International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

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Spatiotemporal Evolution of Regional Tourism Ecosystem Service Value: A Case Study of the Yangtze River Delta

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International Journal of Science and Research Archive, 2026, 18(01), 188-194

Publication history: Received on 25 November 2025; revised on 04 January 2026; accepted on 07 January 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.18.1.0009

Abstract

Based on the theoretical framework of ecosystem cultural services, this study estimates the tourism ecosystem service value in the Yangtze River Delta region from 2005 to 2020 by applying the equivalence factor method revised by Xie Gaodi et al., with coefficient adjustments incorporating the consumer price index and tourism economic factors. Exploratory spatial data analysis is employed to reveal the spatiotemporal evolution of tourism ecosystem service value. The results indicate that: (1) during the study period, the land-use structure of the Yangtze River Delta underwent significant adjustment, characterized by a continuous decline in Arable land and rapid expansion of Construction land, while Woodland remained relatively stable; changes in the structure of ecological land formed the basis for the evolution of tourism ecosystem service value; (2) the total tourism ecosystem service value exhibited a continuous upward trend, with Shanghai, Suzhou, and Hangzhou contributing the largest shares, and Woodland and Waterbody constituting the primary sources of value; and (3) spatially, tourism ecosystem service value displayed a pronounced "higher-in-the-south and lower-in-the-north" pattern, with high-value clusters concentrated in south-central Zhejiang Province and core urban agglomerations, indicating significant spatial heterogeneity across the region. These findings provide scientific evidence for ecological conservation and sustainable tourism development in the Yangtze River Delta region.

Keywords: Yangtze River Delta region; Tourism ecosystem services; Spatial pattern; Land-use change; Sustainable tourism

1. Introduction

In recent decades, increasing intensity of human activities and rapid urban expansion have profoundly altered land-use patterns and landscape structure, leading to ecological problems such as landscape fragmentation and biodiversity loss [1], which in turn constrain the sustainable development of the tourism industry. Ecosystem services refer to the direct and indirect benefits that ecosystems provide to humans, and are commonly classified into provisioning, regulating, supporting, and cultural services [2]. Among these, ecosystem cultural services emphasize the non-material benefits that individuals obtain through interactions with nature and serve as a critical link connecting natural systems, socio-cultural processes, and human well-being. Existing studies indicate that the aesthetic landscape value embedded in cultural services can significantly enhance human well-being by inspiring creativit22y and promoting psychological health and social harmony [3,4].

Ecosystem cultural services are highly coupled with tourism activities and directly influence tourists' experiences and satisfaction. As a core carrier of cultural services, landscape plays a crucial role in attracting tourists [5]. Cultural landscapes not only embody aesthetic values and cultural meanings but can also be transformed into tangible economic benefits through tourism activities [6]. This transformation enables cultural ecosystem services to shift from abstract spiritual values to quantifiable economic values. Therefore, constructing a tourism ecosystem within the framework of

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ecosystem cultural services and examining its value transformation mechanisms are essential for elucidating the intrinsic linkages among natural, social, and economic systems.

The Millennium Ecosystem Assessment systematically defined the major categories of cultural ecosystem services, including aesthetic values, cultural heritage, sense of place, spiritual services, and recreation and ecotourism [7]. The value of cultural ecosystem services is inherently subjective, as it depends on individuals' and groups' perceptions and evaluations of their contributions to human well-being [8]. As a primary pathway through which humans utilize cultural ecosystem services, tourism activities can effectively reflect their multidimensional values. Through experiencing natural landscapes, cultural heritage, and historical sites, tourists obtain sensory enjoyment, spiritual fulfillment, and cultural identity. In this study, tourism ecosystem services are conceptualized as a comprehensive value form centered on cultural ecosystem services, and relevant coefficients are adjusted using the consumer price index and tourism economic factors to enhance the practical applicability of the valuation results.

