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SPECIALTY SECTION

This article was submitted to
Urban Ecology,
a section of the journal
Frontiers in Ecology and Evolution

RECEIVED 20 January 2023

ACCEPTED 14 February 2023

PUBLISHED 24 February 2023

CITATION

Zhu K, Zhou Q, Cheng Y, Zhang Y, Li T, Yan X,
Alimov A, Farmanov E and Dávid LD (2023)
Regional sustainability: Pressures and
responses of tourism economy and ecological
environment in the Yangtze River basin, China.
Front. Ecol. Evol. 11:1148868.
doi: 10.3389/fevo.2023.1148868

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Regional sustainability: Pressures and responses of tourism economy and ecological environment in the Yangtze River basin, China

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The relationship between the tourism economy and the ecological environment is under pressure, and balancing this relationship is crucial for promoting regional sustainability. In this study, the Yangtze River basin, the first largest river in Asia and third largest in the world, was selected as the focus area. The spatial and temporal characteristics of tourism economic development and ecological environmental pressure from 2000 to 2019 were analyzed using the tourism economic development index, ecological environmental pressure index and dynamic change index, and the decoupling process of tourism and the economic system was studied dynamically using the decoupling analysis model. The results show that (1) spatially, the tourism economy in the Yangtze River basin exhibits a pattern of high development in the east and low development in the west, and high in the south and low in the north. Ecological environmental pressures varied greatly, with less pressure in the upstream provinces and more pressure in the middle and downstream provinces. (2) Temporally, the tourism economies of Qinghai and Tibet started with a lower but faster growth rate, while Hunan and Hubei have a higher starting point but limited change. The ecological environmental pressure changes do not show a clear spatial distribution pattern. (3) The decoupling relationship between tourism economy and ecological environment in the Yangtze River basin is moving toward a harmonious development. Achieving a harmonious balance between the two systems is crucial for maintaining ecological balance and regional sustainability.

KEYWORDS

tourism economy, ecological environment, sustainability, regional development, sustainable tourism, pressure and response, dynamic decoupling, Yangtze River basin

1. Introduction

Since the middle of the 20th century, the rapid growth of the global population has led to increasing pressure on the ecological environment caused by human beings, a gradual imbalance in the relationship between society, economy and environment, and frequent environmental pollution and natural disasters (Pata et al., 2021). Thereafter, human beings have paid increasing

attention to the protection and management of the ecological environment. In 1987, the term “sustainable development” was introduced in the report “Our Common Future” published by the United Nations World Commission on the Environment (Brundtland, 1987). Humans are increasingly concerned about the negative impact of their economic and social activities on the environment (Ahmad et al., 2021; Khan et al., 2021; Mofijur et al., 2021). The relationship between humans and nature is closely related, as the natural environment is the prerequisite and foundation for human production and life, and the natural environment guides humans in a series of social activities (Pyle, 2003). In turn, in the process of production and life, human beings have gradually enhanced their ability to adapt and modify the natural environment. The continuous development of society has increased the demands and impacts on the natural environment, which requires that human development should ideally be in harmony with the ecological environment.

After the 21st century, tourism entered a period of rapid development, becoming an important force in global economic recovery and one of the largest industries in the world (MacKenzie and Gannon, 2019; Streimikiene et al., 2021). In 2019, the cumulative number of international tourists worldwide reached 1.5 billion, with total global tourism revenues reaching 5.8 trillion USD, accounting for 6.7% of the global GDP and making a significant contribution to the world economy (León-Gómez et al., 2021). The tourism industry has gradually promoted the development of other related industries, forming a comprehensive cluster effect, and the tourism economy has had a more profound impact on the growth of the social economy (Kim et al., 2021). Tourism is the spatial displacement of tourists to and from tourist places using transportation, and tourists have an impact on the ecological environment both during the trip and at the destination. There is an interactive relationship between the two systems of the tourism economy and the ecological environment, which together constitute a complex system and are constantly exchanging material and energy with the outside world (Farrell and Runyan, 1991; Liu and Suk, 2021). With the establishment of tourism satellite accounts, the ecological impact of tourism has been gradually recognized, and the carbon emissions generated by tourism account for 5%–14% of the total carbon emissions of human society (Luo et al., 2020; Sun et al., 2020). Therefore, seeking green development has become a requirement for sustainable tourism.

The ecological environment is a complex concept, short for “environment consisting of ecological relations,” and refers to the sum of various natural (including secondary nature formed by artificial intervention) forces (material and energy) or effects that are closely related to human beings and affect human life and production activities (Pyke and Ehrlich, 2010). In simple terms, the ecological environment is the general term for the number and quality of water resources (Oki and Kanae, 2006), land resources (Tong et al., 2018), biological resources (Villaseñor et al., 2016) and climate resources (Fatorić and Seekamp, 2017) that affect human survival and development and is a complex ecosystem that is related to sustainable social and economic development. Ecological environmental problems refer to the various negative feedback effects that are harmful to human existence caused by natural destruction and pollution in the process of natural transformation by human beings for their own survival and development (Saxena et al., 2020).

“Ecological environment,” “ecology” and “environment” are three concepts that are related and distinct. “Ecology” refers to the

interconnection between organisms and their surroundings (Carpenter and Folke, 2006; Lowe et al., 2009). “Environment” refers to the geographical environment, which is the overall natural phenomenon surrounding human beings and can be divided into natural, economic and sociocultural environments (Foray and Grübler, 1996; Sherbinin et al., 2007). Environmental science is a comprehensive science that studies the environment and its interrelationship with human beings (Mengist et al., 2020). Although ecology and the environment are two relatively independent concepts, they are closely related to each other, so the new concept of “ecological environment” has emerged. It is the sum of all natural factors and conditions for the survival and reproduction of living things and is a large system consisting of ecosystems and environmental systems (Omernik, 2004). “Ecological environment” and “natural environment” are very similar in meaning, and sometimes scholars mix them up, but strictly speaking, the ecological environment is not the same as the natural environment (Steiner et al., 2013). The natural environment has a wide scope, and all of the various natural factors can be said to be the natural environment, but only the whole of a system with certain ecological relationships can be called the ecological environment. A whole consisting of only abiotic factors can be called a natural environment but not an ecological environment.

Tourism is a typical environment-dependent industry, and the ecological environment not only affects the quality of the tourist experience but also restricts the process of tourism economic development. Tourism is an industry with high dependence on resources and the environment (Wang et al., 2020; Zhou et al., 2023). On the one hand, rich cultural tourism resources, unique regional culture, and beautifully natural and humanistic environments are the basis for tourism development (Richards, 2018). On the other hand, the disorderly expansion of tourism, the overexploitation of resources and the lack of environmental protection will cause great pressure and damage to the ecological environment (Zeng et al., 2022). Tourism is the industry of happiness, and its mission is to make people feel happier (Lee et al., 2021). Many scholars have found that the ecological environment significantly affects residents’ happiness and life satisfaction (Zhong and Chen, 2022). Therefore, the development of tourism cannot be at the expense of resources and the environment and should aim to improve natural and human habitats and achieve the coordinated development of the tourism economy and ecological environment.

China is the world’s largest developing country, and over the past 40 years, China’s economy has grown in strength and become the world’s second-largest economy (Lu et al., 2019). However, unbalanced, uncoordinated and unsustainable problems remain prominent in China’s rapid economic development, which has seriously restricted the quality of China’s economic development (Loke, 2018). Tourism plays an indispensable role as a strategic pillar industry for China’s economic development (Zhang and Zhang, 2021). In 2019, China’s tourism economy continued to maintain a trend of higher growth than GDP, with domestic and international tourists reaching 6.306 billion; among them, inbound tourism reached 145.31 million, a 2.9% increase compared to the previous year; outbound tourism reached 154.63 million, a 3.3% increase compared to the previous year. This resulted in a total tourism revenue of 6.63 trillion CNY, an 11% increase from the previous year. The total tourism revenue accounted for 11.05% of the GDP (Pan et al., 2021). Such large-scale population movement and economic

production activities will inevitably have an impact on the regional ecological environment.

In recent years, with the rapid development of China's tourism economy, environmental pollution and ecological destruction have occurred frequently due to the disorderly development of tourism resources, overloaded tourist flow, and weak environmental awareness of tourism enterprises (Zhong et al., 2011; Zhang and Gao, 2016). For example, China's Zhangjiajie and Lushan scenic areas were given a "yellow card" by UNESCO due to illegal construction, and unreasonable tourism development practices directly led to the destruction of the geological structure of the scenic areas, and this destruction is irreversible (Quan, 2003). The original beautiful natural scenery of tourist attractions has been destroyed, resulting in a significant decline in tourism appeal (Castillo-Manzano et al., 2021; Kim et al., 2023). As a result, the contradiction between China's tourism economy and ecological environment has become increasingly prominent, and the reduction of environmental pollution and ecological damage while promoting the continued rapid development of the tourism economy has gradually become a major concern for the Chinese government and scholars (Wang et al., 2020).

The tourism economy and ecological environment both promote and constrain each other, and the coupling relationship between the two systems has been the focus of scholars' attention. Related research began in the 1920s, and the early stage mainly focused on the impact of tourism activities on the natural environment, including the environmental impact of tourism activities, tourism planning, environmental impact assessment, environmental carrying capacity and other areas (Cohen, 1978; Gössling, 2002; Burns, 2004). Previous literature has mainly used case studies, input-output models, environmental Kuznets curves, and ecological footprints to conduct research and has rarely analyzed the coupling relationship between the tourism economy and ecological environment directly from a system perspective.

In the past few years, the number of studies on the relationship between the two from a system perspective using coupled models has been increasing, and the research scales are mostly focused on the national, regional, provincial and municipal levels, with relatively few studies focusing on the basin level (Tang, 2015; Liu et al., 2019; Zhang and Li, 2021; Tang and Luo, 2022). In addition, the previous literature mainly studied the time dimension and lacked research from both spatial and temporal dimensions. The watershed is a special region linked by water resources, with both natural and economic characteristics, and is both a tourism resource-rich area and an ecological environment fragile area (Zhu et al., 2022a,b).

Therefore, this paper selects the Yangtze River basin, which has a relatively fragile ecological environment, as the study area and analyzes the spatial and temporal coupling characteristics of the tourism economy and ecological environment from a system perspective. The specific objectives of this paper are as follows:

1. Constructed a decoupling analysis system of tourism economic development and ecological and environmental pressure in the Yangtze River basin.
2. The spatial and temporal characteristics of the two systems were analyzed using the tourism economic development index, the ecological environmental pressure index, and the dynamic change index.
3. The decoupling process between the two systems was analyzed using the decoupling analysis model.
4. To provide scientific decision-making support for achieving sustainable economic and ecological development of the Yangtze River basin.

