Ecological Performance Evaluation and Driving Factors Analysis in the Yellow River Basin

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Abstract: Based on the environmental data from 2007 to 2021, this paper takes 9 provinces in the Yellow River Basin as the research object, introduces the PSR model to construct the ecological performance evaluation index system of the study area to evaluate the ecological performance status, and uses the principal component analysis, entropy method and other related methods to calculate the ecological indicators. The results show that: (1) he ecological security index of the Yellow River Basin has been in a relatively unsafe state for a long time. (2) The ecological security status of the upper reaches of the Yellow River is obviously worse than that of the middle reaches. In recent years, the ecology of the lower reaches of the Yellow River is good, which has been greatly improved. (3) The ecological situation of Shandong Province is obviously better than that of other provinces and cities. (4) Through the study of driving factors, it can be found that the level of educational development, financial development, precipitation and other factors have a significant impact on the ecological security index of the 9 provinces.

Keywords: Yellow River Basin; Ecological Performance; PSR Model; The Driving Factors

1. Introduction

With the vigorous development of economy and society and the improvement of the development and utilization of the Yellow River, the increasingly serious ecological problems in the Yellow River basin highlight the necessity and urgency of accelerating ecological governance. First of all, the ecology of the Yellow River basin is very fragile, which is the largest in area, the most types and the most obvious in China. Secondly, the contradiction between the total supply and demand of water resources is prominent, and the mismatch between the allocation of water resources and the consumption and usage of water resources has already led to the overwhelming burden of water resources and ecology in the Yellow River. However, the water bodies in the Yellow River basin are seriously polluted. The natural water resources of the Yellow River only account for about 2% of the national total, while the polluted water bodies account for about 6% of the national total. Finally, the severe water and soil loss in the Yellow River basin is not coordinated with the relationship between water and sediment. The loess Plateau, the largest loess distribution area in the world, rushes into the Yellow River under the sand and sediment during the flood season, resulting in the characteristics of good silting and good flushing in some rivers. In this context, this study focuses on the provinces in the Yellow River Basin, constructs the ecological security index of each province in the Yellow River Basin, deeply analyzes the characteristics and rules of the evolution of the ecological security index of each province in the Yellow River Basin, and clarifies the changes of the ecological governance index in time, which has important theoretical and practical value for the major national strategy of "ecological protection and high-quality development in the Yellow River Basin."

2. Literature Review

The PSR method is mostly used for index construction. HUXJ et al. proposed that PSR model is a kind of evaluation index system model commonly used to measure the environment and sustainable development. Building a scientific, universal and comprehensive index system is the basis to ensure the accuracy of the evaluation results. In the 1980s and 1990s, the OECD proposed the PSR model to analyze the state of the world's environment. After that, many scholars used this framework to evaluate watershed ecological health [1]and land security [2]. In order to improve the comprehensiveness and accuracy of ecosystem management in the Yellow River Basin, Qiumeng et al. [3] used PSR to construct a comprehensive evaluation index system for ecosystem health in the Yellow River basin, and used SMI-P method to calculate and evaluate the comprehensive index of ecosystem health in 63 cities (prefectures) and 192 ecological zones. Zuo Qiting et al.[4] used SMI-P method and spatial autocorrelation analysis method to evaluate and analyze the water ecological security of the Yellow River Basin, and put forward measures to improve the water ecological environment of the Yellow River Basin.

Regarding the research on the development of the Yellow River Basin, some scholars used GDP, difference index, and GDP per capita to analyze spatial differences. Wang used the input-output model to analyze and found that there was strong spatial heterogeneity in the water resources carrying capacity of eight provinces in the Yellow River Basin. Xu et al.[5]established a five-dimensional evaluation index system, used the entropy weight method to measure the high-quality development level of nine provinces in the Yellow River Basin, and concluded that the overall high-quality development level in the Yellow River Basin showed an upward trend. Fan et al. [6] made a comparative analysis of the development conditions in the Yangtze River Basin, studied the high-quality development in geographical units, and proposed that the comparative advantages of local culture and regional ecology should be brought into play. Li and Wang [7] found that the overall level of high-quality development in Jiangsu Province was high, but there were shortcomings in coordinated development and green development.

