

*Original Research*

# Research on Ecological Security Evaluation of Typical Agricultural and Animal Husbandry Interlaced Areas – a Case Study of Yanchi County of Ningxia Hui Autonomous Region, China

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## Abstract

This paper studied the impact of new industrial activities on ecological security in agricultural and animal husbandry interlaced areas, and provided reference for eco-environmental protection and sustainable development. A pressure-state-response (PSR) assessment model was established in the case of Yanchi County, Ningxia Hui Autonomous Region. The comprehensive weights of the indexes were determined by AHP and entropy weight, and the ecological security status of agricultural and animal husbandry interlaced areas was evaluated. The results show that the index of pressure system fluctuated and decreased, and went through the stage from “Safe” to “Unsafe”; The index of the state system showed a rising trend, from “Extremely unsafe” to “Relatively safe”, which showed the sensitivity characteristic; The response system index had been increasing year by year, and had stabilized at a “Safe” level in 2019; The overall ecosystem security index showed a fairly good development trend, with significant improvement in ecosystem functions in 2019. On the basis of the stable state system, we should ease the pressure index in the ecological security system of Yanchi County, control the scale of tourists, reduce the damage of farming and animal husbandry to the cultivated layer, and stabilize the population.

**Keywords:** agricultural and animal husbandry interlaced areas, ecological security, PSR model, comprehensive weight

## Introduction

In 2020, the General Secretary Xi Jinping emphasized that it was necessary to work hard to improve the ecological environment, seek breakthroughs, strengthen ecological protection strictly, control environmental pollution comprehensively, accelerate ecological restoration, ensure the long-term stability of the Yellow River, and strive to build ecological protection and high-quality development in the Yellow River Basin Area. In 2021, the “Proposal of the Central Committee of the Communist Party of China on Formulating the Fourteenth Five-Year Plan for National Economic and Social Development and Long-term Goals for 2035” pointed out that “we should adhere to respect nature, conform to nature, protect nature, and guard the boundaries of natural ecological security”. The interlaced area of agriculture and animal husbandry, also known as the interleaving area of agriculture and animal husbandry, is the boundary between the eastern agricultural area and the western grassland and pastoral area dominated by climatic dry and wet factors. The main range includes the southeastern edge of the Inner Mongolia Plateau and the northern Loess Plateau. Its vegetation type and ecological landscape are unique, and it is easily disturbed by human activities. It is a fragile and sensitive area of my country’s ecological environment [1]. “Eco-environmentally fragile and sensitive areas” are areas with poor ecosystem stability, prone to ecological degradation due to external activities, and difficult to self-repair. They are the bottom line and lifeline for ensuring and maintaining national ecological security, and are also areas that must be strictly protected. Its ecological security is particularly worthy of attention [2].

Scholars began to pay attention to ecological security in the 1940s, mainly studying land health and land functional evaluation [3, 4]. Later, the American environmental research scholar Lester formally proposed the concept of ecological security. In 1990, the United Nations Economic Cooperation and Development Agency proposed the pressure-state-response (PSR) framework model of ecological security, the driving force-state-response (DSR) model, the driving force-pressure-state- Impact-response (DPSIR) index system, driving force-stress-state-exposure-response measure (DPSER) model, etc. Generally speaking, foreign scholars pay more attention to the methodology and empirical research of ecological security assessment. For example, Wynet S. (1996) and Leana E.J. (2006) constructed ecological models and landscape pattern analysis methods on the basis of PSR framework models, and evaluated land and landscape use in combination with geographic information systems such as RS and GIS [5,6].

Samojlik M.S., Dychenko O.Y., Datsenko V.V. (2018) took the ecological environment of Ukraine as a case, and used cluster analysis and principal component analysis to construct an adaptive model for the evaluation

and prediction of resource-ecological security status based on the DSR frame and model [7]. Mashchenko M.A., Klimenko O.M. (2018) and Vetrova N., Shtofer G., Gaysarova A., Ryvkina O. (2020) combined regional and endemic empirical case studies of the problems of ecological security, and studied the sustainability of ecological security in terms of ecological consumption and ecological integrity [8, 9]. On the basis of learning from foreign research foundations and research experience, domestic scholars have carried out extensive research on the measurement and evaluation of ecological security, temporal and spatial patterns, obstacle factors, and early warning mechanisms based on China’s national conditions [10-13]. In terms of ecological safety evaluation, on the basis of learning from the PSR, DSR and DPSER framework models, domestic scholars have gradually expanded to ecological footprint models, material-element models, TOPSIS evaluation models, mutation models and other ecological evaluation methods [14-19]. In determining the weights of evaluation measurement indicators, the subjective weighting method and the objective weighting method are mainly used, and the subjective weighting method mainly adopts the Delphi method [20], the analytic hierarchy method [21], and the grey correlation degree analysis method [22]; The objective weighting method mainly adopts the mean square difference method, the entropy weight method [23], and the principal component analysis method [24].

