, catalyzes the continuous enhancement of cultural services, with each element mutually reinforcing the other (Weng et al. 2023). A pertinent example is the ecological restoration of the Yongding River, where public satisfaction accounted for 39.25 percent of the total value derived from ecosystem services, highlighting the pivotal role of cultural services in ecological restoration efforts. Additionally, prioritizing cultural services within frameworks of ecosystem services offers essential guidance for the allocation of resources and the formulation of policies.

For example, in research concerning lagoon ecosystems, such prioritization has provided a scientific basis for the distribution of resources. Factors such as ecological endowments, transportation infrastructure, and marketing strategies are crucial in realizing the values of cultural ecosystem services. Research indicates that ecological endowments establish the foundational values of cultural services, whereas transportation and marketing strategies enhance the efficiency of service realization by improving accessibility and attractiveness (Lin et al. 2025). Moreover, the spatial distribution of sociocultural values, changes in land use, and public participation significantly affect the realization of cultural service values (Raymond et al. 2009). Types of urban infrastructure also affect the spatial distribution of cultural services; urban cores predominantly offer values related to cultural heritage, identity, and recreation, whereas rural and suburban regions emphasize recreational values, often due to natural landscapes and protected areas (Kaymaz et al. 2024).

Building on this foundation, this study uses the Zhalong Nature Reserve as a case study to systematically analyze factors influencing the values of cultural ecosystem services. By developing a path model, this research connects five factors—geographical environment, resource endowment, governmental intervention, development level, and market demand—to cultural service values. It explores their interrelationships and provides empirical evidence from the Zhalong Nature Reserve. This research aims to furnish theoretical support and practical guidance for enhancing the values of cultural ecosystem services and promoting ecological sustainability.

Materials and Methods

Significance of ecosystem cultural service value

In 1988, the United Nations Environment Programme convened a specialized expert meeting, marking the inception of international conventions on biodiversity and catalyzing global collaboration to safeguard natural ecosystems. Ecosystem cultural services encompass the spiritual, cultural, and nonmaterial benefits that humans derive from ecosystems. The value of these services is acknowledged across diverse fields. Cultural services fulfill human spiritual needs, enhance social well-being, protect biodiversity, stimulate regional economic development, and inform policymaking. Research indicates that in desert tourism regions, cultural services significantly attract visitors and amplify their nonmaterial well-being (Zhang et al. 2025).

In the context of national park management, the valuation of cultural services provides a scientific foundation for policy formulation and planning (Chen et al., 2023). In urban green spaces, cultural services are shown to increase residents' happiness and strengthen social bonds. Within agricultural ecosystems, the valuation of cultural services underpins precise agricultural subsidy policies (Guo et al. 2025). Furthermore, cultural services contribute to regional economic growth. For instance, in Qilian Mountain National Park, enhanced cultural service values have facilitated the dual goals of cultural heritage preservation and economic development (Yang et al. 2024). Despite the challenges posed by the intangible and intricate nature of cultural services, using a variety of evaluation methods can effectively quantify their value (Huang 2024; Wu et al. 2024). Therefore, the assessment and protection of ecosystem cultural service value are imperative for fostering harmony between humans and nature, advancing ecological civilization, and promoting sustainable development.

Factors influencing ecosystem cultural service value

Natural factors.—The effect of the geographical environment on ecosystem cultural service value represents a complex, multidimensional area of research that involves interactions among natural landscapes, land-use patterns, sociocultural backgrounds, and human activities. Studies suggest that the diversity of geographical environments significantly affects the distribution and intensity of cultural services (Vieira et al. 2021; Demeaux et al. 2024). Specifically, topographical features and land-use patterns influence the spatial distribution of cultural services. Mountainous terrains are often associated with higher cultural service values because of their provision of rich natural experiences and cultural identity (Tenerelli et al. 2017; Yee et al., 2024). Moreover, dynamic changes in geographical environments may influence the sustainability of cultural services (Huq et al. 2019; Liu et al. 2023). The sociocultural backdrop of a region also shapes public perception and use of cultural services. Areas with rich historical and cultural legacies are more likely to foster public cultural identification with natural settings (Raymond et al. 2009; Kabisch et al., 2014).

Resource endowment is a pivotal factor that influences the value of ecosystem cultural services. It encompasses natural, sociocultural, and economic resources, which together determine the spatial distribution and functional realization of these services. The endowment of natural resources directly affects the supply of services. For example, research conducted in the Dutch Hoge Veluwe has demonstrated that the distribution and types of field margins significantly affect pest control, which in turn indirectly influences the realization of cultural services (Paulin et al. 2020). Sociocultural resource endowment shapes public cognition and emotional connections to natural environments, thereby influencing the efficiency with which cultural services are used. The Conservation-Compatible Livelihoods model exemplifies this by integrating global biodiversity values with local resource use to achieve equitable and sustainable livelihoods while promoting cultural inclusivity; this model facilitates rational resource usage through stakeholder collaboration (He et al., 2023). Furthermore, economic resource endowment indirectly influences the realization of cultural services by shaping policymaking and resource allocation. The marginal willingness to pay, closely associated with current forest cover levels, decreases as forest cover increases. This relationship underscores the role of economic resources in shaping policy. By estimating the marginal willingness to pay, researchers can provide a scientific foundation for national, regional, and local policies, thereby optimizing the expansion of forest cover (Sagebiel et al. 2017).

Natural factors, including resource endowment and geographical environment, exert complex influences on the value of ecosystem cultural services. A thorough understanding and scientific analysis of these factors are essential to enhance the values of cultural services and to achieve sustainable ecosystem development.