2. Theoretical background

2.1. Sustainable tourism

The concept of sustainable development was first introduced in the 1978 report "Our Common Future" as a development that meets the needs of the present without compromising the ability of future generations to meet their needs (Brundtland, 1987). This concept is a growth model aimed at long-term economic development, which emphasizes the need to focus on both the survival and development of the current generation of human beings and not excessively occupying the resources of future generations. The introduction of this concept signifies that the previous development mode of economic growth at the expense of the environment is no longer desirable, and future economic development needs to consider the protection of the ecological environment at the same time, which means that the quality of human life cannot be improved at the expense of the environment, reflecting the concept of harmonious coexistence between human beings and nature (Silvestre and Țircă, 2019; Dantas et al., 2021; Kabil et al., 2022a). Sustainable development requires meeting basic human survival while limiting the early consumption of future resources, which can endanger natural systems if natural resources are consumed excessively early.

The concept of sustainable development has been widely accepted and recognized by countries around the world in recent years. Due to the excessive pursuit of economic and tourism development benefits, unreasonable planning and development of resources and the environment have caused certain damage to the environment (Halkos and Gkampoura, 2021). The introduction of the concept of sustainable development into the tourism industry has become sustainable tourism, which can provide theoretical guidance for the comprehensive and coordinated development of tourism and is conducive to the harmonious development of the tourism economy and ecological environment (Higgins-Desbiolles, 2018; Rasoolimanesh et al., 2020).

The concept of sustainable development emphasizes the harmonious coexistence between humans and nature (Ruggerio, 2021; Kabil et al., 2022b). The survival and development of human beings is a process in which various natural and human elements interact with each other. In this process, humans tend to focus too much on the need for economic development and neglect the limits of the environment's carrying capacity (Hummels and Argyrou, 2021). The concept of sustainable development deeply reflects the integration of comprehensive economic development and the relationship between humans and nature, challenging the traditional development model and promising sustainable human development. Sustainable tourism development requires treating the tourism system and ecosystem as an organic whole, necessitating the harmonization of ecological, economic, and social benefits of tourism (Obradović et al., 2021). The sustainability of the ecological environment is the most important

manifestation of sustainable tourism development. The ecological environment provides the necessary resource endowment for the development of the tourism industry, and sustainable tourism development must be premised on the sustainability of the ecological environment.

The essence of sustainable tourism is to preserve the integrity of environmental and culture resources, and provide equal development opportunities for tourism areas (Liu, 2003; Ruhanen et al., 2018). Specifically, it is about improving the understanding of the environmental and economic effects of tourism and protecting the future tourism resources and the ecological environment on which they depend (Kabil et al., 2021, 2022a). Sustainable tourism motivates stakeholders to remain highly alert to the social, cultural, and economic environment in the process of developing tourism, bringing about positive impacts and minimizing negative impacts through rational tourism development activities (Guaita Martínez et al., 2019; Higgins-Desbiolles, 2021). Sustainable tourism is proposed with the sustainable development pursued by the social economy. Sustainable economic development emphasizes that the ecological environment on which human beings depend must not be destroyed, and through effective resource development, utilization and management (He et al., 2018), to achieve satisfactory economic development while ensuring that the rate of economic resource use does not exceed the rate of renewal, to ensure that the economic development of contemporary or future human society has sufficient economic resources.

2.2. Ecological economics

Ecological economics, also known as environmental economics, is an interdisciplinary discipline resulting from the interconnection of ecology and economics, which focuses on the interrelationship between economic activities and ecological change (Pirgmaier, 2021). The concept of ecological economics was first introduced after the first industrial revolution. Along with the first industrial revolution, an increasing number of problems emerged in the natural environment on which people depend, such as the increasing demand for ecological resources, the varying degrees of environmental destruction, and the gradual degradation of the natural ecology (Giampietro, 2019). These environmental problems are beginning to impede rapid economic development, and scholars are becoming more aware of the problem and are beginning to analyze the sources and conduct research (Hickel, 2020).

When people realized the conflict between human beings and the land, they began to think about the problem of the destruction of the ecological environment on which human beings depend while science and technology progressed and living standards improved (Liu X. et al., 2022). Robert Costanza, a leading ecological economist, sees ecological economics as the broadest possible link between ecosystems and economic systems, a view that is unique and well recognized by the academic community (Costanza, 2020). The core concept of ecological economics is the harmonious development between ecology and economy. Ecological economics is a relatively independent discipline, and the fundamental goal is to achieve harmonious coexistence between economy, society and ecology within the carrying capacity of the natural environment and to maximize the environmental and ecological economic benefits (Ahmed et al., 2022).

The theory of ecological economics has made great contributions to the sustainable development of human society (Hediger, 1997). It usually focuses on ecological sustainability and economic relations, human-earth relations, ecosystem benefits, etc. It is also widely used in the field of tourism, such as tourism cycle systems and tourism eco-industries. While developing the tourism economy, the law of coordinated development should be followed to achieve a dynamic balance between the tourism economic system and the ecological environment system, thus maximizing the overall benefits.

2.3. Coupling theory

Coupling is a physics concept that refers to the phenomenon of two or more systems affecting each other through various interactions (Reichman and Charbonneau, 2005). A variety of complex correlations between things in nature are prevalent, and this phenomenon is coupling. The types of coupling can be divided into the following seven types: nondirect coupling (no interaction between research objects), data coupling (input and output information is exchanged between research objects through simple data parameters), marker coupling (parameters transmitted between research objects contain complex data structures), control coupling (transmitted parameters contain control information), external coupling (research objects are associated with the same external environment), public coupling (information can be shared between research objects), and content coupling (one module can use information from another module; Gong et al., 2019).

The concept of coupling has been commonly seen in natural and socioeconomic systems in recent years, indicating that two or more systems form a new system that merges into one through intersystem interactions (Cui et al., 2019). The system coupling process contains the interaction of many factors, accompanied by the flow and circulation of matter, energy, and information, which makes the system coupling process more complex. There are good and bad results of system coupling, and a good system coupling can break the division of each system from each other and form a new effective whole to achieve the goal of synergistic development.

The coupling degree is a measure of the strength of the interaction between two or more systems and does not reflect the coordinated development relationship between systems (Cheng et al., 2019). Therefore, the coupling coordination degree is introduced to measure the coordinated development between systems. The coupling coordination degree can quantify the degree of coupling between systems and the actual situation of coordinated development, which can reflect whether coordinated development between systems is achieved or not (Xing et al., 2019).

The tourism economy and ecological environment are two independent but closely related systems that can be included in the coupled system to measure their degree of coordination (Li et al., 2012; Lai et al., 2020; Zhang F. et al., 2022). The coupling coordination degree is used to quantitatively describe the degree of coupling and coordination between the economy, tourism and ecology (Tang, 2015; Xing et al., 2019). The coupling coordination degree can not only measure the coupling coordination degree of the same region at multiple periods but also compare the coupling coordination degree of different regions (Shi et al., 2020). The study of the evolutionary characteristics of the coupling and coordination between the tourism

economy and ecological environment can provide important theoretical support for regional sustainable development (Li et al., 2012).

2.4. Interaction of tourism economy and ecological environment

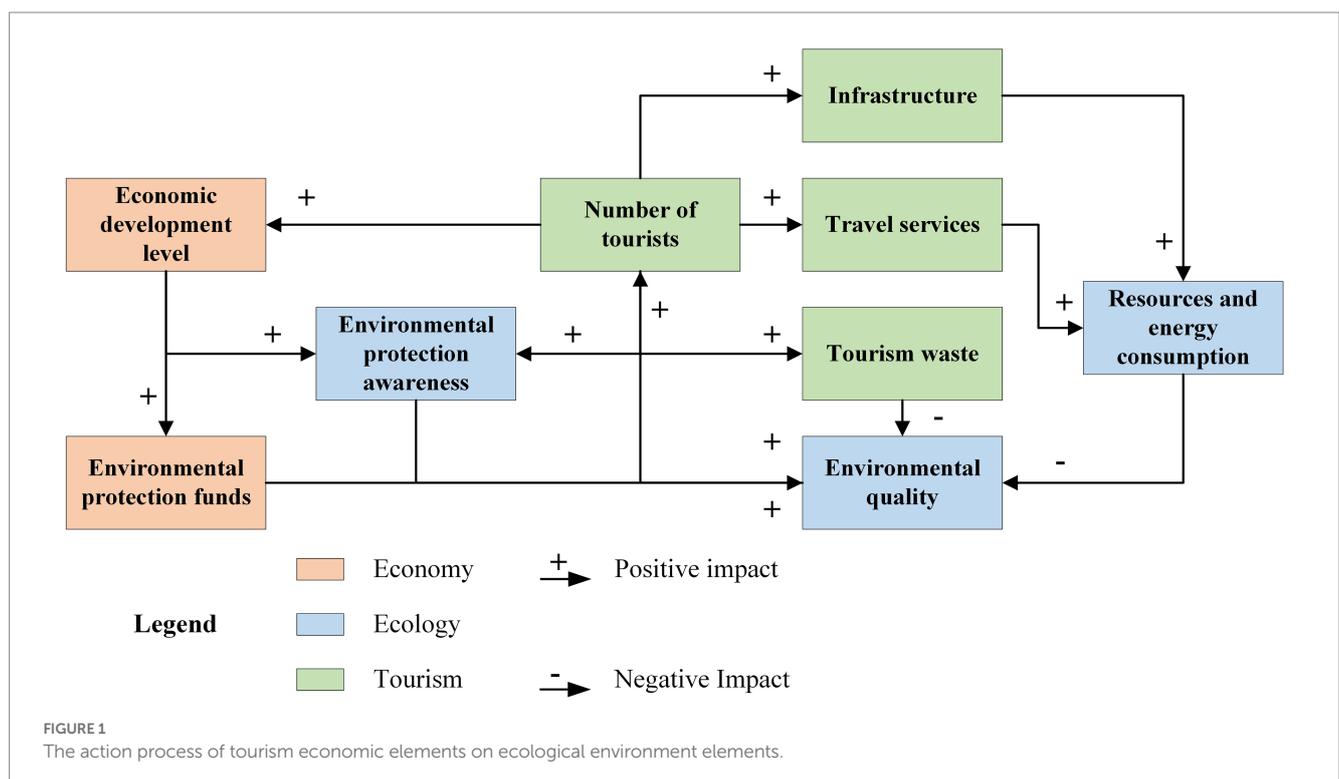
The objectives of the tourism economy and ecological environment are not conflicting, but it is also more than a purely linear relationship (Fei et al., 2021). In the primary stage of tourism economy development, economic growth is the first priority, and a crude development model can damage the ecological environment (Haibo et al., 2020). However, as the social concept progresses, people gradually realize the importance of beautiful nature and begin to consider ways to achieve a sustainable tourism economy. This is a changing process.