The eastern part of Yanchi County, Ningxia Hui Autonomous Region belongs to the important area of windproof and sand fixation, and its ecosystem type is a typical desert-wetland natural ecosystem, which is demarcated as the red line for ecological protection of windproof and sand fixation in the eastern Part of Ningxia Hui Autonomous Region; at the same time, the area is located in the agricultural and pastoral interlaced area in northwest China, which is a transitional zone in terrain, climate, soil, vegetation and resource utilization, which has caused the fragility of the natural environment in the region. In 2018, Yanchi County took the lead in poverty alleviation in Ningxia Hui Autonomous Region and was shortlisted for the list of “2018 China’s 100 Cities”, and global tourism flourished. As early as 2015, the number of tourist receptions in Yanchi County reached 357,000 (far exceeding the local population of 173,000), and the comprehensive tourism income exceeded 100 million yuan<sup>1</sup>. In 2019, the number of tourist visitors in the region reached 1.27 million, and the comprehensive tourism income exceeded 400 million yuan, and its proportion in the national economy continued to rise. However, the influx of tourists and the further intensification of human disturbances have led to a further strengthening of factors that threaten the stability of the ecosystem in the area.

<sup>1</sup> At the time of writing 100 yuan = 14.39 euro

The ecological safety of Yanchi County has attracted the attention of many scholars. Zhang X.J., Zhou L.H. (2012) used DFSR model to evaluate and analyze the ecosystem health status of Yanchi County [25]; Han M.W., Zhuang C.Z., MA C., Wu X., Ma X., Shi Y. (2014) used remote sensing technology and ecological green equivalent evaluation model to evaluate the ecological benefits of Yanchi County [26]; Ma M.D., Xie Y.Z., Mi W.B., Liu C.N., Ma T., Ao H.W. (2014) analyzed the ecological effects and impacts of Yanchi County from the aspects of landscape ecology and ecosystem service value [27]. Zhang X.D., Liu X.G., Zhao Z.P. (2017) used principal component analysis to analyze the Remote Sensing Ecological Index (RSEI) and the Comprehensive Ecological Environment Quality Index (ESI) of Yanchi County, and evaluated the quality of their ecological environment [28]; Wang W.W., Zhou L.H., Chen Y., Sun Y., Hou C.X. (2019) used the “sustainability barometer” theory and method to determine the weight of the index by using the entropy value method, and quantitatively evaluated the sustainable development of Yanchi County [29].

Most of the existing literature studies ecological security based on the pressure-state-response (PSR) framework model, measures and evaluates ecological security, analyzes the pattern of ecological environment development, and the early warning mechanism of ecological risk, laying a solid foundation for the theoretical basis and measurement model. However, when using the weighting method to measure and evaluate ecological security, most of the existing literature uses a single model (subjective empowerment or objective empowerment) for the weight determination of evaluation indicators, which has a certain impact on the research conclusions. Based on this, the paper, taking Yanchi County as the research object, constructing a pressure-state-response (PSR) index measurement system, and using subjective empowerment (analytic hierarchy method) and objective empowerment (entropy method) to determine the index weights comprehensively, which not only effectively avoids the subjective arbitrariness of the index weight determination, but also reflects the regional objective reality in the field of ecological environment, aims to provide a theoretical basis for Ningxia Yanchi County to clarify the current ecological security degree, keep the ecological red line, coordinate the relationship between man and land and achieve regional sustainable development.

## Material and Methods

### Study Areas and Data Sources

Yanchi County is located at the junction of Shaanxi, Gansu, Ningxia and Mongolia provinces (regions), with geographical coordinates (106.15°E, 37.79°N). The total area of the county is 8661.3 km<sup>2</sup>, which has

been known as the “Northwest Gateway, Lingxia Elbow” since ancient times, and is the eastern gate of the traffic of Ningxia Hui Autonomous Region. The terrain is high in the south and low in the north, belonging to the transition section from the Ordos Terrace to the Loess Plateau, and the central and northern parts are gentle slope hilly areas, with gentle undulating terrain and continuous sand dunes, accounting for about 6930 km<sup>2</sup>; the southern part is the Loess Plateau, with vertical and horizontal ravines and ridges and depressions covering about 1732 km<sup>2</sup>. The landform structure is complex. Dry grasslands and desert grasslands are interlaced, and the soils are mostly ordinary gray calcareous soils and light gray calcareous soils. Located in the transition zone of arid and semi-arid areas, it is a typical ecologically fragile area of agriculture and animal husbandry in China, which is very sensitive to climate change and human activities, and has a relatively small carrying capacity. The degree of desertification is serious, the landscape heterogeneity is distinct, and the main landscape element types show obvious complexity in structure. In terms of fauna, the vegetation belongs to the Central Asia Region of the Eurasian Grassland Region, mainly dry grassland, desert grassland, sandy and hidden vegetation, of which desert grassland and sand vegetation account for about 73.5% of the grassland area.

