



Space–time evolution of the ecological security of regional urban tourism: the case of Hubei Province, China

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Abstract While increased tourist demand has brought economic benefits to tourist destinations, it has also put tremendous pressure on tourism-related ecological environments. Therefore, the relationship between regional urban tourism’s economic benefits and tourism ecologies must be considered by increasing the ecological security levels of regional urban tourism and promoting sustainable tourism development. This paper defines the ecological security of regional urban tourism, constructs an indicator system of said ecological security based on a pressure-state-response social-economic-environment (PSR-SEE) model, uses the entropy method to objectively assign weights to the indicator system, constructs a dynamic multi-scenario simulation model to assess ecological security under continuous, economic priority and various ecological protection scenarios, employs ArcGIS software to analyze the spatial distribution patterns of the ecological security of regional urban tourism, and uses a standard deviation ellipse method to analyze the space–time evolutionary track of the ecological security of regional urban tourism. The index system is applied to 16 cities in Hubei Province to measure the ecological security levels and test the viability of the system. The present research focuses on the space–time evolution of the ecological security of

regional urban tourism, addresses the contradictions between socioeconomic development and the ecological security of regional urban tourism, provides an important reference for tourism destination planning, and can assist in improving the levels of the ecological security of regional urban tourism to promote sustainable tourism development.

Keywords Index system · PSR-SEE model · System dynamics · Multi-scenarios

Introduction

Maintaining sustainable ecologies in regional tourism destinations requires a focus on ecological security. However, as destination tourism becomes more popular in regional tourist areas, sustaining the ecological security of tourism, which is balancing tourist economy development and tourist ecology protection, has become a significant challenge (Pang et al., 2011). Therefore, developing ecological security plans for regional tourism can protect fragile ecological environments and promote sustainable tourism development.

In 1941, the American ecologist Aldo Leopold proposed the land health concept, which was the application of ecological security measures to the evaluation of land function status, for which he established an evaluation system to measure the land function health status. The early 1980s, which saw a

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plethora of environmental pollution incidents around the world, raised the profile of ecological security in international ecosystem research (Doronkina et al., 2014), with the focus shifting to finding a systematic solution for sound tourism environmental management, which was the precursor to sustainable tourism development (Neven & Tihomir, 2010). From that time, research on ecological tourism security has focused on the relationship between security and sustainable development.

Research has tended to focus more on tourist security (Hall et al., 2003), the relationship between tourism development and environmental protection, and the ecological, environmental management of tourism (Dey et al., 2018; Neven & Tihomir, 2010). Therefore, to date, no unified definition for the ecological security of tourism has been offered. To develop a comprehensive, scientific evaluation index system of the ecological security of tourism, indicators need to be developed based on study area characteristics focused on the tourism ecological footprint, the tourism ecological carrying capacity (Wang et al., 2014), and the driving force-pressure-state-impact-responses (Qin & Cheng, 2019; Weng et al., 2018; Yang & Weng, 2019). Quantitative studies on the ecological security of tourism have employed various methods, such as an ecology-tourism matrix (ETM) (Jose et al., 2009), a measurement model (Tan et al., 2017), a single-scenario system dynamics model (Espin et al., 2019), a structural equation model (Hedlund, 2011), an analytic network process method (Morteza et al., 2016), and a geospatial assessment method (Brahmasrene & Lee, 2017). However, as the determination of the evaluation index thresholds and evaluation standards was subjective, the evaluation index system and evaluation standards need further systemization (Zheng et al., 2017), and targeted management tools need to be developed to functionally improve regional urban tourism ecological security levels.

Although there has been some research progress, owing to the lack of a unified definition, evaluation index systems for the ecological security of tourism have been uneven, quantification methods have been inaccurate, there has been a lack of representativeness in the research areas, and the management measures suggested have been routine rather than being specifically focused. The purpose of this paper, therefore, is to analyze and then define the concept of the

ecological security of regional urban tourism; construct an indicator system from environmental, economic, and social tourism environment system perspectives; apply the entropy method to determine the appropriate weights for the indicators of the ecological security of regional urban tourism; employ system dynamics to conduct a dynamic multi-scenario simulation; and use ArcGIS to analyze the space–time evolutionary characteristics for the ecological security of regional urban tourism. To conduct this empirical research and propose relevant countermeasures to improve the ecological security levels of regional urban tourism, 16 cities in Hubei Province, China, are taken as case examples to fully realize the “differentiated development” in regional tourist cities.

Defining the ecological security definition of regional urban tourism

Regional cities could be seen as having continuous but limited spatial scopes and as geographic units made up of one or more environmental factors, economic factors, and social factors. This article defines the ecological security of regional urban tourism as a complex tourism ecosystem in which the environmental, social, and economic tourism resources are maintained in a healthy and non-threatening state through the effective resource management of the ecological environment to allow for further sustainable tourism development.

The ecological security of regional urban tourism is related to the balancing of social progress, economic growth, and environmental care to ensure the derivation of social, economic, and environmental benefits from regional urban tourism development. Therefore, it depends on regional tourism system coordination between sustainable tourism activities and the tourism environment, that is, rational human–land interactions determine the ecological security level of regional urban tourism.

Determining an index system and indicator weight

Index system

Assessing the ecological security of regional urban tourism is complex as the economic, social, and

environmental impacts of tourism activities need to be considered from a security perspective. After consulting related studies (Brahmasrene & Lee, 2017), a pressure-state-response social-economic-environment (PSR-SEE) model was constructed, as shown in Fig. 1. Based on this PSR-SEE model, an indicator system is constructed, which had a target layer, a criterion layer, a feature layer, and an indicator layer, for which 30 indicators were developed. The specific index settings are shown in Table 1.

Indicator weights

Before determining the weights, to overcome the inconsistent dimensions in the indicators, the indicators need to be normalized. To prevent any index value from being zero during the normalization process, relevant literature was consulted (Yang & Zhang, 2018) to properly process the positive and negative indicators, the specific processes for which are shown in Eqs. (1) and (2).

$$\text{Positive indicators : } x'_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \times 0.99 + 0.01 \tag{1}$$

$$\text{Negative indicators : } x'_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \times 0.99 + 0.01 \tag{2}$$

In the equations, $i = (1, 2, \dots, m)$ indicates the year, $j = (1, 2, \dots, n)$ indicates the regional urban

tourism ecological security index, x_{ij} indicates the initial value of the index in the first year, $maxx_{ij}$ and $minx_{ij}$ indicated the maximum and minimum index values, and x'_{ij} is the normalized standard value for x_{ij} .

To ensure objectivity, the entropy method is employed to determine the indicator weights. Based on the entropy method principle, after normalizing the ecological security index of regional urban tourism, the proportion of index j in year i to this index is calculated, as shown in Eq. (3).

$$M_{ij} = \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \tag{3}$$

Subsequently, the information entropy value of the j index is calculated, as shown in Eq. (4).

$$N_j = -K \sum_{i=1}^m M_{ij} \ln M_{ij}, \text{ among them, } K = \frac{1}{\ln m} \tag{4}$$

Next, the difference coefficient A_j of the index j is calculated again, as shown in Eq. (5).

$$A_j = 1 - N_j \tag{5}$$

Finally, the weight W_j of the j index is calculated, as shown in Eq. (6).

$$W_j = \frac{A_j}{\sum_{j=1}^n A_j} \tag{6}$$

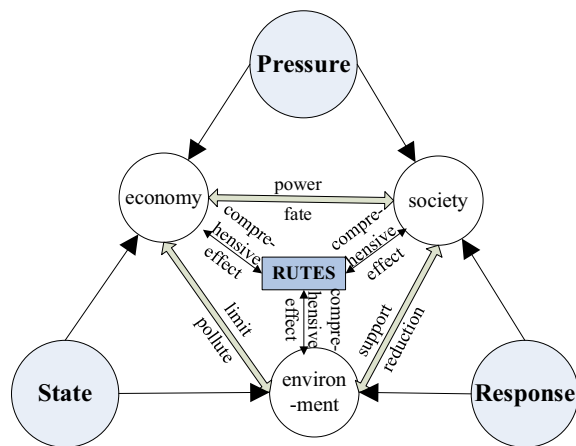


Fig. 1 Pressure-state-response social-economic-environment (PSR-SEE) model

Space-time evolution of the ecological security of regional urban tourism

Time evolution

System dynamics (SD) was first mooted by Professor Forrester of the Massachusetts Institute of Technology in 1956 (Yang & Zhang, 2018). SD is essentially a computer simulation of the structure and dynamic behavior of complex systems, which is currently implemented using Vensim software. SD has been found to have unique advantages when seeking to deal with multi-element, nonlinear, complex system problems. Therefore, SD can be used to dynamically analyze the overall structure, the mathematical model designs, and the simulations to accurately predict the changing regional urban tourism ecological security