Although research on ecosystem services has expanded substantially since the 1960s and 1970s [9], systematic investigations into the relationship between tourism and ecosystem services remain limited [10], with studies explicitly focusing on tourism ecosystems being particularly scarce. Existing studies have explored this topic from perspectives such as regional sustainable development [11], the construction of smart tourism ecosystems [12], and the valuation of tourism ecosystem services [13]. In terms of valuation approaches, current studies mainly employ monetary valuation methods and non-monetary social value assessment methods [14]. Monetary approaches, including the market price method, travel cost method, and willingness-to-pay method, are widely applied [15,16], but they exhibit limitations in capturing the social relationships and spiritual dimensions embedded in cultural services. With the continued refinement of valuation frameworks, ecosystem modeling approaches and the equivalence factor method have been increasingly adopted, among which the equivalence factor method has become an important tool for regional ecosystem service valuation due to its operational simplicity and relatively low data requirements [17].

Overall, although substantial progress has been made in cultural ecosystem service theory and valuation methods, systematic assessments of tourism-related cultural ecosystem service values at the regional scale remain limited. Accordingly, this study adopts the ecosystem cultural service framework and conceptualizes tourism as a key pathway for value realization, constructing a regional tourism ecosystem service valuation framework. Based on land-use data for the Yangtze River Delta from 2005 to 2020, the equivalence factor method is applied with adjustments for the consumer price index and tourism economic factors, and exploratory spatial data analysis is used to examine the spatiotemporal differentiation of tourism ecosystem service values. This study aims to clarify the role of cultural ecosystem services in linking natural, social, and economic value transformation and to provide scientific support for regional ecological conservation and sustainable tourism development.

2. Materials and Methods

2.1. Study Area

The geographical location and spatial distribution of land-use types in the Yangtze River Delta are shown in Figure 1. The Yangtze River Delta is located in the lower reaches of the Yangtze River, at the core of the Yangtze River Delta plain, and borders the Yellow Sea and the East China Sea, occupying a strategic position at the land–sea interface.

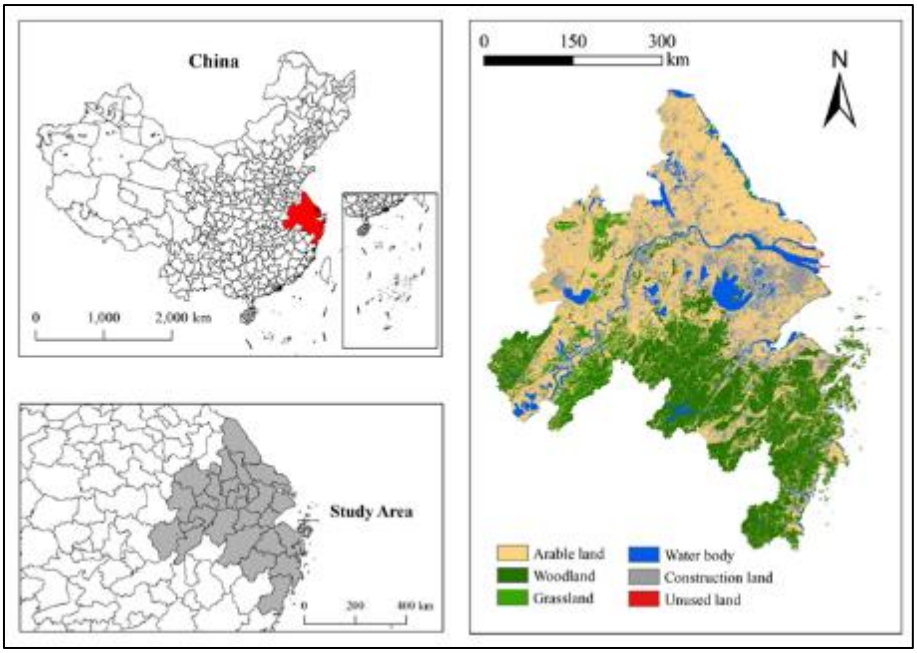

Figure 1 Location of the study area

2.2. Methods

2.2.1. Standard Equivalent Economic Value

According to Xie et al. [18], the economic value of one ecosystem service equivalent factor in a given region is defined as one-seventh of the market value of the national average grain yield in the corresponding year. Based on grain production and sown area data for 2005, 2010, 2015, and 2020, this study calculates the value of the standard tourism ecosystem service (TES) equivalent factor for each year using the national average annual prices of major crops in the study area.

$$E_t = \frac{1}{7} \times P_t \times Q_t \qquad (1)$$

where E_t denotes the economic value of the standard equivalent factor in year t; $P_t$represents the national average annual price of major crops in the study area in year t; and $Q_t$refers to the grain yield per unit area in the study area in year t.