### Data Sources

Considering the impact of the epidemic after 2020, the data collected in this study are mainly derived from the Ningxia Hui Statistical Yearbook (2015-2020), the 2015-2020 government work report of Yanchi County and related literature. From this, the raw data of the ecological safety evaluation index system of Yanchi County are obtained.

## Methods

### Evaluation Model Selection

Ecological security involves three aspects: nature, economy and society. The Pressure-State-Response (PSR) model is used. This is an evaluation model commonly used in the subdisciplinary of ecosystem health assessment in the discipline of environmental quality assessment. According to the basic situation of Yanchi County and the relevant research results, a regional PSR evaluation model for ecological safety evaluation in Yanchi County is constructed, as shown in Fig. 1.

### Construction of Evaluation Index System

The construction of the index system is the first step in the evaluation research, and whether the selection is reasonable is related to the scientific and

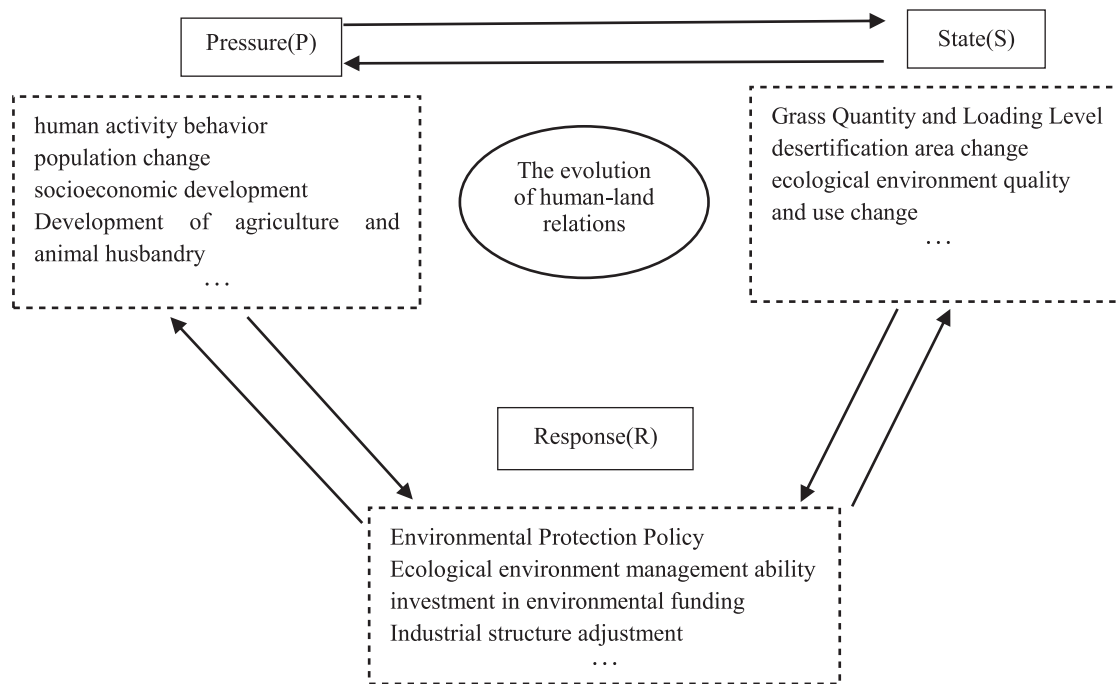


Fig.1. PSR framework model map of ecological security of Yanchi County.

representative nature of the evaluation results. In the process of index selection, the following three aspects are mainly considered: one is to construct a number of indicators based on the evaluation model of Fig. 1, and strictly according to the criteria attributes of pressure, state and response; the second is to refer to

relevant research results and use the Delphi method to judge the feasibility and typicality of the selection of various indicators; the third is to combine the actual development of Yanchi County in the interlaced zone of agriculture and animal husbandry, especially the rise and development of tourism in recent years, the

Table 1. Ecological security evaluation index system of Yanchi County.