Table 1 Index system for the ecological security of regional urban tourism

Target layer	Criterion layer	Feature layer	Indicator layer	Unit	References
Regional urban tourism ecological security C	Regional urban tourism ecological pressure C ₁	Economic pressure C ₁₁	Tertiary industry growth rate C ₁₁₁	%	Li et al. (2015); Xu and Liu (2018)
			Fiscal expenditure as a percentage of GDP C ₁₁₂	%	
			Tourism economic density C ₁₁₃	10,000 CNY/km ²	
		Social pressure C ₁₂	Number of tourists C ₁₂₁	10,000 people	Zhou et al. (2015); Zheng et al. (2017)
			Urbanization rate C ₁₂₂	%	
			Total passenger traffic C ₁₂₃	10,000 people	
			Tourism space density C ₁₂₄	people/km ²	
		Environmental pressure C ₁₃	Daily water consumption per capita C ₁₃₁	L/day	Li et al. (2015)
			Domestic waste treatment capacity C ₁₃₂	10,000 t	
			Total sewage discharge C ₁₃₃	10,000 m ³	
	Regional urban tourism ecological state C ₂	Economic state C ₂₁	Domestic tourism income C ₂₁₁	billion	Zhou et al. (2015); Wu et al. (2013)
			International tourism income C ₂₁₂	Millions USD	
			Total tourism income C ₂₁₃	billion CNY	
		Social state C ₂₂	Employees in the tertiary industry C ₂₂₁	10 thousand People	Zheng et al. (2017); Xu et al. (2021)
			Number of health institutions C ₂₂₂	one	
			Tourist reception and population ratio C ₂₂₃	%	
			Environmental state C ₂₃	Garden green area C ₂₃₁	
Green coverage in built-up areas C ₂₃₂	%				
Park area per capita C ₂₃₃	m ² /person				

Table 1 (continued)

Target layer	Criterion layer	Feature layer	Indicator layer	Unit	References
	Regional urban tourism ecological response C ₃	Economic response C ₃₁	GDP C ₃₁₁	billion CNY	Li et al. (2015); Zhou et al. (2015); Qin and Cheng (2019)
			Tourism income per capita C ₃₁₂	CNY	
			Total tourism income as a percentage of GDP C ₃₁₃	%	
			Proportion of urban tertiary industry C ₃₁₄	%	
			Fiscal revenue as a percentage of GDP C ₃₁₅	%	
		Social response C ₃₂	Energy-saving and environmental protection expenditure as a percentage of GDP C ₃₂₁	%	Qin & Cheng, 2019
			Education expenditure as a percentage of GDP C ₃₂₂	%	
			Number of students in regular colleges and universities C ₃₂₃	10,000 people	
		Environmental response C ₃₃	General industrial solid waste utilization rate C ₃₃₁	%	Li et al. (2015); Zhou et al. (2015)
			Domestic sewage treatment rate C ₃₃₂	%	
	Harmless treatment rate of domestic garbage C ₃₃₃		%		

processes. The tourism eco-environment system is a complex system composed of various elements that need to be evaluated and predicted using SD simulations. The SD model construction is divided into clear problems to determine the system boundary, from which a dynamic hypothesis is proposed, equations are developed, the design is tested, and policies proposed, after which the system is evaluated. To construct the variable equations, the following were used: Eqs. (7)-(10)

$$f(x) = \sum_{i=1}^m a_i \times x_i \tag{7}$$

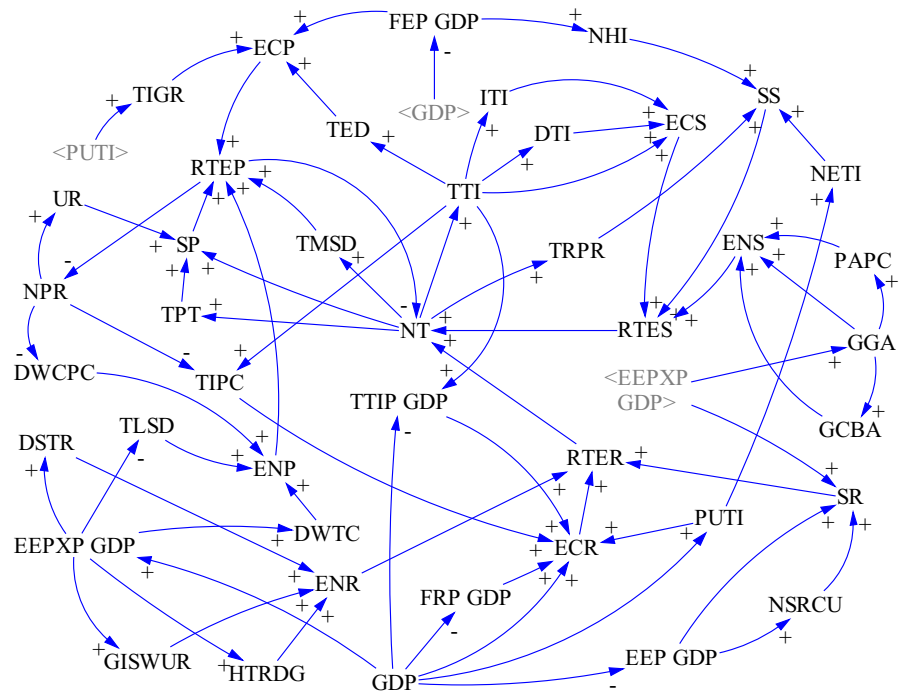
$$g(y) = \sum_{j=1}^n b_j \times y_j \tag{8}$$

$$s = \sum_{k=1}^z c_k \times s_k \tag{9}$$

$$RUTES = w_1 \times f(x) + w_2 \times g(y) + w_3 \times h(s) \tag{10}$$

where a_i , b_j , and c_k are the weights for the relevant regional urban tourism ecological security subsystem indicators; x_i , y_j , and s_k are the numerical values for the relevant indicators; $f(x)$, $g(y)$, and $h(s)$ are the respective values for the pressure, state, and response subsystems; m , n , and k are the respective related indicators for the pressure, state, and response subsystems; RUTES is the regional urban tourism ecological security; and w_1 , w_2 , and w_3 are the respective weights corresponding to the relevant indicators in the pressure, state, and response subsystems.

Fig. 2 Causality diagram of the variables for the ecological security of regional urban tourism



As shown in Fig. 2, a causal relationship between the main indicators of the ecological security of regional urban tourism is constructed from pressure, state, and response subsystem perspectives, from which the SD model is established (Fig. 3). The security scenarios were divided into a “continuous scenario,” an “economic priority scenario,” and an “ecological protection scenario” to conduct the prediction research on the ecological security of tourism and discuss the tourism ecological pressure, the tourism ecological state, and the tourism ecological responses in specific areas.

The following indices are shown in Figs. 2 and 3: tertiary industry growth rate, fiscal expenditure, fiscal expenditure as a percentage of GDP (FEP GDP), tourism economic density, number of tourists, urbanization rate (UR), total passenger traffic, tourism space density (TMSD), daily water consumption per capita, domestic waste treatment capacity (DWTC), total sewage discharge (TLSD), domestic tourism income, international tourism income, total tourism income, number of employees in the tertiary industry (NETI), number of health institutions, tourist reception and population ratio, garden green area (GGA), green coverage of built-up area, park area

per capita (PAPC), GDP/tourism income per capita, total tourism income as a percentage of GDP (TTIP GDP), proportion of urban tertiary industry, fiscal revenue (FR), fiscal revenue as a percentage of GDP (FRP GDP), energy conservation and environmental protection expenditure, energy-saving and environmental protection expenditure as a percentage of GDP (EEPEP GDP), education expenditure, education expenditure as a percentage of GDP (EEPGDP), number of students in regular colleges and universities, general industrial solid waste utilization rate, domestic sewage treatment rate, harmless treatment rate of domestic garbage, number of permanent residents, administrative area, value-added for primary industry, value-added for secondary industry, value-added for tertiary industry, economic pressure (ECP), social pressure (SP), environmental pressure (ENP), regional urban tourism ecological pressure, economic state (ECS), social state (SS), environmental state (ENS), regional urban tourism ecological state, economic response (ECR), social response, environmental response (ENR), and regional urban tourism ecological response. In addition, Δ represents an increase of a certain amount, and $-GR$ represents the growth rate of a certain amount.

