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Spatiotemporal response of ecosystem services to tourism activities in urban forests

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Tourism in urban forests is rapidly becoming an increasing trend; however, rather few studies have used quantitative measurement to describe the relationship between tourism intensity and ecological functions. This study provides a practical framework that integrates ecosystem service value (ESV) assessment, Internet big data mining and spatial regression analysis to identify the spatial response of ESV and land use/land cover change to tourism activities from 2009 to 2019 in the Siming Mountain Region (SMR), a famous tourist resort located in the eastern coastal China. Results showed that between 2009 and 2019 total ESV increased by 7.1%. Nevertheless, there have been drastic transitions in land use types with function adjustments from traditional agricultural production to diversified tourism-oriented services. Significant spatial autocorrelation was identified for the patterns of ESV changes. GWR further highlighted that the relationship between ESV change and rural tourism indicators varied in space. ESV change in the core zone was negatively correlated with changes in catering service spots and recreational venues, whereas it was positively correlated with local lodgings. Ultimately, targeted recommendations and countermeasures for spatial planning and sustainable tourism development of urban forests under new circumstances were discussed.

KEYWORDS

ecosystem service value, land use and land cover, tourism activities, geographically weighted regression, internet big data, tourism management strategies, urban forest

1 Introduction

Intensifying urbanization has caused a series of profound ecological problems and posed a potential threat to regional sustainable development (Su et al., 2014; Yu et al., 2021). It has impacted the capacity of ecosystems to deliver services, which represent the welfare that humans directly or indirectly obtain from the natural environment (Santos-Martín et al., 2013; Wolff et al., 2015). Thus, assessing ecosystem service value (ESV) and investigating how it changes in response to human activities have aroused increasing interest among researchers (Costanza et al., 1997; Rudolf et al., 2012; Mitchell and Devisscher, 2022). Most prior studies have focused on ESV assessments at multiple scales from global to regional extent (Costanza et al., 1997, 2014; Bateman et al., 2013; Kibria et al., 2017), and across different ecosystems (Pendleton et al., 2015; Metzger et al., 2021; Taye et al., 2021; Li et al., 2023). Additionally, a growing number of studies are now focusing on the trade-off and synergies analysis across different ecosystem types and services (Lester et al., 2013), interactions between ecosystem service supply and urbanization (Wu et al., 2013; Helfenstein and Kienast, 2014; Su et al., 2014; Wang et al., 2023), and payments for ecosystem services (Jayachandran et al., 2017). Although various factors that influence ecosystem services have been suggested, such as social-ecological factors and land use/land cover change (Lin et al., 2018; Wang et al., 2022, 2023), there are few studies that investigate the endogenous driving force and its impacts on ecological functions within a specific study site or industry element through temporal and multi-scale analysis (e.g., tourism city, urban forest).

Tourism is a widespread activity worldwide and has expended dramatically in many countries (Su, 2011; Liu, 2018; Kaptan Ayhan et al., 2020). The impact of tourism activities on land use/land cover change and ecosystem services change remains underestimated. The current study attempts to fill the abovementioned research gap with an emphasis on urban forests. As opposed to urban regions, villages in urban forests have experienced rural recessions characterized by people leaving rural areas, population aging and adjustment of agricultural structure in the early era of urbanization (Onitsuka and Hoshino, 2018). Meanwhile, as demand for ecological functions increases, such as ecological agricultural product production, and rural entertainment and culture experience, rural tourism in urban forests has rapidly developed owing to their location advantage. There is consensus that rural tourism can help remote communities become directly involved in and benefit from tourism by generating and diversifying revenues for farmers, and helping to create a value-added market channel for local products and offer employment opportunities (Su, 2011; Dai et al., 2023). Moreover, tourism development can also improve accessibility to natural forests, and thus enhance the use value of cultural ecosystem services (Chen, 2020a). However, challenges brought by tourism are also salient and have recently aroused widespread concerns among tourism scholars and ecologists (Liu et al., 2022; Xiao et al., 2022). For instance, excessive growth of the tourism industry has posed severe threats to biodiversity in ecologically fragile areas (Saadi et al., 2023; Zhang et al., 2023), causing pollution and ecological degradation (Satrovic and Muslija, 2019; Liu et al., 2021). Therefore, it is particularly crucial to quantify the positive and negative effects of increasing tourism activities on the ESV of urban forests.

Previous studies have found that tourism affected ecosystem services in two ways, namely tourism-oriented land use/land cover change (Li et al., 2020b), and the direct disruption of tourists' behavior on the ecological process of local ecosystem (Underwood et al., 2019). In this regard, the present study investigates how ESV changes in response to tourism development from both the perspectives of land use/land cover transformation and tourism activity intensity with a special focus on urban forests in a developed eastern coastal city of China. However, the quantification of tourism activity intensity still remains a challenge, especially within the open space of mountainous area. Majority of the researches use tourism-driven land use change (Li et al., 2020a), the fluxes of tourists and tourism revenue by field survey approach to characterize tourism practices. Nevertheless, the problem of inconsistent caliber and poor timelines remains (Cai et al., 2023). Over the past decade, the use of Internet-based reservation and recommender systems has grown massively. Internet big data can be an effective supplement to traditional data sources (Li H. et al., 2020), both from the perspective of mass data from multiple sources and up-to-date effectiveness.

The Siming Mountain Region (SMR) is chosen as the case study site because it is quite adjacent to an urban district and thus is more vulnerable to anthropogenic interference driven by urbanization. It also serves as a crucial ecological conservation area and water source protection zone, as well as an attractive destination for rural tourism owing to the ongoing activities of agricultural life and cultural characteristics, natural features and diversified topography, along with the unique climatic. These elements combined to make the SMR an ideal subject for examining and quantifying the impact of tourism on ecological functions. This study aimed to investigate the response of ESV and land use/land cover changes (LULC) to rural tourism activities, with respect to their characteristics and intensity at multi-scale levels. Specifically, the study investigated the following three research questions: (1) How do ESV and LULC change in response to tourism development? (2) What are the evolution characteristics of tourism elements and their effects on urban forest ecosystem? (3) What theoretical guidance and practical reference can be developed for ecological conservation and tourist marketing strategies to promote short-term recovery as well as long-term sustainable development of urban forests?