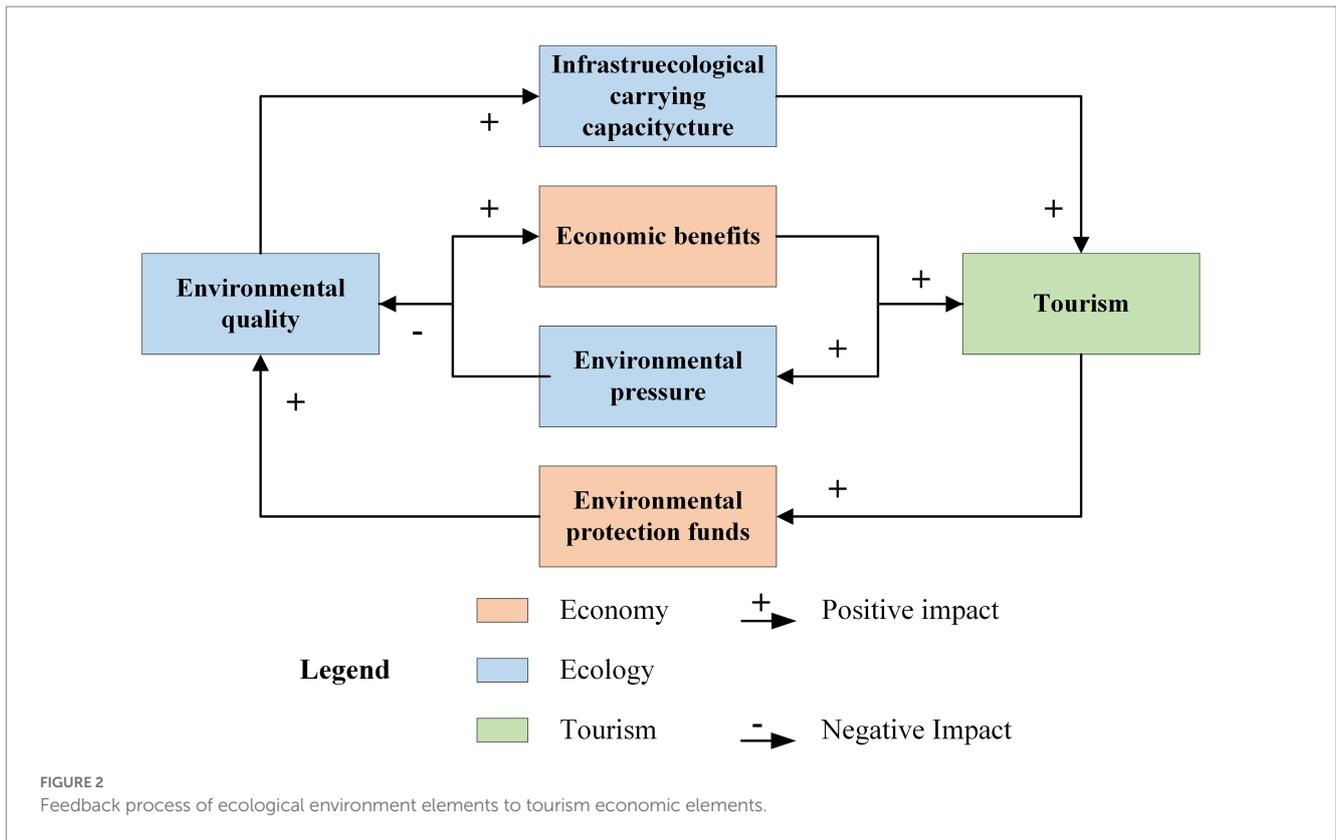
Tourism is an industry that relies heavily on local resources and the surrounding environment (Kongbuamai et al., 2020). This attribute determines the coupling relationship between the tourism economy and the ecological environment of mutual promotion and constraint coercion. A good ecological environment is the basis of the tourism economy, and tourism economic development can also play a role in promoting the protection of the ecological environment. At the same time, there is also a binding coercive relationship between them (Khan A. et al., 2020).

Figure 1 shows the active process of tourism economic elements on ecological environment elements. From the perspective of supply-demand and input-output, people's desire for a better life will generate more tourism demand, and the increase in tourism demand will stimulate an increase in the supply of accommodation and catering, which in turn will consume more ecological resources and energy and

put pressure on the ecological environment (Tasci and Ko, 2017; Kongbuamai et al., 2020). From the perspective of the industry chain, the growth of the tourism industry can drive the development of upstream and downstream industries in the industry chain, increasing local economic income (Fong et al., 2021). On the one hand, higher government revenue increases investment in ecological protection funds (Cao et al., 2021), and on the other hand, higher per capita disposable income raises residents' awareness of environmental protection, both of which are conducive to improving environmental quality (Chen et al., 2019). A high-quality environment attracts more tourists and serves as a subtle educational function for tourists, prompting their environmental awareness and forming a virtuous circle.

Similarly, Figure 2 shows the active process of feedback from ecological environment elements to tourism economic elements. A high-quality ecological environment in tourist destinations can attract a large number of tourists and guide their consumption to increase local tourism income. Tourism sectors and enterprises will take the initiative to optimize local infrastructure, and good infrastructure will improve tourists' tourism experience and further promote the development of the local tourism industry (Boivin and Tanguay, 2019; Zeng et al., 2021). The development of the tourism industry will inevitably hurt the local air, flora and fauna, and soil, thereby damaging the quality of the ecological environment (Ruan et al., 2019). If the negative impact of tourism on the ecological environment exceeds the carrying capacity of the ecological environment, it will damage the ecological environment. On the one hand, it increases the cost of environmental rehabilitation and reduces the economic benefits of the tourism industry; on the other hand, it reduces the attractiveness of attractions to tourists and thus inhibits the development of the tourism industry. If the negative effect of tourism on the ecological environment is less than the





ecological environment’s self-cleaning capacity, it will not destroy the ecological environment (Peng et al., 2019; Wu and Hu, 2020). In general, the positive and negative feedback effects of the ecological environment on the tourism economy depend on whether the negative effects of tourism on the ecological environment exceed the ecological carrying capacity.

3. Study area, data, methods and study design

3.1. Study area

The Yangtze River basin spans three major economic zones in eastern, central and western China, with a total of 19 provinces, and is the largest basin in Asia and the third largest in the world, with a total basin area of 1.8 million km², accounting for 18.8% of China’s land area, and rich natural resources in the basin (Lai et al., 2013). The Yangtze River basin contains the Yangtze River Delta city cluster, the middle reaches of the Yangtze River city cluster, the Chengdu-Chongqing city cluster and other national city clusters, which is an important east–west axis of China’s territorial space development, an important support to promote China’s western development, the rise of central China, the first development of the east and other strategies and is also the most influential inland economic belt in the world (Tian and Sun, 2018; An et al., 2022; Zhou et al., 2022).

The Yangtze River basin is an important ecological barrier and economic zone in China. On the one hand, the Yangtze River basin

is an important tourist source and destination in China, with rich natural and humanistic tourism resources, including natural landscapes such as Three Gorges, Jiuzhaigou, West Lake and Zhangjiajie, as well as humanistic landscapes such as Lijiang Ancient City, Dazu Rock Carvings, Huanghe Lou and Suzhou Gardens (Zhang et al., 2011; Wang et al., 2023). As of 2017, the total number of tourist trips in the Yangtze River basin rose from 651 million in 2000 to 6.770 billion in 2017, and the total tourism revenue grew from 426.903 billion CNY in 2000 to 8,529.394 billion CNY in 2017, accounting for 22.81% of China’s GDP that year (Shi et al., 2021; Wang et al., 2021). This shows that the tourism industry has become an indispensable pillar industry in the Yangtze River basin and plays a pivotal role in promoting the high-quality economic development of the Yangtze River basin. On the other hand, the ecological environment of the Yangtze River basin is very fragile, and local environmental pollution is serious. A total of 12.40% of the 137 water quality cross-sections in 2018 accounted for poor V water, much higher than the national level of 6.7%. River water quality is on a downward trend, a large number of lakes are eutrophic, the Yangtze River water quality is deteriorating, and the main sources of pollution are chemical raw materials and chemical products manufacturing, agricultural and food processing industries, food manufacturing and other industries (Li et al., 2013; Yang X. et al., 2021, p. 2; Zhang et al., 2021, p. 2).

The tourism economy in the Yangtze River basin is growing rapidly, while the ecological environment is fragile, and tourism is a highly resource- and environment-dependent industry. Faced with such significant opportunities and challenges, it is necessary to assess the spatial and temporal coupling characteristics of the tourism economy and ecological environment in the Yangtze River basin. As

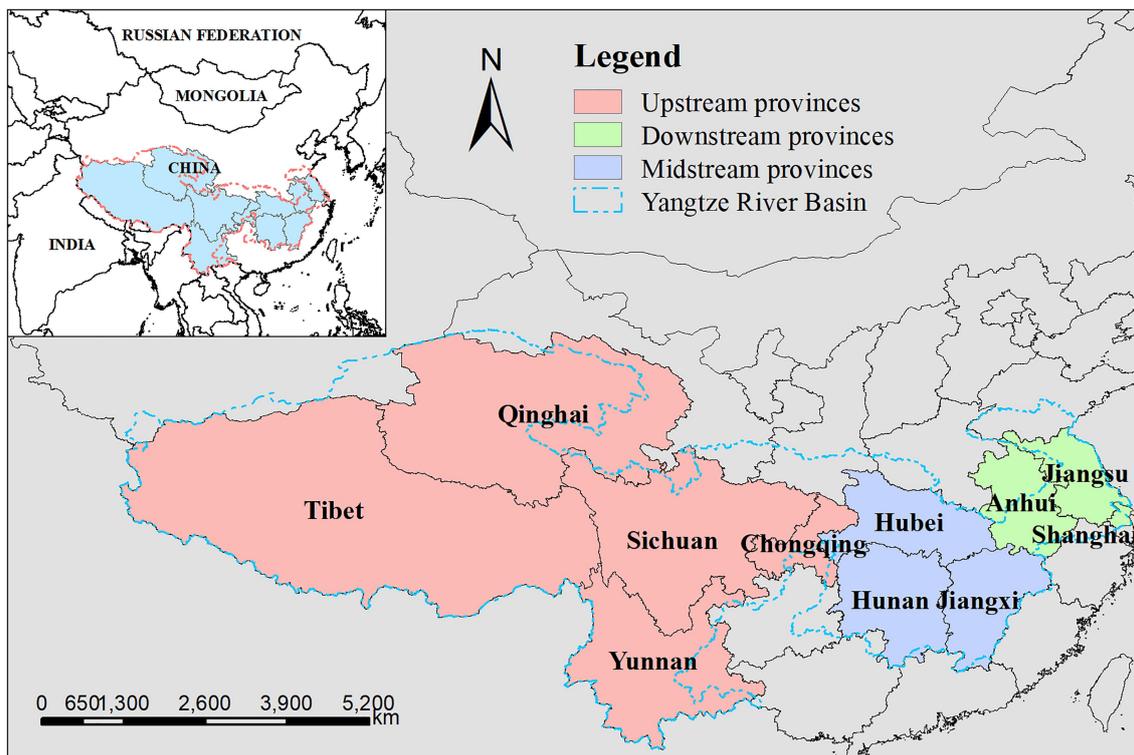


FIGURE 3
The location of the target study area.

shown in Figure 3, this study takes 11 provinces flowing through the Yangtze River mainstream as the study area and classifies Qinghai, Tibet, Sichuan, Yunnan, and Chongqing as the upstream area, Hunan, Hubei, and Jiangxi as the midstream area, and Anhui, Jiangsu, and Shanghai as the downstream area.