System	Project layer	Indicator layer	Unit	Indicator efficacy
Ecological security index of Yanchi County	Pressure (P)	Crop sown area per capita( $C_1$ )	hm <sup>2</sup> /person	Negative
		Natural population growth rate( $C_2$ )	%	Negative
		Population density ( $C_3$ )	People/km <sup>2</sup>	Negative
		Number of tourists ( $C_4$ )	10,000 people	Negative
		Nertilizer application intensity ( $C_5$ )	t/hm <sup>2</sup>	Negative
	State (S)	Forest cover rate ( $C_6$ )	%	Positive
		Precipitation ( $C_7$ )	mm	Positive
		Maximum water speed ( $C_8$ )	0.1m/s	Positive
		Food production per capita ( $C_9$ )	kg	Positive
		Output value of agriculture, forestry, animal husbandry and fishery ( $C_{10}$ )	10,000 yuan	Positive
		Fixed asset investment ( $C_{11}$ )	10,000 yuan	Positive
	Response (R)	Per capita net income of farmers ( $C_{12}$ )	yuan	Positive
		Proportion of animal husbandry ( $C_{13}$ )	%	Positive
		Total power of agricultural machinery ( $C_{14}$ )	kW	Positive
		Proportion of tertiary industry ( $C_{15}$ )	%	Positive
		GDP per capita ( $C_{16}$ )	yuan	Positive

status of farming, the popularization of agricultural and industrial mechanization, and the ecological governance represented by afforestation and windproof and sand fixation projects. Based on this, 16 evaluation indicators were finally identified. These actual conditions directly determine the particularity of the construction of the ecological safety evaluation index system in Yanchi County. See Table 1 for details.

### Establishment of Evaluation Index Weights

When carrying out the ecological safety assessment of Yanchi County, it is necessary to determine the weight of each evaluation index. In order to make the evaluation results more scientific and objective, a comprehensive index combining objective weighting method and subjective weighting method is used to determine the weight of each evaluation index. The specific steps are as follows.

### Establishing the Original Data Matrix and Standardizing Processing

According to the constructed Yanchi County ecological security evaluation index system, the original data matrix  $X$  of the 16 indicators of the Yanchi County ecological security evaluation index system from 2014 to 2019 is established. The matrix elements are represented by  $x_{ij}$ , then the original data forms a matrix  $X(x_{ij})_{m \times n}$  with  $m$  ( $m = 1, 2, \dots, 16$ ) rows and  $n$  ( $n = 1, 2, \dots, 6$ ) columns, which can be expressed as follows:

$$X = (x_{ij})_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

The participating indicators are dimensionlessly processed, and the indicators are normalized to the  $[0,1]$  interval, and the standardized matrix  $T_{mn} = [y_{ij}]_{mn}$  is constructed. Formula (2) is used for cost indicators and formula (3) is used for efficiency indicators. The standardized data are shown in Table 2.

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

$$y_{ij} = \frac{x_{\max}(j) - x_{ij}}{x_{\max}(j) - x_{\min}(j)} \quad (3)$$

Where  $y_{ij}$  represents the standardized value of the indicator;  $x_{ij}$  represents the original value of the  $j$ th indicator in line  $i$ ;  $x_{\max}(j)$  and  $x_{\min}(j)$  represent the maximum and minimum values of the  $j$ th indicator in the original matrix, respectively.

Table 2. Standardized data of ecological security evaluation index of Yanchi County.

Index Layer	2014	2015	2016	2017	2018	2019
$C_1$	0	0	0.1000	0.1000	0.2000	1
$C_2$	0.5984	1	0.5281	0.5482	0	0.1245
$C_3$	1	0.8315	0.6292	0.4382	0.2247	0
$C_4$	1	0.9244	0.8165	0.5765	0.2547	0
$C_5$	1	1	0.8333	1	0.6667	0
$C_6$	0	0.2485	0.4424	0.4970	0.5939	1
$C_7$	0.4105	0	0.6793	0.8086	0.6849	1
$C_8$	0	1	0.4310	0.1897	0.0345	0.2414
$C_9$	0	0.3394	0.6790	0.7186	0.6177	1
$C_{10}$	0	0.3192	0.3526	0.5351	0.7106	1
$C_{11}$	0	0.1165	0.3337	0.7993	1	0.9961
$C_{12}$	0	0.1469	0.3130	0.6447	0.8042	1
$C_{13}$	0.2500	0.0833	0.3333	0	0.5833	1
$C_{14}$	0	0.2062	0.3927	0.5113	0.9209	1
$C_{15}$	1	0.8333	0.5000	0.3333	0.3333	0
$C_{16}$	0	0.1868	0.3290	0.4853	0.6812	1

Objective Weighting Method Weight Calculation

The weight of the index is calculated by the entropy method. First, calculate the information entropy of the indicator. Let the information entropy of the *j*th index be:

$$H_j = -k \sum_{ij=1}^n f_{ij} \ln f_{ij} \tag{4}$$

$$k = \frac{1}{\ln n} \tag{5}$$

$$f_{ij} = y_{ij} / \sum_{j=1}^n y_{ij} \tag{6}$$

Where  $H_j$  represents the information entropy of the *j*th indicator. When  $f_{ij} = 0$ ,  $\ln f_{ij} = 0$ . Next, the entropy weights for each evaluation index are calculated as follows:

$$p_j = (1 - H_j) / (m - \sum_{j=1}^m H_j) \tag{7}$$

Where  $0 \leq p_j \leq 1$ , and  $\sum_{j=1}^m p_j = 1$

Subjective Weighting Method Weight Calculation

The weights of the indicators are calculated using the Analytic Hierarchy Process (AHP). Firstly, the relationship between the decision-making levels of the ecosystem is determined. According to expert experience, we construct a comparison judgment matrix  $A = [a_{ij}]$ ,  $a_{ij} > 0$ ,  $a_{ii} = 1$ ,  $a_{ji} = 1/a_{ij}$ ,  $a_{ij}$  is the importance of target *i* relative to target *j*. Secondly, the subjective weight of the index is obtained. After calculating the maximum eigenvalue of the judgment matrix *A*, and normalizing the corresponding eigenvectors in the judgment matrix, the contribution of the corresponding index relative to the previous level is obtained, which is the subjective weight of the index.

$$\lambda_{\max} = \sum_{j=1}^m \frac{[Aq]_j}{nq_j} \tag{8}$$

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{9}$$

$$CR = \frac{CI}{RI} \tag{10}$$

Where *RI* is a constant, and *CR* is the consistency index. When  $CR < 0.1$ , it means that the judgment matrix

Table 3. Weight of ecological security evaluation index system of Yanchi County.

project layer	Index Layer	Weight of analytic hierarchy process		Entropy weight	Comprehensive Weight
		Single weight	Total weight		
Pressure <i>P</i> (0.2804)	<i>C</i> <sub>1</sub>	0.2017	0.0557	0.0535	0.0546
	<i>C</i> <sub>2</sub>	0.2017	0.0557	0.0671	0.0614
	<i>C</i> <sub>3</sub>	0.0436	0.0120	0.0643	0.0382
	<i>C</i> <sub>4</sub>	0.4641	0.1281	0.0572	0.0927
	<i>C</i> <sub>5</sub>	0.0888	0.0245	0.0427	0.0336
Status <i>S</i> (0.3812)	<i>C</i> <sub>6</sub>	0.1315	0.0495	0.0710	0.0603
	<i>C</i> <sub>7</sub>	0.3559	0.1341	0.0619	0.0980
	<i>C</i> <sub>8</sub>	0.224	0.0844	0.0642	0.0743
	<i>C</i> <sub>9</sub>	0.1599	0.0602	0.0650	0.0626
	<i>C</i> <sub>10</sub>	0.0465	0.0175	0.0694	0.0435
	<i>C</i> <sub>11</sub>	0.0823	0.0310	0.0541	0.0426
Response <i>R</i> (0.3385)	<i>C</i> <sub>12</sub>	0.3579	0.1243	0.0632	0.0938
	<i>C</i> <sub>13</sub>	0.0646	0.0224	0.0671	0.0448
	<i>C</i> <sub>14</sub>	0.1549	0.0538	0.0634	0.0587
	<i>C</i> <sub>15</sub>	0.0646	0.0224	0.0670	0.0447
	<i>C</i> <sub>16</sub>	0.3579	0.1243	0.0688	0.0966

has good consistency, that is, the weight is considered reasonable.

**Comprehensive Weight Calculation**

From the above, it can be seen that  $p_j$  and  $q_j$  are objective weights and subjective weights, respectively, and  $w_j$  is set as a comprehensive weight:

$$w_j = ap_j + (1 - a)q_j \tag{11}$$

Where  $a$  is the weight coefficient. when  $a = 0$ , the subjective weight is used for evaluation. when  $a = 1$ , the objective weight is used. In the paper, take  $a = 0.5$ . The weight of the ecological security index system of Yanchi County shown in Table 3 is obtained.

**Ecological Security Comprehensive Index Calculation and Safety Evaluation Standards**

*Calculation Model of Ecological Security Index of Yanchi County*

The comprehensive index of ecological security degree is used to calculate the ecological security of Yanchi County, and the calculation formula is as

follows:

$$ESI_p = \sum_{i=1}^m w_j y_{ij} \tag{12}$$

$$ESI = \sum_{p=1}^k w_p ESI_p \tag{13}$$

wherein,  $ESI_p$  is the ecological security index of each subsystem ( $p = 1, 2, 3$ ),  $ESI$  is the total ecological security index,  $w_j$  is the comprehensive weight of the  $j$ th index,  $w_p$  is the weight of the  $p$ -item subsystem, and the normalized value of the  $j$ th item of the  $i$  line. The value range of  $ESI$  is  $[0,1]$ , and the larger the value, the higher the ecological security degree of Yanchi County, otherwise, the lower the ecological security.

*Classification Standard for Ecological Security Evaluation in Yanchi County*

Based on the analysis of the ecological security situation in Yanchi County, referring to the existing research results and soliciting expert opinions, the ecological security evaluation is divided into six grades, as shown in Table 4.

Table 4. Classification standard of ecological security level.