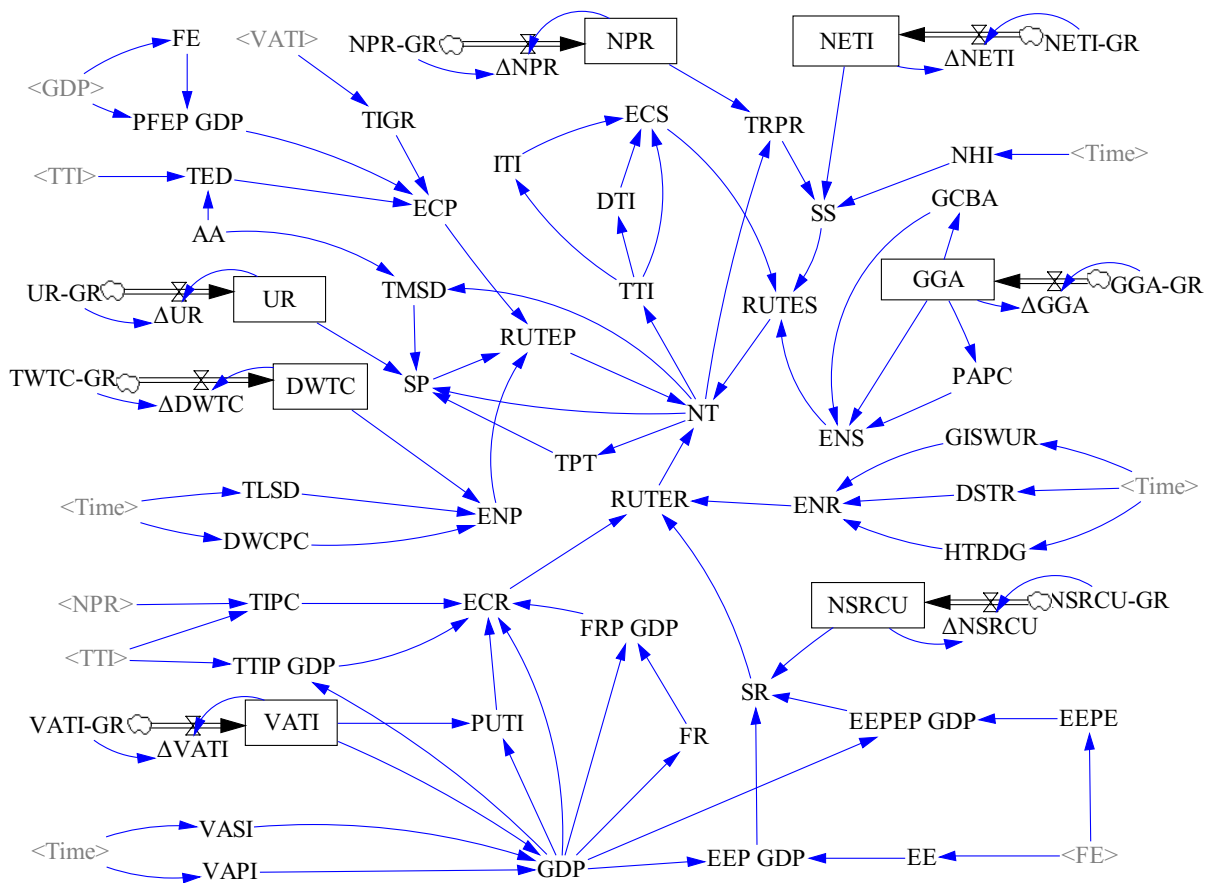


Fig. 3 Stock flow chart for the ecological security of regional urban tourism

Classifying the ecological security of regional urban tourism

There has not yet been a unified standard for the classification of the ecological security of regional urban tourism because of the uneven social-economic development levels in such ecological environments and the inconsistencies in the tourism development policy implementation effects in specific regions. Based on related literature (Bangwayo-Skeete & Skeete, 2020; Shadova et al., 2015), the ecological security levels of regional urban tourism are divided as in Table 2.

Space evolution for regional urban tourism ecological security

The standard deviational ellipse (SDE), which delineates the geographic distribution of concerned features using a GIS tool, was proposed by Lefever in 1926 (Li et al., 2015); therefore, to describe the spatial agglomeration distribution trends and the regional urban tourism ecological security value expansion directions, the space–time evolutionary trajectory of the ecological security of regional urban tourism is analyzed based on the SDE method using the ellipse’s

Table 2 Classification standards for the ecological security of regional urban tourism

Index	[0,0.05]	(0.05,0.10]	(0.1,0.20]	(0.20,0.40]	(0.40,0.60]	(0.60,0.80]	(0.80,1.00]
Level	Deterioration level (I)	Risk level (II)	Sensitivity level (III)	Critical security level (IV)	General security level (V)	Compare security level (VI)	Very security level (VII)

semi-major axis, the semi-minor axis, the direction angle, and other parameters. The specific calculations are shown in Eqs. (11)–(13), with the average center,

$$\bar{X} = \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i}, \bar{Y} = \frac{\sum_{i=1}^n w_i y_i}{\sum_{i=1}^n w_i} \quad (11)$$

the SDE,

$$X_{SDE} = \sqrt{\frac{\sum_{i=1}^n w_i^2 (x'_i \cos\theta - y'_i \sin\theta)^2}{\sum_{i=1}^n w_i^2}} \quad (12)$$

$$Y_{SDE} = \sqrt{\frac{\sum_{i=1}^n w_i^2 (x'_i \sin\theta - y'_i \cos\theta)^2}{\sum_{i=1}^n w_i^2}}$$

and the abscissa direction angle,

$$\tan\theta = \frac{M + N}{Q}$$

$$M = \sum_{i=1}^n w_i^2 x_i'^2 - \sum_{i=1}^n w_i^2 y_i'^2$$

$$N = \sqrt{\left(\sum_{i=1}^n w_i^2 x_i'^2 - \sum_{i=1}^n w_i^2 y_i'^2\right)^2 + 4\left(\sum_{i=1}^n w_i^2 x_i' y_i'\right)^2}$$

$$Q = 2 \sum_{i=1}^n w_i^2 x_i' y_i' \quad (13)$$

where \bar{X} and \bar{Y} represent the horizontal and vertical coordinates of the region's center of gravity, x_i and y_i represent the horizontal and vertical coordinates of the first region, n is the number of regions, x'_i and y'_i represent the regional coordinates and center of gravity deviation, and w_i is the attribute value for the spatial element.

Therefore, the regional urban tourism ecological security level is measured based on the entropy value method, SD, and the SDE method. The ecological security levels of regional urban tourism in different time regions under three different “continuous,” “economic priority,” and “ecological protection”

scenarios are then entered into ArcGIS 10.2 to visualize the changing trends at different times and in different spaces so as to provide practical suggestions for promoting sustainable tourism development in the research area.

Case analysis

Overview of Hubei Province and data sources

Hubei Province is located at 108° 21' 42"–116° 07' E, 29° 01'–33° 6' 47" N, in south-central China on the middle reaches of the Yangtze River and north of Dongting Lake and has a total area of 185,900 km², or 1.94% of China's total area. Hubei Province has a unique strategic location advantage, is an important hub for China in the Yangtze River Economic Belt and the “One Belt and One Road” development strategy, and is an important strategic fulcrum for the huge development potential in central China. Hubei Province has 17 cities: Wuhan, Huangshi, Shiyan, Yichang, Xiangyang, Ezhou, Jingmen, Xiaogan, Jingzhou, Huanggang, Xianning, Suizhou, Enshi Tujia and Miao Autonomous prefecture, Xiantao, Qianjing, Tianmen, and the Shennongjia Forest Area (Fig. 4).

Tourist attraction rating categories refer to a rating system used by the Chinese authorities to determine the quality of an attraction relative to its peers in terms of safety, cleanliness, sanitation, and transportation. There are five categories: A (or 1A, the lowest level), AA (2A), AAA (3A), AAAA (4A), and AAAAA (5A, the highest level). Hubei Province has a long history and rich tourism resources. As of 2018, Hubei Province had 350 star-rated hotels, 1777 travel agencies, and 110 scenic spots above 3A (out of 5 as per the Chinese tourist spot rating system). In 2018, Hubei Province had 7,265,869 million tourists, from which the total tourism revenue was 634.433 billion CNY. While this rapid tourism industry development has driven the growth in the local economy, the negative impact on the tourism ecological environment cannot be ignored. Therefore, it is extremely important to assess the ecological security of regional tourism in Hubei Province. Because of the lack of data from the Shennongjia Forest Area, this article focuses on the regional urban tourism ecological security in the 16 other cities. The data used for the evaluation indicators in this article are taken from the Hubei

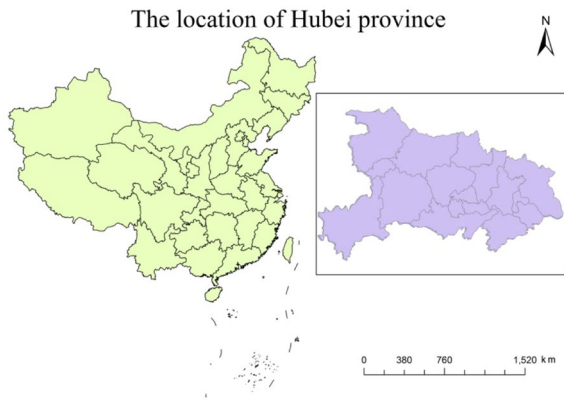


Fig. 4 The location of Hubei Province

Statistical Yearbooks (2010–2019), the China City Construction Statistical Yearbooks, the China Tourism Statistical Yearbooks (2010–2019), various city statistical yearbooks (2010–2019), statistical national economic and social development city bulletins (2010–2019), and the official National Bureau of Statistics website. In instances of missing data, the adjacent data are averaged and an SPSS linear regression is applied.

Ecological security of regional urban tourism in Hubei Province

The current ecological security situations of tourism in the 16 Hubei Province cities and prefectures are determined based on the normalized data from 2009 to 2018 (Eqs. (1) and (2)), with the entropy method used to determine the index system weights (Eqs. (3)–(6)), as shown in Table 3. Eqs. (7)–(10) are applied to measure the ecological security levels of tourism in the 16 Hubei Province cities, the results for which are shown in Table 4.

As can be seen, from 2009 to 2018, the development trends and ecological security levels of regional urban tourism in the 16 cities varied significantly. Except for Shiyan, Xiangyang, Ezhou, and Suizhou, the overall security levels in the other 12 cities are rising, and the development is relatively stable. Therefore, although there is certain volatility during the period, the overall trend is slowly increasing, slowly decreasing, and continuing to develop. However, although the security levels are improving, the overall level is still low. Therefore, joint efforts by relevant

stakeholders such as the government, tourism companies, tourist destination residents, and tourists are needed.