2 Study area

Ningbo, as one of the sub-provincial-level metropolis designated by the central government, is an important port city on the eastern seaboard of China, the economic center on the south wing of Yangtze River Delta. In the sustainable development of this second largest city in Zhejiang Province, the SMR plays a critical role by serving various functions including water resource conversation, ecosystem maintenance, entertainment and cultural heritage. There are 13 towns consisting of 240 villages in the SMR, covering an area of 140,900 ha, with elevations ranging from 0 to 958 m. In 2013, the coexisting forest land of the SMR reached 92,500 ha, with a growing stock of 350,000 m^3. There are four large reservoirs, three medium-sized reservoirs and many small reservoirs located in this region, with a total water storage capacity of 400 million m^3. Additionally, the SMR has emerged as a famous tourism destination in the Yangtze River Delta due to its diverse landscapes and captivating attractions, including mountains, ravines, reservoirs and rivulets, local food and historic building. During the year of 2022, the number of tourists amounted to 7.4 million, generating a total tourism revenue of 2.2 billion RMB (approximately 304.9 million USD). The SMR had experienced disorderly over-development of the nursery stock industry. Later, guided by the theory of "lucid waters and lush mountains are invaluable assets," the local government has paid tremendous efforts in ecological remediation, developing leisure agriculture and rural tourism. Because of the changes in the focus of development, it has experienced drastic transitions of LULC and ecosystem service supply in the past decade.

The natural terrain of SMR consists of hills (110,400 ha), plains (24,000 ha) and water bodies (6,560 ha). Given that elevation is acknowledged as an important factor for the concept of rural tourism (Kaptan Ayhan et al., 2020), we divided our study area into two zones according to the elevation (Figure 1): the core zone (villages with mean elevations greater than 300 meters) and the buffer zone (villages with mean elevation less than 300 meters). In summary, the core zone contained 100 villages and the buffer zone contained 140 villages.

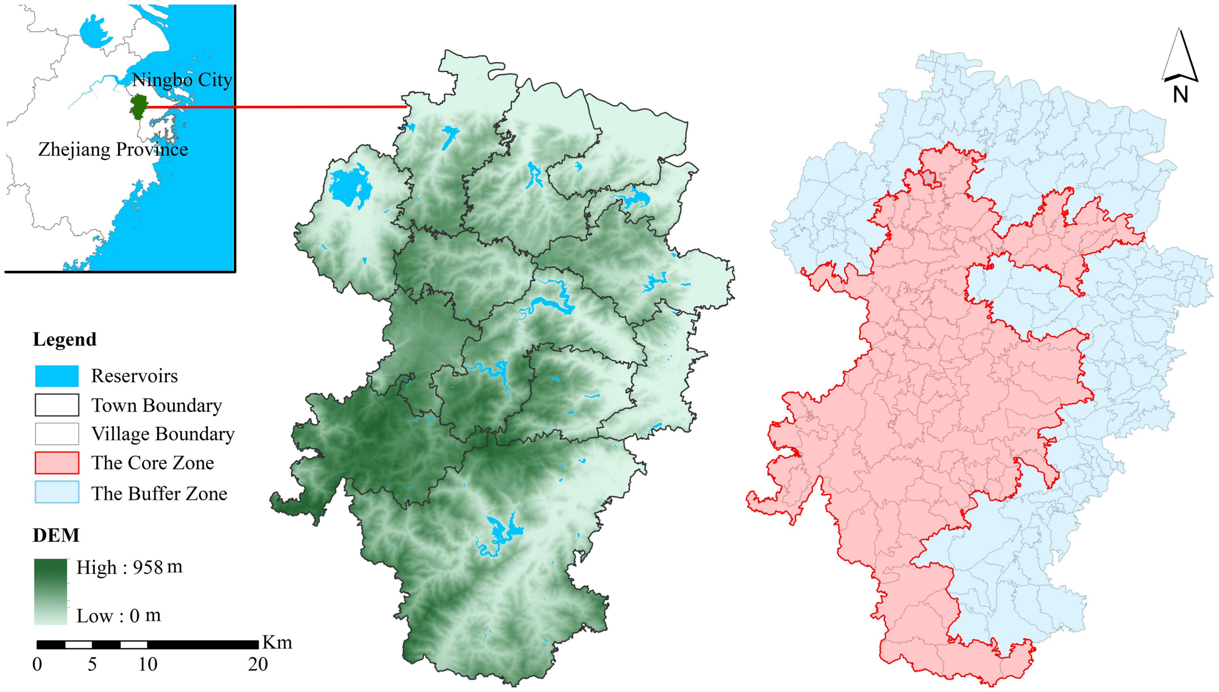

FIGURE 1
The location and divisions of core and buffer zones in the SMR.

3 Materials and methods

3.1 Data and preprocessing

The main datasets used in this study were as follows: (1) Digital LULC maps for the year 2009 and 2019 with one meter spatial resolution, the results of the Second and Third National Land Use Survey, supplemented with the administrative boundary data, were provided by Ningbo Bureau of Natural Resources and Planning. The dataset was interpreted from aerial photographs and land use surveys that ensured high accuracy of the data and the analytical results. In line with the major dominant ecosystems in the study area, we reclassified the land use types into eight categories: forest, tea garden, orchard, arable land, water body, built-up land, bare land and meadow. (2) Digital elevation model (DEM) data with a spatial resolution of 30 m were provided by the Data Center for Resources and Environmental Sciences, China Academy of Sciences[1] was used for topographic calculation. (3) Demographic and other socio-economic data were obtained from the local Statistical Bureau.[2]

3.2 ESV assessment

Costanza's ESV assessment model is well-known globally and was used in the present study, expressed as Eq. (1). Xie et al. modified Costanza's ESV assessment model by dividing 16 global biomes into seven local LULC types based on Chinese terrestrial systems (Xie et al., 2003), and established equivalent coefficients methods for each province of China according to the comprehensive statistical analysis using data from a survey of 700 Chinese ecologists (Xie et al., 2005). We therefore used the adjusted coefficients for Zhejiang Province to assess the ESV of SMR. According to the LULC classification in this study area, tea garden is substituted by orchards and the ecosystem service equivalent value factor of tea garden is applied to orchards (Appendix).

$$ESV = \sum \left(A_K \times VC_K \right) \quad (1)$$

Where VC_K is coefficient for the ESV of proxy biome type "k" and A_k is its corresponding area.