Degree of ecological security	Ecological Safety Index	Alert status	Feature
Extremely unsafe	[0, 0.15)	Extreme alert	Regional human-land relations are seriously unbalanced, ecosystems are extremely damaged, ecosystem structures are incomplete, functions are basically lost, ecosystem restoration and reconstruction are almost impossible to achieve, natural disasters are normalized, and human development and survival are seriously threatened.
Unsafe	[0.15, 0.4)	Serious alert	To a certain extent, the regional human-land relationship is unbalanced, the ecosystem damage is serious, the ecosystem structure is incomplete, some functions are basically lost, the restoration of the ecosystem is difficult and the time is long, the adverse impact of the ecological environment on human social and economic development is obvious, and natural disasters are frequent.
Less safe	[0.4, 0.5)	High alert	Regional human-land relations are facing greater threats, the ecosystem has been seriously damaged, the function of the system has been greatly affected, the restoration and reconstruction are facing certain difficulties, the ecological environment has a greater adverse impact on human social and economic development, and there are many natural disasters.
Critical safe	[0.5, 0.6)	Medium alert	Regional human-land relations face certain threats, the ecosystem suffers certain damage, the function of the system is affected to a certain extent, but it can still be basically regulated, more sensitive to external interference, the ecological environment has a certain adverse impact on human social and economic development, and natural disasters occur from time to time.
Relatively safe	[0.6, 0.85)	Light alert	Regional human-land relations are nearly(almost) coordinated, the damage to the ecosystem is small, the system functions are sound and can operate normally, the self-repair ability of the ecosystem is strong, the adverse impact of the ecological environment on human social and economic development is small, and there are fewer natural disasters.
Safe	[0.85, 1]	No alert	Regional human-land relations are coordinated, the ecosystem is basically unspoiled, the ecosystem is in a safe state, the system functions are intact, the regulation ability is normal, the ecological environment is conducive to the development of human society and economy, and the ecological problems are not obvious.

## Results and Discussions

### Ecological Safety Evaluation Results of Yanchi County Based on PSR Model

According to formula (12) and formula (13), combined with the standardized data and weight values of each index, the results of ecosystem safety evaluation in Yanchi County are obtained, as shown in Table 5.

#### Analysis Of Ecological Security Assessment Results

##### *Pressure System Ecological Security Index (P)*

According to the evaluation results of ecological security, from 2014 to 2019, the ecological security index of the pressure system in Yanchi County showed a fluctuating and declining trend as a whole. However, the whole process can be roughly divided into three stages: from 2014 to 2016, the ecological safety index of the pressure system in Yanchi County was basically maintained at more than 0.6, that was, the system was in a “relatively safe” state, and the alert degree was “light alert”; in 2017, the early warning index of the ecological security pressure system in Yanchi County was reduced to 0.506, that was, the system was in a “critical safety” state, and the alert degree was “medium alert”; from 2018 to 2019, the ecological security index of the pressure system was about 0.23, the system was in an “unsafe” state, and the alert degree was “heavy alert”, that was, the regional human-land relationship was unbalanced to some extent, the ecosystem was seriously damaged, and some functions of the system were basically lost.

From the raw data of each indicator, it could be seen that in 2014-2019, the pressure system in Yanchi County was in a “safer” and “unsafe” state, mainly because: first, the natural population growth rate has increased year by year, which results in an increase in population density and a significant increase in human activities; second, with the integration of tourism resources in Yanchi County and the acceleration of global tourism planning, local tourism activities and foreign tourists have increased sharply, which result in an increase in the pressure of the ecosystem in Yanchi County; the third is the expansion of the agricultural cultivation area

and various characteristic industries in Yanchi County, the excessive application of pesticides and fertilizers and high-intensity land use have led to problems such as shallower tillage layer and decreased organic matter in the soil layer, which destroys the material energy cycle on the basis of compressing the self-repair cycle of the land, and overall shakes the resource and environmental basis of the harmonious evolution of human-land relations. Thus the ecological index of the entire pressure system is reduced and the insecurity of the system is increased.

##### *State System Ecological Security Index (S)*

From the perspective of the index layer under the state criterion of the ecological security evaluation system, it reflects the current ecological natural background and economic development status of Yanchi County. From 2014 to 2019, the state ecological security index of Yanchi County showed an upward trend. In 2014, the state system safety index was 0.1461, which was less than 0.15, that was, the system was in a “extremely unsafe” state, and the alert degree was “extreme alert”; in 2015, the safety index of the state system was greater than 0.15 and less than 0.4, that was, the system was in an “unsafe” state, and the alert degree was “serious alert”; in 2016 and 2018, the safety index of the state system was 0.5489 and 0.5437 respectively, the system was in the “critical safety” state, and the alert degree was “medium alert”; in 2017 and 2019, the security index of the state system was 0.6012 and 0.8298 respectively, and the system was in a “relatively safe” state, and the alert degree was “light alert”.