Social factors.—Government intervention plays a dual role in the protection and management of ecosystem cultural services. On one hand, government-led ecological projects have demonstrated significant achievements in reducing pesticide use and increasing rice yields (Horgan et al. 2022). On the other hand, excessive reliance on government support and information dissemination mechanisms can undermine the autonomy and cultural identity of local communities. Joly et al. (2019) observed that although multilevel political intervention and legal enforcement are essential for the protection of biodiversity and ecosystem services in Brazil, challenges such as low-management efficiency and insufficient incentives can impede sustainable development pathways. Therefore, it is imperative that government intervention uses a multistakeholder collaborative governance framework that balances scientific, policy, and community interests to ensure sustainable management of cultural services (Joly et al. 2019).

The relationship between development levels and the valuation of ecosystem cultural services is intricate and multifaceted. From one perspective, enhanced economic development, which often coincides with urbanization and infrastructural improvements, provides the necessary material basis for the realization of cultural services. Wang et al. (2022) observed that regions with advanced economic development display markedly higher economic valuations of cultural services. This suggests that capital accumulation and technological innovation are potent drivers that enhance the realization of cultural services. In contrast, from a restraining viewpoint, Smart et al. (2021) have shown that in coastal regions of South Carolina, USA, cultural services are at risk of decline because of the combined pressures of urban expansion and rising sea levels. Likewise, Chowdhury et al., (2021) report that sociocultural transformations and environmental degradation diminish the value of traditional water-related cultural services. Moreover, technological progress, a key element of development levels, bolsters the value of cultural services by refining land-management strategies. For instance, Wang et al., (2023) advocated for the use of smartphone location data to quantitatively assess cultural services spatiotemporally, thus facilitating cross-cultural comparisons. Similarly, Himes et al. (2020) highlighted the role of technology in optimizing land-use strategies to enhance the efficiency of cultural service realization.

Market dynamics significantly affect the valuation of ecosystem cultural services. Research conducted in Morocco's Todgha Oasis revealed that tourist willingness to pay serves as a vital reference for policymakers and demand-driven economic values can internalize positive externalities via ecological compensation mechanisms (Ahrabous et al. 2023). The spatial heterogeneity and temporal dynamics of market demand add complexity to the assessment of cultural service values (Sagebiel et al. 2017; Liu et al. 2023; Yu et al. 2024). Moreover, the diversity of market demand necessitates that evaluation methods are adaptable across different cultural contexts (Hatan et al. 2021). From the perspective of value realization, market demand indirectly influences the social and economic attributes of ecosystem services by affecting the supply-demand interplay. This bidirectional mechanism underscores the need for sustainable management of ecosystem cultural services that balances market-demand satisfaction with the preservation of cultural values.

Social factors such as government intervention, development levels, and market demand exert complex influences on the value of ecosystem cultural services. Effective government intervention should strike a balance between efficiency and equity in institutional design. Development levels must harmonize technological advancement with cultural heritage preservation, and market demand should aim for an ecological and economic co-optimization through value transformation mechanisms. This multidimensional interplay offers both a theoretical framework and practical insights for the sustainable management of ecosystem cultural services.

Model specification

Factors influencing the value of ecosystem cultural services can be categorized into natural and social dimensions (Fig. 1). The foundation of these values in nature reserves primarily derives from the combined influences of the geographical environment and resource endowment. These elements shape the fundamental characteristics of ecosystems, influencing public cognitive pathways and value perceptions of cultural services. As pivotal determinants, the geographical environment and resource endowment exhibit complex and multidimensional mechanisms in shaping the values of cultural services. Social factors encompass three

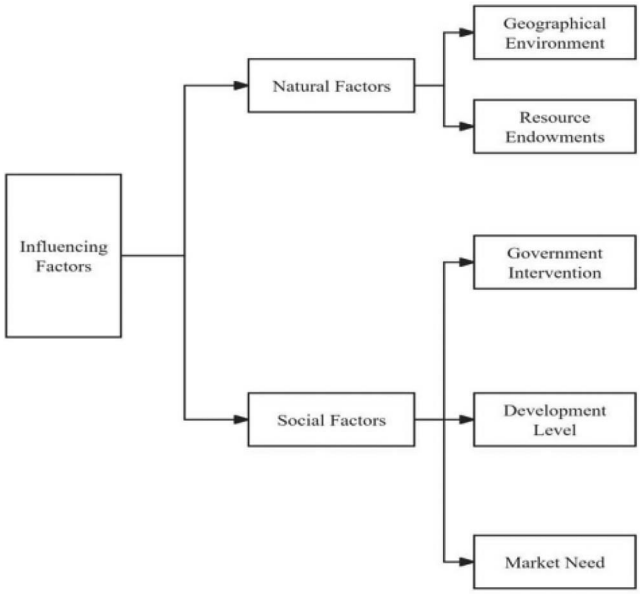

Figure 1.—Factors influencing the value of ecosystem cultural services in nature reserves.

dimensions: government intervention, development levels, and market demand.

Government intervention entails regulating cultural service industries through a top-down institutional framework and providing policy support for the sustainable development of these services. Development levels reflect regional economic and technological progress, indirectly shaping the pathways for the realization of cultural service values through monetization metrics. Market demand represents a direct reflection of public needs for cultural services and products within nature reserves, serving as the most immediate influencing factor based on utility value theory.

Consequently, both natural and social factors collaboratively drive the formation and realization of ecosystem cultural service value: Natural factors define foundational ecosystem attributes through geographical and resource endowments, whereas social factors influence value transformation and societal significance through institutional design, economic development, and market dynamics. This interplay provides a theoretical framework and practical guidance for the assessment and management of ecosystem cultural service value.

Therefore, this study proposes the following hypothesis:

Hypothesis 1: Government intervention, development level, market demand, geographical environment, and resource endowment each exert a positive influence on the value of ecosystem cultural services.