Dynamic time simulation of the ecological security of regional urban tourism in Hubei Province

As shown in the SD model in Fig. 3, to build the theoretical SD model for the ecological security of regional urban tourism in relation to the 16 Hubei Province cities and test the theoretical model, the start time is set at 2009 and the end time is set at 2025 (units: year), with the time step being 1 (units: year). The model is revised based on the indicator sensitivities such as UR, DWTC, NETI, and GGA, with the statistical data from 2009 to 2018 being tested within a floating range of 10% (Dogru et al., 2019) (the UR was taken as an example in Table 3). Using Vensim software, dynamic simulations and ecological security predictions for the 16 cities are conducted, the change trends in and evolutionary characteristics of the ecological security of regional urban tourism are explored over time, as shown in Fig. 5, and the ecological security levels of regional urban tourism are simulated under multi-scenarios, as shown in Table 5.

As shown in Fig. 5, over time, the overall ecological security levels in the 16 Hubei Province cities have an upward trend. Under the continuous, economic priority, and ecological protection scenarios from 2009 to 2015, the ecological security levels of urban tourism appear to converge. However, after 2015, there are obvious differences in the ecological security levels in the three different scenarios. The ecological security levels of regional urban tourism under the ecological protection scenario have the fastest growth rate and the highest development, and the overall ecological security level of tourism under the economic priority scenario is higher than under the continuous scenario. Although when compared to maintaining the status quo, accelerating economic development could improve the ecological security of regional urban tourism, a one-sided pursuit of rapid economic development and an ignorance of the ecological environmental protection of tourism would not conducive to sustainable tourism development (Banerjee et al., 2018). Only increasing ecological environmental protection can improve the ecological security of regional urban tourism.

Table 3 Evaluation index weights for the ecological security of regional urban tourism in Hubei Province

Index	Wuhan	Huangshi	Shiyan	Yichang	Xiangyang	Erzhou	Jingmen	Xiaogan	Jingzhou	Huanggang	Xianning	Suizhou	Enshi	Xiantao	Qianjiang	Tianmen
C ₁₁₁	0.0157	0.0267	0.0193	0.0176	0.0179	0.0381	0.0130	0.0264	0.0198	0.0183	0.0242	0.0147	0.0177	0.0130	0.0145	0.0368
C ₁₁₂	0.0478	0.0202	0.0178	0.0185	0.0352	0.0238	0.0378	0.0326	0.0260	0.0269	0.0224	0.0182	0.0197	0.0875	0.0164	0.0391
C ₁₁₃	0.0316	0.0356	0.0194	0.0237	0.0236	0.0535	0.0272	0.0266	0.0206	0.0187	0.0284	0.0326	0.0226	0.0156	0.0154	0.0271
C ₁₂₁	0.0320	0.0330	0.0237	0.0254	0.0238	0.0402	0.0271	0.0268	0.0293	0.0202	0.0284	0.0317	0.0234	0.0146	0.0161	0.0279
C ₁₂₂	0.0438	0.0522	0.0397	0.0324	0.0320	0.0465	0.0310	0.0328	0.0310	0.0283	0.0343	0.0380	0.0342	0.0240	0.0320	0.0453
C ₁₂₃	0.0355	0.0414	0.0214	0.0177	0.0175	0.0260	0.0280	0.0319	0.0367	0.0204	0.0262	0.0287	0.0155	0.0166	0.0285	0.0325
C ₁₂₄	0.0320	0.0330	0.0237	0.0257	0.0238	0.0402	0.0271	0.0268	0.0293	0.0202	0.0284	0.0317	0.0234	0.0146	0.0161	0.0279
C ₁₃₁	0.0143	0.0409	0.0283	0.0263	0.0276	0.0191	0.0167	0.0204	0.0230	0.0414	0.0327	0.0309	0.0197	0.0207	0.0212	0.0271
C ₁₃₂	0.0344	0.0285	0.0743	0.0228	0.0205	0.0335	0.0672	0.0267	0.0715	0.0679	0.0302	0.0358	0.0654	0.0360	0.0263	0.0291
C ₁₃₃	0.0219	0.0356	0.0354	0.0211	0.0432	0.0387	0.0245	0.0478	0.0257	0.0313	0.1005	0.0204	0.0208	0.0135	0.0291	0.0142
C ₂₁₁	0.0344	0.0353	0.0426	0.0509	0.0364	0.0281	0.0357	0.0375	0.0396	0.0409	0.0426	0.0345	0.0446	0.0310	0.0459	0.0199
C ₂₁₂	0.0375	0.0446	0.0261	0.0381	0.0165	0.0514	0.0511	0.0254	0.0701	0.0240	0.0343	0.0710	0.0243	0.0525	0.0902	0.0353
C ₂₁₃	0.0346	0.0353	0.0425	0.0508	0.0365	0.0282	0.0358	0.0374	0.0394	0.0410	0.0426	0.0345	0.0406	0.0300	0.0461	0.0199
C ₂₂₁	0.0339	0.0212	0.0437	0.0445	0.0470	0.0379	0.0310	0.0279	0.0307	0.0432	0.0365	0.0360	0.0322	0.0233	0.0393	0.0330
C ₂₂₂	0.0998	0.0598	0.0740	0.0186	0.0298	0.0325	0.0315	0.0663	0.0242	0.0535	0.0365	0.0390	0.0148	0.0816	0.0133	0.0287
C ₂₂₃	0.0315	0.0288	0.0386	0.0417	0.0321	0.0237	0.0311	0.0356	0.0364	0.0355	0.0425	0.0354	0.0334	0.0327	0.0451	0.0244
C ₂₃₁	0.0427	0.0265	0.0446	0.0334	0.0368	0.0192	0.0573	0.0251	0.0182	0.0453	0.0178	0.0293	0.0343	0.0316	0.0230	0.0544
C ₂₃₂	0.0457	0.0214	0.0575	0.0393	0.0862	0.0555	0.0226	0.0340	0.0547	0.0168	0.0158	0.0226	0.0626	0.0667	0.0457	0.0279
C ₂₃₃	0.0306	0.0688	0.0260	0.0266	0.0317	0.0537	0.0751	0.0241	0.0159	0.0232	0.0211	0.0510	0.0889	0.0639	0.0281	0.0493
C ₃₁₁	0.0157	0.0250	0.0275	0.0281	0.0276	0.0283	0.0275	0.0260	0.0285	0.0279	0.0324	0.0320	0.0309	0.0250	0.0284	0.0335
C ₃₁₂	0.0478	0.0350	0.0427	0.0505	0.0362	0.0281	0.0358	0.0380	0.0395	0.0390	0.0415	0.0337	0.0396	0.0296	0.0459	0.0211
C ₃₁₃	0.0316	0.0410	0.0405	0.0575	0.0405	0.0262	0.0342	0.0648	0.0314	0.0352	0.0321	0.0254	0.0293	0.0346	0.0615	0.0319
C ₃₁₄	0.0320	0.0430	0.0402	0.0463	0.0552	0.0633	0.0409	0.0174	0.0458	0.0479	0.0428	0.0561	0.0661	0.0417	0.0544	0.0673
C ₃₁₅	0.0438	0.0259	0.0167	0.0393	0.0331	0.0262	0.0277	0.0317	0.0292	0.0328	0.0334	0.0317	0.0286	0.0148	0.0209	0.0228
C ₃₂₁	0.0355	0.0412	0.0224	0.0432	0.0323	0.0188	0.0354	0.0534	0.0356	0.0565	0.0365	0.0337	0.0321	0.0462	0.0300	0.0587
C ₃₂₂	0.0320	0.0226	0.0213	0.0232	0.0337	0.0381	0.0197	0.0277	0.0159	0.0318	0.0247	0.0371	0.0374	0.0185	0.0252	0.0324
C ₃₂₃	0.0143	0.0234	0.0152	0.0244	0.0538	0.0253	0.0324	0.0445	0.0211	0.0256	0.0228	0.0647	0.0409	0.0483	0.0416	0.0683
C ₃₃₁	0.0344	0.0190	0.0401	0.0426	0.0307	0.0280	0.0189	0.0278	0.0551	0.0140	0.0420	0.0170	0.0235	0.0097	0.0149	0.0138
C ₃₃₂	0.0219	0.0163	0.0141	0.0276	0.0199	0.0156	0.0189	0.0440	0.0141	0.0181	0.0186	0.0149	0.0203	0.0297	0.0202	0.0283
C ₃₃₃	0.0344	0.0185	0.0206	0.0420	0.0189	0.0123	0.0376	0.0127	0.0417	0.0543	0.0278	0.0176	0.0131	0.0327	0.0648	0.0220

Table 4 Ecological security levels of regional urban tourism in Hubei Province (2009–2018)