3.3 Evaluating tourism intensity

In this study, we obtained tourism-oriented practice data as the key indicators of tourism activities from Dianping.com, the largest online tourism and consumption recommender platform in China. The website's current active user number is 470 million, accounting for one third of total population in China. With such a large user base, this website not only plays a significant role in providing guidance for consumers, but also profoundly influences the reputation of destinations and businesses. We gathered all the scenic spots and tourism-related merchants along with their coordinates using Python software on Aug. 10th, 2023. After coordinate transformation and correction, we categorize the merchants into four tourism elements according to their type tags, namely scenic attractions, catering,

1 http://www.resdc.cn/
2 http://tjj.ningbo.gov.cn/

TABLE 1 Terms and attributes for the four tourism elements.

Tourism elements	Terms and attributes for the respective elements
Scenic attractions	Natural sights, historical and cultural attractions, theme parks. Etc.
Catering	Agritainment, cafes and agricultural product stores
Lodgings	Hotels and homestays
Recreational venues	Leisure agriculture such as farms, camping sites, study tour camps, fishing pools, sports clubs. Etc.

lodgings and recreational venues. The specific terms and attributes for each element are demonstrated in Table 1. Verified by registration time and on-site visits, the final sample contains 1,009 and 2,843 rural tourism-related merchants in 2009 and 2019, respectively.

3.4 Geographically weighed regression

Moran's *I* was utilized to characterize the spatial autocorrelation of ESV and rural tourism indicators changes over time. Moran's *I* was calculated using ArcGIS 10.2 software with the nearest neighbor distance matrix. Then, the GWR model was employed to examine the spatially non-stationary relationships between ESV changes and tourism activity indicators. GWR extends ordinary least squares (OLS) in characterizing the spatial non-stationarity of the parameters in different regions by incorporating spatial dimensions into modeling, and thus has been proved to be capable in explaining the relationships of variations (Fotheringham et al., 2002). It relies on a Gaussian distance decay function, where the contribution of one sample is weighed based on its proximity to the location of the sample being considered. GWR is described as Eq. (2).

$$y_i = \beta\left(v_i, u_i\right) + \lambda\left(v_i, u_i\right) X_i + e_i \quad (2)$$

Where y_i is the dependent variable; (v_i, u_i) is the spatial position of sample i; β is the intercept; λ is the coefficient; X_i is the independent variable; and e_i is the error term.

GWR was estimated whereby the optimal bandwidth is determined by minimizing the value of AIC value (Fotheringham et al., 2002). All the statistical analyses were done with the software ArcGIS 10.2.

4 Results

4.1 Dynamic LULC change and conversion

During the study period, forest, cropland and built-up land remained as three primary land use types in the SMR. In 2009, these land use types accounted for 66.2, 12.0 and 6.5%, respectively. In 2019, the percentages changed to 74.6, 7.1 and 8.0%. It was worth noting that there was a net decrease of 12534.8 ha in cropland areas (55.5% of the total cropland area in 2009), followed by tea gardens (2435.4 ha, 36.9%), meadows (923.0 ha, 83.2%) and bare land (77.4 ha, 91.2%). In contrast, forests, build-up land, orchards and water bodies all increased significantly. Forest experienced the greatest increase, 11803.9 ha in area, equivalent to 12.7% of the total forest area in 2009. According to the transition matrix (Table 2), approximately 39.1, 8.6 and 7.0% of cropland were converted to forest, orchards and built-up land from 2009 to 2019. Moreover, almost all of the bare land and meadow area were replaced by forest. Simultaneously, 2805.8 ha of tea gardens (42.5% of the tea garden area in 2009) and 1532.7 ha of orchards (62.3% of the orchard area in 2009) were converted to forest.

The direction and extent of the changes in LULC was different between the two zones, as shown in Figure 2. Specifically, 67.5% of the cropland (5633.0 ha), 43.4% of tea gardens (2226.8 ha) and 71.6% of orchards (546.9 ha) in the core zone were replaced by forest. In the buffer zone, on the other hand, the transition direction of cropland was more diverse, including conversion to forest (3210.6 ha), orchards (1651.6 ha) and built-up land (1289.5 ha). The greatest disparity lied in the area changes of tea garden and orchards. The area of tea gardens decreased by 1783.0 ha in the core zone and 561.8 ha in the buffer zone, while orchard area increased by 54.6 ha in the core zone and 1454.1 ha in the buffer zone.

4.2 ESV changes in the SMR

Land use structure underwent substantial changes under the influence of rural tourism, leading to variability in ecological services. As shown in Table 3, the total ESV exhibited a 7.1% overall trend of increase from 2009 to 2019. Except for food production, which declined by 32.6%, values for all categories of ecosystem services significantly increased over this period. The three categories with the greatest increases were raw materials (11.6%), entertainment and culture (11.3%), and gas regulation (9.5%).

Figure 3 illustrates the changes in the ESV of different categories of ecosystem services in the two zones. On average, the ESV changes more dramatically in the core zone than in the buffer zone from 2009 to 2019. Except for food production and waste disposal, the ESV of the remaining seven categories increased in both zones. It was noteworthy that the ESV of food production declined by 40.4% in the core zone and 26.4% in the buffer zone. The ESV of entertainment and culture in the core zone witnessed the largest increase (15.0%). These changes imply the functional adjustment from agricultural production to diversified ecotourism during the study period.