To sum up, most of the current academic analysis of the ecological performance of the Yellow River Basin focuses on the water ecology, soil desertification, and high-quality development level of all provinces and cities in the Yellow River Basin, adopting a single evaluation method, and there are few studies on the ecological performance of the Yellow River Basin. Therefore, this paper takes the provinces and cities in the Yellow River Basin as the research object, establishes a comprehensive evaluation index system of ecological performance based on the PSR model, uses the entropy method to determine the corresponding weight of each index, and makes a comprehensive evaluation of the ecological performance of the Yellow River Basin through the SMI-P method. At the same time, the coupling coordination degree is used to study the ecological coordination degree and mutual restriction degree of all provinces and cities in Gansu stream section of the Yellow River Basin, which is of great significance to the status and coordination of the ecological performance of the Yellow River Basin.

3. Index System Construction and Data Sources

3.1 Index System Construction

3.1.1 Indicator construction method

Pressure-state-response framework model [5] Starting from the interaction between human and environment, this model can well explain the logical relationship between human society and environment in a complex system [6] As a framework based on causal organizational information and related indexes, PSR model divides the evaluation indicators into three levels of pressure, state and response for representation. PSR model can be widely used precisely because its spiritual kernel can integrate multiple evaluation indicators [7], screen and classify corresponding indicators, and has strong systematization [1], which can accurately describe the coupling system of society-natural environment. Where P represents the natural ecology as a complex and complete ecosystem, which is affected by various human activities; S refers to the result of the change of resource and environment state caused by pressure; R is the performance and feedback generated by the environmental system under the combined action of pressure and state.

3.1.2 Selection of indicators

The panel data of 9 provinces and cities in the Yellow River Economic Belt from 2007 to 2021 are selected. It can be seen that in the evaluation of ecological indicators, pressure indicators generally include environmental pressure, economic pressure and social pressure, and social pressure generally includes energy consumption per unit GDP, and social pressure generally includes natural population growth rate and population density. Environmental pressure is different, and resource pressure is rarely mentioned. The status indicators generally involve the per capital public green area, the number of days with air quality > Level 2 standard, and the coverage rate of noise reaching the standard. The latter two indicators are basically not mentioned in the provincial research. In the response indicators, the proportion of environmental protection investment in GDP, waste gas treatment rate and centralized treatment rate of domestic sewage are repeatedly mentioned. In actual operation, there are a large number of missing values in waste gas treatment rate, so industry-related waste gas indicators are adopted. In order to ensure the scientificity, operability and comprehensiveness of the index system (Zuo Qiting) [4]and on the basis of previous studies, a total of 27 indicators were selected this time, including 9 pressure indicators, 7 state indicators and 11 response indicators, as shown in Table 1:

Table 1. Ecological Evaluation Index System Based on PSR Framework

criterion	index
P	Birth rate A11
	Density of population A12
	Natural population growth rate A13
	Municipal sewage discharge A21
	Sulfur dioxide emissions A22
	Ammonia nitrogen discharge in wastewater A23
	Total water content A24
	Chemical oxygen demand discharge in wastewater A25
	Application rate of agricultural chemical fertilizer A26
	Energy consumptions per GDP A27
S	Greenery coverage of urban area B1
	Area of nature reserve B2
	Urban park area B3
	Green coverage rate of built-up area B4
	Area of desertified land B5
	Arable land per capita B6
R	Afforestation area C1
	Water-saving irrigation area C2
	Investment in industrial waste gas treatment projects has been completed C3
	Investment in industrial wastewater treatment projects was completed C4
	Other industrial governance projects to complete investment C5
	Urban household garbage harmless treatment capacity C6
	Area of soil erosion control C7
	treatment rate of domestic sewage C8
	Utilization of urban sewage regeneration C9
	Ratio of environmental protection expenditure to GDP C10
	Cities conserve water consumption C11

3.1.3 Index calculation method

The current weighting methods of evaluation indicators can be divided into subjective weighting methods represented by analytic hierarchy process and objective weighting methods represented by entropy method, gray comprehensive evaluation method and factor analysis method [3]. In order to emphasize the information content and correlation degree of evaluation indicators, and to avoid the deviation caused by the subjectivity of artificial weighting, this paper uses the entropy method to weight indicators. Entropy method reflects the utility value of index information through entropy value, which can reflect the difference degree of the change of each index value, that is, the influence degree of the numerical change of each index on the system. The steps are as follows:

1.These indicators are standardized, and the specific formula is as follows: set m evaluation samples and n evaluation indicators to obtain the normalized matrix $R = (R_{ij})_{m*n}, i = 1,2,...,m; j = 1,2,...,n;$ Where R_{ij} represents the standard value of the ith evaluation object on the JTH index [8]:the larger the better type indicator the smaller the better type indicator.