Notably, natural and social factors influencing ecosystem cultural services are interconnected (Fig. 2). Specifically, variations in geographical environment and resource endowment can lead to regional differences in government intervention strategies. Resource endowment significantly affects the manner and intensity of government intervention (Yan et al. 2019). In resource-rich regions, governments tend to promote the rational development of resources and industrial layouts through policy guidance and infrastructure construction. Conversely, in areas with scarce resources, the focus shifts

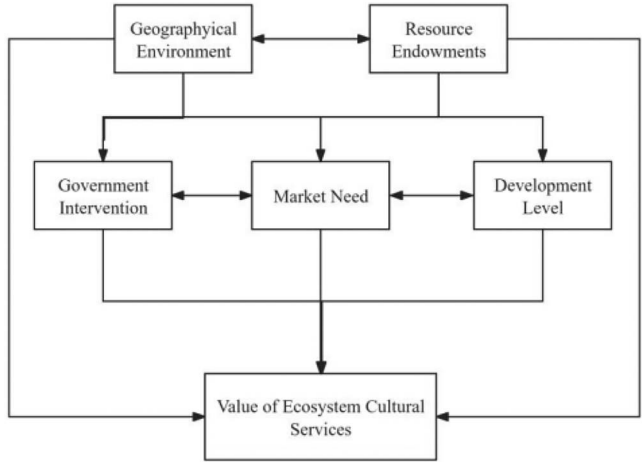

Figure 2.—Mechanism relationship diagram of influencing factors of the value of ecosystem cultural services.

toward the optimal allocation and efficient use of resources. Governments encourage innovative enterprises to integrate limited resources through technological means and develop knowledge-intensive industries, thereby compensating for economic development constraints imposed by insufficient resources (Weng et al. 2023).

Resource endowment significantly influences market demand. In regions abundant with resources, industries frequently develop around these advantageous resources, thereby generating substantial demand for related resource-based products and supporting services (Kong and Chen 2019). For instance, the copious oil reserves in the Middle East stimulate a high demand for petrochemical products and oil exploitation services. Conversely, resource-deficient areas prioritize efficient usage and substitution of resources, tending toward environmentally friendly and high-tech products and services. Moreover, variations in resource endowment lead to diverse market-demand structures across regions, affect interregional trade patterns and resource flows, and foster the global optimal allocation of resources.

The level of economic development in a region profoundly affects market demand. In economically advanced areas, residents typically experience higher incomes, possess greater purchasing power, and exhibit robust demand for high-quality and value-added products and services. Concurrently, businesses are more inclined to invest and innovate in these regions, thereby enriching market supply and promoting the diversification and enhancement of market demand. In contrast, in regions with lower economic development, market demand predominantly focuses on basic necessities (e.g., grain, inexpensive clothing), and the consumption structure remains relatively simplistic. As the economy continues to develop, market demand progressively shifts orientation from survival to development and enjoyment, guiding the adjustment of industrial structures and the reallocation of resources.

The level of development significantly affects government intervention and resource endowment. In regions with lower economic development, governments often seek to attract investment and boost economic vitality through expansive infrastructure projects and provision of preferential policies, resulting in relatively more substantial

intervention (Wang et al. 2021). In economically advanced regions, government intervention tends to decrease, with a greater focus on creating a favorable policy environment and regulating the market (Han et al. 2018). In summary, the higher the level of development in a region, the more government intervention shifts toward macroeconomic regulation and policy guidance.

Natural and social factors interactively influence the formation and realization of ecosystem cultural service value. This multidimensional relationship provides a theoretical and practical framework for their assessment and management. Accordingly, this study proposes the following hypotheses:

Hypothesis 2: Resource endowment has a significant positive effect on market demand and government intervention.

Hypothesis 3: Development level has a significant positive effect on market demand and government intervention.

Unit of analysis

This research uses the Zhalong Nature Reserve as a case study to investigate the determinants of ecosystem cultural service value. The observed variables are categorized into several dimensions. Geographical environment includes climate conditions, environmental conditions, and infrastructure development. Resource endowment encompasses biological diversity, historical and cultural heritage, and natural scenery. For government intervention, variables in this category include industrial policies, financial support, and publicity orientation. Development level is represented by economic development and technological progress. Market demand pertains to the demand for recreational activities, scientific research, and educational functions within the reserve. Ecosystem cultural service value comprises aesthetic, recreational, scientific and educational, cultural heritage, and inspirational service values.

The specific variables for the development-level factor include the economic development level (X_{41}) and the degree of technological progress (X_{42}). Market-demand variables are categorized as demand for ecosystem cultural services in nature reserves (X_{51}), demand for scientific research (X_{52}), and demand for educational functions (X_{53}). The components of ecosystem cultural service value are defined as aesthetic (Y_1), scientific and educational (Y_2), recreational (Y_3), cultural and heritage (Y_4), and inspirational service values (Y_5). Table 1 provides a detailed classification and definitions of related variables.

Data collection

Data collection was conducted using a Likert 5-point scale to quantify the observed variables, with scores ranging from 1 to 5, indicating increasing levels of the attribute measured. The questionnaire design was tailored to accommodate variations in respondents' educational backgrounds, ensuring clarity and conciseness to minimize comprehension errors and measurement biases.

To ensure statistical reliability and validity, the minimum sample size was determined using the following sample-size calculation formula (Eq. 1):

Table 1.—Observed variables for factors influencing ecosystem cultural service value.

Variable	Number	Observed variable
Geographical environment	X_{11}	Climatic conditions
	X_{12}	Environmental conditions
	X_{13}	Degree of infrastructure perfection
Resource endowments	X_{21}	Biodiversity
	X_{22}	Historical and cultural heritage
	X_{23}	Natural scenery
Government intervention	X_{31}	Industrial policies
	X_{32}	Financial support
	X_{33}	Publicity orientation
Development level	X_{41}	Economic development level
	X_{42}	Scientific and technological progress
Market demand	X_{51}	Demand for recreational activities
	X_{52}	Demand for scientific research
	X_{53}	Demand for educational functions
Value of ecosystem cultural services	Y_1	Aesthetic value
	Y_2	Scientific and educational value
	Y_3	Recreational service value
	Y_4	Cultural and heritage value
	Y_5	Inspiration service value

$$n = \frac{Z^2_{a/2} P(1-P)}{e^2} \quad (1)$$

where

n = required sample size,
Z = Z score corresponding to a 95 percent confidence level (1.96),
p = estimated proportion of the population (0.5 to maximize sample size), and
e = margin of error (0.05).