4.3 Spatiotemporal dynamics of tourism activities

According to Dianping.com, there were 1,009 rural tourism-related merchants in the SMR in 2009. By 2019, this number surged to 2,843 (Figure 4). Of the tourism elements assessed, the number of local lodgings experienced the largest growth of 313.5% during the study period. In contrast, the number of scenic attractions increased slightly by 20.8%. In particular, the composition of tourism elements and the pattern of the changes over time also varied between two zones. In the

TABLE 2 The transition matrix of LULC in Siming Mountain Region from 2009 to 2019 (unit: ha).

		2019								
		Cropland	Forest	Tea garden	Orchard	Water body	Built-up land	Bare land	Meadow	Total
Whole region, 2009	Cropland	8949.9	8843.7	729.6	1940.7	544.3	1581.0	0.3	1.4	22590.9
	Forest	312.5	90048.3	433.8	1118.0	245.8	1094.7	5.3	24.4	93282.8
	Tea garden	363.3	2805.8	2957.8	249.3	31.4	180.1	0.0	14.1	6601.8
	Orchard	63.4	1532.7	22.3	740.3	11.5	81.9	0.1	7.6	2459.8
	Water body	85.9	240.2	4.8	13.8	4983.5	195.7	0.0	23.1	5547.0
	Built-up land	263.9	553.9	14.2	76.8	98.2	8138.9	0.4	82.4	9228.7
	Bare land	1.2	73.2	0.2	0.8	1.6	3.6	1.3	3.0	84.9
	Meadow	16.0	988.9	3.7	26.8	14.6	28.9	0.1	30.9	1109.9
	Total	10056.1	105086.7	4166.4	4166.5	5930.9	11304.8	7.5	186.9	140905.8
Core zone, 2009	Cropland	1459.7	5633.0	579.0	289.1	94.9	291.5	0.3	0.5	8348.1
	Forest	160.6	50366.5	290.7	212.7	159.1	521.8	2.3	4.1	51717.9
	Tea garden	251.4	2226.8	2367.6	124.0	23.4	132.0	0.0	8.0	5133.2
	Orchard	11.8	546.9	7.9	95.7	2.2	11.1	0.0	4.0	679.6
	Water body	4.5	73.1	2.7	1.4	754.4	27.6	0.0	1.6	865.2
	Built-up land	32.1	148.6	10.2	8.9	16.6	1069.6	0.1	4.9	1291.1
	Bare land	0.4	39.8	0.1	0.3	0.1	0.9	0.5	0.1	42.3
	Meadow	6.0	544.2	2.1	2.1	5.7	9.6	0.1	8.2	578.0
	Total	1926.6	59578.9	3260.2	734.2	1056.6	2064.2	3.2	31.5	68655.4
Buffer zone, 2009	Cropland	7490.2	3210.6	150.6	1651.6	449.4	1289.5	0.0	0.9	14242.7
	Forest	151.9	39681.8	143.1	905.3	86.6	572.9	3.0	20.3	41564.9
	Tea garden	111.9	579.0	590.2	125.3	8.0	48.2	0.0	6.0	1468.6
	Orchard	51.6	985.8	14.4	644.6	9.3	70.8	0.1	3.6	1780.2
	Water body	81.4	167.1	2.1	12.5	4229.1	168.1	0.0	21.5	4681.8
	Built-up land	231.7	405.3	4.0	67.9	81.6	7069.1	0.3	77.5	7937.6
	Bare land	0.8	33.4	0.2	0.5	1.5	2.7	0.9	2.9	42.7
	Meadow	9.9	444.8	1.6	24.7	8.9	19.3	0.0	22.7	531.8
	Total	8129.4	45507.9	906.2	3432.3	4874.2	9240.6	4.3	155.3	72250.3

core zone, scenic attractions took the largest percentage among the four tourism elements in 2009, and lodgings became the dominant tourism element later in 2019. However, in the buffer zone, catering kept as the dominant tourism element throughout the study period. Especially in 2019, the number of catering merchants was 9.8 times that of scenic attractions, and 7.6 times that of recreational venues.

Figure 5 illustrates the spatial distribution of tourism elements. It is obvious that there was a strong tendency of spatial clustering at the village scale. Catering service were primarily provided in the northern SMR. More specifically, they tended to cluster near Yuyao county, a satellite of downtown Ningbo. Villages with more than five recreational venues were all located in the buffer zone.

4.4 Response of ESV to rural tourism activities

Moran's *I* for ESV was significant with a positive value of 0.54, which was statistically significant at the 0.01 level, implying that pattern of ESV changes was autocorrelated in space and it is spatially non-stationary. Therefore, the GWR model is more appropriate to describe the spatial relationships between ESV and tourism indicators (scenic attractions, catering, lodgings and recreational venues) at the village level. The regression coefficients of individual indicator for different villages were obtained through GWR (Figure 6). It illustrates that the factors affecting ESV varied by spatial location, with both positive and negative correlations between ESV changes and tourism indicators, except for scenic attractions. The influence of scenic attractions on ESV was relatively low and insignificant. For relationships between ESV changes and the other three tourism indicators, GWR was more explanatory in the northeastern and southwestern region, while it was less capable to predict the relationship in the central part. In terms of lodgings, the coefficients increased from northeast to southwest of the region. It was noteworthy that ESV change in the southwestern core zone were negatively correlated with the changes in the number of catering and recreational venues, whereas they were positively correlated with lodgings, such patterns implied that