The bigger the better the indicator:

$$R_{ij} = \frac{x_{ij}-x_{min}}{x_{max}-x_{min}} \quad (1)$$

The smaller the better the indicator:

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

2.The specific gravity of each evaluation index is transformed, where P_{ij} represents the corresponding specific gravity coefficient of the ith evaluation object on the JTH index, and the formulas are shown in (3):

$$P_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} (j=1, 2, ..., n) \quad (3)$$

(3) E_j represents the entropy value of index j and is calculated as follows:

$$E_j = -\frac{l}{\ln m} \sum_{i=1}^{m} P_{ij} * \ln P_{ij} (= 1,2,3, ..., m) \quad (4)$$

(4) W_j is the weight of the JTH evaluation index, and the calculation formula is as follows:

$$W_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \quad (5)$$

3.2 Data Sources

In order to meet the research needs, and considering the actual situation of each province and city and the difficulty of obtaining index data, the data mainly come from the statistical yearbooks of each province and city, and some missing data come from the China Statistical Yearbooks and China Energy Statistical Yearbooks issued by the National Bureau of Statistics of China.

4. Status Analysis

Two indicators were selected from the ecological evaluation index system based on PSR framework for descriptive statistics. For the pollution status part, urban sewage emissions and urban sulfur dioxide emissions of ten thousand yuan of GDP were selected; for the ecological status part, forest coverage rate and green coverage rate of built-up area were selected. The harmless treatment capacity of urban household garbage and the treatment rate of urban sewage are selected in the part of pollution treatment status. The specific analysis is as follows, so as to better understand the pollution, ecology and pollution treatment status of each province.

4.1 Status Quo Of Terrestrial Ecology in Each Province and City

The forest coverage rate and the green coverage rate of the built-up area in the provinces and cities of the Yellow River Basin showed a slow upward trend as a whole. As can be seen from Figure 1, except for Shaanxi Province, Henan Province, and Qinghai Province, which declined slightly in 2011-2012, 2016-2017, and 2021, and soon recovered to the previous level, the forest coverage of the other six provinces and cities from 2007 to 2021 showed a slow upward trend, and the increase was generally not large. The forest coverage rate of Shaanxi province was the highest, followed by Sichuan province and Henan Province, and Qinghai Province was the lowest. It can be clearly seen from Figure 2 that in terms of the green coverage rate of the built-up area, the green coverage rate of the built-up area in the 9 provinces and cities shows a slow upward trend, ranging from -6% to 13%. According to this data, the overall trend of the green coverage rate is relatively stable. Generally speaking, the green coverage rate of the built-up area in Shandong Province is the highest. The green coverage rate of built-up areas in Gansu and Qinghai provinces is basically at the bottom. In addition, the green coverage rate of Shanxi Province is developing rapidly, with the growth rate of Shanxi reaching 34% from 2007 to 2021. In 2007, the green coverage rate of Shanxi was only in the middle, but in 2019, it surpassed Shandong and became the first.

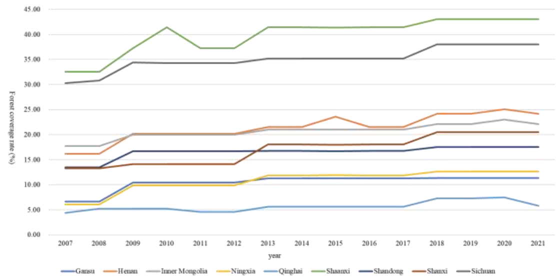

Figure 1. Trend Change of Forest Coverage in Each Province (%)

