Analysis of the Cost-benefit on Ecological Environment

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Abstract: With the development of the society, the eco-environmental problems have gradually attracted people's attention, and the environmental cost needs to be considered in investors' budget plans. Based on the current situation of China's ecological environment, this paper will use analytic hierarchy process, fuzzy comprehensive evaluation and principal component analysis to analyze the indexes affecting ecological cost-effectiveness by establishing AHP-FCE model. The purposes of the study are to incorporate ecological costs into the economic costs of land development projects, and help land users to conduct cost-benefit analysis.
For stage II, we take 11 prefecture-level cities in Shanxi Province as the research object. First, input the data of 11 prefecture-level cities into the hierarchical structure of stage I so that we can polish relevant indexes according to the different characteristics. Then, we obtained the weight of each index and establish the AHP-FCE model, using MATLAB to evaluate comprehensively the ecological benefits of prefecture-level cities and calculate the scores. Finally, the eco-efficiency scores of them are ranked. The results showed that there are half of the 11 autonomous counties having achieved good ecological benefits.
For stage III, we use 31 provinces in China as the research object. Based on the research findings above, we use the PCA to reduce dimensionality and screen indicators, selecting three principal components such as social factor, environmental factor and energy factor that have a good explanation for ecological cost-effectiveness, and establish an ecological cost-benefit assessment model. Finally, using SPSS to evaluate the ecological costs and benefits of 31 provinces in China, and the rankings of eco-efficiencies in 31 provinces were gained.
At last, we conducted error analysis and sensitivity analysis of the models while comprehensively evaluating the advantages and disadvantages of the models, and popularized the models.

Keywords: Eco-cost-effectiveness; Ecosystem services; AHP; FCE; PCA; MATLAB

1. Introduction

1.1. Problem analysis

In order to evaluate the real economic cost of land use projects when considering the cost of ecosystem services, we need to establish an ecological benefit assessment model for cost-benefit analysis of land use development projects. Based on the first-stage model foundation, the second phase is based on 11 prefecture-level cities in Shanxi Province. For this problem, we will analyze the following three steps. First, we must determine the evaluation indicators for measuring the cost of ecological benefits in the region. Based on the full consideration of the authenticity and availability of the data, we use AHP[4] to establish a set of regional ecological assessment. We quantify the influencing factors and calculate the weights to analyze their impact on the cost of ecological benefits. Secondly, we use fuzzy clustering analysis to analyze the K-means clustering of the ecological benefit scores of 11 prefecture-level cities in Shanxi Province, and divide the ecological benefits into five grades: excellent, better, good, general and poor. Finally, we have a total ranking of the eco-efficiency scores of 11 prefecture-level cities in Shanxi Province, in order to objectively assess the eco-efficiency costs of different prefecture-level cities.

1.1.1. Building an indicator system

On the basis of fully considering the principles of the construction of the indicator system, we have selected 10 indicators including per capita net income, vegetation green coverage and environmental pollution control investment based on social, environmental and energy consumption, so as to evaluate Cost-effectiveness of the ecological environment. The specific indicator system is shown in the table below.[5][6]

Table 1. Evaluation index system of ecological benefits

Level 1 index	Mark	Level 2 index	Mark	Level 3 index	Mark
Thedevelopment level of urban ecological benefits	Q	social developmen	N1	Per capita cultivated area	M1
				Farmers' per capita net income	M2
				Drainage pipe length	M3

				Green area per 10,000 people	M4
		vegetation greening	N2	Green coverage rate in built-up areas	M5
				Farmland irrigation water	M6
		water treatment	N3	Domestic sewage treatment rate	M7
				Gross media consumption per unit of GDP	M8
		energy consumption	N4	Investment in environmental pollution control	M9
				Urban and rural residents' electricity consumption	M10

1.1.2. Basic steps of fuzzy comprehensive evaluation model

(1)Give the set of objects being evaluated.

