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Article

Spatial Differences and Drivers of Tourism Ecological Security in China's Border Areas

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Abstract: Tourism activities generally have a ∩-type lock on the level of tourism ecological security in an area, but when applied to the border areas of China, there are certain specificities in the spatial evolution of tourism ecological security (TES) compared to traditional findings. This paper measures tourism ecological security in China's border areas from 2009 to 2020 by using the DPSIR model with the superefficient SBM-DEA and analyzes the spatial differences, evolutionary characteristics, and driving factors of tourism ecological security in border areas by using Pearson's correlation coefficients, center of gravity models, and geographic probes: (1) The overall tourism ecological security index of China's border provinces is relatively good. Tourism activities do not completely affect the traditional "∩ lock" of the border provinces. The tourism ecological security level of the border provinces presents three spatial-temporal changes ("∩" type, "U" type, "\" type) and four evolution trends ("high–high–high", "middle–middle–medium", "medium–low–low", and "low–low–low"). (2) The overall tourism ecological security level in border areas is polarized between high and low levels, and the ecological security efficiency of the three large areas is spatially characterized as "Southwest Area > Northeast Area > Northwest Area", and the center of gravity of ecological security is mostly concentrated in Xinjiang, Tibet, and Neimenggu, where the ecological security level is higher. (3) Social and environmental factors are the main factors that influence tourism ecological security in border areas, while economic factors account for a smaller proportion. Accordingly, this thesis also proposes the driving mechanism of the ecological security of tourism sites in border areas in China with a view to providing theoretical support for policy formulation.

Keywords: border areas; tourism ecological security; spatial evolution; drivers

1. Introduction

Ecological security is a condition whereby people's ecological system is stable and resilient, and the ecological environment on which a nation depends for its life and development is unharmed, or is less in danger of being damaged[36]. It has a direct bearing on people's wellbeing as well as on the long-term health of the economy and society[9]. It has an immediate effect on people's wellbeing as well as long-term economic and social growth. As important areas between one's own country and neighboring countries, border areas are crucial for the preservation of the environment, economic development, cultural exchange, and national security. Under "the Belt and Rode", "Western Development", "Cross-Border Economic Cooperation Zone", "Border Tourism Experimental Zone", and other measures and policies, the border areas are advocated for and promoted in China.

Three major border tourism zones in the northeast (Heilongjiang, Jilin, Liaoning, and Inner China), northwest (Gansu and Xinjiang), and southwest (Tibet, Yunnan, and Guizhou) have been formed[34]. In 2020, China issued the document "Chinese Important Ecosystems Protection and Restoration Major Project Master Plan (2021~2035)", which, from a macroperspective of geography and space for the "Qinghai–Tibet Plateau Ecological Barrier Area", "Loess Plateau–Chuan–Yunnan Ecological Barrier Area", and "Northeast Forest Belt", which involve border areas. The "Northeast Forest Belt" and the "Northern Anti-Sand Belt" have been laid out from a geospatial perspective. Due to the environmental dependence of tourism activities, in the context of the increased importance of

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sustainable tourism development and ecological security, one of the divisions of regional ecological security is now tourism ecological security, a stable and secure security environment that supports the regular functioning of tourism ecosystems, as well as being a crucial metric for assessing the tourism industry's sustainable growth in the area[26,27]. It is also a significant indicator of the tourism industry's ongoing development in the area.

Although tourism activities in China's border areas were strictly controlled at the beginning of the new crown epidemic, since the World Health Organization downgraded the global risk level of the new crown and the successive introduction of China's Border Tourism Management Measures, the "New Ten Articles on Epidemic Prevention and Control", and the "New Entry and Exit Management Measures", China's border provinces, such as Xinjiang, Yunnan, and Tibet, have become popular tourism destinations with explosive growth in the number of travelers. At present, the border provinces have been the first of many destinations to recover in terms of tourism development, with huge market demand. Nevertheless, recently, the expansion of tourism in border areas has been greatly constrained by the specificity of the geographical space in which they are located, the sensitivity of bilateral political relations, their reliance on tourism, and the vulnerability of their own natural systems, while the mobility of tourism activities also poses corresponding challenges for border areas that function as ecological barriers. Therefore, it is urgent and necessary to explore the implementation measures for the successful expansion of tourism in border areas and the sustainable development of the regional ecological environment, according to an evaluation of the degree of ecological security for tourism in border spaces.

2. Review of the Literature

The ecological security of border areas and the inter-relationship between border development and ecological security have received extensive attention from the academic community, and the research results are rich and mature, involving the internal structural nature of the border area ecosystems themselves [16,24,39],vulnerability[3,10,11], and restoration [3,4,40], and the interference[14,19,38], support[41], and services [13,32] generated by the interaction between ecosystems and human society. The evaluation method is mainly based on 3S technology, the PSR (Pressure-State-Response) model, and index system construction [8,9]as well as gray correlation analysis[20,21], the DPSIR model[18,42], ecological footprint analysis[2007], and CA prediction models[7]. This research is carried out at all geographical scales.

Due to the pressure on ecological protection brought on by multidirectional flows and exploitation in geographic space, tourism activities have significant impacts on regional economic development and the ecological environment. Empirical studies on tourism ecological security at various scales of tourism geographic space have drawn attention based on the more developed research framework in the field of ecological security. Yang and Weng et al. studied tourism ecological security in Hubei province and five provinces along the Belt and Road and carried out simulations of tourism ecological security in different contexts and evaluated the change process of the tourism ecological security level within the area[35,39]. The Chengdu–Chongqing urban agglomeration, a developed inland economy, was chosen by Xiao et al. as their research region. They examined the degree and geographical development of tourism ecological security in these cities using systematic assessment and spatial statistical techniques.[37]. Ruan, Ma, and Cheng, on the other hand, started with the Yangtze, Yellow, and Han River basin areas, where ecological vulnerability is strong and used indicator systems and single ratios to measure tourism ecological security in basin-like barrier areas, covering the spatial consistency analysis of tourism ecoefficiency and safety, spatial, and temporal changes in ecological security levels and development predictions, and pointed out the close proximity of geographical space in the region. It was also pointed out that the close spatial proximity of the area causes the internal drivers of tourism ecological security show correlations and the spatial spillover phenomenon[5,22,27]. It was also pointed out that the close spatial proximity of areas has led to the phenomenon of correlation and spatial spillover of the internal drivers of tourism ecological security. Firstly, the growth of tourism activities affects regional ecological security and produces a "∩-type" lock in the development of local ecological security;