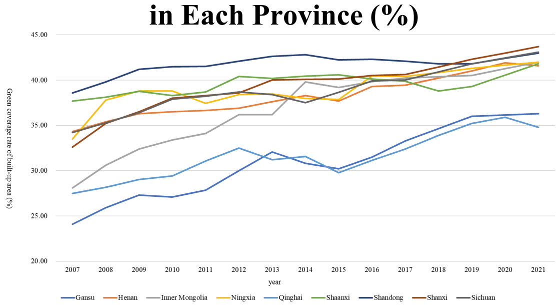

Figure 2. Change Trend of Green Coverage Rate in Built-Up Area (%)

4.2 Current Situation of Pollutant Discharge in Various Provinces and Cities

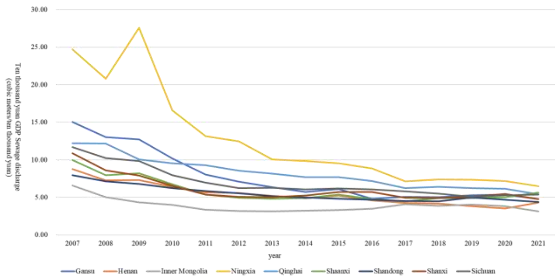

Figure 3. Urban Sewage Discharge In 10,000 Yuan GDP (Ton / 10,000 Yuan)

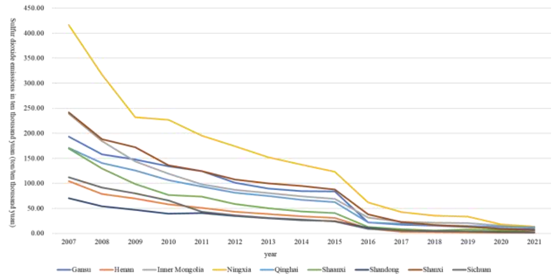

Figure 4. Trend of Sulfur Dioxide Emissions in Cities with A GDP Of 10,000 Yuan (Ton/Yuan)

The ratio of pollutant emissions to GDP in all provinces and cities generally shows a downward trend. It can be clearly seen from Figure 3 that although the urban sewage discharge of ten thousand yuan GDP of all provinces and cities in the Yellow River Basin from 2007 to 2021 fluctuates slightly, it shows an overall downward trend. Among them, Ningxia Province has the largest decline from 29.45 tons/ten thousand yuan to 6.48 tons/ten thousand yuan, and Shandong Province has the smallest decline. From 7.39 tons / 10,000 yuan to 4.39Kg; It can be seen from Figure 4 that the urban sulfur dioxide emissions of ten thousand yuan of GDP of all provinces and cities show a downward trend, among which Ningxia Province has the highest ratio in 2007, reaching 421.61 tons/yuan. Meanwhile, the absolute value of this value changes the most, reaching the minimum value of 13.33 tons/yuan in 2021 in the 13 years of ecological governance, and Shandong Province has the smallest decline. Decreased from 70.09 tons/yuan to 1.99 tons/yuan.

4.3 Current Situation of Pollution Control in Various Provinces and Cities

The provinces and cities in the Yellow River basin have achieved good results in pollution control. It can be seen from Figure 5 that, on the whole, Shandong Province has the highest harmless disposal capacity of MSW, followed by Sichuan Province and Henan Province, and Qinghai Province has the lowest. From 2007 to 2008, the sequential growth rate was as high as 200%, and from 2009 to 2010, the sequential growth rate was -52.26%, with a large change rate. It can be seen from Figure 6 that Shandong Province has the highest urban sewage treatment rate, while Qinghai Province has the lowest. On the whole, the current situation of pollution control in all provinces and cities is more effective.

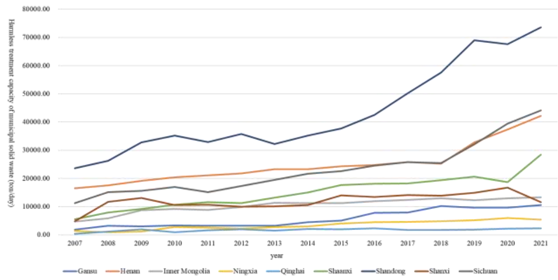

Figure 5. Trend of Harmless Treatment Capacity of MSW (Ton/Day)