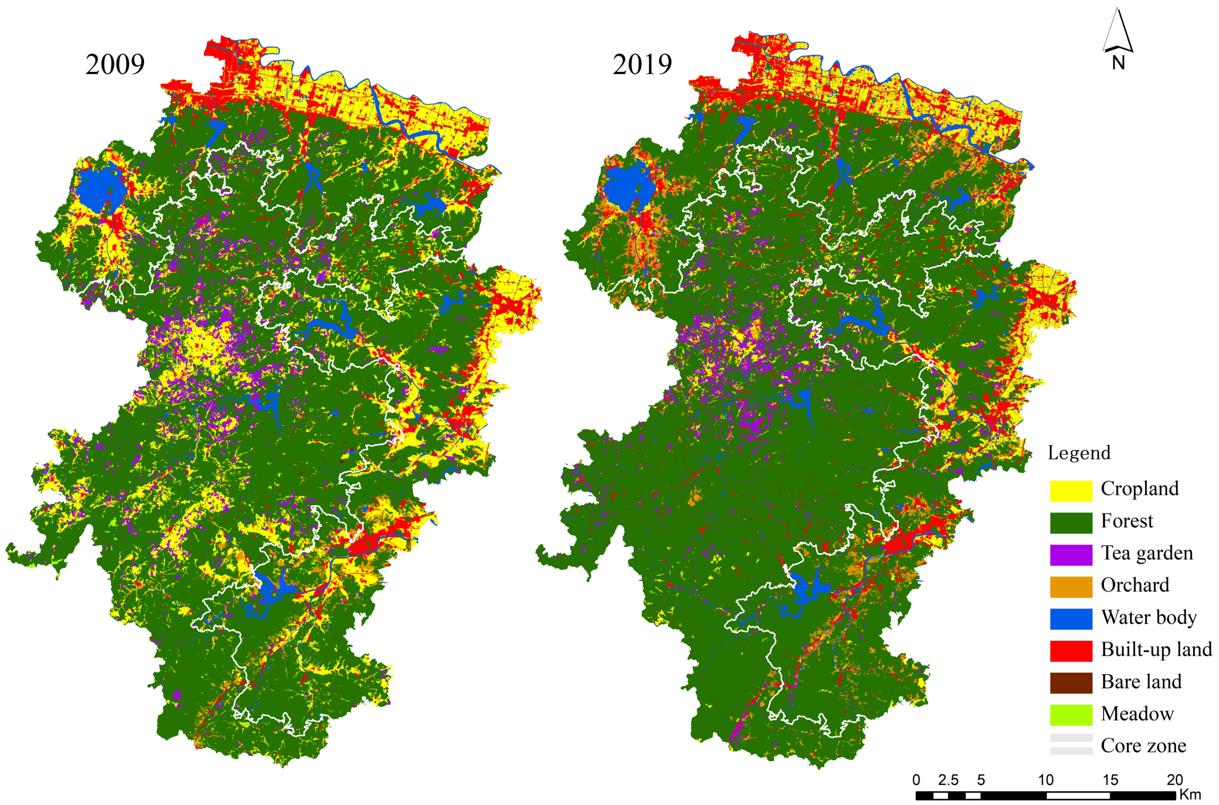

FIGURE 2
LULC of the Siming Mountain Region in 2009 and 2019.

TABLE 3 ESV changes in the SMR from 2009 to 2019 (million RMB).

Category of ecosystem services	2009	2019	Changes between 2009 and 2019 (%)
Gas regulation (GR)	547.6	599.5	9.5
Climate regulation (CR)	447.7	477.5	6.6
Water reservation (WR)	664.0	722.1	8.7
Soil formation and protection (SFP)	634.1	673.5	6.2
Waste disposal (WD)	418.8	419.0	0.0
Biodiversity conservation (BC)	527.8	573.3	8.6
Food production (FP)	56.8	38.3	−32.6
Raw materials (RM)	388.6	433.8	11.6
Entertainment and culture (EC)	225.3	250.7	11.3
Total value	3910.9	4187.5	7.1

the expansion of catering and recreational venues led to ESV reduction.

5 Discussion

5.1 Development of rural tourism in urban forests

Tourism is not only widely recognized as an effective solution to alleviate typical socioeconomic challenges in mountainous areas, but also has important implications for the provision of ecosystem services, especially under strict land use restrictions. The SMR is an important drinking water conservation zone for Ningbo. Its important role in providing ecological goods and services, together with the complex geographic conditions in China's mountainous areas (Lu et al., 2019), strict land use control in rural China, and the eco-environmental conservation red lines (ECRLs) restrict large-scale socioeconomic development in the SMR. Villages in the SMR experienced a serious recession, characterized by emigration of population and abandonment of arable land. In 2005, in his capacity as secretary of the CPC Zhejiang Provincial Committee, Xi Jinping

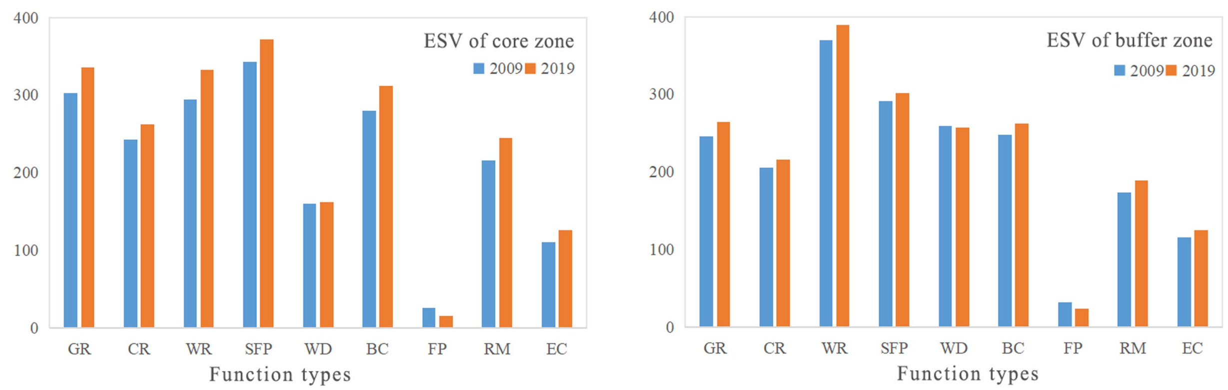

FIGURE 3
Change of ESV of different ES functions in the two zones from 2009 to 2019 (unit: million RMB).