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hence, the answer to the question of whether tourism activities influence local ecological security is yes. Typically, the level of tourism ecological security is trapped in a ∩-shaped evolutionary path of initial construction damage (low)—medium-term ecological recovery (high)—late development damage (low). Secondly, the degree of regional economic growth is correlated with the amount of tourism ecological security. Third, the main factors affecting tourism ecological security involve multiple areas, such as each region's own environment, economy, and society, presenting a more complex set of internal influences.

Despite the above consensus in empirical research on tourism ecological security regarding the ecological protection of tourism in this region of China's border territories, the following issues need to be investigated: Firstly, does the development of tourism activities in border areas also impact regional tourism ecological security? Most previous studies have focused on ecologically sensitive areas in close geographical proximity with strong spatial linkages, developed inland economies, and obvious policy orientations, but no systematic measurement of tourism ecological security has been made for border areas, which are special areas with low spatial proximity, initial tourism development, simple forms of development, and backward economic levels. Secondly, for border regions with ecological security, has the geographical and temporal evolution followed a particular pattern? Does the degree of ecological security in tourism in border areas show the traditional "∩-type" path locking, or does it differ due to the specificity of the geographical location, ecological environment, planning layout, and governance policies? In the context of the dual ecological pressures at home and abroad and the strong recovery of tourism in border areas, there are gaps in research on the degree of tourism ecological security in border areas, the influencing factors, and the driving mechanisms. These are crucial foundations for future use in the development of ecological protection policies and to guide the growth of tourism in border areas.

In summary, this paper, guided by sustainable development and national security, although still starting from a spatial evolutionary perspective in a general sense, combines the very effective SBM-DEA model with the DPSIR model to estimate the development degree of tourism ecological security in China's border areas from 2009 to 2020. Using nine additional border provinces as the study subjects, it analyzes the evolutionary changes and spatiotemporal aspects of their tourism ecological security using the Pearson's correlation coefficient and ArcGIS technologies. Based on the results of the geographic detector's exploration of the factors influencing spatial differentiation, we expect to conduct a new exploration and analysis of the above three issues and make an effort to build a driving mechanism for ecological security in tourism in China's border regions, which will be helpful for the long-term growth of the tourism ecological environment on the border and the ecological security governance in each area. It is hoped that the above three issues can be explored and analyzed in a new way.

3. Data Sources and Research Methods

3.1. Overview of the Study Area

The nine land border provinces of China are the focus of this study's examination of border area tourism and ecological security, the main research area is shown in Figure 1 With 22,800 km of land borders with 14 neighboring countries, such as North Korea, Russia, Mongolia, Laos, and Vietnam, the front lines of China's openness to the outside world are the border areas. The rich natural scenery of plateaus, deserts, grasslands, and rainforests, along with the diverse ethnic culture and the exotic and special border landscapes of the border areas, have allowed tourism activities to emerge, develop, and gradually become a significant strategy for advancing the area's social and economic development. This paper, therefore, examines, in depth, the issues related to the ecological security of tourism in this highly representative geographical space.

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Figure 1. Study area.

3.2. Construction of an Evaluation System Based on the DPSIR Model

The ecological security system of tourism activities is a complex system with complexity, hierarchy, and comprehensiveness, so this paper uses the comprehensive and logical DPSIR model framework as a reference [6]. It creates an index system for evaluating the special tourism ecological security system in China's border areas [30].The DPSIR model is a framework with five subsystems, drivers, pressures, states, impacts, and responses, and it uses the connections between travel operations and the ecological environment as a way to efficiently find beneficial ecological regulation in complicated scenarios as well as assessing the advancement of each area's ecological security23. The paper also incorporates the superefficient SBM ecological model. The paper also combines the input and output constructs of the superefficient SBM-DEA model to measure the level of ecological security of tourism sites in border areas and refines 15 primary indicators and 32 secondary indicators, including inputs, desired outputs, and nondesired outputs as a measurement and evaluation system with reference to the indicators in the relevant literature and factors unique to border areas, as shown in Table 1.

Table 1. Indicator system for TES in China's border areas.

Dimensional Layer	System Layer	Evaluation Index	Measuring Unit
Driver (D) (input)	D1 Economic driver (in.)	X1 GDP per capita	yuan
	D2 Social driver (in.)	X2 Urbanization rate	%
		X3 population	10,000 people
		X4 Total number of visitors	10,000 people
	D3 Environmental driver (in.)	X5 Graded highway mileage	km
		X6 Urban Park green space	hectare
		X7 Number of ports	a
		X8 Number of 5A scenic spots	a
pressure (P) (output)	P1 Economic pressure (ex.)	X9 Water consumption per ten thousand yuan of the GDP	m3/10,000-yuan GDP
	P2 Social pressure (ex.)	X10 Tourist density	/
		X11 Population density	person/km²
	P3 Environmental pressure (N-ex.)	X12 Tourism space density	person/km²
State(S) (output)	S1 Economic state (ex.)	X13 Gross tourism income	100 million yuan
		X14 The proportion of the tertiary industry in GDP	%
	S2 Social state (ex.)	X15 Tourist traffic reception capacity	km/10,000 people
		X16 Number of star hotels	a
		X17 Number of travel agencies	a
	S3 Environmental state (N-ex.)	X18 Solid waste production per unit area	t/km²
		X19 Sulfur dioxide emissions per unit area	t/km²
		X20 Discharge of wastewater per unit area	t/km²