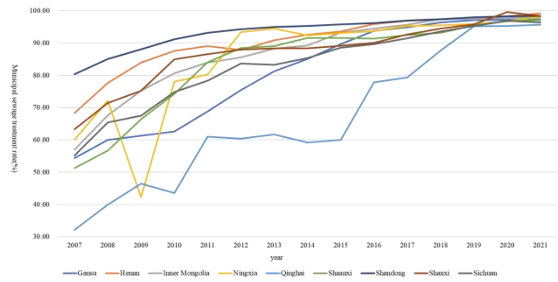

Figure 6. Trend of Urban Sewage Treatment Rate in Various Provinces and Cities (%)

5. Calculation of Comprehensive Index of Ecological Performance

5.1 Index of Screening

The index system is the concretization of the comprehensive evaluation of ecological security, and the scientific index system is the basis of the objective evaluation [9]. This paper conducts KS normal distribution test on the selected 27 candidate evaluation index data, conducts Pearson correlation analysis on the candidate index conforming to the normal distribution, and conducts Spearman correlation analysis on the candidate index not conforming to the normal distribution. Based on the correlation analysis, four candidate indicators with weak correlation, namely, sulfur dioxide emissions, nature reserve area, per capita cultivated land area and afforestation area, are eliminated, so that the remaining candidate index data matrix forms a positive definite data matrix.

Table 2. Results of PCA Analysis of Candidate Evaluation Indicators

	F1	F2	F3	F4	F5
A21	0.94	0.20	0.00	-0.04	-0.17
C6	0.92	0.12	0.17	-0.07	-0.22
B3	0.89	0.12	0.29	0.13	-0.15
C10	-0.84	0.20	0.18	0.05	-0.23
A12	0.81	0.45	-0.12	-0.07	-0.02
A24	0.79	-0.17	-0.21	0.26	-0.20

A27	0.78	-0.12	-0.06	-0.35	-0.26
A26	0.78	0.19	-0.23	0.04	-0.07
C2	0.77	-0.19	0.34	0.38	-0.11
C11	0.74	0.36	-0.03	0.16	0.24
A25	0.70	-0.01	-0.50	0.17	-0.13
C9	0.67	0.18	0.45	C9	0.67
C3	0.61	0.32	0.32	C3	0.61
C8	0.56	-0.20	0.31	C8	0.56
C4	0.51	0.27	-0.26	C4	0.51
C7	0.22	-0.86	0.09	C7	0.22
A11	-0.36	0.85	0.09	A11	-0.36
A13	-0.49	0.79	0.09	A13	-0.49
B1	0.49	-0.54	-0.23	B1	0.49
A23	0.58	0.12	-0.68	A23	0.58
C5	0.54	0.09	0.55	C5	0.54
B5	-0.25	-0.51	0.30	B5	-0.25

PCA analysis was performed on the standardized values of the remaining 23 candidate evaluation indicators. It is found that the KMO test statistic value is 0.791, the Bartlett test value is 4723.894, and the concomitant probability is 0.00, indicating that the data matrix composed of these 23 candidate evaluation indicators is suitable for PCA analysis. The maximum variance rotation method (Varimax) is adopted to extract five principal components (F1-F5) according to the principle that the cumulative variance contribution rate of Jiang Feng [10] exceeds 80%, as shown in Table 2:

The candidate evaluation indexes whose factor loading value is greater than 0.65 are retained. The variance contribution rate of F1 was 45.127%, Among them, the factor loading values of urban sewage discharge, harmless treatment capacity of urban household garbage, area of urban parks, proportion of environmental protection expenditure in GDP, population density, total water use, energy consumption per unit GDP, amount of agricultural chemical fertilizer application, water-saving irrigation area, urban water conservation, and total chemical oxygen demand discharge in wastewater are relatively large. F1 mainly represents the pollution control capacity of each province and city to be evaluated and the pressure caused by people on the environment, especially the pollution control capacity of each province and city has a great impact on each province and city. The variance contribution rate of F2 is 15.156%, among which the factor loading values of soil erosion control area, population birth rate and natural population growth rate are large, indicating that the ecological security status of the Yellow River Basin is affected by land loss and population to a certain extent. The variance contribution rate of F3 is 8.955%, among which the factor loading value of ammonia nitrogen discharge in wastewater is relatively large. F3 mainly represents the pollution of water sources, indicating that the ecosystem security is strongly affected by water security. The variance contribution rate of F4 is 7.257%, among which the factor loading value of desertification land area is relatively large. F4 mainly represents the land situation of the provinces and cities in the Yellow River Basin to be evaluated, indicating that the land situation has a better characterization effect on the land security situation of the 9 provinces in the Yellow River Basin.