The calculated minimum sample size was 385. Data collection commenced with a survey first administered July to August 2021 using stratified random sampling that targeted research institutions, universities, and stakeholders associated with nature reserves. After initial data collection and a pilot survey, items were tested for reliability and validity, with subsequent optimization of variable definitions. A follow-up survey was conducted in the same period in 2023, yielding a total of 405 valid responses, a response rate of 95.5 percent, and an effective sample coverage of 93.75 percent.

The sample structure was diverse, comprising the following: forestry economics researchers, 46 (11.36%); ecosystem service value practitioners, 53 (13.09%); frontline nature reserve staff, 107 (26.42%); students in related fields, 165 (40.74%); and students in other disciplines, 34 (8.40%).

Table 2 provides details of the basic demographic and professional characteristics of the participants, including occupational categories, educational backgrounds, and affiliations with nature reserves. All subgroups successfully met the requirements for the chi-square test, thereby establishing the statistical power necessary for the subsequent application of structural equation modeling (SEM).

Results

Descriptive statistics

Survey data were analyzed descriptively using SPSS version 26 (Maza et al., 2025). The analysis encompassed various indicators, including mean, standard deviation, skewness,

Table 2.—Statistical summary of sample distribution characteristics.

Indicator	Basic characteristics	Frequency	Percentage	Cumulative percentage
Gender	Male	207	51.1	51.1
	Female	198	48.9	100
Age	Younger than 20 years old	10	2.5	2.5
	20 to 29 years old	128	31.6	34.1
	30 to 39 years old	146	36.1	70.2
	40 to 49 years old	96	23.7	93.9
	50 years and older	25	6.1	100
Professional background	Forestry economy	46	11.4	11.4
	Realization of ecosystem Service value	53	13.1	24.5
	Natural reserve staff	107	26.4	50.9
Educational background	Students	165	40.7	91.6
	Others	34	8.4	100
	Doctor	20	4.9	4.9
	Master	148	36.5	41.4
	Bachelor	196	48.5	89.9
	Junior college	36	8.9	98.8
	High school or less	5	1.2	100

and kurtosis (Table 3). The statistical tests confirmed that all variables within the sample maintained absolute kurtosis values below 10 and absolute skewness values below 3, satisfying the criteria for normal distribution. Consequently, the data adhere to the normality assumption required for further SEM. This adherence establishes a reliable statistical basis for the study, ensuring the scientific validity and reliability of the data analysis.

Data analysis and testing

The questionnaire data were verified through a reliability analysis. Results revealed Cronbach's alpha coefficients as follows: 0.824 for geographical environment, 0.926 for resource endowment, 0.906 for government intervention, 0.854 for development level, 0.852 for market demand, and 0.843 for ecosystem cultural service value (Table 4). These values surpass the commonly recommended threshold of 0.7, indicating a strong internal consistency among the observed variables. Furthermore, corrected item–total correlation values for all items exceeded 0.5, thus reinforcing the appropriateness of the variables. Additionally, analyses of Cronbach's alpha values postdeletion confirmed that no single item's removal would enhance the reliability, indicating that the variables are optimally combined.

The feasibility of the confirming factor analysis was affirmed by the Kaiser-Meyer-Olkin (KMO) test and Bartlett's sphericity test (Table 5). The KMO value reached 0.813, well above the recommended minimum of 0.7, and the Bartlett's sphericity test was significant (<0.005), validating the suitability of the data for factor analysis. Factors were extracted based on an eigenvalue criterion greater than 1 and were turned using Varimax rotation to optimize the factor structure (Table 6). This methodological rigor ensures the scientific validity and reliability of the factor analysis, providing a robust foundation for further SEM.

The total variances explained by the six latent variables in the study were, respectively, 17.547, 14.849, 14.807, 12.856, 9.742, and 8.587 percent. The cumulative explanatory power amounted to 78.388 percent, which significantly exceeds 50 percent, indicating that the six chosen latent

Table 3.—Descriptive statistics results.

Variable number	Number of cases	Minimum value	Maximum value	Mean value	Standard deviation	Skewness	Kurtosis
X_{11}	405	1	5	3.590	1.332	−0.052	−0.782
X_{12}	405	1	5	2.919	1.345	−0.125	−0.887
X_{13}	405	1	5	2.898	1.465	−0.091	−0.456
X_{21}	405	1	5	3.964	1.543	−0.173	−0.570
X_{22}	405	1	5	3.871	1.606	−0.014	−0.866
X_{23}	405	1	5	3.946	1.458	−0.061	−0.119
X_{31}	405	1	5	3.875	1.347	−0.057	−0.361
X_{32}	405	1	5	3.916	1.372	−0.047	−0.179
X_{33}	405	1	5	2.821	1.369	−0.085	−0.596
X_{41}	405	1	5	3.917	1.385	−0.099	−0.696
X_{42}	405	1	5	3.914	1.447	−0.184	−0.317
X_{51}	405	1	5	3.867	1.451	−0.205	−0.434
X_{52}	405	1	5	3.997	1.407	−0.199	−0.655
X_{53}	405	1	5	3.861	1.652	−0.444	−0.568
Y_1	405	1	5	2.908	1.444	−0.470	−0.636
Y_2	405	1	5	3.877	1.479	−0.125	−0.576
Y_3	405	1	5	2.898	1.478	−0.135	−0.479
Y_4	405	1	5	3.907	1.541	−0.277	−0.422
Y_5	405	1	5	3.930	1.448	−0.196	−0.324

Table 4.—Reliability analysis.