City	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Wuhan	0.1416	0.1602	0.1812	0.2017	0.2181	0.2357	0.2660	0.2858	0.3087	0.3447
Huangshi	0.0562	0.0408	0.0514	0.0516	0.0525	0.0519	0.0594	0.0573	0.0600	0.0613
Shiyan	0.0948	0.0444	0.0292	0.0200	0.0248	0.0344	0.0438	0.0581	0.0653	0.0746
Yichang	0.0697	0.0730	0.0805	0.0884	0.1009	0.1139	0.1176	0.1303	0.1422	0.1623
Xiangyang	0.1017	0.0491	0.0596	0.0529	0.0570	0.0592	0.0678	0.0744	0.0812	0.0828
Ezhou	0.0917	0.0791	0.0820	0.0636	0.0628	0.0522	0.0560	0.0651	0.0686	0.0674
Jingmen	0.0540	0.0368	0.0371	0.0373	0.0301	0.0452	0.0484	0.0534	0.0623	0.0615
Xiaogan	0.0564	0.0573	0.0611	0.0569	0.0523	0.0519	0.0545	0.0549	0.0498	0.0681
Jingzhou	0.0590	0.0670	0.0772	0.0851	0.0689	0.0764	0.0788	0.0952	0.1011	0.0972
Huanggang	0.0900	0.0877	0.0824	0.0831	0.0856	0.0880	0.0907	0.1000	0.1050	0.1141
Xianning	0.0513	0.0358	0.0361	0.0337	0.0371	0.0365	0.0396	0.0519	0.0505	0.0562
Suizhou	0.0458	0.0098	0.0116	0.0097	0.0136	0.0173	0.0216	0.0217	0.0279	0.0306
Enshi	0.0850	0.0606	0.0567	0.0588	0.0636	0.0664	0.0804	0.0826	0.0905	0.1262
Xiantao	0.0594	0.0627	0.0590	0.0592	0.0580	0.0590	0.0687	0.0684	0.0701	0.0764
Qianjiang	0.0356	0.0357	0.0310	0.0325	0.0369	0.0464	0.0562	0.0491	0.0483	0.0517
Tianmen	0.0490	0.0300	0.0311	0.0439	0.0439	0.0419	0.0538	0.0461	0.0507	0.0563

Spatial dynamic simulation of the ecological security of regional urban tourism in Hubei Province

The results from the dynamic simulation and prediction of the ecological security levels in the 16 Hubei Province cities are imported into ArcGIS 10.2 for visualization, and the spatial change trends and evolutionary characteristics spatially explored, as shown in Fig. 6.

As can be seen in Fig. 6, in 2009, there were no differences in the 16 Hubei Province cities under the three different scenarios. Over time, the ecological security levels of regional urban tourism in the 16 cities gradually increased, with Wuhan, the capital of Hubei Province, having a larger growth rate and final value under the economic priority and ecological protection scenarios, which also confirmed that vigorously developing the economy and increasing ecological and environmental protections had obvious effects in Wuhan. Besides Wuhan, Yichang have the fastest growing levels under the continuous and economic priority scenarios, with its ecological security level ranging from a risk level to a sensitive level to a compare security level. Under the ecological protection scenario, the ecological security level of regional urban tourism is expected to eventually move to a very secure level, indicating that developments would need to be focused on continuous or economic

development scenarios. That is, although the level in Yichang is expected to improve, to ensure sustainable tourism development, greater efforts should be placed on increasing ecological and environmental tourism protection to increase the security level more quickly.

Compared to Wuhan and Yichang, the ecological security level growth rates and final values in the remaining 14 cities are lower. However, they are higher under the “ecological protection scenario” than under the “economic priority” or “continuous” scenarios.

According to Eqs. (12)–(13), the change trends for the SDE and the center of gravity evolution trajectory are drawn using ArcGIS 10.2. To more deeply study the temporal and spatial evolutionary characteristics of the ecological security of regional urban tourism in Hubei Province, data from 2009, 2018, and 2025 are selected under the three scenarios to examine the status quo continuity, economic priority, and ecological protection. Figure 7 and Table 6 show the specific SDE parameters for the ecological security levels in Hubei Province under the different scenarios.

As can be seen from Fig. 7 and Table 6, under the continuous scenario from 2009 to 2018, the ecological security of regional urban tourism in Hubei Province moved to the southeast, indicating that the overall ecological security in the southeast is increasing. From 2019 to 2025, the ecological security level