According to the results of PCA analysis, 18 indicators including A11, A12, A13, A21, A23, A24, A25, A26, A27, B3, B4, B5, C2, C6, C7, C9, C10 and C11 are finally selected from the remaining 21 candidate evaluation indicators to construct the ecological performance evaluation system of all provinces and cities in the Yellow River Basin.

5.2 Composite index calculation

5.2.1 Determination of index weights

The specific results according to the entropy weight method are shown in Table 3:

Table 3. Weights of Ecological Performance Evaluation Indicators

Criterion	Indicators	Direction	Weight
P	A11	-	1.43%
	A12	-	3.52%
	A13	-	2.41%
	A21	-	1.91%
	A23	-	1.77%
	A24	-	4.73%
	A25	-	1.64%
	A26	-	2.44%
	A27	-	2.33%
S	B3	+	10.22%
	B4	+	1.59%
	B5	+	2.85%
R	C2	+	7.39%
	C6	+	9.27%
	C7	-	1.82%
	C9	+	23.62%
	C10	+	6.36%
	C11	+	14.69%

From the perspective of index layer, the ecological security status of 9 provinces in the Yellow River Basin is mainly affected by the response layer under the evaluation system. From the index layer, the weight of urban sewage recycling utilization C9 and urban water saving consumption C11 is significantly higher than that of other evaluation indicators, accounting for 38.31% of the total system. In addition, the total water use A24 provides the most effective information for the description of pressure layer characteristics; The area of nature reserve B3 provides the most effective information for the feature description of the state layer; the utilization rate of urban sewage regeneration C9 provides the most effective information for the feature description of the response layer.

5.2.2 Composite index calculation

The ecological security Composite index (ESI) is calculated by weighted summation, and the calculation formula is as follows:

$$ESI = \sum_{i=1}^{n} W_i Y_i \quad (6)$$

In the formula, Y_i is the standardized value of the ith point, and W_i is the weight coefficient of the ith scheme layer to the target layer. The value of ESI is [0,1], and the larger the value is, the higher and safer the regional ecological environment is. According to the above formula, the calculation results are shown in Table 4.

Referring to Hu Jingyang [11] and the K-mean clustering results of the comprehensive index of ecological security, the evaluation results can be divided into five levels: (0.75, 1] is a very ideal safe state, (0.5, 0.75] is a satisfactory safe state, (0.38, 0.5] is a tolerable critical safe state, (0.20, 0.38] is a sensitive less safe state, and [0,0.25] is a tense unsafe state. Specific definitions are shown in Table 5.

Table 4. Calculation Results of the Composite Index

	Gansu	Henan	Mongolia
2007	24.20%	23.50%	25.90%
2008	25.20%	23.50%	26.90%
2009	25.70%	23.80%	28.00%
2010	26.10%	24.00%	27.70%
2011	25.90%	22.30%	27.90%
2012	23.80%	19.20%	24.90%
2013	25.40%	22.10%	27.60%
2014	25.70%	23.10%	28.80%
2015	26.50%	24.00%	30.40%
2016	27.40%	27.20%	30.50%
2017	28.00%	30.60%	31.30%
2018	29.30%	35.30%	32.70%
2019	28.70%	35.80%	32.60%
2020	28.80%	39.20%	33.50%
2021	28.50%	44.80%	33.40%
	Ningxia	Qinghai	Shandong
2007	25.60%	27.40%	32.80%
2008	26.00%	26.70%	34.00%
2009	26.70%	28.50%	35.20%
2010	26.90%	27.50%	40.10%
2011	27.00%	28.50%	44.10%
2012	27.10%	28.30%	39.50%
2013	26.40%	30.20%	42.80%
2014	26.80%	27.70%	45.90%
2015	27.50%	29.50%	50.20%
2016	27.10%	28.50%	54.00%
2017	28.40%	27.90%	56.50%
2018	28.90%	27.90%	58.60%
2019	28.50%	28.20%	64.50%
2020	29.10%	29.50%	65.20%
2021	29.40%	29.20%	70.40%
	Shanxi	Shaanxi	Sichuan
2007	27.70%	26.40%	23.80%
2008	29.70%	27.00%	33.30%
2009	30.90%	27.60%	29.40%
2010	47.30%	27.80%	25.80%
2011	29.80%	27.60%	24.20%
2012	28.00%	25.90%	21.60%
2013	30.00%	28.70%	25.10%
2014	30.70%	27.60%	25.30%
2015	31.20%	34.00%	25.60%
2016	33.10%	34.30%	28.70%
2017	32.40%	32.80%	34.10%
2018	34.20%	27.90%	30.00%
2019	35.50%	28.70%	34.20%
2020	37.00%	33.10%	38.20%
2021	35.90%	35.50%	42.10%