2.2.2. Adjustment of Unit-Area Coefficients

- Consumer Price Index (CPI) Adjustment

$$a_j = \frac{CPI_j}{100} \qquad (2)$$

$$M_t = \frac{a_1}{a_0} \times \frac{a_2}{a_1} \times \frac{a_3}{a_2} \times \cdots \times \frac{a_n}{a_{n-1}} = \frac{a_n}{a_0} \qquad (3)$$

where CPI denotes the Consumer Price Index; $a_j$represents the CPI value in year $j$after removing the base-unit effect; a_1/a_0 indicates the month-on-month CPI ratio for the first period; and $M_t = a_n/a_0$ denotes the year-on-year CPI adjustment factor for year t.

- Tourism Economic Factor Adjustment

$$S_t = R_t \times A_t \qquad (4)$$

$$R_t = W_{th}/W_{tg} \qquad (5)$$

$$W = 2/(1 + e^{-m}) \quad (6)$$

$$m = 1/E_t - 2.5 \quad (7)$$

$$O_t = O_{tr} \times (1 - P_{tu}) + O_{tu} \times P_{tu} \quad (8)$$

$$A_t = G_{th}/G_{tg} \quad (9)$$

where S_t, R_t, A_t, and W_{th} denote the tourism factor adjustment coefficient, willingness-to-pay adjustment index, ability-to-pay adjustment index, and the combined parameter of willingness to pay and ability to pay for the study-area city in year t, respectively; W_{tg} represents the national willingness-to-pay parameter in year t. O_t, O_{tr}, O_{tu}, and P_{tu} refer to the total Engel coefficient of the study-area city, the rural Engel coefficient, the urban Engel coefficient, and the proportion of the urban population to the total population in year t, respectively. G_{th} and G_{tg} denote per capita tourism income of the study-area city and the national level in year t, respectively.

2.2.3. Calculation of Tourism Ecosystem Service Value

$$VC_m = equivalence \times E_t \times M_t \times S_t \quad (10)$$

$$TES = \sum_{m=1}^{n} (LUC_m \times VC_m) \quad (11)$$

where VC is the TES coefficient; LUC denotes land-use area; m refers to the m-th land-use type; n is the number of land-use categories in the study area; and TES represents tourism ecosystem service value. For spatial autocorrelation analysis, n denotes the number of spatial units; x_i and x_j are the observed values for spatial units i and j, respectively; w_{ij} is the spatial weight matrix defining spatial interactions; and s_0 is the sum of all spatial weights, given by $s_o = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}$。

3. Results

3.1. Changes in Land-Use Area

Land use underpins ecosystem service value, and changes in land-use types directly drive its variation. Land-use data for 2005, 2010, 2015, and 2020 were therefore analyzed to quantify the extent and dynamics of land-use change in the Yangtze River Delta urban agglomeration (Figure 2). Arable land and Woodland dominated the regional land-use structure.

Between 2005 and 2020, Arable land declined continuously, decreasing from 109,344.95 km^2 to 99,809.27 km^2, a net loss of 9,535.67 km^2. Woodland slightly decreased during 2005–2015 but increased during 2015–2020, remaining relatively stable overall under the combined effects of human activities and afforestation policies. Grassland decreased during 2005–2015 due to reclamation but rebounded thereafter. Waterbody area initially increased and then declined. In contrast, Construction land expanded markedly from 20,129.19 km^2 to 30,328.81 km^2, reflecting rapid urbanization and economic growth. Unused land accounted for only a negligible share throughout the study period.