From 2014 to 2019, it could be seen that the change of the state system was relatively frequent, mainly because the precipitation in Yanchi County over the years was scarce, the annual wind (>8) days was 45.8 days, the wind was strong and the sunshine time was long, which accelerated the rate of water evaporation. In addition, the state system was very sensitive to external stimuli, and the positive and negative slight changes in the index factor could significantly change the state system index. In 2019, the county’s forest coverage and vegetation coverage reached 21% and 54% respectively, the NDVI index had been significantly improved, and the per capita grain output and the rapid increase in the output value of agriculture, forestry and animal husbandry had

Table 5. Ecosystem Safety Index of Yanchi County.

Index type	2014	2015	2016	2017	2018	2019
Pressure System Ecological Security Index(P)	0.7172	0.7558	0.6071	0.5062	0.2276	0.2268
State System Ecological Security Index(S)	0.1461	0.3354	0.5489	0.6012	0.5437	0.8298
Response System Ecological Security Index (R)	0.0808	0.2106	0.3444	0.5052	0.7335	0.9353
Comprehensive index of ecological security	0.2973	0.4266	0.4842	0.5206	0.5192	0.6806
Overall ecological security	Unsafe	Less safe	Less safe	Critical safe	Critical safe	Relatively safe



contributed to the transformation of the state system from “extreme alert” to “light alert”. Although it had been improved from the perspective of the state system, the future development still could not be developed with high intensity. The main consideration is that the local ecological environment is very fragile, and it is difficult to plant trees. Although the government has been advocating tree planting, grass planting, attaching importance to ecological environment construction, vegetation coverage and ecological engineering penetration year by year, the growth rate is relatively slow. In particular, the growth rate and local human activities will normalize the natural erosion rate, ecological bearing threshold fluctuation range, and self-organization repair rate, resulting in a space-time mismatch. In addition, the local ability to resist natural disasters needs to be enhanced. Therefore, it is necessary to further broaden the upward space under the condition of consolidating the existing status system “light alert” achievements.

#### *Response System Ecological Security Index (R)*

The ecological security index of the response system in Yanchi County, like the state system, showed an upward trend. In 2014, the safety index of the response system was 0.0808, that was, the system was in a state of “extremely unsafe”, and the alert degree was “extreme alert”; during 2015-2016, the safety ecological index of the response system was greater than 0.15 and less than 0.4, that was, the system was in an “unsafe” state, and the alert degree was “serious alert”; in 2017, the ecological security index of the response system was 0.5052, the system was in a “critical safety” state, and the alert degree was “medium alert”; in 2018, the ecological security index of the response system was 0.7335, the system was in a “relatively safe” state, and the alert degree was “light alert”; in 2019, the ecological security index of the response system reached 0.9353, and the system was in a “safe” state.

It can be seen that with the development of tourism and the development of the local economy, especially the local government continuing to improve the openness of networked government affairs and the degree of service for the people, lead the local people to actively carry out industrial poverty alleviation, ecological governance, rural revitalization and other measures, the ecological security index of the response system of Yanchi County has increased almost linearly, and the fluctuation amplitude is the smallest in the three evaluation subsystems.

It is foreseeable that with the improvement of the local ecological environment, the development of the economy, and the rapid increase of per capita income, the security level of the response system will inevitably be further improved, and it will become an important driving system for the overall coordination of human and land in the regulation area.

#### Overall Ecosystem Security Index

The ecosystem security index of Yanchi County had been improved rapidly in the research time series. In 2014, its ecosystem security index was 0.2973, the system was in an “unsafe” state, the alert degree was “serious alert”, and the regional human-land relationship was in a certain degree of imbalance, and some functions of the ecosystem were basically lost; in 2015-2016, the security index of its ecosystem was between 0.4-0.5, the system was in a “less secure” state, the alert situation was “high alert”, the regional human-land relationship was facing a greater threat, and the ecosystem was a little seriously damaged; in 2017-2018, the ecosystem security index was between 0.5 and 0.6, the system was in a “critical safety” state, and the alert situation was “medium alert”. At this time, although the regional human-land relationship faced certain threats, it could still be basically adjusted and more sensitive to external disturbances; in 2019, the ecosystem safety index was 0.6806, the system was in a “relatively safe” state, and the alert situation was “light alert”, indicating that Yanchi County has increased the ecological security index year by year after the correction of development concepts, long-term ecological self-organization restoration and man-made engineering restoration, which reflected the gradual harmonization of regional human-land relations. Judging from the results of the 2019 index, it could be assumed that the overall ecosystem of Yanchi County had tended to be stable, and the damage to the external force interface and the endoplasmic interface was small, and it had a certain repair ability. In particular, the reduction of the threat of natural disasters and the improvement of ecosystem functions had provided a good development environment and basic resources for local economic development and human settlement environment transformation, which had contributed to the current “light alert” situation of the ecosystem in Yanchi County.