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Impact(I) (output)	I1 Economic impact (ex.)	X21 Per capita tourism income	yuan/person
		X22 Economic density of tourism	yuan/km²
		X23 Contribution of tourism to the GDP	%
	I2 Social impact (ex.)	X24 Social product realization depth coefficient	/
	I3 Environmental impact (ex.)	X25 Green coverage of built-up areas	%
		X26 Nature reserve area	10,000 hectares
Response(R) (input)	R1 Economic response (in.)	X27 Educational expenditure	100 million yuan
		X28 Budget support for energy conservation and environmental protection	100 million yuan
	R2 Social response (in.)	X29 The proportion of tertiary industry employees in employment	%
		X30 Number of college graduates	10,000 people
	R3 Environmental response (in.)	X31 Rate of centralized sewage treatment	%
		X32 Harmless treatment rate for household garbage	%

Driving forces (D), as the main input elements during the building of tourism ecological security, include the three main aspects of tourism in border areas: economic, social, and environmental drivers. As the initial driver of tourism development in border areas, economic development promotes the optimization of the social environment and an increase in tourism demand, so specific indicators include the GDP per capita and urbanization rates, which represent the productive and creative capacities of local residents and the level of economic development; the total number of tourists received, which represents the number of people and tourist arrivals at the regional labor level; the area of urban parks and green spaces, which represents the level of attraction and turnover of tourism activities in the area; the number of scenic spots; the number of miles of graded roads; and the number of special border crossings.

Pressure (P) refers to the different types of social, economic, and ecological pressures faced by tourism ecosystems in border areas after the impact of the driving forces. As output elements, they include water consumption of 10,000 Yuan GDP, which reflects the degree of resource demand for tourism GDP growth, the population density, and the tourism spatial density in terms of the regional population and tourist and land carrying capacity and the tourist density in terms of the ratio of tourists to the regional population.

State (S) refers to the actual situation and output elements presented by the tourism ecology of the border area under the activity of regional pressures, including the social state, economic state, and environmental state. The specific indicators are the total tourism revenue and the proportion of the tertiary sector in the GDP, which represents the economic benefits of regional tourism; the transport reception capacity; the number of hotels and travel agencies, which represents the various types of reception capacity at the social level; and the emissions of three wastes, which represents an undesired environmental state.

Impact (I) refers to the combined effect on the level of regional tourism ecological security and socioeconomic dimensions in the process of tourism development in border areas, equally involving economic, social, and environmental impacts. As the main desired output category, the higher the value is, the more favorable it is to the achievement of a safe and stable level of tourism ecology in border areas. The specific indicators of economic impact include the tourism income per capita, which represents the economic benefits of tourism for the population of the area; the tourism economic density, which represents the relationship between tourism income and the carrying capacity of the area; and the contribution of tourism to GDP, which represents the effect of tourism development on the gross regional product. The specific indicators of social impact include the depth of the social product realization coefficient, which represents the level of labor conversion, and the environmental impact, which represents the level of the green environment. The environmental impact is based on the greening coverage of the built-up area and the area of the nature reserve representing the level of regional ecological and environmental protection.

Response (R) is the direct response and specific input of the tourism ecosystem in border areas to the society, economy, and environment under the combined effect of a series of measures. Specific indicators include education expenditure and energy saving and environmental protection budgets, which represent the level of regional support for talent cultivation and environmental protection; the

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number of university graduates and the proportion of tertiary sector workers to employed workers, which represent the level of social return from regional talent; and the rates of centralized sewage treatment and harmless domestic waste treatment, which represent the level of implementation of regional environmental protection infrastructure measures.

3.3. Data Sources

The China Statistical Yearbook, the China Environmental Statistical Yearbook, the China Ports Yearbook, the statistical bulletins on national economic and social development of each area, and government work reports on official government websites were used to collect the statistical data needed for this study. Some missing data were filled in using the data fitting method of linear interpolation.

3.4. Research Methodology

3.4.1. SBM-DEA Evaluation Model

Traditional DPSIR models do not fully assess the mechanisms of action and efficacy of circulation that exist within the tourism ecology. Instead, they concentrate on assessing the growth of the different players in regional tourism ecological security. Efficiency is the best metric to determine whether tourism sites are having the best effects while using the least resources and causing the least damage to the environment [25]. Additionally, it serves as the foundation for the creation and application of policies and practices for sustainable development[28]. For the purpose of determining the system's actual operating status and assessing it realistically in China's border areas, the Super-SBM evaluation model, which is optimized for SBM evaluation, is referred to in the research methodology. It focuses on the efficiency measures of the inputs and outputs while allowing unit rate values ≥ 1 on the basis of unexpected outputs, dealing with the issue of the nonzero relaxation of inputs or outputs with unexpected results[33]. It is calculated as shown in (1):

$$\begin{cases} minp = \left(1 - \frac{1}{m}\sum_{i=1}^{n}\frac{s_i^-}{x_{ik}}\right) / \left[1 + \frac{1}{q_1+q_2}\left(\sum_{r=1}^{q_1}\frac{s_r^+}{y_{rk}} + \sum_{r=1}^{q_2}\frac{s_i^{b-}}{y_{ik}}\right)\right] s_t t. \\ x_k = X\lambda + s^-, y_k = Y\lambda - s^+, b_k = b\lambda + s^{b-} \\ \lambda \geqslant 0, s_i^- \geqslant 0, s_r^+ \geqslant 0, s_1^{b-} \geqslant 0 \end{cases} \quad (1)$$

where p is the efficiency value of tourism ecological security for each area at the border. m, q_1, and q_2 are the number of indicators generated for each area based on the indicator construction of the inputs and desired and undesired outputs, respectively. x_k, y_k, and b_k denote the input, output, and undesired output variables for each area, respectively. x_{ik}, y_{rk}, and y_{tk} are the elements of the input and output vectors for each area. X, Y, and b are input–output matrices for each region; si^-, si^+, and $s_1{}^{b-}$represent the relaxed variables of the inputs and expected and unexpected outputs in the calculation of the ecological security efficiency in each region. λ represents column vectors[29].