$$X\{x_1,x_2,x_3,\cdots x_k\}$$

(2) Determine the set of factors.

$$U=\{u_1,u_2,u_3,\cdots u_n\}$$

(3) Confirm the comment set.

$$V=\{v_1,v_2,v_3,\cdots v_m\}$$

(4) from the factor set and the comment set .a membership matrix t

$$R_i=\begin{bmatrix} r_{11}^{(i)}r_{12}^{(i)} & \cdots & r_{1m}^{(i)} \\ \vdots & \ddots & \vdots \\ r_{n1}^{(i)}r_{n2}^{(i)} & \cdots & r_{nm}^{(i)} \end{bmatrix}$$

can be obtained.

(5) For each U_i, make a comprehensive decision, assuming the fuzzy weight vector of each factor weight in U_i be $A_i=\left(a_1^{(i)}.a_2^{(i)},\cdots a_n^{(i)}\right)$, $\sum_{i=1}^{ni} a_t^{(i)}=1$ .If is a single factor matrix, get the first evaluation vector $A_iOR_i=(b_{i1},b_{i2},\cdots b_{im})\Delta B_i$, $i=1,2\cdots s$.

(6) Think of each U_i as a factor, $U=\{U_1,U_2,\cdots U_S\}$. Therefore, the judgment matrix of U is:

$$R=\begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_S \end{bmatrix}=\begin{bmatrix} b_{11}b_{12} & \cdots & b_{1m} \\ \vdots & \ddots & \vdots \\ b_{s1}b_{s2} & \cdots & b_{sm} \end{bmatrix}$$

So the second-level fuzzy comprehensive evaluation model is:

$$B=AOR=(b_1,b_2,\cdots b_m)$$

1.2. Model establishing & solving

1.2.1. Model establishing

(1)Establish hierarchical structure

First of all, according to the structure of the index system to establish hierarchical structure, The decision problem is divided into four levels: Target layer Q, Criteria layer $N_i(N_1,N_2,N_3,N_4,)$, Program layer $M_i(M_1,M_2,...M_{10})$. The lowest level M_i followed by per capita cultivated area, farmers' per capita net income, drainage pipe length and so on, a total of 10 indexes affect the target layer.[7]

(2)Construct the discriminated matrix

On the basis of the established evaluation index system, we consulted the data in multiple ways and according to the expert score and the geographical situation of Shanxi Province, the relative importance between the indicators was based on the scale of 1-9, and the judgment matrix of the two pairs was constructed. The weights of the criteria layer and the indicator layer are determined separately, and the specific process is as follows.

Take two indicator factors X_i and X_j at a time, the ratio of the influence of X_i and X_j on the target layer N is represented by a_{ij}. The comparison result is represented by the matrixA=(a_{ij}) , which we call A comparison judgment matrix[8]between N-X.If the ratio of the influence of X_i and X_j on N is a_{ij} , then the ratio of the influence should be $a_{ij}=\frac{1}{a_{ij}}$.

If $A=(a_{ij})_{n\times n}$ is satisfied

$$(i)a_{ij}>0,\quad (ii)a_{ji}=\frac{1}{a_{ij}}(i,j=1,2,\cdots n)$$

Then both are positive reciprocal matrices,

$$a_{ii}=1, i=1,2,\cdots n$$

In order to determine the value of a_{ij}, this paper performs a data-level scale on the relative importance of each variable factor. The table below shows the meaning of each scale.