3.2. Data source and preprocessing

This paper takes 11 provinces in the Yangtze River basin as the basic unit and a total of 10 years from 2000 to 2019 as the time series. To ensure the scientific nature of the data indicators, tourism economic data are mainly obtained from the China Tourism Statistical Yearbook, the China Regional Economic Statistical Yearbook, the China Culture and Related Industries Statistical Yearbook and the Statistical Bulletin of National Economic and Social Development published by each province. The number of national-level intangible cultural heritage items is the total number of representative national-level intangible cultural heritage items in five batches announced by each province, and the data are from the China Intangible Cultural Heritage Network. The ecological environment data are derived from the China Environmental Statistical Yearbook and the China Statistical Yearbook. For the missing data of individual years in the decoupling analysis system, this paper uses the growth rate and moving average method to fill in the gaps (Barrow, 2016).

Referring to previous literature (Tang, 2015; Wang et al., 2018; Zhang X. et al., 2022), this paper constructs a decoupled analysis system of tourism economic development and ecological environment

pressure in the Yangtze River basin consisting of 2 major systems, 6 dimensions and 24 indicators, as shown in Table 1. Among them, 11 quantitative indicators were selected from 3 aspects of the tourism economic development system, including tourism resources, economic benefits and industry scale, and 13 quantitative indicators were selected from ecological resources, environmental pollution and environmental management in the ecological environment pressure system.

In the ecological environmental pressure system, larger indicators of resource endowment and ecological governance indicate that the ecological environmental pressure in the region will be smaller. Therefore, this paper sets the indicators of nature reserve area, forest coverage rate, *per capita* park green area, *per capita* water resources and investment in environmental pollution control, domestic waste removal, sewage treatment capacity, comprehensive utilization of industrial solid waste and disposal of industrial solid waste in this system as negative indicators to reverse characterize the ecological environmental pressure state of the province.

To eliminate the differences in data scale and positive and negative values of indicators in the decoupling analysis system, the indicators need to be standardized, and the extreme difference method is used for data standardization in this paper. In addition, before the empirical measurement of tourism economic development and ecological environment pressure, the weights of each indicator need to be calculated to enhance the objectivity and scientificity of the measurement results based on the entropy value method for weight calculation and combined with the hierarchical analysis method to adjust the weights of each indicator.

TABLE 1 Decoupling analysis system and index weight of tourism development and ecological environmental pressure.

System	Constraint layer	Indicators	Unit	Weights	Type*
Tourism economy	Tourism resources	Number of tourist attractions above Grade 3A**	Number	0.091	+
		Number of scenic spots, parks and world heritage sites	Number	0.132	+
		Number of national-level intangible cultural heritage	Number	0.097	+
		Number of performing arts groups institutions	Number	0.041	+
	Economic benefits	Domestic tourism receipts	10 ⁸ CNY	0.109	+
		Income from inbound tourism	10 ⁴ USD	0.058	+
		Domestic tourist arrivals	10 ⁴ person times	0.129	+
		Inbound tourism arrivals	10 ⁴ person times	0.043	+
	Industry scale	Number of tourism employees	Number of people	0.173	+
		Number of Star hotels	Number	0.065	+
		Number of travel agents	Number	0.062	+
Ecological environment	Ecological resources	Nature reserve area	10 ⁴ hm ²	0.089	–
		Forest coverage	%	0.078	–
		Green space <i>per capita</i>	m ²	0.125	–
		Water resources <i>per capita</i>	m ³	0.071	–
	Environmental pollution	Total wastewater discharge	10 ⁴ t	0.161	+
		Total sulfur dioxide emissions	10 ⁴ t	0.053	+
		Total emissions of smoke and dust	10 ⁴ t	0.078	+
		Total industrial solid waste production	10 ⁴ t	0.091	+
	Environmental management	Investment in environmental pollution control	10 ⁸ CNY	0.035	–
		Amount of domestic waste removed	10 ⁴ t	0.063	–
		Wastewater treatment capacity	10 ⁴ m ³	0.052	–
		Integrated industrial solid waste volume	10 ⁴ t	0.059	–
		Industrial solid waste disposal volume	10 ⁴ t	0.045	–

**+” means that the indicator is positive, and “–” means that the indicator is negative.

**3A is one of the levels of China’s tourism scenic quality classification, divided into five levels, from high to low AAAA, AAAA, AAA, AA, and A. Grade 5A is the highest level of China’s tourist attractions, representing the grade of China’s world-class boutique tourist scenic spots.

3.3. Methods

3.3.1. Entropy method

The entropy weighting method is used to determine the dispersion degree of an index, and the dispersion degree is positively correlated

with the comprehensive evaluation results. A higher degree of dispersion indicates a greater impact on the overall evaluation, and vice versa (Chen, 2019). The entropy method does not require expert intervention and can effectively eliminate human subjective influence. The calculation steps are as follows.

The extreme difference standardization method was selected to standardize the obtained data and eliminate the effect of the difference in magnitude. For the positive impact indicators:

$$u_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} + 0.01 \quad (1)$$

For negative impact indicators:

$$u_{ij} = \frac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}} + 0.01 \quad (2)$$

where x_{ij} denotes the value of indicator j in sample i (i.e., indicator j in year i), and a total of n samples and m indicators are selected. u_{ij} denotes the standardized value of indicator j in year i , and $x_{j\max}$ and $x_{j\min}$ denote the maximum and minimum values of indicator j , respectively. The standardization result is uniformly added with 0.01 to avoid the final result of 0, which makes the data meaningless.

Find the ratio of indicator j in year i to the sum of the indicators:

$$p_{ij} = \frac{u_{ij}}{\sum_{i=1}^n u_{ij}}, (i = 1, 2, \dots, n; j = 1, 2, \dots, m) \quad (3)$$

Find the entropy value of the j indicator:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (4)$$

Determining the weights of each indicator through the entropy value e_j :

$$w_j = \frac{d_j}{\sum_{j=1}^m d_j} \quad (5)$$

$$d_j = 1 - e_j \quad (6)$$

where d_j denotes the difference coefficient of indicator j , w_j denotes the weight of each indicator, and the calculation results are shown in [Table 1](#).

3.3.2. Tourism economic development index

This paper constructs a tourism economic development index to analyze tourism development in the Yangtze River basin provinces, referring to previous literature ([Zhang X. et al., 2022](#)). The calculation formula is as follows:

$$TEDI = aTRI + bTEBI + cTISI \quad (7)$$

$$TRI = \sum_{j=1}^n TRI'_{ij} \delta_j \quad (8)$$

$$TEBI = \sum_{j=1}^n TEBI'_{ij} \delta_j \quad (9)$$

$$TISI = \sum_{j=1}^n TISI'_{ij} \delta_j \quad (10)$$

where $TEDI$ denotes the tourism economic development index; the larger its value is, the better the tourism economic development of the province; TRI , $TEBI$ and $TISI$ denote tourism resources, economic efficiency and tourism industry scale indices, respectively; TRI'_{ij} , $TEBI'_{ij}$, and $TISI'_{ij}$ denote the standardized values of tourism resources, economic efficiency and industry scale, respectively; a , b , and c denote the dimensional weights of TRI , $TEBI$, and $TISI$, respectively; n denotes the number of indicators of each dimension in the tourism economic system; and δ_j denotes the weight of each indicator in the tourism economic development system.

3.3.3. Ecological environment pressure index

The ecological environment pressure index reflects the carrying capacity of a province's ecosystem and the pressure on the environment caused by tourism economic development ([Large et al., 2013](#); [Downie et al., 2020](#)). In this paper, the ecological environment pressure index of each province in the Yangtze River basin is constructed from the resources, pollution and governance dimensions.

$$EEPI = dERI + eEPI + gEGI \quad (11)$$

$$ERI = \sum_{j=1}^n ERI'_{ij} \omega_j \quad (12)$$

$$EPI = \sum_{j=1}^n EPI'_{ij} \omega_j \quad (13)$$

$$EGI = \sum_{j=1}^n EGI'_{ij} \omega_j \quad (14)$$

where $EEPI$ denotes the ecological environmental pressure index; the larger its value is, the greater the pressure caused by the tourism economy on the ecological environment, and vice versa, the lower the pressure; ERI , EPI , and EGI denote the ecological resource index, environmental pollution index, and environmental governance index, respectively; ERI , EPI , and EGI denote the data standardized values of ecological resources, environmental pollution, and environmental governance, respectively; d , e , and g denote the dimensional weights

of *ERI*, *EPI*, and *EGI*, respectively; ω_j denotes the weight of each indicator in the ecological environmental pressure system; and n denotes the number of indicators of the ecological environment.

3.3.4. Dynamic change index

The dynamic change index can reflect the magnitude and speed of changes in attributes over time, and the method has been used more often in climate change (Zhang and Wei, 2015) and land use (Liping et al., 2018) because it is easy to operate and intuitive to reflect. In this paper, the index is used to analyze the changes in tourism economic development and ecological environmental pressure in the Yangtze River basin from 2000 to 2019.

$$K = \frac{U_{\max} - U_{\min}}{U_{\min}} \times \frac{1}{t_2 - t_1} \times 100\% \quad (15)$$

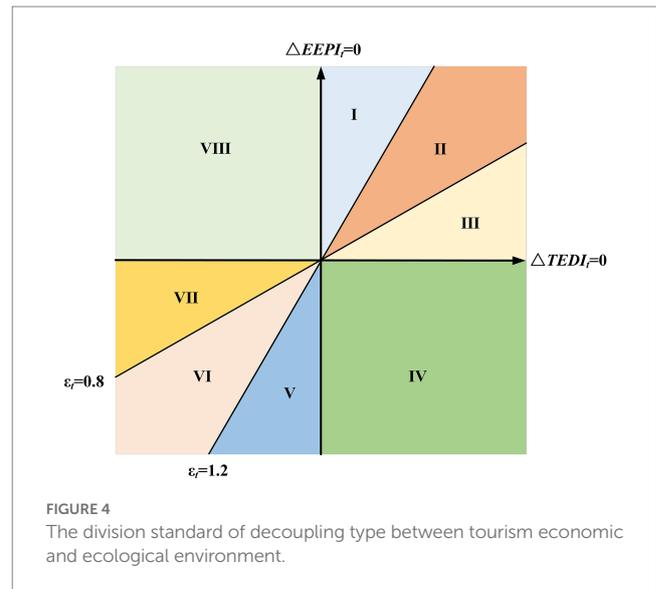
where K denotes the dynamic change in tourism development and the ecological environmental pressure index from t_1 to t_2 . The larger the value of K is, the greater the change in tourism development and the level of ecological environmental pressure in the period. The smaller the value of K is, the smaller the change in the above two indices, and the greater the development tends to stabilize. U_{\max} and U_{\min} denote the maximum and minimum values of the tourism development index and the ecological environmental pressure index, respectively. Based on the empirical results and concerning previous literature, this paper uses the natural breakpoint method to classify the two indices into four types: high, medium-high, medium and low dynamic change.