3.4.2. Pearson's Correlation Coefficient

The Pearson's correlation coefficient is mostly used to measure the similarities or correlations among system structures over time[1]. This paper analyzes the evolutionary state of the level of ecological security of tourism in border areas based on its measurement results, calculated as shown in (2):

$$P_k = \frac{n\sum x_i y_i - \sum x_i y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2} \times \sqrt{n\sum y_i^2 - (\sum y_i)^2}} \quad (2)$$

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where P_k denotes the tourism ecological security correlation coefficient of area k at stage x and stage y. x_i, y_i denotes the value of indicator i of area k at stages x and y. n represents the number of indicators measured.

3.4.3. Center of Gravity Model

The center of gravity is covered in both mathematics and physics, emphasizing the intersection of points and the integration of forces acting on space [17]. This paper uses it to measure the migration trajectory of tourism ecological security in border areas in terms of the spatial location, calculated as shown in (3):

$$Lon = \sum_{i=1}^{n} M_i Lon_i / \sum_{i=1}^{n} M_i$$
$$Lat = \sum_{i=1}^{n} M_i Lat_i / \sum_{i=1}^{n} M_i \quad (3)$$

where Lon and Lat represent the longitude and latitude of the center of gravity. Lon_i, Lat_i represent the longitude and latitude of the center of gravity of the i_{th} area. M_i represents the ecological security level of the i_{th} area.

3.4.4. Geodetectors

The geodetector principle is to analyze the extent to which factor Xi explains the spatial differentiation of attribute Y and to use the explanatory power q for the dominant representation[15]. This is calculated as shown in Equation (4):

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \quad (4)$$

where h = 1,...,L is the stratification of variable Y or factor X, i.e., the classification or partition. Nh and N are the numbers of cells in stratum h and the whole area, respectively. σ2h and σ2 are the variance of Y values, i.e., the level of safety in each area for stratum h and the whole area, respectively. If the stratification is generated from a series of indicators affecting spatial differences in tourism ecological security in border areas, a larger value of q indicates a stronger explanatory power for the independent variable X for attribute Y.

4. Analysis of the Empirical Results

4.1. The Spatial Evolution of Tourism Ecological Security in Nine Border Provinces

The tourism ecological security efficiency values of China's border provinces from 2009 to 2020 are all greater than 1, indicating that the overall tourism ecological security index in the border areas is better developed, and the process of tourism activities does not show a more obvious negative trend (Table 2). This is based on the results of the superefficient SBM-DEA model, which were used to obtain the results for the tourism ecological security efficiency in nine provinces in China's border areas from 2009 to 2020. There is no more blatant evidence of a detrimental influence on the ecological security of regional tourism during the growth process of tourism activities.

Table 2. TES efficiency in nine Chinese border provinces.

Year	Heilongjiang	Jilin	Liaoning	Neimenggu	Guangxi	Yunnan	Tibet	Xinjiang	Gansu
2009	1.121	1.236	1.254	1.452	1.183	1.443	1.599	1.236	1.143
2010	1.054	1.103	1.199	1.288	1.185	1.415	1.756	1.184	1.096
2011	1.081	1.302	1.174	1.233	1.176	1.359	3.074	1.121	1.047

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2012	1.067	1.051	1.125	1.237	1.197	1.265	2.422	1.302	1.065
2013	1.043	1.134	1.185	1.248	1.172	1.350	3.321	1.144	1.045
2014	1.056	1.142	1.257	1.253	1.184	1.341	3.125	1.179	1.020
2015	1.042	1.165	1.184	1.253	1.164	1.311	3.350	1.088	1.020
2016	1.059	1.170	1.125	1.234	1.105	1.260	2.479	1.214	1.028
2017	1.081	1.180	1.137	1.335	1.153	1.276	3.013	1.068	1.041
2018	1.163	1.289	1.149	1.315	1.162	1.200	1.737	1.182	1.077
2019	1.151	1.446	1.119	1.300	1.163	1.108	1.851	1.188	1.039
2020	1.117	1.322	1.115	1.661	1.386	1.129	1.975	1.215	1.040

A visual comparison analysis of the spatial and temporal evolution of tourism ecological security from the tourism ecological security index for the 12-year period between 2009 and 2020 (Figure 2) revealed that the level of tourism ecological security changes more obviously in each border province and area under the development of tourism activities, with the dominant areas being primarily concentrated at the northern border and western border. In 2009, the higher tourism ecological security indices in China's border provinces were found in Tibet, Neimenggu, and Yunnan with a value range of [1.255, 1.600], followed by Xinjiang, Jilin, and Liaoning with a value range of [1.184, 1.254], and the lowest tourism ecological security indices were found in Gansu and Heilongjiang with a value range of [1.120, 1.183]. In 2020, the tourism ecological security index range shifted from [1.120, 1.600] in 2009 to [1.039, 1.980], while four of China's nine border provinces—Tibet, Gansu, Neimenggu, and Jilin—remained unchanged relative to the overall regional tourism ecological security index level. Yunnan shifted from a relatively high area to the lowest area, and the border provinces in the next highest tourism ecological security level shifted to Guangxi and Liaoning with a numerical area of [1.216, 1.386], while the provinces with relatively low ecological security indices were Yunnan, Xinjiang, Gansu, Heilongjiang, and Liaoning with a numerical area of [1.039, 1.215].