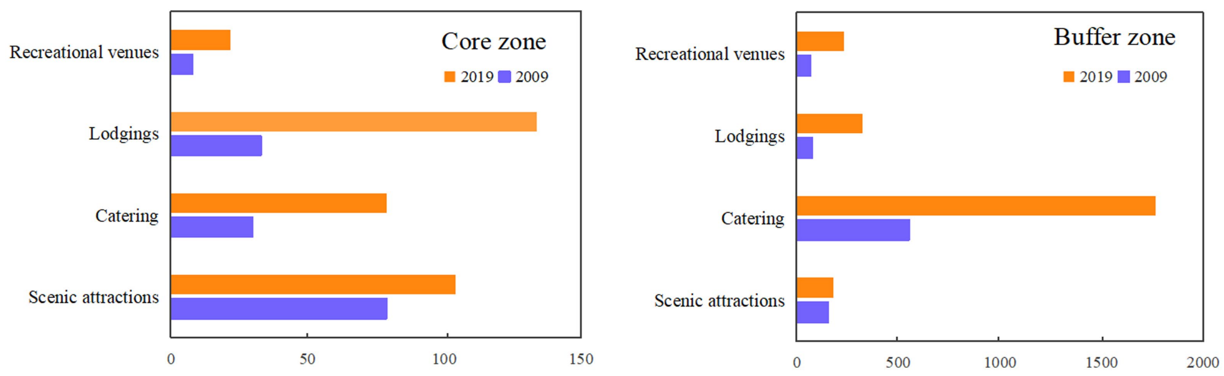

FIGURE 4
Numbers of tourism-related merchants in the core zone (left) and the buffer zone (right) in 2009 and 2019.

proposed the concept of "lucid waters and lush mountains are invaluable assets." With growing demand for ecotourism, this important concept of development has provided great opportunities for villages with abundant tourism resources. As a result, an increasing number of commercial activities, such as rural homestays, agritainments and leisure farms, been emerged in various villages across China. Tourism was strongly promoted because it can be an useful way to balance ecological security and economic development, gradually become a key driver of China's rural revitalization process (Bi and Yang, 2023).

Ecotourism development has been prioritized in many rural regions, especially for ecological conversation areas like the SMR. As opposed to western developed countries, China's government plays a leading role in rural tourism development (Zhou et al., 2017). This involvement includes policy formulation at the central government level, and the policy implementation with specific development plans by local governments (Dai et al., 2023). The primary focus of government's efforts has been on improving infrastructure, transportation, ecological conservation, and rural landscapes. These efforts aim to attract investments on rural tourism industry from all types of investors, with the ultimate goal of enhancing the quality of accommodation, catering services and the recreational experience. Big data technology offers a useful and effective alternative to traditional approaches for obtaining and utilizing data related to rural tourism.

Our findings demonstrated that catering and recreational venues were highly agglomerated within a specific area, especially around a scenic area, providing evidence that the development of scenic spots contributes to the clustering of surrounding tourism services (Xi et al., 2014). Meanwhile, rural tourism had evolved from a single focus on visiting farms or participating in agricultural activities, into multi-dimensional experience of culture, village life and agricultural education, as suggested in related studies (Nair et al., 2015; Kaptan Ayhan et al., 2020).

5.2 Tourism-oriented land use transformations in urban forests

Previous studies indicated that tourism development could also drive shifts in local economy and service industry, which results in land use transformation (Song et al., 2017; Yang et al., 2021). Our results show that a large area of land originally used for agriculture production had been converted to natural forests and orchard for enhancing recreational functions and improving the visual appeal of landscape. Besides, there are other reasons accounting for the changes. First of all, difficulty in applying farming machinery and a shortage of agricultural labor force in mountainous areas directly caused substantial reduction in croplands and tea gardens. Secondly, cash