Table 2. The relative importance of the value of the situation

Scale	Rule
1	On a layer of factors as a criterion layer, the level of factors i and j compared to equally important
3	On a layer of factors as a criterion layer, the level of factor i and j than j slightly important
5	On a layer of a factor as a criterion layer, the level of factor i and j compared to j is significantly important
7	On a layer of factors as a criterion layer, the level of factors i and j compared to j is strongly important
9	On a layer of factors as a criterion layer, the level of factors i and j than j extremely important
2.4.6.8	The importance level is between 1,3,5,7,9

(3)Consistency test

Based on the above calculations, the judgment matrix is tested for consistency to verify its acceptance. We calculate the consistency indicator CI:

$$CI = \frac{a-n}{n-1}$$

We look up the corresponding average random consistency indicator RI. Calculating the consistency ratio C, n>3, CR<0.1 [9], it is considered that the consistency of the judgment matrix is acceptable, otherwise the judgment matrix should be appropriately modified. The RI value of the second-order matrix is 0, and the second-order judgment matrix itself has complete consistency, so the second-order matrix does not need to judge consistency.

1.2.2. Model solving

(1)Establishment of indicator matrix judgment matrix

Table 3. Indicator layer judgment matrix

N1	M1	M2	M3	N4	M8	M9	M10
M1	1	1/5	1/3	M8	1	1/7	1/9
M2	5	1	1/2	M9	7	1	1/3
M3	3	2	1	M10	9	3	1
N2	M4	M5		N3	M6	M7	
M4	1	1/7		M6	1	1/5	
M5	7	1		M7	5	1	

(2)Establishment of the target layer judgment matrix

Table 4. Target layer judgment matrix

Q	N1	N2	N3	N4
N1	1	1/2	1/5	1/7
N2	2	1	1/4	1/6
N3	5	4	1	1/3
N4	7	6	3	1

(3)Hierarchical single sorting and consistency check

After the judgment matrix is established, the index data is hierarchically sorted and checked for consistency. Using MATLAB software, the eigenvector W of the maximum eigenvalue l_{max} corresponding to the judgment matrix A is calculated, and after normalization, it is the ranking weight of the corresponding factor of the same level for the relative importance of a certain factor of the previous level.

After the row vector of the judgment matrix is normalized, the feature vector of N-M is obtained as:

$$N_1 = (0.6413, 0.2280, 0.1306)$$

$$N_2 = (0.8750, 0.1250), N_3 = (0.8333, 0.1667)$$

$$N_4 = (0.7526, 0.1834, 0.0639)$$

$$Q = (0.4602, 0.3528, 0.1365, 0.0504)$$

Multiply the value in the judgment matrix N-M by the corresponding number in N_1, and then add them together:

$$B_1^T = N_1 A_1 = [0.6413 \quad 0.2280 \quad 0.1306]\begin{bmatrix} 1 & 1/5 & 1/3 \\ 5 & 1 & 1/2 \\ 3 & 2 & 1 \end{bmatrix} = \begin{bmatrix} 2.1731 \\ 0.6175 \\ 0.4584 \end{bmatrix}$$

$$a = \frac{1}{3}\left(\frac{2.1731}{0.6413} + \frac{0.6175}{0.2280} + \frac{0.4584}{0.1306}\right) = 3.1082$$

$$B_2^T = N_2 A_2 = [0.8705 \quad 0.1250]\begin{bmatrix} 1 & 1/7 \\ 7 & 1 \end{bmatrix} = \begin{bmatrix} 1.7455 \\ 0.2494 \end{bmatrix}$$

$$a = \frac{1}{2}\left(\frac{1.7455}{0.8705} + \frac{0.2494}{0.1250}\right) = 2.0002$$

$$B_3^T = N_3 A_3 = [0.8333 \quad 0.1667]\begin{bmatrix} 1 & 1/5 \\ 5 & 1 \end{bmatrix} = \begin{bmatrix} 1.6668 \\ 0.3334 \end{bmatrix}$$

$$a = \frac{1}{2}\left(\frac{1.6668}{0.8333} + \frac{0.3334}{0.1667}\right) = 2.0001$$