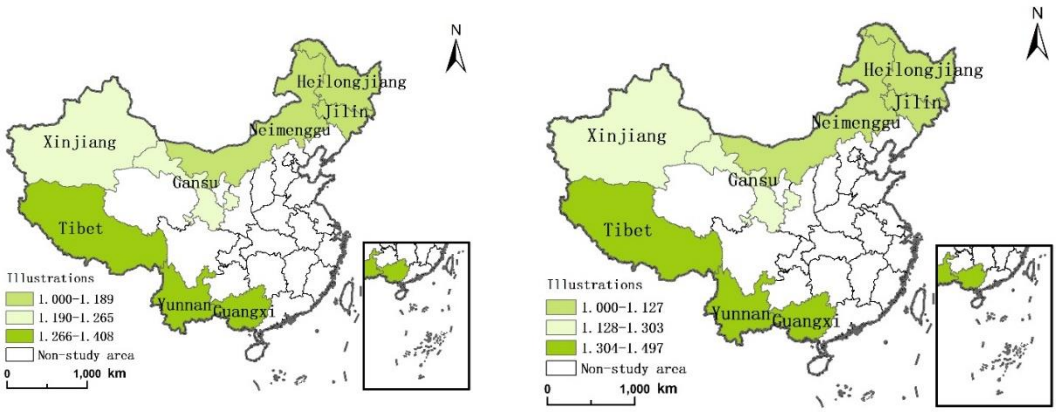

Figure 2. Evolution of TES in nine border provinces.

In terms of dynamic evolution, the spatial evolution pattern and characteristics of tourism ecological security in the nine border provinces derived from the natural breakpoint zoning were further collated into three stages of tourism safety ecological grade trends in the early (2009–2012), middle (2013–2016), and late (2017–2020) stages, and the tourism ecological security grade and structural changes for China's border provinces under the influence of tourism activities was identified. As shown in Table 3 the characteristics of change show four types: high–high–high, medium–middle–middle, medium–middle–low, and low–low–low. The structural changes represented by Pearson's correlation coefficients are similar in all stages, indicating the existence of a more primary dependence phenomenon in the border provinces, but according to the overall trend of change, the development of tourism activities has not yet led the border provinces to fully fall into

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a state of construction damage, as seen in urban clusters and river basins. (The development of tourism activities has not yet led the border provinces to fall into the ∩-type path dependency of construction damage (low)—ecological restoration (high)—construction damage (low), as seen in urban agglomerations and river basins). In terms of the characteristics of the evolutionary process of the tourism ecological security level in each province, the greatest number of provinces have evolved from medium to low levels, and the lowest number of provinces have evolved from high levels. In terms of the specific evolution pattern of each province, only Tibet, which has evolved dynamically in a "∩-type decline", has undergone a high–high–high level trend, and its ecological security level has always been at a high level among the border provinces, and its tourism ecological security level shows a high level of path dependence. The change trend of Jilin, Neimenggu, and other provinces is medium–middle–medium, showing a medium-level locked-in trend. Although the change trend of Jilin and Neimenggu is medium–medium, showing a medium level of locking, there are obvious differences in the dynamic evolution of the grade trend, in which the dynamic evolution process is a "\-shaped decline" for Jilin and a "U-shaped rise" for Neimenggu. The provinces showing medium–medium–low negative dependence are Liaoning with a ∩-shaped decline, Xinjiang and Guangxi with a U-shaped rise and Yunnan with a \-shaped decline. Gansu and Heilongjiang show a "U-shaped decline" and a "U-shaped rise" are shown, respectively, showing a relative low–low–low ranking trend and a low level of dependence.

Table 3. Evolution of TES levels in nine Chinese border provinces.

Rank trends	Percentage (%)	Province	Evolutionary Process	Pearson
High—High—High	11.11%	Tibet	∩-type decline	Similarity
Medium-Medium-Medium	22.22%	Jilin	\-type decline	Similarity
		Neimenggu	U-shaped rise	Similarity
Medium—Medium—Low	44.44%	Liaoning	∩-type decline	Similarity
		Xinjiang, Guangxi	U-shaped rise	Similarity
		Yunnan	\-type decline	Similarity
Low-low-low	22.22%	Gansu	U-shaped decline	Similarity
		Heilongjiang	U-shaped rise	Similarity

4.2. The Spatial Evolution of Tourism Ecological Security in the Three Large Border Areas

According to the degrees of effectiveness for tourism ecological security in China's three main border areas (Figure 3), tourism activities have led to a trend of "southwest > northeast > northwest" in the border areas. The overall tourism ecological security index, despite its jagged fluctuations, shows a relatively small and stable value change. The overall tourism ecological security index, despite the jagged fluctuations, has a relatively small and stable value. Compared to the other two areas, the southwest area, which is in a dominant position, has greater variation in the ecological security index, and its annual average values are higher than those of the other areas, demonstrating that the southwest areas have a greater degree of ecological security overall. The northeast and southwest areas' tourism ecological indices vary more from one another, and their values fall between that of the whole area and the northwest area. However, in recent years, the northeast area's ecological security development curve has gradually become closer to, or even crossed over, the level of the overall area, displaying a stable development trend, indicating that its level of tourism ecological security has increased, and the creation of the regional ecological environment has produced certain results. In contrast, except for 2012, when the value was higher than that of the northeast area, the value of the northwest area was lower than that of the overall regional level and the northeast area's level in the other periods, and there was a big difference compared with the southwest area, demonstrating that the coordinated growth of the area's tourism sector and the building of its tourism ecological environment were not suitable.

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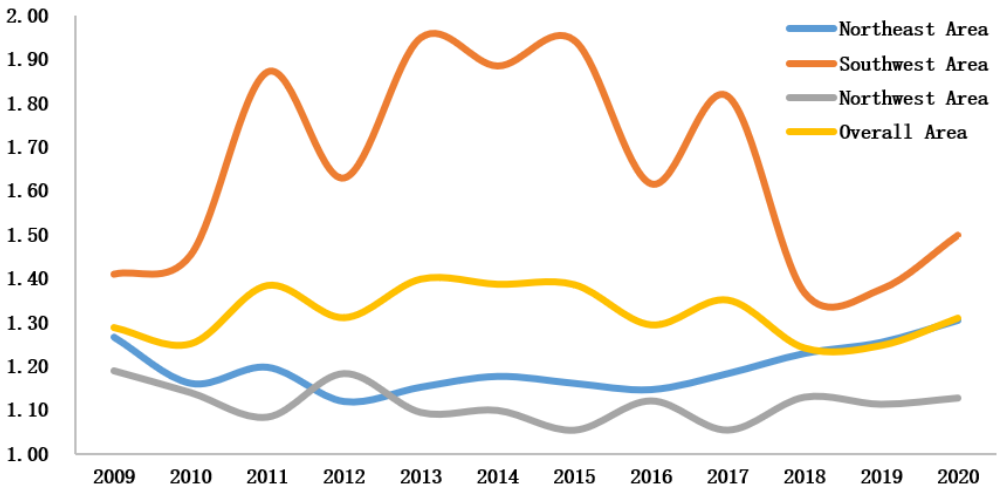

Figure 3. Levels of TES efficiency in three large border areas.