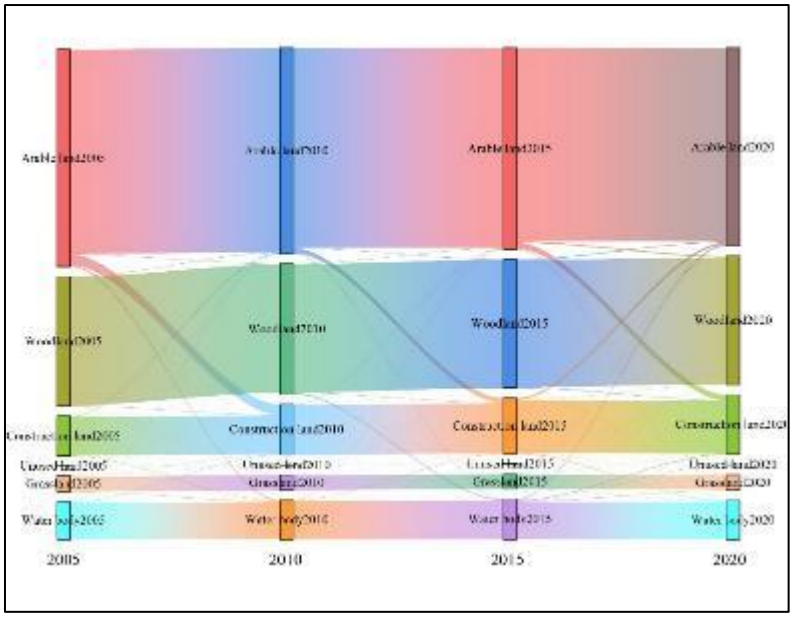

Figure 2 Area transition matrix of land-use types

3.2. Temporal Variation Analysis

The tourism ecosystem service value of the Yangtze River Delta was estimated (Figure 3). Overall, total tourism ecosystem service value increased steadily from 2005 to 2020, reflecting strengthened ecological conservation, industrial upgrading, and water pollution control under increasingly effective regional collaborative governance, which jointly improved environmental quality and tourism attractiveness.

At the city level, Shanghai, Suzhou, and Hangzhou were the primary contributors to regional tourism ecosystem service value, highlighting the role of urban economic strength and city prominence. Their leading positions were reinforced by advantages in economic development, infrastructure, and the integration of cultural and tourism resources.

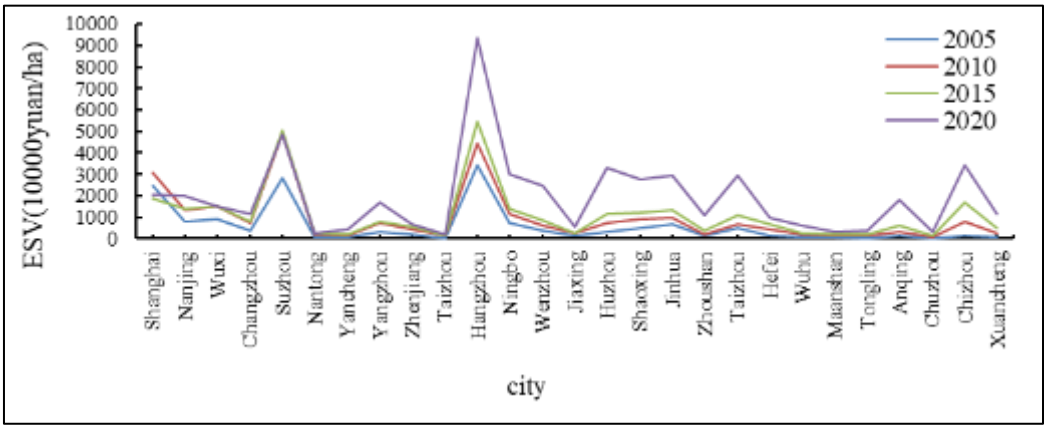

Figure 3 Tourism ecosystem service value of cities in the Yangtze River Delta (10,000 yuan/ha)

3.3. Spatial Evolution Characteristics

To examine the spatial distribution and temporal evolution of tourism ecosystem service value in the Yangtze River Delta, values for 2005–2020 were visualized (Figure 4). At the city scale, a clear "higher in the south and lower in the north" pattern was observed. During 2005–2010, southern areas dominated by Woodland and characterized by favorable ecological conditions exhibited higher values, whereas northern areas, mainly composed of Arable land, experienced greater ecological pressure from intensive agriculture and showed lower values.