3.3.5. Decoupling analysis

Coupling is a physical concept used to measure the phenomenon that two systems are influenced by internal and external factors and can determine the coordination relationship between the tourism economy and the ecological environment (Cai et al., 2021). The decoupling elasticity coefficients of tourism economic development and ecological environmental pressure in the Yangtze River basin were further constructed concerning the decoupling elasticity index as follows:

$$\begin{aligned} \varepsilon_t &= \frac{\Delta EEPI_t}{\Delta TEDI_t} \\ &= \frac{(EEPI_e - EEPI_s) / EEPI_s}{(TEDI_e - TEDI_s) / TEDI_s} \end{aligned} \quad (16)$$

where ε_t denotes the decoupling elasticity coefficient in period t ; $EEPI_s$ and $EEPI_e$ denote the ecological environmental pressure indices in the base year and the final year of period t , respectively; $\Delta EEPI_t$ denotes the rate of ecological environmental pressure change in period t ; $TEDI_s$ and $TEDI_e$ denote the tourism economic development indices in the base year and the final year; $\Delta TEDI_t$ is the rate of tourism economic development change in period t . With $\Delta TEDI_t = 0$, $\Delta EEPI_t = 0$ and $\varepsilon_t = 0.8$, $\varepsilon_t = 1.2$ as the dividing line. As shown in Figure 4, the decoupling states of the two systems are divided into eight types, and the interpretation of the decoupled states is shown in Table 2.



3.4. Study design

In this study, the entropy method (section 3.3.1) was used to process the tourism economic and ecological environment data from 11 provinces in the Yangtze River basin. The spatial patterns of tourism economic development (section 4.1.1) were obtained through the tourism economic development index method (section 3.3.2). The spatial patterns of ecological environmental pressure (section 4.2.1) were obtained through the ecological environmental pressure index method (section 3.3.3). The dynamic change in tourism economic development and ecological environmental pressure (sections 4.1.2 and 4.2.2) was obtained through the dynamic change index method (section 3.3.4). The dynamic decoupling process of tourism economic development and ecological environmental pressure (section 4.3) is obtained through the decoupling analysis method (section 3.3.5). The specific steps are shown in Figure 5.

4. Results

4.1. Spatiotemporal characteristics of tourism economic development

4.1.1. Spatial patterns of tourism economic development

Figure 6 shows the spatial patterns of tourism economic development in the Yangtze River basin, showing the distribution characteristics of high in the east and low in the west, high in the south and low in the north. In terms of east–west differences, Anhui and Shanghai in the east belong to the higher tourism economic development zone. Anhui is an important part of the Yangtze River Delta in the connection zone of several major economic plates in China, and its economy and culture have natural links with other regions. Anhui has rich cultural tourism resources, consisting of four cultural circles: Huizhou culture, Huaihe culture, Wanjiang culture, and Luzhou culture (Li et al., 2016; Xu and Wang, 2022). Shanghai is an internationally renowned historical and cultural city with a dense road network, convenient transportation, rich tourism resources, and

TABLE 2 Eight different types of decoupling states.

Code	Decoupling	Explanation	Status
I	Expansive negative decoupling zone	The ecological environment pressure and tourism economic development increase simultaneously, and its increase is greater than the tourism economic development.	-
II	Expansive coupling zone	The ecological environmental pressure and tourism economic development level increase at the same time, and the increase of both systems is the same.	-
III	Weak decoupling zone	The ecological environment pressure and tourism economic development increase at the same time, but its increases less than the tourism economic development.	Relatively ideal state
IV	Strong decoupling zone	The ecological environmental pressure decreases with the tourism economy.	Ideal state
V	Declining decoupling zone	Both the ecological environmental pressure and tourism economic development are reduced, but the ecological environmental pressure is reduced more than the tourism economic recession degree.	-
VI	Declining coupling zone	The ecological environmental pressure and tourism economic development declined at the same time, and the rate of decline was the same for both systems.	-
VII	Weak negative decoupling zone	The ecological environmental pressure and tourism economic development declined simultaneously, but the ecological environmental pressure reduction was relatively small.	-
VIII	Strong negative decoupling zone	The ecological environmental pressure has increased and the tourism economy has declined.	Most unfavorable state

a good economic base, and the level of tourism economic development in the entire Yangtze River basin is in the leading position (Li, 2020; Mou et al., 2020). Tibet and Qinghai in the west are low zones. Among them, Tibet is located on the Qinghai-Tibet Plateau, with an average altitude of more than 4 km, known as the “roof of the world,” with complex and diverse terrain and unique tourism resources but poor infrastructure conditions (Zhang et al., 2015). Qinghai’s single tourism resource, fragile natural environment and weak economic base are the main constraints to the development of the tourism economy in Tibet and Qinghai (Xue, 2018).

In terms of the difference between the north and the south, Yunnan, Chongqing and Hunan in the south have better tourism economic development with diverse climatic conditions, rich landscape scenery and well-developed infrastructure. They are the middle-high zone with stronger development momentum than Sichuan, Hubei and Jiangxi in the north. The tourism economic development of the provinces in the Yangtze River basin is better matched with the local economic base and is also closely related to the diverse climate types, rich tourism resources, perfect infrastructure, and developed transportation conditions.

4.1.2. Dynamic changes of tourism economic development

Figure 7 shows the dynamics of tourism economic development in the Yangtze River basin. From 2000 to 2019, Qinghai and Tibet in Northwest China were among the high zones of dynamic changes in the tourism economy, both of which were characterized by low starting points but fast development of the tourism economy. In recent years, thanks to the national strategies of the Chinese government, such as Western Development (Lai, 2002), the Sanjiangyuan Nature Reserve (Zhang Y. et al., 2022, p. 200) and the construction of national parks (Xu and Fox, 2014), the scale and development rate of the local tourism economy have greatly improved.

Yunnan, Sichuan and Jiangsu belong to the middle-high zone, whose tourism resources and economy have a certain foundation and

belong to the “high start and high go” type. Anhui, Jiangxi and Shanghai are consistent with the level of change in tourism economic development and are at a medium level, indicating that their tourism economic development in recent years is more general. In addition, Hubei and Hunan in the middle reaches and Chongqing in the upper reaches belong to the low zone, showing a high starting point but little change. In the future, these provinces need to enhance the development momentum of the tourism economy through tourism product innovation, stimulating the tourism consumption market and optimizing product supply.

4.2. Spatiotemporal characteristics of ecological environmental pressure

4.2.1. Spatial patterns of ecological environmental pressure

Figure 8 shows the spatial patterns of ecological environmental pressures in the Yangtze River basin. The environmental conditions in the upstream provinces are generally good, with Tibet, Qinghai, and Sichuan belonging to the low and middle zones of ecological pressure, respectively, indicating that the tourism economy is causing less pressure on the ecological environment. The upstream areas of the Yangtze River have more fragile ecosystems and low environmental carrying capacity, and these provinces have long attached great importance to water conservation, ecological protection, and restoration and management (Wang et al., 2022). In addition, Jiangxi and Shanghai also belong to the middle zone.

Chongqing, Hubei, Hunan, Anhui, and Jiangsu are in the middle-high zone of ecological and environmental stress. Most of these provinces belong to the midstream and downstream areas, with more developed industrial economies, higher energy production and consumption compared to other provinces, and problems such as excessive pollutant emissions and misuse of land resources have led to serious environmental damage and frequent natural disasters

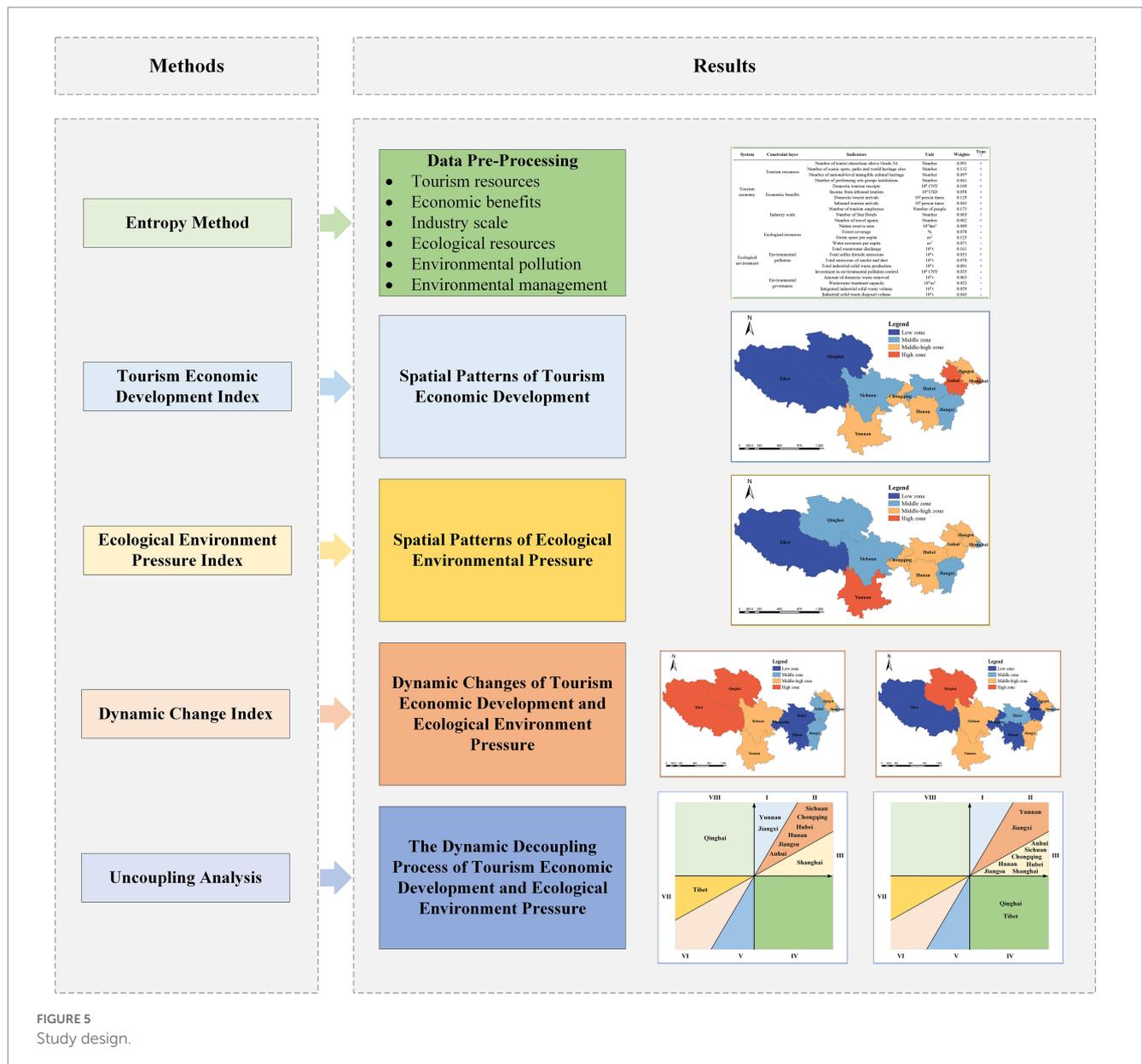


FIGURE 5 Study design.