Variable	Items	Cronbach's alpha	Observed variable	Corrected item–total correlation	Cronbach's alpha after deleting an item
Geographical environment	3	0.824	X_{11}	0.684	0.952
			X_{12}	0.695	0.913
			X_{13}	0.753	0.853
Resource endowment	3	0.926	X_{21}	0.741	0.869
			X_{22}	0.753	0.796
			X_{23}	0.811	0.896
Government intervention	3	0.906	X_{31}	0.795	0.912
			X_{32}	0.711	0.714
			X_{33}	0.753	0.777
Development level	2	0.854	X_{41}	0.742	—
			X_{42}	0.852	—
Market demand	3	0.852	X_{51}	0.678	0.768
			X_{52}	0.613	0.754
			X_{53}	0.754	0.763
Ecosystem cultural service value	5	0.843	Y_1	0.763	0.845
			Y_2	0.774	0.863
			Y_3	0.785	0.875
			Y_4	0.712	0.828
			Y_5	0.743	0.811

variables exhibit strong representativeness. The rotated component matrix demonstrates that all observed variables have factor loadings above 0.5, whereas cross-loadings remained below 0.4, thus affirming good construct validity (Table 7).

Confirmatory factor analysis

Model fit.—Confirmatory factor analysis (CFA) begins with an evaluation of the measurement model to verify that it accurately represents the associations between latent variables and observed variables. This step ensures the model's appropriateness for further analysis. If the initial model fit is satisfactory, one may proceed; otherwise, it necessitates modifications informed by empirical insights or mathematical adjustments.

In this study, CFA was used to validate the measurement model further. Table 8 presents the model fit indices' results as follows: CMIN/DF(Chi-Square Divided by Degrees of Freedom) = 1.935 (below the threshold of 3); GFI(Goodness-of-Fit Index) = 0.874; AGFI(Adjusted Goodness-of-Fit Index) = 0.865 (both above the benchmark of 0.8); and IFI(Incremental Fit Index), TLI(Tucker–Lewis Index), and CFI(Comparative Fit Index) all surpassed 0.9. The RMSEA(Root-Mean-Square Error of Approximation) stood at 0.043, under the acceptable limit of 0.08. These indices collectively suggest that the model achieves a satisfactory fit, complying with the standard criteria for SEM and accurately capturing the relationships between latent and observed variables.

Confirmatory factor analysis.—Results of the CFA indicate that all latent variables, except for the market demand factor, exhibited standardized factor loadings above 0.7 (Table 9). The market demand factor, however, demonstrated slightly lower standardized factor loadings, with a value of 0.622 ($X_{51} = 0.622$), which is below the customary threshold of 0.7. Despite this, the relevant literature suggests that in CFA, a factor loading greater than 0.5 is acceptable (Shi et al. 2020). Therefore, with a loading of 0.622, the market demand factor meets this criterion and possesses sufficient merit to justify its retention.

Table 5.—Kaiser-Meyer-Olkin and Bartlett's sphericity test results.

	Kaiser-Meyer-Olkin	0.813
Bartlett's sphericity test value	10,435.20	10,435.20
	542	542
	0	0.000

Furthermore, market demand plays a crucial role as a primary driver of economic activity, reflecting consumer willingness and capability to purchase. This factor significantly influences enterprise development and the adjustment of industrial structures. Thus, despite its loading not reaching 0.7, the substantial economic implications encapsulated within this factor are too significant to disregard. Retaining this factor in the model construction enhances the model's comprehensiveness, prevents the deterioration of fit, and accurately mirrors the actual economic relationships.

All factor loadings were significantly positive ($p < 0.05$), with no anomalies in estimation observed. Composite reliability (CR) and average variance extracted (AVE) were computed for each latent variable: geographical environment is CR = 0.891, AVE = 0.568; resource endowment is CR = 0.902, AVE = 0.598; government intervention is CR = 0.913, AVE = 0.634; development level is CR = 0.876, AVE = 0.764; market demand is CR = 0.834, AVE = 0.531; and ecosystem cultural service value is CR = 0.888, AVE = 0.673.

All CR values surpassed 0.7, and AVE values exceeded 0.5, thereby confirming convergent validity. Additionally, model fit indices fell within acceptable ranges (Table 8), leading to the retention of all observed variables for subsequent path analysis.

Discriminant validity, which ensures the statistical independence of latent variables, was confirmed through the square root of the AVE method. Table 10 depicts that the square root of AVE for each latent variable exceeded its respective correlation coefficients with other variables (as shown in the diagonal elements). For example, the square root of AVE for the geographical environment (0.754) was greater than its correlation with resource endowment (0.265),

Table 6.—Total variance explanation.

	Initial eigenvalue			Sum of squared loadings of extracted			Sum of squared loadings of rotated		
Component	Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %
1	6.570	22.565	22.565	6.570	22.565	22.565	4.416	17.547	17.547
2	4.385	17.789	40.354	4.385	17.789	40.354	3.351	14.849	32.396
3	3.360	12.658	53.012	3.360	12.658	53.012	3.337	14.807	47.203
4	2.286	9.969	62.981	2.286	9.969	62.981	2.703	12.856	60.059
5	2.157	8.494	71.475	2.157	8.494	71.475	1.843	9.742	69.801
6	1.124	6.913	78.388	1.124	6.913	78.388	1.649	8.587	78.388
7	0.688	2.928	81.316						
8	0.435	1.845	83.161						
9	0.499	1.757	84.918						
10	0.570	1.907	86.825						
11	0.418	1.832	88.657						
12	0.475	1.706	90.363						
13	0.464	1.745	92.108						
14	0.320	1.614	93.722						
15	0.279	1.499	95.221						
16	0.235	1.77	96.991						
17	0.218	0.781	97.772						
18	0.296	1.684	99.456						
19	0.120	0.544	100						

thereby substantiating significant discriminant validity. Correlation analysis revealed that all latent variables were positively correlated, with coefficients ranging from 0.264 to 0.469 ($p < 0.05$). The lowest correlation occurred between government intervention and market demand (0.028), yet it was still statistically significant ($p < 0.05$), further validating the independence of the constructs.