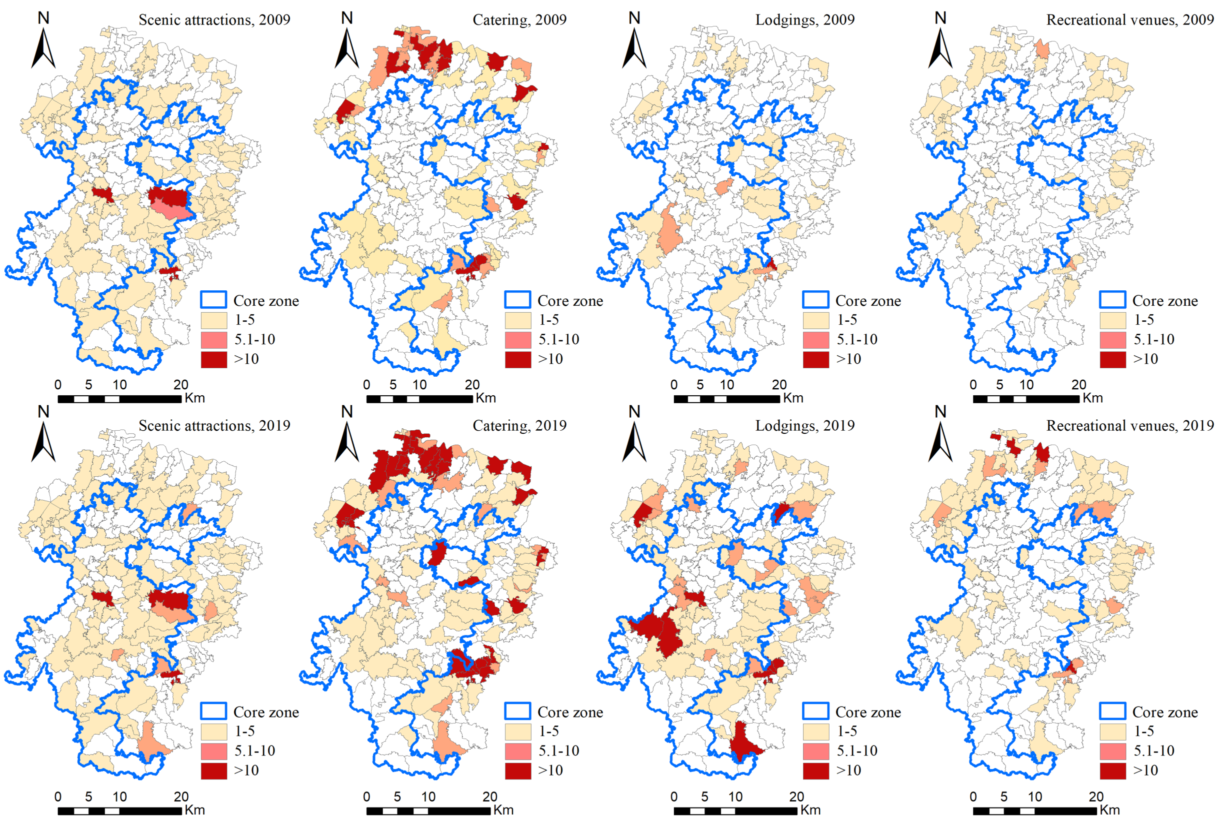

FIGURE 5
Spatial distribution of tourism elements at the village-scale in 2009 and 2019.

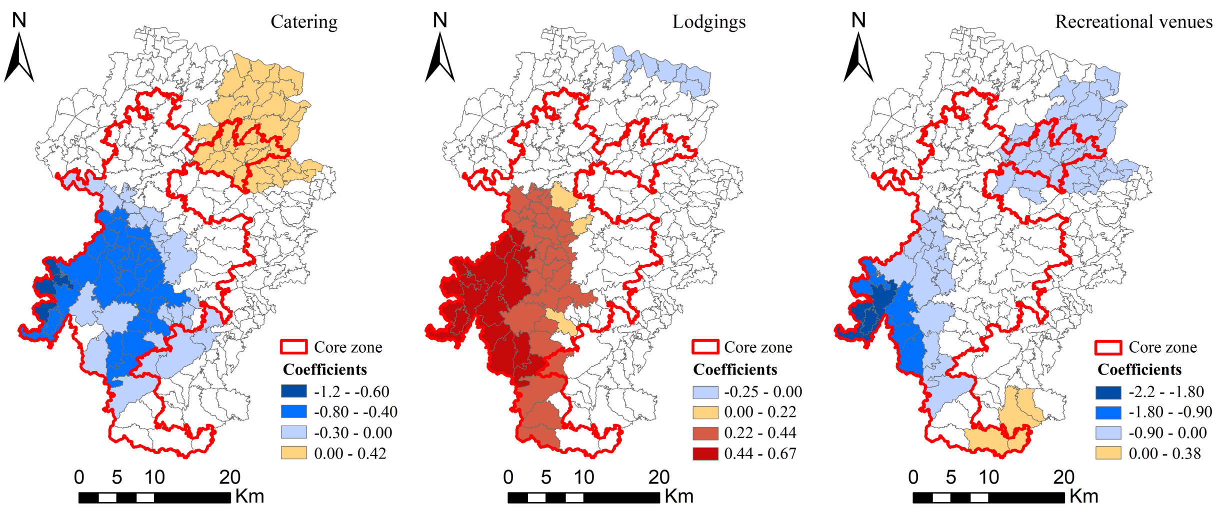

FIGURE 6
Coefficients of GWR between ESV changes and tourism-related merchant changes.

trees like fruit and horticultural plants generate higher income per hectare than vegetables, grains and oil crops. Colored species, such as cherry blossoms, gingko trees and maple tree, are particularly favored for their distinctive aesthetic value to the landscape. Furthermore, as tourism develops, the associated increased investment in ecological restoration efforts, land remediation of abandoned land or virescence of bare land for instance, can also improve the proportion of vegetation (Wang and Dai, 2020). However, since cropland had experienced drastic loss, it is critical to conserve the remaining cropland through building multifunctional cropland and ecological agriculture for both short-term recovery and long-term sustainable development.

In terms of the tourism-driven construction in the SMA, an analysis into the changes in different categories of built-up area revealed a diminishing trend of rural settlements during the study period. This can be attributed to population emigration and the implementation of the "one house site for one household" policy. In fact, the construction of the traffic network accounted for the majority of built-up land expansion, among with the area of roads increased by 844.4 ha and 1080.4 ha in the core and buffer zones, respectively. It is evident that the local government promoted tourism development through improving the transportation network within the district other than expansion of rural settlements. These finding is accordant with previous studies which indicate that tourism development contribute to the construction of road area to maintain their touristic appeal (Currie and Falconer, 2014; Liu et al., 2018). However, deffer from rampant expansion of built-up land for catering, hospitality and residential use in most rural tourist areas (Tolessa et al., 2017; Li et al., 2020a; Pandya et al., 2023), renovation of existing rural settlement to enhance the amount of tourism facilities is commonly adopted in developed eastern coastal China (Bi and Yang, 2023).

5.3 Ecological response to tourism activities in urban forests

Large amount of studies suggested that tourism development has influenced ecological functions via socioeconomic development and land use change (Liu et al., 2018; Pueyo-Ros, 2018; Chen, 2020b). Excessive tourism development can cause irreversible damage to ecosystems, especially in areas with fragile ecosystems, such as islands (Grilli et al., 2021) and nature reserves (Zhang et al., 2023). Dramatic increase in tourism revenue, at the expense of agriculture, grass and forest, due to tourism boom resulted in deteriorating water quality in Erhai Lake and causing severe environmental problems in Erhai Lake Basin (Li et al., 2020a). Focusing on the specific study area of urban forests, our study showed that despite of the dramatic land use transformations between 2009 and 2019, ecological problems triggered by rural tourism have not yet been detected in the SMR. Instead, ESV increased profiting from strict land use polices and ecological conservation. Coincidentally, the increase in the value of tourism and leisure services, as well as low LULC change, played the most important role in ESV increasing in Huangshan Scenic Area (Zhu et al., 2019).