Based on the center of gravity concept, this study utilizes the ArcGIS spatial statistics tool to map the migratory trajectory of the tourism ecoefficiency center of gravity in the three main locations along the Chinese border (Figure 4). On the whole, the center of gravity for tourism ecological security in the southwest, northwest, and northeast areas has shifted over time, and the center of gravity is mostly concentrated in provinces with higher levels of ecological security, such as Xinjiang, Tibet, and Neimenggu. Further comparison reveals that the migration trajectories of the northeast and northwest areas are smaller in scope, indicating that, under the requirements of sustainable and high-quality development, the changes in tourism ecological security levels in the internal provinces are relatively stable, and the pulling effect of the ecological center of gravity is more prominent in the ecologically advantageous tourism provinces, while in the southwest area, due to the vigorous development of tourism activities at the beginning of the study period, there has been a certain degree of impact on the ecological environments of Yunnan and Guangxi. Later, with the adjustment of policies and tourism forms in Yunnan and Guangxi, such as the development of the tourism revolution in Yunnan, the construction of international recreation tourism destinations, and the construction of forestry ecotourism and forest recreation industries in Guangxi, a series of plans were introduced and implemented, the relevant policies focusing on ecological security and long-term development played significant roles, and the center of gravity of tourism ecological security in the southwest area gradually moved back.

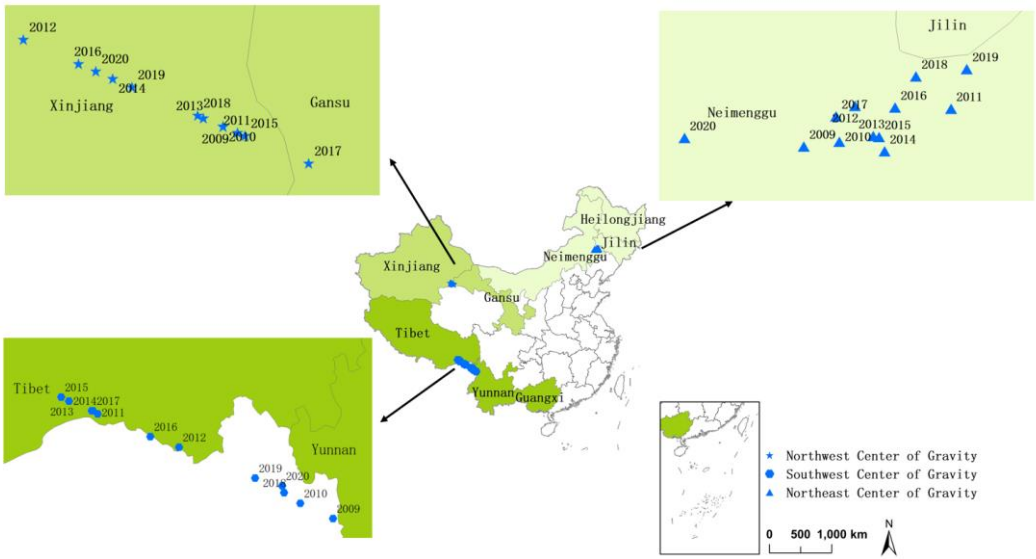

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Figure 4. The center of gravity for TES in the three major border areas.

4.3. Ecological Security of Tourism in China's Border Areas Drive

4.3.1. Drivers of Tourism Ecological Security in Border Areas

Since border areas, as postdevelopment areas, have low population densities, backward economic levels, little regional construction damage, and rudimentary tourism development, there are significant background differences compared with inland areas of countries with dense populations, high urbanization levels, and earlier tourism development. While the above studies have confirmed the existence of spatial and temporal divergence in the existing border areas, this study used geoprobing to investigate the spatial factors. The main drivers of spatial variation and evolution of tourism ecological security in China's border areas were explored using geographic surveys (Table 4). Contrary to conventional wisdom, which holds that economic growth significantly affects tourism ecological security in other places, social and environmental factors were shown to be the primary drivers of tourism ecological security in border areas.

Table 4. Drivers of TES in the border areas of China: detection results.

Dimension	Index	Prophase P	Rank	Late P	Rank	Average Value	Rank
Driver	X1	0.073	25	0.010	31	0.041	32
	X2	0.751	3	0.781	2	0.766	2
	X3	0.758	2	0.738	3	0.748	3
	X4	0.035	27	0.145	17	0.090	25
	X5	0.650	6	0.518	8	0.584	5
	X6	0.152	19	0.052	27	0.102	21
	X7	0.264	17	0.243	12	0.253	14
	X8	0.108	23	0.236	13	0.172	19
Press	X9	0.437	10	0.547	7	0.492	10
	X10	0.008	32	0.079	24	0.044	30
	X11	0.114	22	0.117	19	0.116	20
	X12	0.019	31	0.090	23	0.055	28
	X13	0.021	30	0.158	16	0.090	26
State	X14	0.750	4	0.041	30	0.395	12
	X15	0.530	9	0.622	5	0.576	6
	X16	0.761	1	0.289	11	0.525	7
	X17	0.404	11	0.602	6	0.503	8
Impact	X18	0.033	28	0.050	28	0.042	31
	X19	0.124	20	0.068	25	0.096	23
	X20	0.121	21	0.048	29	0.084	27
	X21	0.068	26	0.130	18	0.099	22
	X22	0.032	29	0.066	26	0.049	29
	X23	0.247	18	0.098	21	0.172	18
	X24	0.328	15	0.111	20	0.219	16
	X25	0.362	13	0.009	32	0.185	17
Response	X26	0.749	5	0.732	4	0.741	4
	X27	0.639	7	0.900	1	0.769	1
	X28	0.638	8	0.364	10	0.501	9
	X29	0.096	24	0.092	22	0.094	24
	X30	0.266	16	0.222	14	0.244	15
	X31	0.357	14	0.189	15	0.273	13
	X32	0.396	12	0.429	9	0.412	11