Cities including Shanghai, Suzhou, Hangzhou, Nanjing, Ningbo, Jinhua, and Shaoxing consistently exhibited higher tourism ecosystem service values, closely associated with strong economic bases, well-developed infrastructure, and abundant ecological and cultural tourism resources.

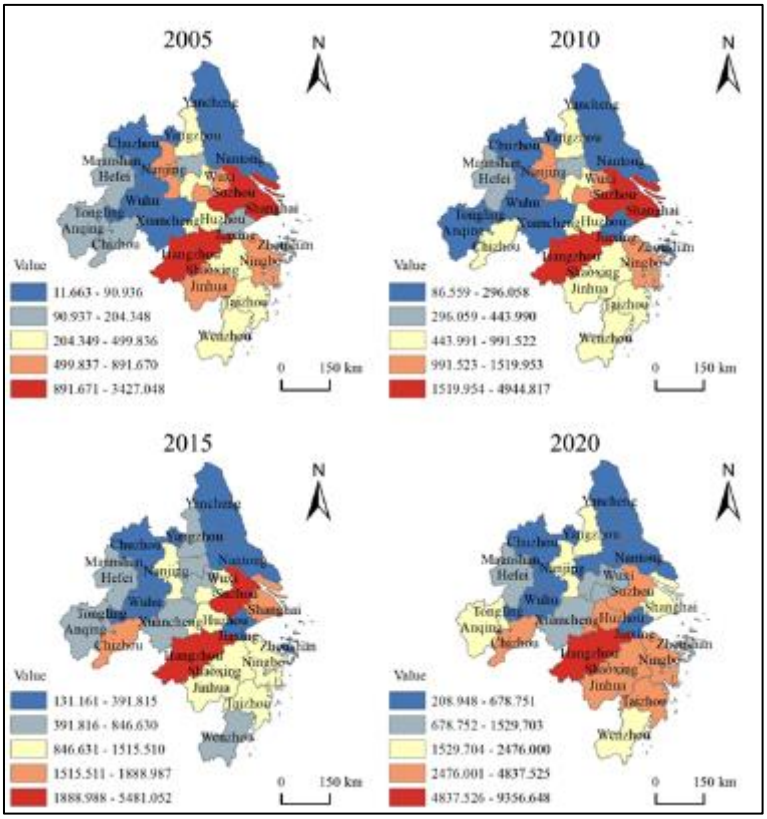

Figure 4 Spatial distribution of tourism ecosystem service values at the city scale in the Yangtze River Delta (10,000 yuan/ha)

4. Conclusions

Using data from 2005 to 2020, this study applies exploratory spatial analysis to examine the spatiotemporal dynamics of tourism ecosystem service value in the Yangtze River Delta. The results indicate that:

- In terms of land-use change, the land-use structure of the Yangtze River Delta urban agglomeration underwent significant adjustment during the study period. Arable land continuously decreased, while Construction land expanded rapidly, reflecting the dominant role of urbanization in land resource allocation. Woodland remained relatively stable, whereas Grassland and Waterbody exhibited stage-specific fluctuations, suggesting that ecological protection policies partially mitigated the pressure of human activities on ecological space. Overall, the expansion of Construction land and the restructuring of ecological land jointly shaped the evolution of regional ecosystem service value.
- In terms of temporal dynamics, the total tourism ecosystem service value in the Yangtze River Delta increased steadily from 2005 to 2020. At the city level, Shanghai, Suzhou, and Hangzhou made the largest contributions, indicating that urban economic development and city prominence play an important role in shaping regional tourism ecosystem service value. From a land-use perspective, Woodland and Waterbody constitute the primary sources of tourism ecosystem service value in the Yangtze River Delta.
- In terms of spatial distribution, tourism ecosystem service value in the Yangtze River Delta exhibits a pronounced “south–high, north–low” pattern at the city scale during 2005–2020, with high-value areas mainly concentrated in south-central Zhejiang and core urban agglomerations.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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