Table 5. Classification of Comprehensive Index of Ecological Security

0.75<ESI	Level I, Safety status: social activity interference and other external pressure is very small
0.5<ESI≤0.75	Level II, safer state: less external pressure such as interference from social activities
0.38<ESI≤0.5	Level III, critical safety state: external pressures such as interference from social activities are still within the tolerance range, and the ecosystem structure is still stable
0.25<ESI≤0.38	Level IV, there are a few ecological and environmental

	problems
ESI<0.25	Level V, Unsafe state: external pressure such as interference from social activities is severe, and ecological and environmental problems occur frequently

5.3 Analysis of Indicators

According to Table 4 and Table 5, the ecological security index of the 9 provinces in the Yellow River Basin can be further obtained as shown in Table 6.

Table 6. Comprehensive Index of Ecological Security in All Provinces and Cities

	Gansu	Sichuan	Mongolia
2007	V	V	IV
2008	IV	IV	IV
2009	IV	IV	IV
2010	IV	IV	IV
2011	IV	V	IV
2012	V	V	V
2013	IV	IV	IV
2014	IV	IV	IV
2015	IV	IV	IV
2016	IV	IV	IV
2017	IV	IV	IV
2018	IV	IV	IV
2019	IV	IV	IV
2020	IV	III	IV
2021	IV	III	IV
	Ningxia	Qinghai	Shaanxi
2007	IV	IV	IV
2008	IV	IV	IV
2009	IV	IV	IV
2010	IV	IV	IV
2011	IV	IV	IV
2012	IV	IV	IV
2013	IV	IV	IV
2014	IV	IV	IV
2015	IV	IV	IV
2016	IV	IV	IV
2017	IV	IV	IV
2018	IV	IV	IV
2019	IV	IV	IV
2020	IV	IV	IV
2021	IV	IV	IV
	Shanxi	Henan	Shandong
2007	IV	V	IV
2008	IV	V	IV
2009	IV	V	IV
2010	III	V	III
2011	IV	V	III
2012	IV	V	III
2013	IV	V	III
2014	IV	V	III
2015	IV	V	II
2016	IV	IV	II
2017	IV	IV	II
2018	IV	IV	II
2019	IV	IV	II
2020	IV	III	II
2021	IV	III	II

On the whole, from 2007 to 2021, the ecological security index of the Yellow River Basin has been in a relatively unsafe state for a long time, which can account for 76.30% of the total, and the second is the unsafe state, accounting for 11.11%. Secondly, the Yellow River basin is divided into the upper, middle and lower reaches. The upper reaches include Gansu Province, Sichuan Province, Inner Mongolia Province, Ningxia province and Qinghai Province, the middle reaches include Shaanxi province and Shanxi Province, and the lower reaches include Henan province and Shandong Province. The unsafe state, less safe state and critical safe state in the upper reaches of the Yellow River accounted for 8.00%, 89.33% and 2.67%, respectively; the less safe state and critical safe state in the middle reaches accounted for 3.33% and 96.67%, respectively. In the lower reaches of the Yellow River, the unsafe state, relatively safe state, relatively unsafe state and critical safe state account for 30.00%, 23.33%, 23.33% and 23.33% respectively. The proportion of unsafe state in the lower reaches is the highest in the upper, middle and lower reaches. Obviously, the ecological security state in the lower reaches of the Yellow River Basin has a large span. From the perspective of the situation of each province and city, the ecological security state in the upstream basically maintains a relatively unsafe state, but the ecological security state of Sichuan Province changes the most, gradually changing from the initial unsafe state to the relatively unsafe state, and changing to the critical safety state in 2020. The ecological security status of Shanxi and Shaanxi provinces has basically maintained a relatively unsafe state without major changes, while Henan and Shandong provinces in the downstream have made significant progress. The ecological situation of Shandong Province is obviously better than that of other provinces and cities, and there is a safer state that does not appear in other provinces and cities.