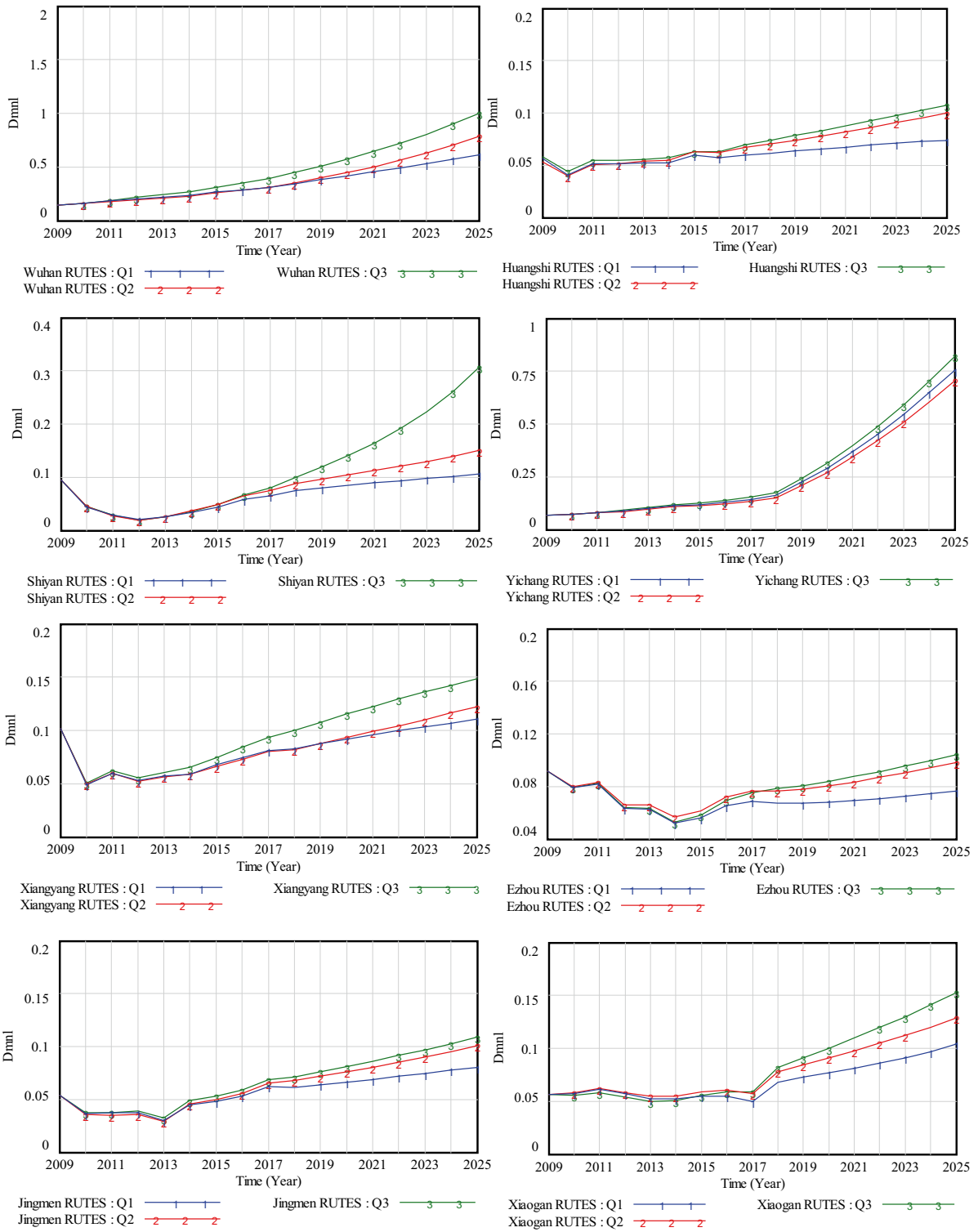


Fig. 5 Ecological security levels of regional urban tourism in Hubei Province

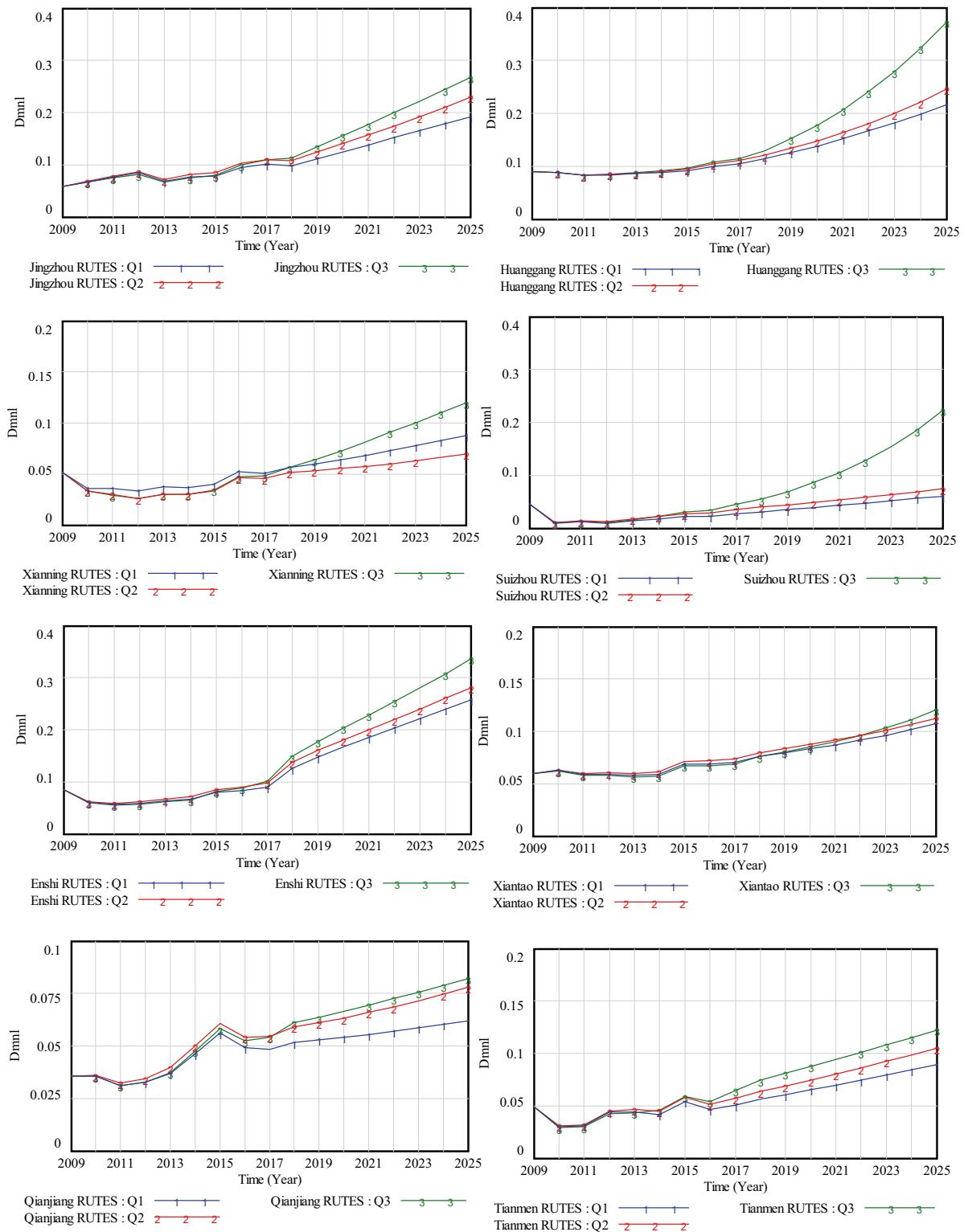


Fig. 5 (continued)

Table 5 The levels of regional urban tourism ecological security in Hubei Province under different scenarios

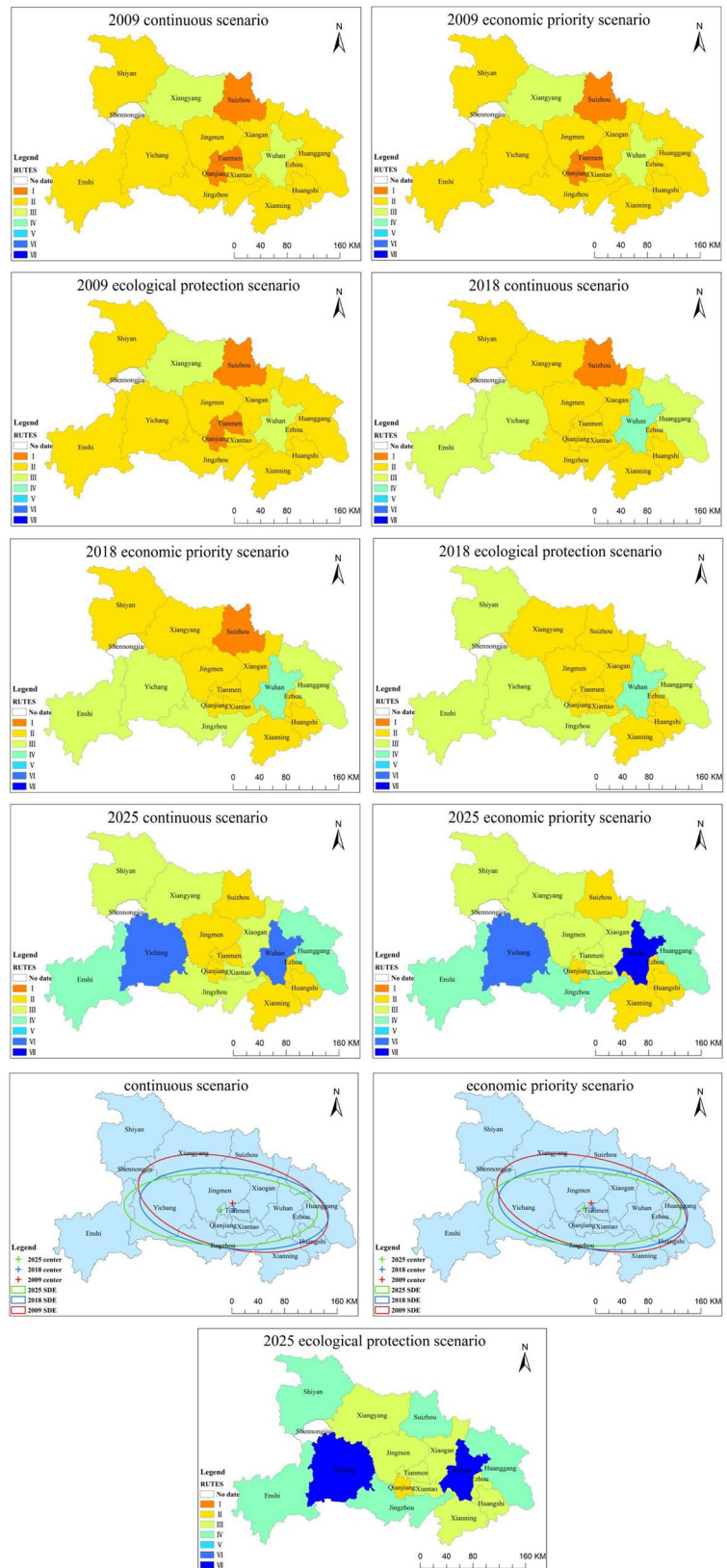
City	Scenario	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Wuhan	Q1	0.1416	0.1602	0.1812	0.2017	0.2181	0.2357	0.2660	0.2858	0.3087	0.3447	0.3807	0.4172	0.4543	0.4921	0.5307	0.5705	0.6116
	Q2	0.1416	0.1577	0.1766	0.1957	0.2116	0.2297	0.2611	0.2833	0.3108	0.3538	0.3992	0.4482	0.5016	0.5605	0.6260	0.6996	0.7831
	Q3	0.1417	0.1630	0.1887	0.2158	0.2408	0.2691	0.3125	0.3480	0.3893	0.4466	0.5076	0.5732	0.6439	0.7208	0.8049	0.8975	1.0000
Huangshi	Q1	0.0562	0.0408	0.0514	0.0516	0.0525	0.0519	0.0594	0.0573	0.0600	0.0613	0.0636	0.0656	0.0674	0.0692	0.0708	0.0725	0.0740
	Q2	0.0533	0.0396	0.0507	0.0516	0.0537	0.0545	0.0627	0.0623	0.0670	0.0701	0.0741	0.0780	0.0821	0.0862	0.0906	0.0952	0.1000
	Q3	0.0582	0.0438	0.0546	0.0551	0.0554	0.0570	0.0626	0.0631	0.0695	0.0734	0.0782	0.0830	0.0879	0.0927	0.0977	0.1026	0.1076
Shiyan	Q1	0.0948	0.0444	0.0292	0.0200	0.0248	0.0344	0.0438	0.0581	0.0653	0.0746	0.0806	0.0851	0.0891	0.0931	0.0972	0.1015	0.1061
	Q2	0.0948	0.0446	0.0275	0.0195	0.0258	0.0371	0.0483	0.0644	0.0744	0.0878	0.0967	0.1043	0.1120	0.1203	0.1293	0.1393	0.1502
	Q3	0.0948	0.0456	0.0283	0.0193	0.0248	0.0360	0.0479	0.0661	0.0796	0.1002	0.1196	0.1407	0.1642	0.1913	0.2231	0.2609	0.3066
Yichang	Q1	0.0697	0.0730	0.0805	0.0884	0.1009	0.1139	0.1176	0.1303	0.1422	0.1623	0.2223	0.2907	0.3674	0.4524	0.5457	0.6473	0.7572
	Q2	0.0697	0.0722	0.0793	0.0862	0.0976	0.1094	0.1114	0.1231	0.1335	0.1514	0.2071	0.2706	0.3419	0.4210	0.5082	0.6036	0.7075
	Q3	0.0697	0.0737	0.0819	0.0906	0.1042	0.1186	0.1240	0.1383	0.1525	0.1755	0.2397	0.3131	0.3958	0.4877	0.5891	0.7001	0.8208
Xiangyang	Q1	0.1017	0.0491	0.0596	0.0529	0.0570	0.0592	0.0678	0.0744	0.0812	0.0828	0.0873	0.0919	0.0961	0.0999	0.1035	0.1070	0.1104
	Q2	0.1017	0.0497	0.0599	0.0524	0.0561	0.0590	0.0659	0.0727	0.0799	0.0821	0.0875	0.0934	0.0990	0.1045	0.1102	0.1161	0.1225
	Q3	0.1017	0.0507	0.0617	0.0554	0.0605	0.0651	0.0746	0.0842	0.0938	0.0996	0.1074	0.1153	0.1225	0.1294	0.1359	0.1423	0.1486
Ezhou	Q1	0.0917	0.0791	0.0820	0.0636	0.0628	0.0522	0.0560	0.0651	0.0686	0.0674	0.0670	0.0679	0.0692	0.0707	0.0725	0.0745	0.0767
	Q2	0.0918	0.0798	0.0834	0.0659	0.0662	0.0566	0.0614	0.0717	0.0767	0.0767	0.0780	0.0804	0.0834	0.0867	0.0904	0.0943	0.0985
	Q3	0.0918	0.0791	0.0824	0.0638	0.0632	0.0528	0.0579	0.0690	0.0750	0.0782	0.0805	0.0838	0.0874	0.0913	0.0954	0.0996	0.1040
Jingmen	Q1	0.0540	0.0368	0.0371	0.0373	0.0301	0.0452	0.0484	0.0534	0.0623	0.0615	0.0636	0.0662	0.0689	0.0717	0.0746	0.0776	0.0806
	Q2	0.0540	0.0354	0.0352	0.0359	0.0295	0.0457	0.0497	0.0556	0.0652	0.0680	0.0716	0.0758	0.0802	0.0849	0.0899	0.0952	0.1008
	Q3	0.0540	0.0371	0.0378	0.0388	0.0325	0.0487	0.0529	0.0586	0.0686	0.0716	0.0760	0.0809	0.0861	0.0915	0.0970	0.1028	0.1089
Xiaogan	Q1	0.0564	0.0573	0.0611	0.0569	0.0523	0.0519	0.0545	0.0549	0.0498	0.0681	0.0725	0.0768	0.0812	0.0859	0.0912	0.0971	0.1038
	Q2	0.0564	0.0578	0.0618	0.0582	0.0543	0.0551	0.0589	0.0606	0.0575	0.0775	0.0846	0.0911	0.0976	0.1046	0.1120	0.1201	0.1291
	Q3	0.0564	0.0558	0.0582	0.0537	0.0496	0.0508	0.0559	0.0586	0.0588	0.0816	0.0910	0.1002	0.1097	0.1195	0.1298	0.1409	0.1529
Jingzhou	Q1	0.0590	0.0670	0.0772	0.0851	0.0689	0.0764	0.0788	0.0952	0.1011	0.0972	0.1109	0.1245	0.1380	0.1515	0.1651	0.1787	0.1925
	Q2	0.0590	0.0675	0.0785	0.0872	0.0720	0.0807	0.0842	0.1022	0.1097	0.1081	0.1239	0.1400	0.1564	0.1734	0.1911	0.2096	0.2291
	Q3	0.0590	0.0670	0.0748	0.0818	0.0666	0.0757	0.0801	0.0996	0.1089	0.1127	0.1341	0.1555	0.1772	0.1993	0.2217	0.2446	0.2679
Huanggang	Q1	0.0900	0.0877	0.0824	0.0831	0.0856	0.0880	0.0907	0.1000	0.1050	0.1141	0.1257	0.1382	0.1518	0.1665	0.1822	0.1990	0.2169
	Q2	0.0900	0.0881	0.0829	0.0841	0.0872	0.0905	0.0942	0.1041	0.1106	0.1206	0.1334	0.1476	0.1633	0.1807	0.2001	0.2217	0.2458
	Q3	0.0900	0.0884	0.0831	0.0846	0.0877	0.0915	0.0959	0.1070	0.1152	0.1298	0.1521	0.1776	0.2069	0.2405	0.2790	0.3231	0.3736
Xianning	Q1	0.0513	0.0358	0.0361	0.0337	0.0371	0.0365	0.0396	0.0519	0.0505	0.0562	0.0594	0.0637	0.0683	0.0730	0.0779	0.0828	0.0879
	Q2	0.0513	0.0330	0.0299	0.0261	0.0300	0.0300	0.0333	0.0463	0.0456	0.0514	0.0532	0.0552	0.0575	0.0601	0.0629	0.0659	0.0693
	Q3	0.0513	0.0330	0.0295	0.0258	0.0297	0.0298	0.0339	0.0477	0.0479	0.0563	0.0637	0.0723	0.0813	0.0906	0.1001	0.1097	0.1195