(Zhu et al., 2022a). Yunnan in the southern part of the basin has a high ecological stress index, is a large population and agricultural province, has a limited ecological carrying capacity, and the situation of environmental protection is still more severe. In conclusion, the ecological status of the upstream provinces in the Yangtze River basin is relatively good, while the ecology of the middle and downstream provinces is under greater pressure, and there is an urgent need to strengthen ecological protection and environmental management.

4.2.2. Dynamic changes of ecological environment pressure

Figure 9 shows the dynamics of ecological environmental pressures in the Yangtze River basin. From 2000 to 2019, the changes in ecological environmental pressure did not show a significant spatial distribution pattern. The provinces with high and middle-high dynamic changes are Qinghai, Sichuan, Yunnan, Jiangxi and Jiangsu. Among them, Qinghai, Sichuan and Jiangxi belong to the category of

ecological environmental pressure with small but large variability, while the other provinces have larger pressure and variability. These provinces are either more ecologically fragile, have more prominent population pressure, or have serious pollutant emissions (Ouyang et al., 2021; Liu Y. et al., 2022), and they need to take diverse measures to strengthen environmental management according to local conditions.

In addition, Chongqing, Hunan and Anhui belong to the low zone of ecological environmental pressure change, and although these provinces have been effective in the management of soil and water conservation, air pollution and other aspects in recent years, compared with other provinces in the basin, their ecological damage problems are still more prominent, and optimization is not large. In the future, they still need to accelerate the promotion of resource-based economic transformation, promote ecological environment improvement and high-quality development by developing high technology and promote industrial structure upgrading.

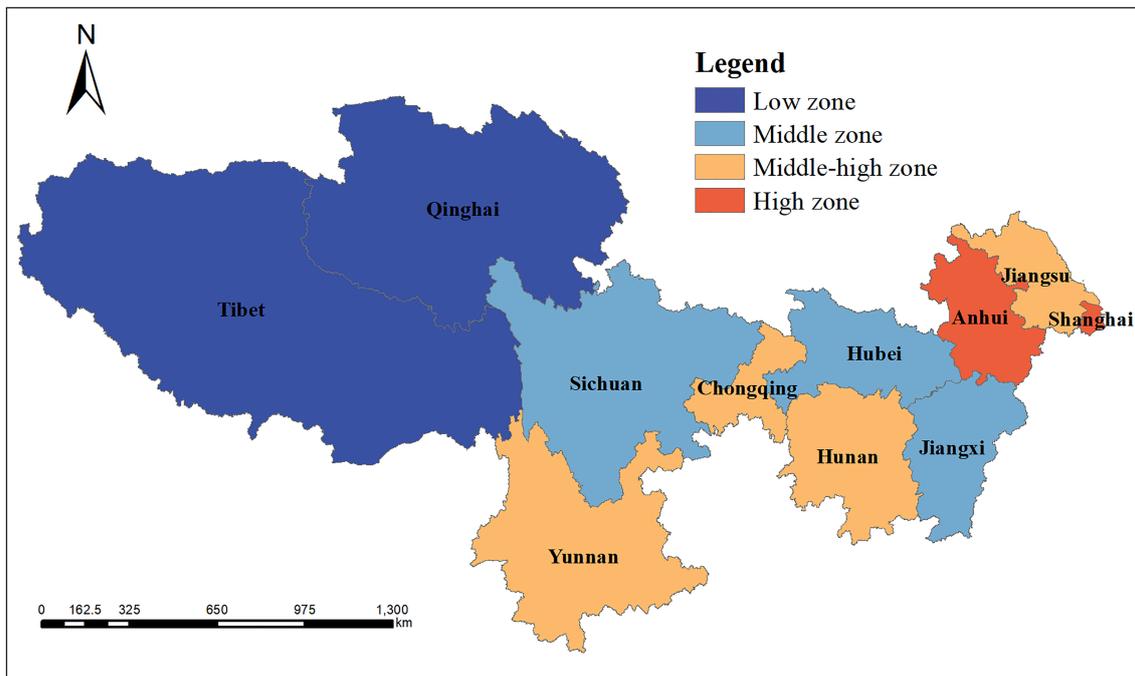


FIGURE 6 Spatial patterns of tourism economic development in the Yangtze River basin.

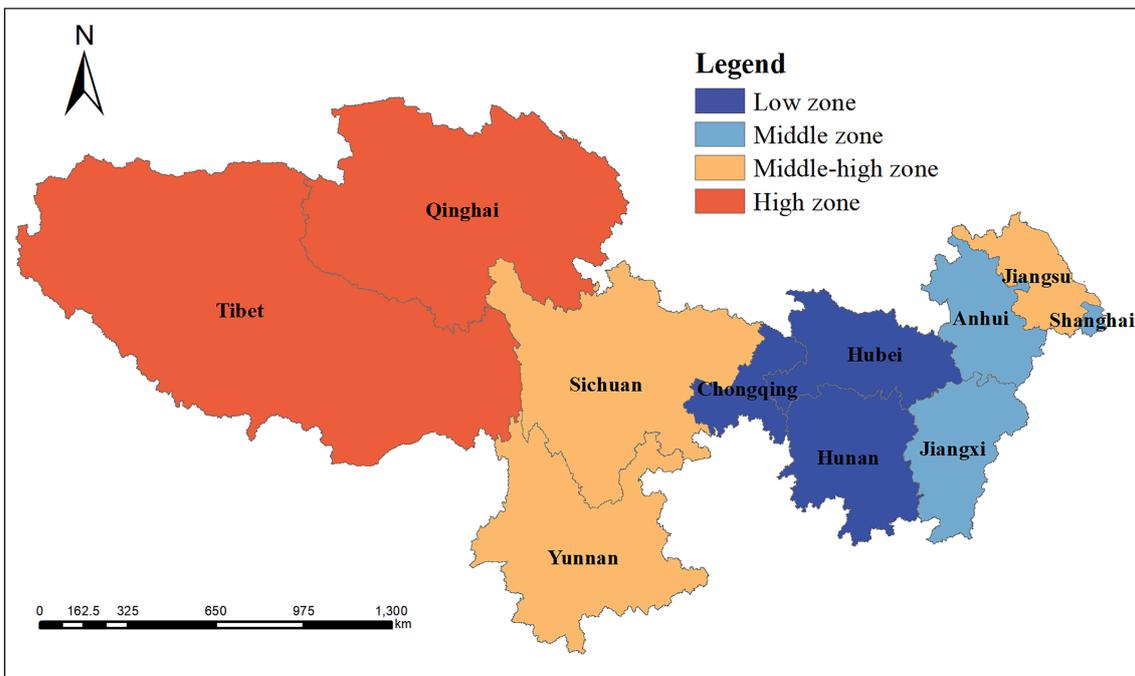


FIGURE 7 Dynamic changes of tourism economic development in the Yangtze River basin.

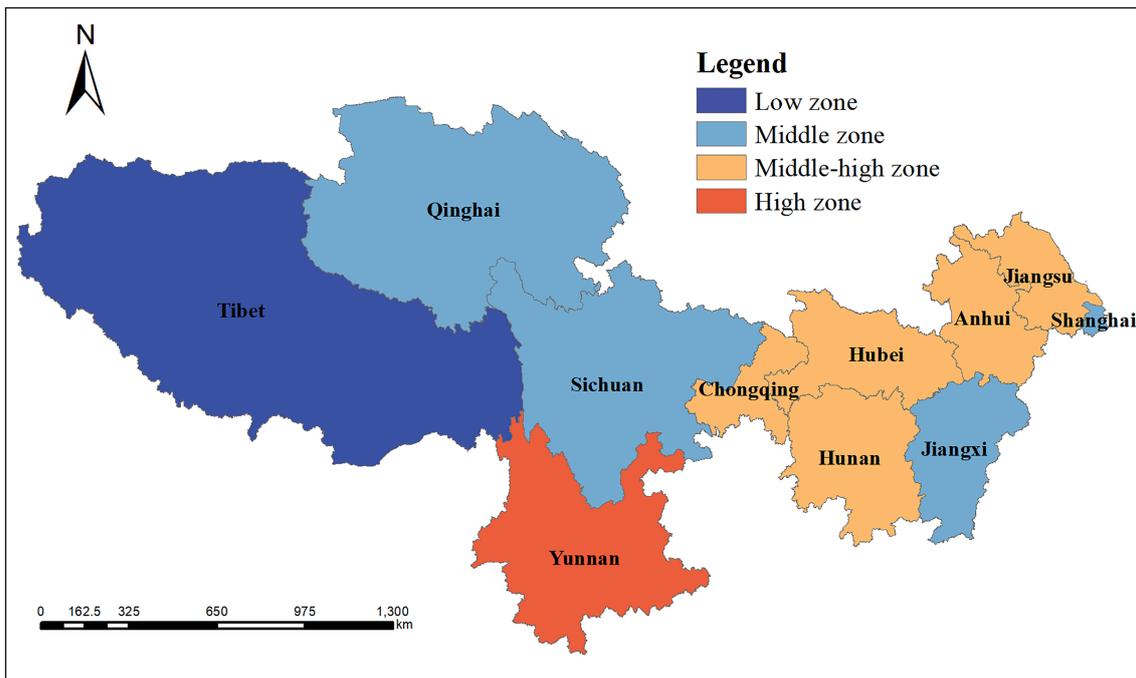


FIGURE 8 Spatial patterns of ecological environment pressure in the Yangtze River basin.