6. Driving Factor Analysis

6.1 Selection of Indicators

The ecological security index is affected by many factors [12], and combined with the regional characteristics of the Yellow River Basin, the influence of natural, social, economic and other factors on the ecological security index is comprehensively investigated. Specific proxy variables and measurement methods are shown in Table 7.

Table 7. Indicators of Influencing Factors of Ecological Security Index

Factors	Influencing factors	Method of measurement
Nature	Amount of precipitationX1	Average annual precipitation
	TemperatureX2	Average annual temperature
Society	Density of population X3	Population with household registration/area of administrative region at the end of the year
	Educational developmentX4	Education expenditure /GDP
	Intensity of economyX5	Fixed asset investment /GDP
Economy	Degree of opening-upX6	Total industrial output value /GDP of foreign investment
	Financial developmentX7	Balance of deposits and loans of financial institutions at the end of the year /GDP
	Industrial structureX8	The added value of the tertiary industry /GDP

6.2 Driving Factor Analysis

Table 8. OLS Model Estimation Results

Variables	Coefficient	Standard deviation	-
length of intercept	0.803^{***}	0.020	-
X1	0.086^{***}	0.029	-
X2	0.004	0.037	-
X3	-0.086^{***}	0.033	-
X4	0.825^{***}	0.026	-
X5	-0.047^{**}	0.025	-
Variables	T value	P Value	VIF
length of intercept	39.76	0	-
X1	2.96	0.003	2.05
X2	0.1	0.922	3.27
X3	-2.6	0.009	2.70
X4	9.58	0.000	1.66
X5	-1.91	0.057	1.49

In order to explore the global impact of each factor on the ecological security index of the Yellow River Basin, the significance level and other characteristics of each factor were estimated based on the ordinary least square (OLS) method. It can be seen from Table 8 that the variance inflation factor (VIF) of each factor is less than 7.5, indicating that the factors are reasonably selected and there is no multicollinearity problem. According to Table 8, a total of six factors have a significant impact on EWP under the condition of 5% significance level and below. The importance degree from large to small is X4, X7, X1, X3, X8, X5. Among them, the coefficients of X7, X3, X8 and X5 are negative; The coefficients of X1 and X4 are positive.

7. Conclusions and Recommendations

In this paper, the PSR index system is constructed, and the principal component analysis and entropy weight method are used to measure the ecological security index of 9 provinces in the Yellow River Basin from 2007 to 2021. (1) From 2007 to 2021, it can be seen from the analysis of the current situation that the pollution emission status, ecological status and pollution control status of provinces and cities have all improved, among which Shandong province has excellent performance in all aspects, which is also consistent with the analysis results in the ecological performance evaluation. (2) On the whole, the ecological security index of the Yellow River Basin has been in a relatively insecure state for a long time from 2007 to 2021, which can account for 76.30% of the total; Secondly, the ecological security of the upper reaches of the Yellow River is obviously worse than that of the middle reaches, and the safer states all appear in the downstream, but at the same time, there are great changes in the ecological security state in the downstream. From the perspective of the situation of each province and city, the ecological security status of Sichuan Province in the upstream has changed the most, from the initial unsafe state to the critical safe state in 2021. The ecological situation of Shandong Province is obviously better than that of other provinces and cities. (3) Precipitation, population density, educational development level, economic intensity, financial development level and industrial structure level have a significant impact on the ecological security index. Among them, precipitation, educational development level and industrial structure level have significantly positive promoting effects on the improvement of ecological security index, so it is suggested to adjust the educational development level and change the industrial structure; Population density, economic intensity and financial development level have significantly negative inhibitory effects on the improvement of ecological security index.

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