$$B_4^T = N_4 A_4 = [0.7526 \quad 0.1834 \quad 0.0639]\begin{bmatrix} 1 & 1/7 & 1/9 \\ 7 & 1 & 1/3 \\ 9 & 3 & 1 \end{bmatrix} = \begin{bmatrix} 2.6115 \\ 0.4826 \\ 0.2087 \end{bmatrix}$$

$$a = \frac{1}{3}\left(\frac{2.6115}{0.7526} + \frac{0.4826}{0.1834} + \frac{0.2087}{0.0639}\right) = 3.1025$$

$$B_5^T = QA_5 = [0.4602 \quad 0.3528 \quad 0.1365 \quad 0.0504]\begin{bmatrix} 1 & 1/2 & 1/5 & 1/7 \\ 2 & 1 & 1/4 & 1/6 \\ 5 & 4 & 1 & 1/3 \\ 7 & 6 & 3 & 1 \end{bmatrix} = \begin{bmatrix} 2.2011 \\ 1.4313 \\ 0.4679 \\ 0.2204 \end{bmatrix}$$

$$\alpha = \frac{1}{4}\left(\frac{2.2011}{0.4602} + \frac{1.4313}{0.3528} + \frac{0.4679}{0.1365} + \frac{0.2204}{0.0504}\right) = 4.1602$$

$$\mathrm{CR} = \frac{CI}{RI}$$

$$CR_1 = \frac{CI_1}{RI} = \frac{3.1682-3}{2} \times \frac{1}{0.58} = 0.0932$$

$$CR_4 = \frac{CI_4}{RI} = \frac{3.1025-3}{2} \times \frac{1}{0.58} = 0.0884$$

$$CR_5 = \frac{CI_5}{RI} = \frac{4.1602-4}{3} \times \frac{1}{0.9} = 0.0593$$

From the above calculation, CR<0.1 is obtained, so the consistency test is passed.

1.3. Result analysis

Table 5. Weight of ecological benefit evaluation indicators

Level1 index	Level 2 index	Weight	Level 3 index	Weight	Comprehensive weight
Thedevelopmentlevel of urban ecological benefits	Social development	0.4602	Per capita cultivated area	0.6413	0.2951
			Farmers' per capita net income	0.2280	0.1049
			Drainage pipe length	0.1306	0.0601

			Green area per 10,000 people	0.8750	0.3087
	vegetation greening	0.3528	Green coverage rate in built-up areas	0.1250	0.0441
			Farmland irrigation water consumption	0.8333	0.1137
	water treatment	0.1365	Domestic sewage treatment rate	0.1667	0.0228
			Gross media consumption per unit of GDP	0.7526	0.0379
	energy consumption	0.0504	Investment in environmental pollution control	0.1834	0.0092
			Urban and rural residents' electricity consumption	0.0639	0.0032

2. Model III

2.1. Model establishment

(1)Determining the impact factor set

Based on evaluation factors $U=U_1,U_2,U_3,...U_n$ establish a set of primary evaluation indicator factors U_1=(N_1,N_2,N_3,N_4), corresponding to social environmental factors, vegetation greening factors, water resources treatment factors, energy consumption factors. Establishing a secondary evaluation index factor set U_{N1}=(M_1,M_2,M_3) ,corresponding to the per capita arable land area, per capita net income of farmers, and the length of drainage pipes. U_{N2}=(M_4,M_5), corresponding to the green area per 10,000 people and the green coverage rate of the built-up area.U_{N3}=(M_6,M_7), corresponding to farmland irrigation water consumption and domestic sewage treatment . rate.U_{N4}=(M_8,M_9,M_{10}),corresponding to the energy consumption per unit of GDP in the unit area, the electricity consumption of urban and rural residents[10][11], and the domestic water consumption of residents.