The standardized path coefficients and significance levels presented in Table 11 reveal the relationships among various variables. Resource endowment exerts a significant positive influence on government intervention, as indicated by a standardized path coefficient of 0.321 ($p < 0.05$). Similarly, resource endowment positively affects market demand with a coefficient of 0.288 ($p < 0.05$). The development level also has a favorable effect on government intervention (coefficient 0.121, $p < 0.05$) and market demand (coefficient 0.264, $p < 0.05$). Moreover, the geographical environment substantially enhances the value of ecosystem cultural services, as denoted by a coefficient of 0.164 ($p < 0.05$). Resource endowment significantly boosts the value of these services (coefficient 0.358, $p < 0.05$), as does government intervention (coefficient 0.152, $p < 0.05$) and market demand (coefficient 0.201, $p < 0.05$). Furthermore, development level positively contributes to the value of ecosystem cultural services (coefficient 0.121, $p < 0.05$).

Among the array of factors influencing the realization of ecosystem cultural service value, resource endowment emerges as the principal determinant, closely followed by market demand and government intervention. Resource endowment indirectly influences the value of ecosystem cultural services

Table 7.—Rotated component matrix.

		Component					
Variable	Number	1	2	3	4	5	6
Geographical environment	X_{11}	0.768					
	X_{12}	0.697					
	X_{13}	0.796					
Resource endowment	X_{21}		0.918				
	X_{22}		0.872				
	X_{23}		0.896				
Government intervention	X_{31}				0.814		
	X_{32}				0.792		
	X_{33}				0.865		
Development level	X_{41}						0.845
	X_{42}						0.907
Market demand	X_{51}			0.743			
	X_{52}			0.766			
	X_{53}			0.741			
Ecosystem cultural service value	Y_1					0.760	
	Y_2					0.743	
	Y_3					0.725	
	Y_4					0.809	
	Y_5					0.832	

Table 8.—Model fit indices.

Fit indicator	Acceptable range	Measurement value
CMIN		967.564
DF		500
CMIN/DF	<3	1.935
GFI	>0.8	0.874
AGFI	>0.8	0.865
RMSEA	<0.08	0.043
IFI	>0.9	0.957
TL (NNFI)	>0.9	0.947
CFI	>0.9	0.954

Note: The CMIN/DF (minimum discrepancy divided by degrees of freedom, also called the relative chi-square); The GFI (Goodness-of-Fit Index, measuring the proportion of the observed covariance matrix explained by the model); AGFI (Adjusted Goodness-of-Fit Index, which adjusts the GFI for model complexity); The IFI (Incremental Fit Index, comparing the improvement of the target model over the null model); TLI (Tucker–Lewis Index, a non-normed incremental fit index that penalizes model complexity); CFI (Comparative Fit Index, indicating how much better the model fits than the independence model); RMSEA (Root Mean Square Error of Approximation, estimating the discrepancy per degree of freedom in the population).

Table 9.—Confirmatory factor analysis.

	Nonstandardized factor loading	Standard error	Composite reliability (t value)	P^a	Standardized factor loading	Composite reliability	Average variance extracted
Geographical environment							
X_{11}	1				0.810		
X_{12}	1.623	0.034	23.543	***	0.767	0.891	0.568
X_{13}	1.045	0.036	21.675	***	0.826		
Resource endowment							
X_{21}	1				0.754		
X_{22}	1.101	0.072	16.187	***	0.822	0.902	0.598
X_{23}	1.210	0.073	17.184	***	0.8181		
Government intervention							
X_{31}	1				0.829		
X_{32}	0.936	0.052	17.898	***	0.896	0.913	0.634
X_{33}	1.134	0.054	18.102	***	0.774		
Development level							
X_{41}	1				0.753	0.876	0.764
X_{42}	0.952	0.076	12.145	***	0.768		
Market demand							
X_{51}	1				0.622		
X_{52}	1.043	0.074	13.876	***	0.787	0.834	0.531
X_{53}	0.834	0.072	13.497	***	0.842		
Ecosystem cultural service value							
Y_1	1				0.858		
Y_2	1.176	0.064	19.032	***	0.824		
Y_3	1.184	0.066	18.123	***	0.877	0.888	0.673
Y_4	0.984	0.062	18.142	***	0.752		
Y_5	1.023	0.061	16.601	***	0.791		

*** $P < 0.001$.

through mechanisms such as capital investment, taxation, and heightened human awareness. Market demand acts as a secondary but significant factor, where the increasing focus on fulfilling these demands propels the market to expedite the development of demand value, subsequently enhancing the realization of ecosystem cultural service value. As a predominant agent in achieving the value of ecosystem services, the government actively engage through policy guarantees and ecological compensation, directly influencing the value of ecosystem cultural services within nature reserves.

The development level affects the value of ecosystem cultural services; however, this effect is mediated through the indirect influence of government intervention on service value. The advancement of science and technology pertaining to ecosystems represents a critical aspect of development level that profoundly affects the value of ecosystem cultural services in nature reserves. Hence, a vigorous pursuit of scientific and technological research related to ecosystems, aimed at enhancing the realization of ecosystem cultural service value, is imperative to generate greater benefits for humanity.