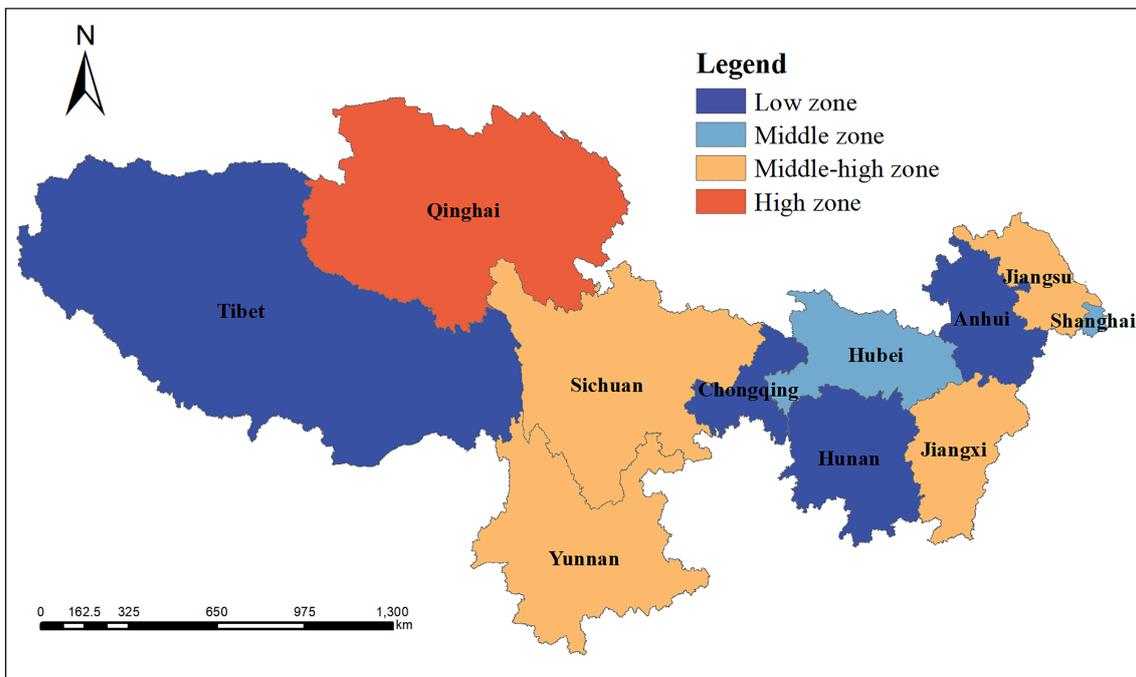


FIGURE 9 Dynamic changes of ecological environment pressure in the Yangtze River basin.

4.3. The dynamic decoupling process of tourism economic development and ecological environment pressure

4.3.1. Period 2000–2009

The study period was divided into two periods for analysis, from 2000 to 2009 (T_1) and from 2010 to 2019 (T_2), using 2010 as the cutoff year. In November 2012, China's central government elevated the construction of ecological civilization to the status of a fundamental national strategy. Since then, China has made unprecedented efforts to protect the ecological environment, further improve the construction of the ecological civilization system, and gradually achieve significant results in ecological environmental management (Luo et al., 2019; Yang R. et al., 2021; Liu H. et al., 2022).

Table 3 shows the decoupling relationship between tourism development and ecological environmental pressure in the Yangtze River basin during the T_1 period, and Figure 10 shows the decoupling states in different provinces. Expansionary coupling (II) is dominant within this period. Sichuan, Chongqing, Hubei, Hunan, Anhui, and Jiangsu all belong to the expansive coupling state, and the ecological environmental pressure increases continuously with tourism economic development, and both increase similarly. The tourism economy in these provinces developed rapidly in this period but mainly relied on natural tourism resources and beautiful ecological environments and did not pay sufficient attention to environmental protection in the process of tourism product development and scenic area construction, which led to the same magnitude increase in regional ecological pressure with the tourism economy.

The decoupling state of Tibet in the T_1 period is weak negative decoupling (VII), i.e., both ecological environmental pressure and tourism economic development are decreasing to some extent, and the decrease in ecological environmental pressure is smaller. Qinghai, which is also upstream of the basin, has a strong negative decoupling (VIII) state, i.e., tourism economic development is decreasing while ecological environmental pressure is also increasing. This indicates that tourism economic development has not been taken seriously in this period, and at the same time, ecological environmental protection

awareness is also very lacking, which leads to the destruction of natural resources and the environment in the process of tourism economic development, thus increasing the pressure on the local ecological environment.

4.3.2. Period 2010–2019

Table 4 shows the decoupling relationship between tourism development and ecological environmental pressure in the Yangtze River basin during the T_2 period, and Figure 11 shows the decoupling states in different provinces. Compared with the T_1 period, the decoupling relationship of the Yangtze River basin in the T_2 period is dominated by the weak decoupling state (III), including Sichuan, Chongqing, Hubei, Hunan, Anhui, Jiangsu and Shanghai. During this period, China's tourism industry was fully integrated into the national strategic system and began to become a strategic pillar industry of the national economy, and the scale of the tourism economy in the Yangtze River basin was expanding with a significant growth trend. In addition, due to the sustainable development of the tourism industry and the general emphasis on ecological protection, the ecological pressure in these provinces has increased to some extent, but the increase is significantly smaller than that of the tourism economy, and a trend of decoupling between the tourism economy and the ecological environment has begun to emerge (Chen et al., 2020; Wu et al., 2021).

It is noteworthy that Shanghai is in a weakly decoupled (III) state in both the T_1 and T_2 periods, indicating that the decoupling relationship between its ecological environment and tourism economy is in a relatively stable and favorable state. In Yunnan and Jiangxi, due to the sustainable development of tourism resources and the integration of cultural and tourism industries, the tourism economy development rate is significantly accelerated in the T_2 period, the ecological environment pressure changes from the previous expansive negative decoupling (I) to expansive coupling (II), and the coupling degree between systems increases. In addition, Qinghai and Tibet show a strong decoupling (IV) state in the T_2 period, i.e., the ecological environment pressure decreases while the tourism economy development level has significantly increased and reaches the ideal system decoupling target, which is more related to the high importance of cultural tourism and ecological environmental protection in Qinghai and Tibet in recent years.

In general, the relationship between tourism economic development and ecological environmental pressure tends to develop in a benign direction in most provinces of the Yangtze River basin from 2000 to 2019, transforming from weak negative decoupling (VII) to strong decoupling (IV) and from expansive coupling (II) to weak decoupling (III), which intuitively reflects that the scale and level of the tourism economy in each province continues to improve while its ecological environment quality has also improved significantly.

5. Discussion

5.1. Main findings

This paper constructs a decoupling analysis system of the tourism economy and ecological environment in the Yangtze River basin from the perspective of spatial and temporal changes, analyzes the dynamic change characteristics of the two systems by using the tourism economic development index, ecological environment pressure index

TABLE 3 Dynamic decoupling analysis of tourism economic development and ecological environment pressure in the Yangtze River basin from 2000 to 2009.

Basin	Province	T_1			Status
		TEDI	EEPI	ϵ	
Upstream	Qinghai	-0.3724	0.2754	-0.7395	VII
	Tibet	-0.3156	-0.0233	0.0738	VII
	Sichuan	0.1198	0.1152	0.9616	II
	Yunnan	0.3563	0.4642	1.3028	I
	Chongqing	0.3993	0.3465	0.8678	II
Midstream	Hubei	0.2531	0.2462	0.9727	II
	Hunan	0.3959	0.3267	0.8252	II
	Jiangxi	0.1032	0.1873	1.8149	I
Downstream	Anhui	0.4532	0.3663	0.8083	II
	Jiangsu	0.3139	0.2732	0.8703	II
	Shanghai	0.4982	0.1358	0.2726	III

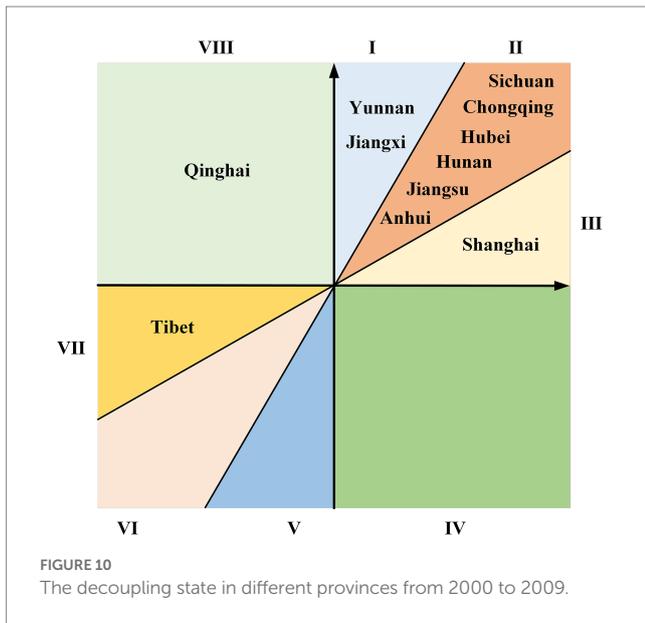


FIGURE 10 The decoupling state in different provinces from 2000 to 2009.

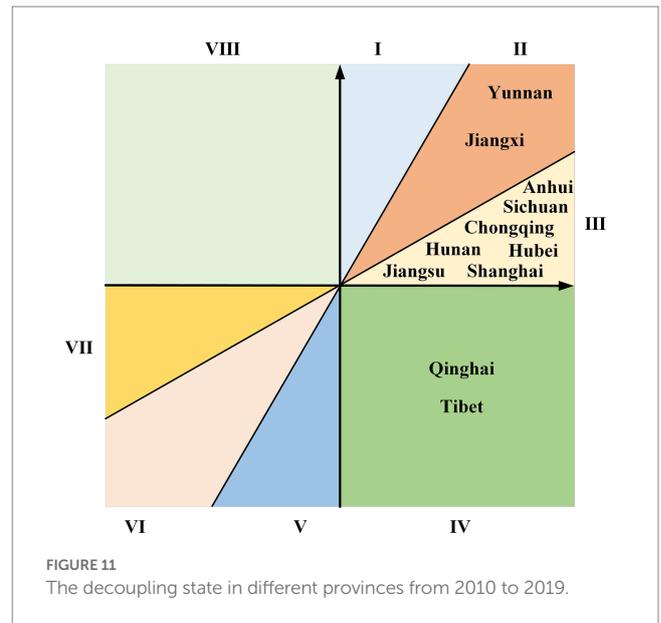


FIGURE 11 The decoupling state in different provinces from 2010 to 2019.

TABLE 4 Dynamic decoupling analysis of tourism economic development and ecological environment pressure in the Yangtze River basin from 2010 to 2019.

Basin	Province	T ₂			Status
		TEDI	EEPI	ε	
Upstream	Qinghai	0.2375	-0.0142	-0.0598	IV
	Tibet	0.2632	-0.0563	-0.2139	IV
	Sichuan	0.4872	0.2134	0.4380	III
	Yunnan	0.6421	0.5754	0.8961	II
	Chongqing	0.5356	0.3872	0.7229	III
Midstream	Hubei	0.4028	0.3092	0.7676	III
	Hunan	0.4760	0.3013	0.6330	III
	Jiangxi	0.2719	0.2905	1.0684	II
Downstream	Anhui	0.6321	0.3976	0.6290	III
	Jiangsu	0.6939	0.4325	0.6233	III
	Shanghai	0.7297	0.2073	0.2841	III

and dynamic change index, and analyzes the decoupling process of the two systems by using a decoupling analysis model. The main findings of this paper are as follows.