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(1) The urbanization rate is the main driving factor. The q-values of the natural population growth rate, urbanization rate, and graded road mileage are consistently ranked highly in the driving force system for the early (2009–2014) and late (2015–2020) periods of the study, demonstrating that the quantity of workers and the accessibility of transportation have significant beneficial impacts on the local tourism industry. Additionally, the ranking of the driving role of regional tourism ecological security indicates an increased trend in the number of ports with border area characteristics, suggesting that the driving role of the regional urbanization process and the degree of openness are progressively developing.

(2) Water consumption accounting for 10,000-yuan of the GDP is the main pressure factor. The use of natural resources to drive the economic development of the water consumption of 10,000-yuan GDP in the study period has a more direct impact, and the q value ranking from 10 to 7 shows an increasing trend change, indicating that regional resources in ecological security bear a certain pressure. However, the q value of each tourism ecological security density is low, which may be because the research region is near China's borders, the area is large, and the pressure bearing is still within controlled bounds. This could be because the research region is near the Chinese border, where the pressure carrying capacity is still under control, meaning that the effect on ecological security is minimal.

(3) The tourism transportation capacity is the main state factor. The factors that had the main influences in the early stage of the study were the number of star-rated hotels, the proportion of the tertiary industry in terms of the GDP, and the tourism transportation reception capacity, which were ranked 1st, 4th, and 9th, respectively. This shifted to the tourism transportation reception capacity and the number of travel agencies, ranked 5th and 6th, respectively, in the later stage of the study. This shows that better development of each tourism-related industry and tertiary sector in the area contributes to an increase in the area's overall attractiveness, but having too many facilities for reception services or rapid development could result in the overuse of local resources and have a negative impact on the environment.

(4) The area of nature reserves is the main influencing factor. The q-value ranking of the area of nature reserves has increased, indicating that the regional ecological security index is influenced by nature reserves. This is due to the fact that nature reserves serve as important leading and exemplary areas in the construction of regional ecological security in terms of ecological security concerns and resource investment. Nature reserves are key protection areas that have been specifically established by localities for the construction of ecological security, involving core, buffer, and pilot areas. Some national parks have even merged with nearby nature reserves to serve as the primary drawcards for the expansion of the area's tourism industry. Nature reserves are a major category for the interaction between tourism activities and the development of tourism ecological security, because they have a significant impact on the creation of tourism ecological security in the area.

(5) Expenditure on education is the main response factor. The rank of education expenditure and energy saving and environmental protection support changed from 7th and 8th in the earlier period to 1st and 10th, which demonstrates that the development of ecological security in local tourism is significantly influenced by investment in education and environmental protection assistance. At the same time the technical embodiment of the rate of harmless disposal of domestic waste in the later part of the study and the prominence of the extent of the role of education personnel training further indicate that the establishment of ecological security awareness and the improvement of environmental protection technology cannot be ignored in the future construction of the district's tourism ecological security system.

4.3.2. Drivers of Tourism Ecological Security in China's Border Areas

According to the DPSIR paradigm, regional ecological security is defined by a certain degree of "circularity" in how regional development operates[31]. The SBM-DEA model and the DPSIR framework served as the foundations for this study. Consequently, using the SBM-DEA model and the DPSIR model framework, this study further determined the internal driving relationships of the ecological security system in border areas with reference to the main barriers in the five dimensions

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of the formation process of tourism ecological security in border areas: drivers, pressures, states, impacts, and responses (Figure 5). The driving relationship of the ecological security of tourism sites in border areas takes ecological security factor inputs and outputs as the main part, which involves social aspect drivers, such as the urbanization rate, and open reception aspect drivers, such as the mileage of graded roads and the number of ports, as input factors, stimulating the tourism ecological security system with sensitivity and a certain degree of ecological and environmental pressure while the regional tourism industry develops. The subsequent pressure on economic security and environmental protection is accompanied by the development of tourism activities, gradually transmitting and changing the economic state in terms of the development of the region by the service sector or the social state in terms of the continuous improvement of service facilities. The subsequent series of states is transmitted in layers, resulting in positive or negative impacts on the overall environment of the regional socioeconomic–ecological system in terms of tourism revenue, social consumption structures, and the extent of nature reserves. These influences drive the regional system to make further responses involving education, science and technology, environmental protection, and so on in order to safeguard the ecological security of the region. After internal integration, these more encouraging replies will also serve as the input and impetus for the development of the local ecological security system, positively influencing the reduction of the local ecological pressure, the restoration of good tourism status, and the offsetting of negative components of the system. Through this, the objectives of synergistic growth and the virtuous cycle of tourism and ecological security in China's border areas are realized, improving the development of the regional tourism sector and ecological security.