Further analysis

Government intervention is poised to act as a critical mediating variable, effectively leveraging policy guidance and the regulation of resource allocation to transform the inherent economic and technological potential of regional development into tangible improvements in the value of ecosystem cultural services. Specifically, through mechanisms such as ecological compensation and cultural protection regulations, governments can materialize abstract economic advantages into tangible ecological and cultural benefits. Without this policy-driven transformation, the enhancement of ecosystem cultural values through mere improvement in regional economic development levels is unlikely to occur automatically or comprehensively. This finding provides a robust theoretical foundation for the establishment of a collaborative linkage mechanism between policy and economy, underscoring the indispensable role of policy formulation and implementation in actualizing ecological and cultural values. Consequently, it is essential to further quantify the mediating role of government intervention to fortify the theoretical framework of this domain and to increase the precision and effectiveness of relevant policies.

Table 10.—Discriminant validity and correlation matrix.

	Geographical environmenta	Resource endowmenta	Government interventiona	Development levela	Market demanda	Ecosystem service
Geographical	0.754					
Resource endowment	0.189**	0.766				
Government intervention	0.187**	0.314**	0.800			
Development level	0.112**	0.087*	0.253**	0.888		
Market demand	0.276**	0.265**	0.028**	0.231**	0.713	
Service value	0.265**	0.469**	0.371**	0.264**	0.342**	0.873

** = 5 percent significance level.

Table 11.—Model path fit results.

Path relationship	Standardized estimate	Standard error	Composite reliability (*t* value)	P^a
Government intervention ← resource endowment	0.321	0.058	6.012	***
Market demand ← resource endowment	0.288	0.061	5.366	***
Government intervention ← development level	0.121	0.063	2.309	0.02
Market demand ← development level	0.264	0.042	5.064	***
Service value ← geographical environment	0.164	0.045	3.853	0.005
Service value ← resource endowment	0.358	0.044	6.976	***
Service value ← government intervention	0.152	0.053	3.432	***
Service value ← market demand	0.201	0.047	3.879	***
Service value ← development level	0.121	0.051	2.75	0.006

*** $P < 0.001$. "←" = significant effect.

Table 12 illustrates that the indirect effect of government intervention on the cultural service value of ecosystems, mediated through the level of development ($\beta = 0.048$), is associated with a 95 percent confidence interval of [0.012, 0.091], which notably excludes zero. Thus, it is statistically significant ($p = 0.003$). This finding robustly validates the mediating role of government intervention, indicating that despite a high level of regional development, economic and technological advantages are unlikely to be directly converted into ecosystem cultural service value without effective policy transformation. Only through the application of policy tools such as ecological compensation and cultural protection regulations can the potential economic benefits be actualized into concrete ecological and cultural gains, thereby providing an empirical basis for the development of a policy economy synergy mechanism.

Discussion

Geographical environments act as conduits for natural landscapes and the transmission of cultural heritage. Their diversity supports cultural diversity and provides benefits such as tourism resources, venues for spiritual and cultural activities, and community gathering spaces (Zhao et al. 2024). Unique geographical environments furnish natural materials for landscape aesthetics and influence the spatial distribution and overall configuration of natural landscapes, thereby enhancing their aesthetic value (Zhang et al. 2025). Path analysis has demonstrated that the geographical environment exerts a significant and positive effect on the cultural service value of ecosystems (Table 11). The distinctive cold and dry climate of the Zhalong Nature Reserve in Heilongjiang fosters unique vegetation and animal communities, enriching the diversity of wildlife resources and plant species (Geng et al. 2020). The Zhalong Reserve, characterized by its uneven terrain and abundance of lakes, rivers, and wetlands, offers habitat protection for diverse species and affords visitors opportunities to appreciate natural scenery and partake in outdoor activities. Thus, geographical environments substantially influence the cultural service value of ecosystems through factors such as landscape aesthetics, tourism, cultural formation, and spiritual benefits. It is crucial to preserve specific natural geographical environments to bolster this service value (Guo et al. 2025).

Governments can lay the groundwork for ecosystem protection and sustainable utilization by promulgating and enforcing relevant laws and regulations and by establishing mechanisms for compensation and the realization of value, thereby augmenting the cultural service value of ecosystems (Luo et al. 2025). Path analysis has demonstrated that government intervention exerts a significant and positive effect on the cultural service value of ecosystems (Table 11). The enactment of the Wetland Protection Law has provided legal safeguards for the Zhalong Nature Reserve. Furthermore, increased government financial investment in ecosystem restoration and the facilitation of private capital involvement enhance the capacity to supply ecosystem cultural services and secure financial support for value enhancement (Wang 2024). The establishment of the Zhalong Wetland Ecological Environment Judicial Protection Base furnishes legal backing for ecological protection and restoration efforts within the reserve.

Abundant natural resources and well-preserved ecosystems constitute the foundation for the development of ecotourism. These natural landscapes, endowed with unique aesthetic values, offer spaces for observation, leisure, and relaxation. Stable ecosystems support high-quality cultural services, and robust resource endowments bolster resilience against external disturbances. Regions with superior resource endowments frequently attract cultural industries, such as creative arts and cultural production (Zheng et al., 2023). Path analysis has demonstrated that resource endowment exerts a significant and positive effect on the cultural service value of ecosystems (Table 11). Historical and cultural heritage present within nature reserves mirrors local hunting cultures and lifestyles, enhancing the appeal of cultural tourism and experiences. The complex terrain and abundant water bodies in the Zhalong Reserve provide visitors with opportunities to enjoy natural scenery and participate in outdoor activities, thereby elevating the cultural service value of the reserve.

The demand for cultural services provided by ecosystems intensifies with economic development and increases in

Table 12.—Bootstrap-sampling inspection results.