(2)Establish eco-efficiency reviews

When evaluating the urban ecological benefits, the ecological benefits are divided into five levels from the perspective of expert scoring, giving “10 ”, “30”, “50”, “70” and “90” respectively. So the comment set can be expressed as:

$$V=\{10,30,50,70,90\}$$

(3)Determining the membership matrix

For the determination of the membership matrix, based on the model 1, the jury is used to determine the degree of membership[17]. If there are n judges, then for a certain city, the membership of an indicator in the indicator layer in V is expressed as:

$$r_{ij}=\frac{(\text{ a factor } u_{ij} \text{in M, the number of people in the judges who are judged as the j rank})}{n}$$

Based on the above analysis, the following membership matrix is established:

$$R_1=\begin{bmatrix} r_{11}r_{12}r_{13}r_{14}\ r_{15} \\ r_{21}r_{22}r_{23}r_{24}\ r_{25} \\ r_{31}r_{32}r_{33}r_{34}\ r_{35} \end{bmatrix}$$

$$R_2=\begin{bmatrix} r'_{11}\ r'_{12} \\ r'_{21}\ r'_{22} \end{bmatrix}$$

$$R_3=\begin{bmatrix} r''_{11}\ r''_{12} \\ r''_{21}\ r''_{22} \end{bmatrix}$$

$$R_4=\begin{bmatrix} r'''_{11}r'''_{12}r'''_{13}r'''_{14}\ r'''_{15} \\ r'''_{21}r'''_{22}r'''_{23}r'''_{24}\ r'''_{25} \\ r'''_{31}r'''_{32}r'''_{33}r'''_{34}\ r'''_{35} \end{bmatrix}$$

2.2. Model solving

Combine the weight matrix of each city with the weight of each index in the evaluation index system, then establish a fuzzy comprehensive evaluation model of social development factor evaluation, vegetation greening factor evaluation, water resources treatment factor evaluation, energy consumption factor evaluation and overall evaluation of urban ecological benefits. We carry out fuzzy calculations to analyze the results. The following analysis is based on Taiyuan City.

(1)Evaluation result of the criteria layer

The social development factor evaluation model is

$$C_1^T=N_1R_1=(0.6413,0.2280,0.1306)\begin{bmatrix} 0.1, & 0.3, & 0.3, & 0.7, & 0.5 \\ 0, & 0.3, & 0.4, & 0.7, & 0.5 \\ 0, & 0.1, & 0.3, & 0.6, & 0.3 \end{bmatrix}=\begin{bmatrix} 0.0641 \\ 0.2739 \\ 0.3228 \\ 0.6869 \\ 0.4738 \end{bmatrix}$$

The vegetation greening factor evaluation model is:

$$C_2^T=N_2R_2=(0.8750,0.1250)\begin{bmatrix} 0.3, & 0.5, & 0.6, & 0.1, & 0 \\ 1, & 0.7, & 0.5, & 0.2, & 0.1 \end{bmatrix}=\begin{bmatrix} 0.3875 \\ 0.5250 \\ 0.5875 \\ 0.1125 \\ 0.1250 \end{bmatrix}$$

The water resource treatment factor evaluation model is

$$C_3^T=N_3R_3=(0.8333,0.1667)\begin{bmatrix} 0, & 0, & 0.5, & 0.5, & 0.1 \\ 0.1, & 0.1, & 0.4, & 0.5, & 0.5 \end{bmatrix}=\begin{bmatrix} 0.0167 \\ 0.0167 \\ 0.4833 \\ 0.5000 \\ 0.1667 \end{bmatrix}$$

The energy consumption factor evaluation model is:

$$C_4^T = N_4 R_4 = (0.7526, 0.1834, 0.0639)\begin{bmatrix} 0.1, & 0.1, & 0.5, & 0.7, & 0.5 \\ 0, & 0.2, & 0.5, & 0.2, & 0.1 \\ 0.3, & 0.5, & 0.5, & 0.7, & 0.7 \end{bmatrix} = \begin{bmatrix} 0.0944 \\ 0.1439 \\ 0.4999 \\ 0.6082 \\ 0.4394 \end{bmatrix}$$