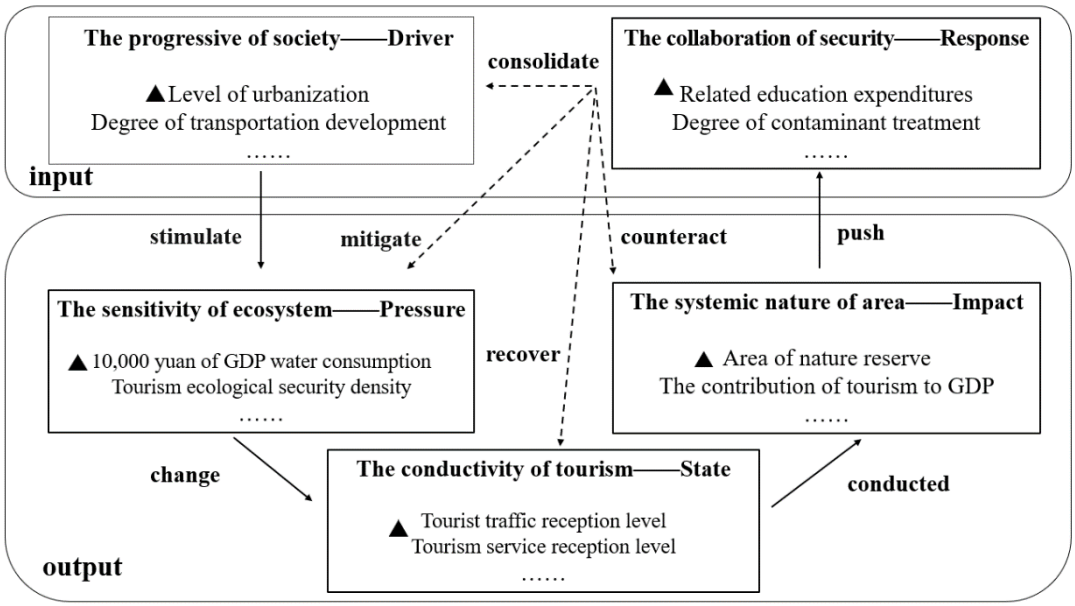

Figure 5. Drivers of TES in China's border areas. Triangle represents the main influencing factors of each dimension

5. Discussion and Conclusions

5.1. Conclusions

(1) The tourism ecological security index of the nine border provinces for the period of 12 years between 2009 and 2020 is usually favorable, and tourism-related activities have not yet significantly harmed tourism ecological security. The evolutionary path of the tourism ecological security level is significantly different from the single "∩-type" path dependence of inland urban agglomerations, such as the Yellow River Basin and the Yangtze River Economic Belt. Specifically, it is in the "∩"-type and "U-type forms, and there are three kinds of path evolution processes and four hierarchical evolution trends: high–high–high, medium–middle–middle, medium–middle–low and low–low.

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(2) During the 2009–2020 period, the level of tourism ecological security in China's border areas showed a distribution trend of "southwest area > northeast area > northwest area". The overall tourism ecological security index had a narrow range of swings that resembled a sawtooth form, but the trend was generally steady. Spatially, each region's concentration on tourism ecological security was mostly in environmentally beneficial places.

(3) The primary elements influencing the ecological security of tourism in border areas are mostly social and environmental factors, with economic factors accounting for a smaller proportion in contrast to the traditional phenomenon of inland areas where economic factors are the main source of influence. In addition, the input and output levels are the major components of the dynamic mechanism of the border's tourism ecological security system, specifically involving social progress brought about by the driving force, ecological sensitivity brought about by the pressure, as well as tourism transmission generated by the state, the regional system generated by the impact, and security synergy generated by the responses of the five zones of action. The internal factors of each zone of action work together to promote an orderly cycle of tourism ecological security in border areas through synergistic development.

5.2. Discussion

This paper investigated the spatial differences in the level of tourism ecological security in China's border areas and the driving factors based on the DPSIR model and the superefficient SBM-DEA model, which are widely used in the fields of ecology and economics. It bridges the gap between the ecological security of tourism in land border areas and draws conclusions that are different from traditional academic views, and it offers support for the conservation of tourism ecological security. The research supports both the sustainable growth of top-notch tourism in national border areas and the preservation of the tourism ecosystem. However, owing to space restrictions, thorough municipal-level research on particular border cities in China's border provinces has not been conducted. The assessment and geographic implications of tourism ecological security at medium and small scales, such as national border cities, counties, and even bilateral territories along the border, might be subjects of future study.

Based on the findings of the above study, important insights in terms of enhancing the degree of tourism ecological security and environmental protection in border areas are presented:

(1) Tourism development in border areas should be differentiated from tourism development models in inland areas. Border areas should make use of the conditions of low development, low destruction, a good ecological environment, and excellent tourism resources to break the existing tourism ecological security dilemma and avoid falling into ∩-type tourism ecological security path dependence. The relationship between the contemporary needs of the development of the tourism industry in the border areas and the creation of the regional ecological environment should be coordinated on the basis of a positive response to the national ecological protection and restoration management plan, and on the basis of the tourism ecological security mechanism in border areas, a reliable local compensation mechanism under ecological protection should be established. The development model of "environmental health, ecological civilization, green water, and green mountains" describes the development of standardized tourism industries and special tourism products in line with the ecological conditions and functional positioning of the region according to local conditions, and the promotion of the rational transformation of the local economy with high-quality and diversified green tourism products.

(2) We can work with neighboring countries to reach a cooperative mechanism for managing the ecological environment at the border. In terms of biodiversity, we need to reach an early agreement with neighboring countries and provinces about a coordinated management and protection mechanism for the border's ecological environment and effectively solve the problems of overlapping tourism and ecological protection and the fragmented management of ecologically fragile areas to achieve a mutually beneficial and win–win situation for the tourism industry and ecological protection in border areas.

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(3) Border areas can establish a system-driven mechanism for tourism ecological security around inputs and outputs. This can focus on ecological and environmental education, enhanced funding for environmental protection infrastructure, support for the balance and stability of the ecosystem with modern scientific and technological means, and the realization of a circular mechanism of co-construction and sharing between nature education, scientific and technological investment, and regional development by means of innovative propaganda and education, the use of multiple platforms, and the reasonable implementation of scientific research, education, and recreation activities in the controlled areas of national parks and other demonstration areas so that border regions safeguard the environment and ecology. The ideas of a community of human destiny with good neighborliness and the enrichment of the border are in harmony and are connected with the preservation of the environment.

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