Path relationship	Indirect effect (β)	Boot standard error	95% confidence interval	*p*
Development level → government intervention → ecosystem service value	0.048	0.022	[0.012, 0.091]	0.003
Resource endowment → market demand → ecosystem Service value	0.058	0.018	[0.025, 0.096]	0.001

household income, transitioning from mere sightseeing to more profound, high-quality experiences. This heightened demand incentivizes businesses and societal stakeholders to enhance and expand their offerings of ecosystem cultural services, thereby increasing both value and competitiveness. Furthermore, this augmented demand facilitates the dissemination and exchange of these services across various regions and cultures (Wang 2024). Path analysis has demonstrated that market demand and development level exert a significant and positive effect on the cultural service value of ecosystems, thus supporting Hypothesis 1 (Table 11). In the context of the Zhalong Reserve, a noted breeding site for red-crowned cranes in China, market demand is predominantly evidenced through recreational activities, scientific research, and educational endeavors. The reserve has cultivated economic and social value through the development of crane-watching tourism and science education programs.

Advancements in development lead to heightened household incomes and enhanced consumption capacity, which shift consumption patterns from basic necessities to spending oriented toward development and enjoyment. Upon reaching a specific threshold of per capita gross domestic product, a pronounced surge in demand for services such as education, health care, and cultural entertainment occurs. The level of development exerts a substantial and positive influence on market demand (Hypothesis 3). This shift in consumption structure catalyzes a stronger demand for high-quality, personalized, and diverse products and services, thus amplifying both the volume and the quality of market demand.

Overall, path analysis elucidates that several factors significantly enhance the value of ecosystem cultural services. These include geographical environment, government intervention, resource endowment, market demand, and the level of development. The geographical environment substantially enriches the aesthetic value of landscapes, providing essential materials for tourism and cultural activities, influencing the spatial distribution and layout of natural landscapes, and serving as a conduit for the transmission of natural and cultural heritage.

Government intervention plays a crucial role by establishing a robust institutional framework and financial support for ecosystem protection and the enhancement of cultural service value through the formulation of laws, the creation of compensation mechanisms, and the augmentation of financial investments. Regions rich in resources not only possess abundant natural assets but also attract cultural industries, thereby enhancing ecosystem stability and resilience against external disturbances. As the economy develops and household incomes rise, the market demand for ecosystem cultural services grows correspondingly. This evolving demand encourages enterprises and social actors to deliver products and services of higher quality. Moreover, the improvement in development level promotes a shift in consumption structure, further stimulating the demand for high-quality, personalized, and diversified products and services.

This study conducts a thorough analysis of multiple factors, including geographical environment, governmental intervention, resource endowment, market demand, and development level, to elucidate the formation mechanism of the value of ecosystem cultural services. Incorporating path analysis, the study delineates direct and indirect pathways of influence among these factors and uses bootstrap sampling to rigorously test the mediation effects. This approach exemplifies the selection of empirical research methodologies, underscores the significance of using advanced statistical techniques for precise analysis of complex relationships, and contributes to enhancing the reliability and validity of research findings.

From a theoretical perspective, the identification of the mediating role of government intervention not only augments the understanding of mechanisms through which the value of ecosystem cultural services is realized but also lends robust empirical support to the synergy theory of policy economy. This finding suggests that future research should explore the adaptability of policy tools and economic factors, uncover additional potential theoretical insights, and further elaborate and deepen the corresponding theoretical framework.

In practical terms, the study elucidates the pivotal role various factors play in enhancing the value of ecosystem cultural services, thereby offering a targeted basis for ecological conservation practices. Specifically, the study advocates for the protection of the geographical environment tailored to local conditions, the optimization of government intervention policies, the judicious use of resource endowments, the guidance of market demand, and the enhancement of the overall development level. These recommendations aim to foster the sustainable growth of ecosystem cultural service value and promote regional sustainable development, thereby providing a scientific foundation and theoretical backing for the creation of ecological protection policies and strategies.

Contributions

This research first integrates factors influencing ecosystem cultural services, constructs a path model, and systematically analyzes their interrelationships and effects, thereby addressing a significant theoretical gap. By using China's Zhalong Nature Reserve as a case study, the study then provides pragmatic insights into enhancing the value of cultural services across multiple dimensions and levels, thus offering substantial applicational value. Finally, through a synthesis of case analysis and empirical methods, this work furnishes a scientific framework and methodological support, which are instrumental for future research in the valuation of ecosystem cultural services.

Limitations and future research

This study has not fully accounted for the dynamic nature of the value of ecosystem cultural services and their influencing factors over time. Future research could use dynamic methodologies, such as time-series analysis, to investigate trends in these factors and their interplays, thereby providing more proactive recommendations for ecosystem management. Although the study identifies five principal factors, it may not encompass all pertinent variables or their intricate relationships. Subsequent research could broaden the analytical scope to incorporate additional variables, such as sociocultural dimensions or technological advancements, to augment the explanatory and predictive capacities of the model. Conclusions drawn from a singular case study necessitate validation through exploration of diverse ecosystems (e.g., urban parks, wetlands, forest reserves), thereby enhancing the generalizability of the findings. Furthermore, future studies should

explore emergent factors such as climate change, stakeholder perceptions, or policy innovations, which could deepen the understanding of the value of ecosystem cultural services and their determinants.

Conclusions

The enhancement of cultural service values within ecosystems necessitates the identification of influencing factors. This study empirically examines five categories of such factors—geographical environment, resource endowment, governmental intervention, development level, and market demand—using the Zhalong Nature Reserve as a case study. The findings elucidate the interdependencies among these factors and their cumulative effect on the value of cultural services. The research explores avenues for multidimensional and multilevel enhancement of cultural service value within ecosystems, aiming to augment the overall value of ecosystem services. These results hold significant implications for the protection of ecosystems and the enhancement of the social value of cultural services. To elevate the value of ecosystem cultural services, strategies should be precisely tailored to both natural and societal factors, fostering beneficial improvements and sustainable environmental development.

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