The identification of relationship between ESV changes and tourism-related activity evolution can thus facilitate the implementation of specific development strategies in urban forests. Response of ESV changes to tourism activities turned out to be spatially non-stationary and varied in space. The effect of scenic attractions on ESV was insignificant for the following reasons. The construction of scenic attractions is largely dependent on the natural landscape and rural culture symbols (Bi and Yang, 2023). In addition to this, ESV in the core zone increased as local lodgings increased, implying that local lodging merchants in the high-elevation areas were inclined to improve their surrounding environments. Hotel and homestay managers, as well as local government, pay much attention to harmoniously integration of architectural style, surrounding environments and leisure activity, which was consistent with previous studies (Anupam et al., 2012; Bi and Yang, 2023). It effectively enhances aesthetic and recreational ecosystem services and thus improves tourists' experience, simultaneously reach a win-win situation between tourism development and environment preservation. Nevertheless, the expansion of catering and recreational venues in the core zone, especially urban forests with high elevations, might cause ecological degradation. Given this negative relationship, policy makers should carefully evaluate the construction plans in advance and take necessary precautions with consideration of environmental capacity and flexibility.

6 Limitations and future work

This study still has some limitations that lend to further investigation. First, the ESV assessment model adopted in this study was used to underestimate the value-added effect of ESV brought about by tourism development in urban forests, such as the increase in the values of agricultural products and entertainment requirements. More advanced models that are able to measure the dynamics of ESV and characterize their response to tourism activities in urban forests should be applied in future works. Second, the in-depth evaluation of negative impacts brought by rural tourism activities was insufficient and lacked data support. For example, dramatic transformations in agricultural structure could increase the risk of ecological degradation, unregulated restaurants might cause eutrophication in water bodies, and massive expansion of the transportation network could intensify landscape fragmentation and thus threaten biodiversity. Third, the temporal dimension was relatively limited, with a span period of 10 years that from 2009 to 2019. Actually, it covered both stages of rural recession as well as rapid urbanization and rural revitalization. Undoubtedly, there are many other factors contributing to the fluctuation of ESV and it remains a challenge to disentangle the effects of these factors from the influence of tourism development. Future works should use long-term and multi-temporal analysis to investigate how ESV responds to human activities. Lastly, obtaining tourism-related data from one single online tourism recommender platform seemed to be insufficient. Further investigation are necessary by incorporating more rural tourism indicators based on multi-source Internet platform where data are available to gain more generalizable conclusion.

7 Conclusion

Tourism is recognized as an effective driver for socioeconomic development and rural revitalization, so it has been supported and encouraged in many developing and developed countries through a range of policies. Over the past decade, such anthropogenic impacts have intensively manipulated urban forests in developed coastal cities of China. To evaluate the ecological pressures that are likely to arise from rural tourism activities, this paper provides a temporal and spatial analysis of ESV and land use change, and investigates the response of ESV changes to tourism activities in urban forests at both regional and sub-regional scales. Our results show that the forest area increased by 12.7% from 2009 to 2019 at the expense of cropland and tea garden, which led to a decline in food production service and an increase in total ESV. The patterns of ESV changes was also found to be significantly spatial auto-correlated. GWR further highlighted that the relationship between ESV change and tourism intensity indicators varied in space. Specifically, ESV change in the core zone was negatively correlated with changes in catering service spots and recreational venues, whereas it was positively correlated with local lodgings.

In conclusion, besides providing a scientific framework that integrated ESV assessment, Internet big data mining and spatial regression analysis, this study represents a valuable reference source for further research on the interaction between ecological function and tourism activities in urban forests. Urban forest ecosystems are highly ecologically fragile and vulnerable to human-driven threats along with rapid urbanization. This study concluded several policy and planning implications for management practices. First, we argue that both positive and negative impacts of tourism activities on ESV change need to be taken into account in tourism development of urban forests. More specifically, tourism resources, traffic accessibility, as well as environment carrying capacity, should be thoroughly evaluated when formulating tourism development strategies. Second, we propose that food production as an ecosystem service should be maintained for the sake of farming cultural inheritance and tourism experience enrichment in urban forests. The multifunctionality of cropland land should also be considered in urban forests to improve tourism experience and attractiveness for long-term sustainable development. Third, we suggest that tourism activities in the form of catering and recreational venues expansion need to be determined through a comprehensive and scientific assessments. Since rural recessions and transformations remain as global challenges, the present framework and practical implications can be applied not only to urban forests, but also to vast rural areas for achieving the economic-ecological balance.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: http://www.resdc.cn/http://tjj.ningbo.gov.cn/.

Author contributions

JL: Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing, Data curation, Investigation. XZ: Data curation, Supervision, Validation, Writing – review & editing. QG: Data curation, Formal analysis, Writing – review & editing. ZZ: Data curation, Supervision, Validation, Writing – review & editing. KW: Investigation, Resources, Writing – review & editing. ZX: Funding acquisition, Investigation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Appendix

TABLE A1 **Coefficients of ESVs for each LULC type in Zhejiang Province, China (unit: RMB Yuan/ha).**

Category of ecosystem services	Cropland	Forest	Orchard	Water body	Built-up land	Bare land	Meadow
Gas regulation	778.6	5450.7	2231.2	0.0	0	0.0	1245.7
Climate regulation	1386.0	4204.8	2059.7	716.3	0	0.0	1401.7
Water reservation	934.4	4983.4	66.6	31738.4	0	46.6	1245.9
Soil formation and protection	2273.7	6073.6	1402.4	15.5	0	31.2	3036.9
Waste disposal	2554.1	2040.2	1270.5	28312.4	0	15.5	2040.2
Biodiversity conservation	1105.6	5076.9	640.3	3877.8	0	529.4	1697.5
Food production	1557.4	155.8	628.1	155.8	0	15.5	467.3
Raw materials	155.8	4049.1	793.7	15.5	0	0.0	77.8
Entertainment and culture	52.2	1993.4	71.9	6758.8	0	0.0	62.3