1. In terms of the spatial distribution of the two systems, the level of tourism economic development in the Yangtze River basin shows the spatial distribution characteristics of high in the east and low in the west, high in the south and low in the north. The tourism economy in the eastern provinces has been at the leading level, while the western provinces are constrained by various factors, such as the natural environment, resource endowment and economic foundation. In addition, the tourism economic development index of the provinces on the south bank of the Yangtze River is higher than that on the north bank. The spatial distribution of ecological environmental pressure, on the other hand, has significant river segment

variability characteristics, with the upstream provinces having less ecological environmental pressure and overall good natural environmental conditions, while the middle and downstream provinces have higher pressure, and the situation of ecological protection and management is still more severe.

2. In terms of the time course of the two systems, the tourism economy of the western provinces shows the characteristics of change with a lower starting point but faster development, and the scale and speed of development of the tourism industry are outstanding. The degree of change in the eastern provinces, on the other hand, is consistent with the level of tourism economic development, which is medium. The tourism economy development in the midstream provinces shows a higher starting point but little change. In addition, the changes in ecological environmental pressure in the Yangtze River basin do not show a significant spatial distribution pattern.
3. In terms of dynamic decoupling between the two systems, the coupling between tourism development and ecological environmental pressure in most provinces of the Yangtze River basin developed toward benign decoupling from 2000 to 2019. By period, the relationship between the tourism economy and ecological environment is dominated by extended coupling from 2000 to 2009. 2010 to 2019 were dominated by a weak decoupling state, with Qinghai and Tibet showing a desirable strong decoupling state.

5.2. The coupling mechanism of tourism economic and ecological environment

Tourism is a human-centered industry, and tourism activities are an important part of human activities (Camilleri, 2018). Ecology is a geographical environment in a narrow sense, and the human-earth relationship is the root of the study of the coupling of the tourism economy and ecology and is an important approach to achieving sustainable regional development (Roberts et al., 1998). In this paper,

the tourism economy and the ecological environment are considered an open system that interact and constrain each other.

In terms of the role of tourism development on the ecological environment, on the one hand, tourism development has a positive role in promoting ecological environmental protection. Economic growth can effectively promote technological progress. As a national pillar industry, tourism development brings economic benefits that can promote regional economic growth and provide more financial support for ecological environmental protection. At the same time, the economic benefits of tourism promote technological changes in the tourism industry, and technological advances in the tourism industry can optimize the allocation of tourism resources and reduce the consumption of natural resources in the process of resource development (Katircioglu et al., 2018; Pueyo-Ros, 2018). On the other hand, tourism is a comprehensive industry with strong correlation; the act of tourism brings about regional movements of people, services, and transportation, and the crowd effect brought about by the movement of people, the wastewater, solid waste, and domestic waste produced by the tourism service sector represented by hotels and scenic spots in the service process, and the exhaust gas generated by the movement of tourism traffic can cause great pressure on the ecological environment (Priatmoko et al., 2021; Mallinguh et al., 2022; Wicaksono and Illes, 2022). In addition, the tourism economic benefits brought by tourism induce enterprises to blindly develop tourism resources in pursuit of maximizing economic benefits, which will also have a coercive effect on the ecological environment.

In terms of the role of the ecological environment on tourism development, on the one hand, tourism is a resource-dependent industry, a good ecological environment is the basis and guarantee for its development, and a good ecological environment is a resource with economic value for tourism. A beautiful natural environment is an indispensable capital input in the economic output of tourism (Lakner et al., 2018; Khan M. A. et al., 2020; Mihalic et al., 2021; Priatmoko et al., 2021). At the same time, tourism is an externally dependent industry, and a good ecological environment provides strong support for tourism services, attracts tourists, increases tourist satisfaction, increases the rate of repeat visits, and brings good economic benefits to tourism development (Olya et al., 2019). On the other hand, the limited ecological carrying capacity can have a constraining effect on tourism development. Once tourism exceeds the ecological carrying capacity in the development process, tourism activities will cause great damage to the ecological environment, leading to a decrease in the environmental support capacity of the scenic area and inhibiting or even reversing tourism development (Wall, 2020).

In the system of tourism economy and ecological environment, the development of tourism resources, tourism behavior brings people, traffic flow and various kinds of waste generated by the local pristine ecological environment has a huge pressure, and the ecological environment state changes in turn affect the tourism activities and ecological benefits, and then through the external government's environmental protection policy, awareness and behavior change to respond to these changes, forming a tourism economy and The "pressure-response" coupling relationship between tourism economy and ecological environment. The harmonious symbiosis between the tourism economy and ecological environment depends on the healthy coupling of all system elements to achieve the sustainability of the whole region.

5.3. Policy recommendations

To achieve sustainable development in the Yangtze River basin, the following policy recommendations are made based on the main findings of this paper:

1. Transform the tourism development mode and improve the tourism eco-efficiency of the Yangtze River basin. Gradually abandon the linear development mode characterized by high energy consumption, high pollution and low revenue and form a green development mode characterized by low consumption, low pollution and high revenue. The provinces in the Yangtze River basin should develop green, low-carbon and energy-saving tourism products, such as ecotourism and recreation tourism, to reduce the carbon footprint of tourists and the total regional carbon emissions.
2. Strengthen interprovincial cooperation within the basin to protect the ecological environment of the whole basin. There is significant spatial heterogeneity in the tourism economy and ecological environment of the Yangtze River basin. This spatial variation mainly comes from internal differences in the upper, middle and lower reaches. Therefore, governments in the Yangtze River basin should strengthen external cooperation and internal communication. The downstream region should give full play to its technical and management advantages and promote the transformation of tourism development in the midstream and upstream regions through resources such as knowledge, capital and talent. Other provinces should actively learn advanced technology and management experience to continuously reduce the differences in tourism eco-efficiency within the basin.
3. Adjust the tourism development strategy and promote the synergistic development of the tourism economy and ecological environment. The tourism economy and ecological environment can promote each other to a certain extent; therefore, the provinces in the Yangtze River basin should expand the scale of the tourism industry, give full play to the incremental effect of scale payoff, and provide economic support for the low-carbon transformation of the regional tourism industry. At the same time, they must also give full play to the positive guiding effect of the ecological environment and provide more high-quality tourism resources for the development of the regional tourism economy through environmental protection projects to finally realize the coupled and coordinated development of the tourism economy and ecological environment.

5.4. Limitations and future work

The relationship between the tourism economy and ecological environment is a highly contemporary and forward-looking scientific issue, and how to promote the two systems from coupling to decoupling and from conflict to synergy is a topic of great interest to scholars worldwide. As an important economic, ecological and tourism belt in China, the economic development and ecological protection of the Yangtze River basin are of great significance to achieving regional sustainability.

This paper focuses on the spatial and temporal dynamic characteristics of the tourism economy and ecological environment in the Yangtze River basin, which to a certain extent makes up for the shortcomings of previous literature and can provide a basis for decision-making on sustainable regional development. This paper has the following limitations:

1. Considering the availability of data, this paper focuses on the decoupling relationship between the tourism economy and ecological environment in the provincial administrative units of the Yangtze River basin, and the research scale can be further narrowed down to the municipalities or counties in the basin in the future.
2. This paper divides two time periods by 2010, and future work can expand the range of years and divide more periods to study the dynamic relationship between the tourism economy and ecological environment more carefully.
3. The influencing factors and driving mechanisms of the coupled system can be further quantified in the future by using geographic probes, gray correlation analysis, multiple regression models, etc.

6. Conclusion

This paper takes the Yangtze River basin as the study area, analyzes the coupling mechanism between tourism development and the ecological environment, constructs a decoupling analysis system, and quantitatively measures the spatial, temporal and dynamic characteristics of tourism development and the ecological environment in the Yangtze River basin from 2000 to 2019. The conclusions of this paper are as follows.

We developed an analysis system to examine the decoupling of tourism economic development and ecological environmental pressure in the Yangtze River basin. The system is based on two systems: the tourism economic system and the ecological environmental system. It includes six dimensions: tourism resources, economic benefits, industry scale, ecological resources, environmental pollution, and environmental management, and is comprised of 24 specific indicators.

In terms of the spatial distribution of the two systems, the tourism economic development level of the Yangtze River basin shows the spatial distribution characteristics of high in the east, low in the west, high in the south and low in the north. Anhui and Shanghai in the east have led the tourism economic development level, while Tibet and Qinghai in the west are constrained by various factors, such as the natural environment, resource endowment and economic foundation. In addition, the tourism economic development index of the south bank provinces of the Yangtze River, such as Yunnan, Chongqing and Hunan, is higher than that of Sichuan, Hubei and Jiangxi in the north bank. The ecological environmental pressure in the Yangtze River basin has significant river segment variability, with Tibet, Qinghai and Sichuan in the upstream facing less ecological environmental pressure and overall healthy natural environmental conditions, while Chongqing, Hubei, Hunan, Anhui and Jiangsu in the midstream and downstream are under great pressure.

In terms of the time course of the two systems, the tourism economies of Qinghai and Tibet started from a lower but faster development, and the scale and development speed of the tourism industry is outstanding. The change trend in Anhui, Jiangxi and Shanghai is consistent with the tourism economy development level, which is medium. Hubei, Hunan and Chongqing have higher starting points, but the changes are not significant. In addition, the changes in ecological pressure in the Yangtze River basin did not show a significant spatial distribution trend. Qinghai, Sichuan, Yunnan, Jiangxi and Jiangsu show large variations, while Tibet, Chongqing, Hunan and Anhui show small variations.

In terms of the dynamic decoupling between the two systems, from 2000 to 2019, the relationship between tourism development and ecological environmental pressure in most provinces of the Yangtze River basin tended to develop benignly, shifting from weak negative decoupling to strong decoupling and from expansive coupling to weak decoupling. By period, from 2000 to 2009, the relationship between the tourism economy and ecological environment was dominated by expansionary coupling, and from 2010 to 2019, it was dominated by weak decoupling, and Qinghai and Tibet showed an ideal strong decoupling state.

To achieve sustainable development in the Yangtze River basin, this paper proposes some policy recommendations from the perspectives of the tourism development model, interprovincial cooperation and development strategy.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

KZ: conceptualization, methodology, visualization, formal analysis, data curation, resources, writing—original draft, and writing—review and editing. QZ, YC, YZ, TL, and XY: data curation, resources. AA and EF: validation. LD: funding acquisition and supervision, and writing—review and editing. All authors contributed to the article and approved the submitted version.

Funding

This research was supported by the Hungarian University of Agriculture and Life Sciences (MATE) and the Stipendium Hungaricum Scholarship.

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.

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