Table 5 (continued)

City	Scenario	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Suizhou	Q1	0.0458	0.0098	0.0116	0.0097	0.0136	0.0173	0.0216	0.0217	0.0279	0.0306	0.0346	0.0389	0.0431	0.0474	0.0517	0.0561	0.0606
	Q2	0.0458	0.0107	0.0137	0.0124	0.0174	0.0221	0.0273	0.0282	0.0356	0.0396	0.0441	0.0487	0.0535	0.0584	0.0635	0.0691	0.0751
	Q3	0.0458	0.0101	0.0122	0.0107	0.0162	0.0221	0.0297	0.0339	0.0458	0.0554	0.0691	0.0856	0.1048	0.1273	0.1539	0.1857	0.2238
Enshi	Q1	0.0850	0.0606	0.0567	0.0588	0.0636	0.0664	0.0804	0.0826	0.0905	0.1262	0.1475	0.1664	0.1848	0.2030	0.2210	0.2391	0.2571
	Q2	0.0850	0.0614	0.0583	0.0623	0.0670	0.0708	0.0850	0.0890	0.0987	0.1374	0.1600	0.1802	0.2000	0.2199	0.2399	0.2602	0.2808
	Q3	0.0850	0.0602	0.0555	0.0572	0.0621	0.0657	0.0823	0.0879	0.1013	0.1486	0.1776	0.2030	0.2281	0.2536	0.2800	0.3073	0.3359
Xiantao	Q1	0.0594	0.0627	0.0590	0.0592	0.0580	0.0590	0.0687	0.0684	0.0701	0.0764	0.0798	0.0834	0.0872	0.0914	0.0961	0.1013	0.1071
	Q2	0.0594	0.0629	0.0595	0.0604	0.0599	0.0614	0.0715	0.0717	0.0733	0.0798	0.0834	0.0873	0.0914	0.0959	0.1008	0.1062	0.1122
	Q3	0.0594	0.0622	0.0582	0.0581	0.0565	0.0573	0.0670	0.0667	0.0689	0.0759	0.0802	0.0849	0.0901	0.0961	0.1030	0.1110	0.1205
Qianjiang	Q1	0.0356	0.0357	0.0310	0.0325	0.0369	0.0464	0.0562	0.0491	0.0483	0.0517	0.0529	0.0541	0.0555	0.0570	0.0586	0.0603	0.0621
	Q2	0.0356	0.0362	0.0322	0.0345	0.0396	0.0500	0.0606	0.0543	0.0547	0.0590	0.0611	0.0634	0.0659	0.0686	0.0715	0.0747	0.0780
	Q3	0.0356	0.0355	0.0310	0.0326	0.0373	0.0475	0.0583	0.0525	0.0539	0.0610	0.0637	0.0665	0.0695	0.0725	0.0756	0.0788	0.0821
Tianmen	Q1	0.0490	0.0300	0.0311	0.0439	0.0439	0.0419	0.0538	0.0461	0.0507	0.0563	0.0606	0.0651	0.0697	0.0745	0.0794	0.0844	0.0896
	Q2	0.0490	0.0305	0.0318	0.0452	0.0463	0.0452	0.0579	0.0513	0.0571	0.0634	0.0687	0.0742	0.0800	0.0860	0.0922	0.0986	0.1052
	Q3	0.0490	0.0294	0.0300	0.0424	0.0428	0.0457	0.0592	0.0541	0.0645	0.0746	0.0811	0.0876	0.0944	0.1012	0.1081	0.1151	0.1221

Q1 is “continuous scenario”, Q2 is “economic priority scenario”, Q3 is “ecological protection scenario”

Fig. 6 Space–time evolution of the ecological security of regional urban tourism in Hubei Province



of regional urban tourism moves to the southwest, indicating that the overall ecological security level in the southwest is increasing; from 2009 to 2025, the ecological security level fluctuates and moves to the southwest as a whole, with the center of gravity being mainly in Tianmen. Under the continuous scenario, the overall security level is shrinking, with the standard deviation for the semi-minor ellipse axis falling from 0.9814 in 2009 to 0.7793 in 2025, a reduction of 0.2021. At the same time, the standard deviation for the semi-major axis expanded from 2.4848 in 2009 to 2.4983 in 2025, an increase of 0.0135. Therefore, the ecological security level of regional urban tourism in Hubei Province is observed to fluctuate, deviating from true north and rotating in a clockwise direction from 101.7681° in 2009 to 96.1651° in 2018 to 93.3408° in 2025.