#### Conclusions

In this paper, Yanchi County, a typical agricultural and pastoral area, is selected as the research area, and the PSR model is used to calculate the ecological security index. It breaks through the limitations of the previous studies on ecological security in typical agricultural and pastoral areas, which pay more attention to the factors of agricultural and pastoral activities, fully considers the rise of tourism activities in this area, and determines the index weight by using the comprehensive method combining subjective and objective. Thus it will make the evaluation of its whole ecological security more scientific. The specific conclusions are as follows:

(1) The ecological security index of the pressure system in Yanchi County as a whole showed

a downward trend of fluctuation, which was divided into three stages from the perspective of time series: the ecological safety index of the pressure system was above 0.6 in 2014-2016; the index fell to 0.506 in 2017; and the index hovered at 0.2 in 2018-2019. System security had experienced a phased state of “relatively safe”, “critical safety” and “unsafe”, in which the annual increase in the number of tourists had a great impact.

(2) The state ecological safety index of Yanchi County showed an upward trend, the state system safety index in 2014 was 0.1461; and by 2016 and 2018, there was “critical safe”; and in 2017 and 2019, both were “relatively safe” states, and the system changes fluctuated significantly, which reflected obvious sensitivity characteristics.

(3) The ecological security index of the response system in Yanchi County showed an upward trend. In 2014, the security index of the response system was 0.0808; and by 2017, the critical value of the index was 0.5052, and the system was in a “critical safe” state; and in 2019, the index reached 0.9353, stabilizing in the “safe” state. The development of the tourism industry and the improvement of the overall level of economic development are conducive to the stability of the ecological security response system of Yanchi County.

(4) The development of the ecosystem security index in Yanchi County is relatively good. From the “serious alert” level in 2014 to the critical point of the ecosystem security index of 0.5206 in 2017, with the system alert situation was the “medium alert” level; and in 2019, the system alarm reached the “light alert” level. The ecosystem function was significantly improved. Ecosystem restoration not only depends on economic development, but also on the basis of economic development. The two can achieve positive interaction.

So, first of all, although the development and application of ecological security assessment tend to mature in the academic community, the overall ecological security system of Yanchi County is an open, complex and huge dissipative organization, and there are multiple factors interacting. Different from the existing literature, in the selection of indicators, the rise and development of tourism in this typical agricultural and pastoral interlaced area is taken into account, and it is found that tourism plays an important role in the ecological security of Yanchi County, and plays a certain role in the increase of pressure on the ecological security state system and the relief of the pressure of the response system, unlike the previous ecological security research on typical agricultural and pastoral areas, which only focuses on agricultural and animal husbandry industry activities. In the future, we need to further improve the more representative index values and multi-factor combination analysis. Secondly, when determining the weight of each index, we combine AHP and entropy weight analysis to get the subjective and objective comprehensive weight, so as to reduce the subjective interference and make

the research result accord with the objective reality. However, it is still necessary to construct the weight model through the comprehensive contribution rate of each index criterion layer in order to completely solve the subjective selection. In the future, when discussing the contribution rate of each index in the ecological security system, we should deeply explain the formation mechanism of the ecological state and the reasons behind the index. In order to get more scientific conclusions, we need to extend the serial years to get panel data.

Thus, first, it is necessary to stabilize the state system index and vigorously alleviate the pressure index in the ecological security system of Yanchi County, which is the focus and difficulty of further promoting the coordination of regional human-land relations. Stabilize the natural population growth rate, control the population size above the existing population base, and alleviate the pressure on the natural ecology from the source of the increase in the intensity of human activities. At present, the total population of Yanchi County is 173,000, the natural growth rate has maintained a stable upward trend, and the population density growth has a great impact on the security of the ecosystem. Second, it is necessary to carry out strict ecological management and control of agricultural production, improve the water-saving farming technology and pasture management technology of dry farming, and reduce the damage of farming operations to the plough layer through scientific production methods such as fallow, rotational grazing, and rational use of chemical fertilizers. It is necessary to reduce the sown area of crops per capita, appropriately expand the area suitable for farming under the condition of relatively stable ecological security, and make reasonable use of the “flow of arable land” to achieve ecological compensation and ensure food security through external allocation of rations. Increase the scientific research investment and governance level of the sand control model, and improve the forest coverage rate of the county. Third, it is necessary to make scientific tourism planning, taking ecological safety as the red line and bottom line for the construction, operation and maintenance of tourist attractions, and allocate scenic land in strict accordance with the main functional zoning. With the increase in the number of tourist arrivals in Yanchi County year by year, it is necessary to strictly calculate the ecological footprint of tourism, while ensuring the stable progress of global tourism, reasonably control the scale of tourists, and carry out new tourism methods and projects such as low-carbon tourism and green tourism.

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### Conflict of Interest

The authors declare no conflict of interest.

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