Under the economic priority scenario from 2009 to 2018, the ecological security of regional urban tourism

in Hubei Province level moves to the northeast, indicating that the overall ecological security in the northeast is increasing. From 2019 to 2025, the ecological security level of regional urban tourism moves to the southwest, indicating that the overall ecological security in the southwest is increasing, and from 2009 to 2025, the ecological security level of regional urban tourism in Hubei Province fluctuates, moving to the southwest as a whole, and with the center of gravity mainly in Tianmen. Therefore, under the economic priority scenario, the ecological security level in Hubei Province is shrinking, with the standard deviation for the semi-minor ellipse axis falling from 0.9821 in 2009 to 0.8042 in 2025, a reduction of 0.1779, and the standard deviation for the semi-major axis expanding from 2.4832 in 2009 to 2.4993 in 2025, an increase of 0.0161. Therefore, under the economic priority scenario, the ecological security level of regional urban tourism in Hubei Province fluctuates, deviating from true north and

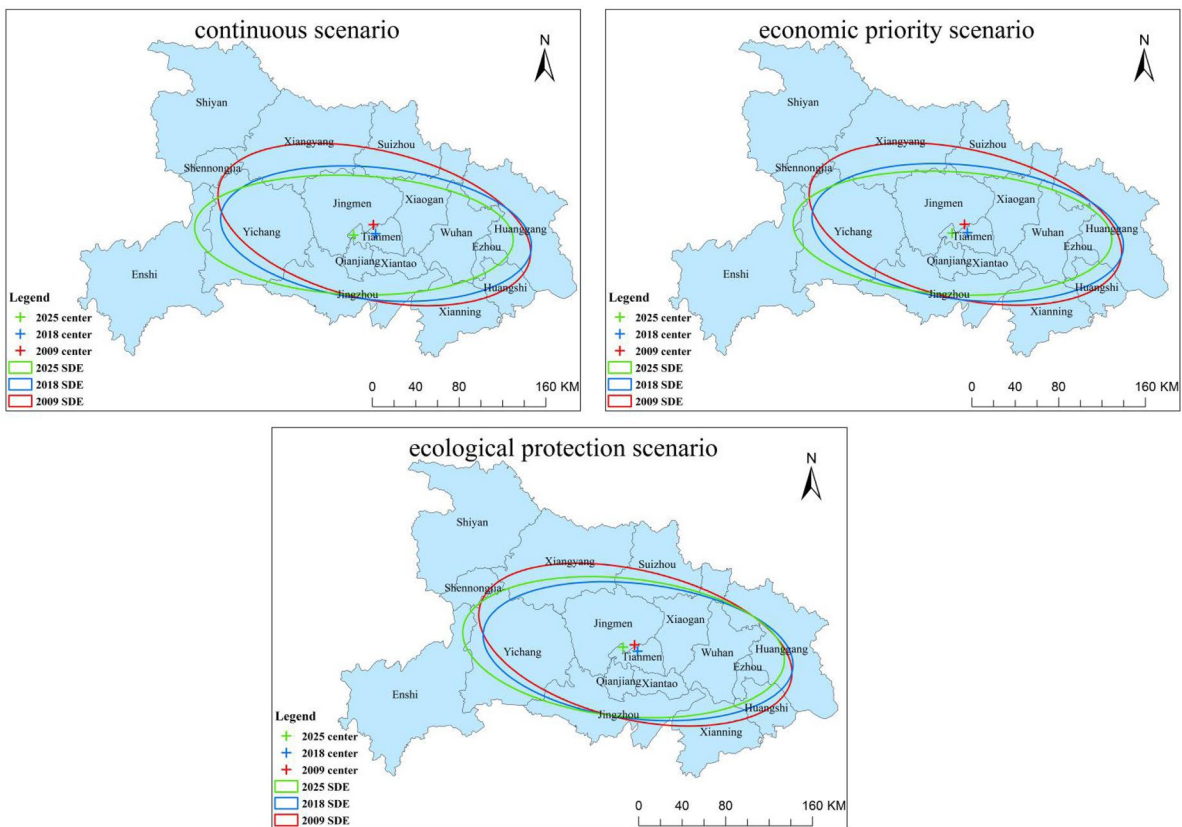


Fig. 7 Standard deviation ellipse for the ecological security levels of regional urban tourism in Hubei Province under the different scenarios

Table 6 Elliptic parameters for the standard deviations in the ecological security levels of regional urban tourism in Hubei Province under the different scenarios

Scenario	Year	Center X	Center Y	Semi-major axis	Semi-minor axis	Rotation angle
Q1	2009	113.0005	30.8081	2.4848	0.9814	101.7681
	2018	113.0307	30.6901	2.4430	0.8666	96.1651
	2025	112.6863	30.6810	2.4983	0.7793	93.3408
Q2	2009	112.9954	30.8103	2.4832	0.9821	101.7142
	2018	113.0351	30.6998	2.4488	0.8818	96.3898
	2025	112.7981	30.7000	2.4993	0.8042	94.0219
Q3	2009	113.0037	30.8066	2.4858	0.9809	101.8036
	2018	113.0487	30.7222	2.4344	0.8838	96.6292
	2025	112.8236	30.7804	2.5264	0.9024	95.9448

rotating in a clockwise direction from 101.7142° in 2009 to 96.3898° in 2018 to 94.0219° in 2025.

Under the ecological protection scenario from 2009 to 2018, the ecological security level of regional urban tourism in Hubei Province moves to the northeast, indicating that the overall ecological security in the northeast is increasing. From 2019 to 2025, the ecological security level of regional urban tourism in Hubei Province moves to the southwest, indicating that the overall ecological security level in the southwest is increasing. Overall, from 2009 to 2025, the ecological security of regional urban tourism in Hubei Province fluctuates, moving to the southwest as a whole, with the center of gravity mainly in Tianmen. Therefore, under the ecological protection scenario, the overall ecological security level of regional urban tourism in Hubei Province is shrinking, with the standard deviation of the semi-minor ellipse axis falling from 0.9809 in 2009 to 0.9024 in 2025, a reduction of 0.0785, and the standard deviation of the semi-major axis expanding from 2.4858 in 2009 to 2.5264 in 2025, an increase of 0.0406. Therefore, under the ecological protection scenario, the ecological security level of regional urban tourism in Hubei Province fluctuates, deviating from true north and rotating in a clockwise direction from 101.8036° in 2009 to 96.6292° in 2018 to 95.9448° in 2025.

Conclusions

In the human–land tourist destination relationship system, research on progressive tourism and ecological security is needed to alleviate the contradictions between the tourist ecological supply and demand

systems in regional tourist destinations, to predict “hotspots” or “sensitive” areas in terms of the ecological security of regional urban tourism, and provide theoretical and practical support for the active promotion of early warning systems for ecological conflicts related to regional tourist destinations.

This study takes the regional urban space as the core perspective and, based on the influencing factors of the ecological security of regional urban tourism, assesses the economic, social, and environmental benefits of regional urban tourism development, discusses a theoretical system, and conducts empirical research to promote the resilient development of regional urban tourist destinations in China.

The main conclusions of this article are as follows:

1. Ecological security research systems based on time and space need to be built based on local conditions to determine the ecological security levels of regional urban tourism and ensure sustainable tourism development from environmental, social, and economic perspectives.
2. Taking Hubei Province as an example for empirical research, the ecological security levels of regional urban tourism in 16 Hubei Province cities are examined to assess the trends, from which it is found that under the “ecological protection scenario,” the ecological security in the 16 cities has obvious differences, with Wuhan and Yichang having the higher levels. Overall, the ecological security levels of regional urban tourism in Hubei Province are fluctuating, with the overall movement being to the southwest and the center of gravity being mainly in Tianmen.
3. Relevant countermeasures are proposed to improve the ecological security level of regional urban tour-

ism in Hubei Province, such as raising stakeholder awareness of ecological security issues related to tourism, strengthening regional tourism cooperation, and increasing tourism resource investments.

Suggestions

At the end of 2019 and early 2020, the coronavirus disease of 2019 broke out in Wuhan City, Hubei Province. Ecological security was threatened, and the tourism industry suffered heavy losses. At this time, stakeholders such as the government, tourism companies, tourists and residents of tourist destinations must collaborate to improve the ecological security level of regional urban tourism and restore the development of tourism in Hubei Province.

Based on the above research, this article puts forward the following suggestions. (1) As an “invisible hand,” the government should increase its investment in social public resources and tourism environmental resources, ease tourism ecological pressure, improve the state of ecological tourism, and enhance ecological tourism responses to improve the level of ecological security in Hubei Province. (2) Tourism enterprises should establish a reward and punishment system to reward those who have made contributions to the protection of the tourism ecological environment and punish those who damage the ecological environment to ensure the quality of tourism practitioners. (3) Residents of tourist destinations should receive education on environmental protection on a regular basis to establish residents’ self-control and self-education mechanisms so that residents can continue to receive tourism environmental protection education in their daily lives and improve their ecological security awareness in relation to tourism. (4) Tourists should enhance their awareness of green and low-carbon tourism, establish reasonable consumption concepts, rationally use tourism resources, and protect the ecological environment. To restore the development of tourism in Hubei Province as soon as possible, it is necessary to improve the level of the ecological security of regional urban tourism in Hubei Province and create a safe and harmonious atmosphere to attract more domestic and foreign tourists.

Author contribution Xiuping Yang contributed to the conception of the study and analysis, manuscript preparation,

and performed the experiment. Yunting Jia and Chunmei Li performed the data analyses. Qinghe Wang and Shixin Zhang helped perform the analysis with constructive discussions.

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Availability of data and materials The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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