(2)Evaluation result of the Target layer

The overall evaluation model of urban ecological benefits is:

$$C^T = Q^T R = \begin{bmatrix} 0.4602 \\ 0.3528 \\ 0.1365 \\ 0.0504 \end{bmatrix}\begin{bmatrix} 0.0641, 0.2739, 0.3228, 0.6869, 0.4738 \\ 0.3875, 0.5250, 0.5875, 0.1125, 0.1250 \\ 0.0167, 0.0167, 0.4833, 0.5000, 0.1667 \\ 0.0944, 0.1439, 0.4999, 0.6082, 0.4394 \end{bmatrix} = \begin{bmatrix} 0.1732 \\ 0.3208 \\ 0.4470 \\ 0.3547 \\ 0.3074 \end{bmatrix}$$

In order to more intuitively represent the city's effective total score, this paper compares each evaluation result with a numerical value to make the result clearer. The score table is shown in the following table.

Table 6. Comment level

Comment level	Poor	General	Good	Better	Excellent
score	10	30	50	70	90

According to this, the ecological benefit scores of cities in Shanxi Province can be obtained. Here, the ecological benefit score of Taiyuan City is calculated as:

$$Z = C^T V = \begin{bmatrix} 0.1732 \\ 0.3208 \\ 0.4470 \\ 0.3547 \\ 0.3074 \end{bmatrix}[10, 30, 50, 70, 90] = 86.20$$

It is calculated that Taiyuan City, Shanxi Province has a score of 86.20, indicating that the city has a good eco-efficiency rating. In this rating, the water treatment factor weight reaches 0.1365, the sewage treatment consumption ratio is 0.1667, and the energy consumption factor weight is 0.0504. The largest environmental consumption cost is the unit GDP energy consumption, the weight is 0.7526, environmental pollution control The weight of the investment amount is 0.1834, and the water treatment factor and energy consumption factor are regarded as the environmental consumption cost. The total proportion is 0.1869. It can be concluded that the environmental consumption cost has a certain influence on the urban ecological benefit assessment, so the country or enterprise is implementing a land planning project, the environmental consumption cost should be fully considered and included in the economic cost of the budget project.

2.3. Result analysis

According to the expert rating of the evaluation results of the various cities in Shanxi Province, at the same time refer to the multi-party literature, combined with the regional reality to obtain the results of the ecological benefits of cities in Shanxi Province, as shown in the following table.

Table 7. Ecological benefit results of cities in Shanxi Province

City	Ecological benefit score	Evaluation level	Ranking	Gradient ranking
Taiyuan	86.20	Better	1	First gradient
Changzhi	54.59	Good	2	
Yangquan	54.14	Good	3	Second gradient
Jinzhong	51.78	Good	4	
Shuozhou	50.79	Good	5	
Jincheng	48.70	General	6	
Datong	47.61	General	7	
Linfen	47.04	General	8	Third gradient
Yuncheng	45.81	General	9	
Lvliang	34.37	General	10	
Xinzhou	29.98	Poor	11	Fourth gradient

The results of the above table show that in the ecological benefit ranking of cities in Shanxi Province, the ecological benefits of Taiyuan City are the most optimistic, followed by Changzhi City, Yangquan City, Jinzhong City and Zhangzhou City as the second title gradient city, and the ecological benefit rating is good. Once again, Jincheng City, Datong City, Linyi City, Yuncheng City and Luliang City are the third gradient cities, and the eco-efficiency rating is general. Finally, Cangzhou City is the fourth gradient city, and the eco-efficiency rating is poor.

The results of the model show that the better the eco-efficiency rating, the lower the environmental cost of the budget input, and the more pessimistic the eco-efficiency evaluation, the higher the environmental cost of the budget input that investors use to compensate for environmental losses. According to the above rating results, land development users can be provided with decision-making basis for selecting projects to enter the city.

3. Model IV

3.1. Problem analysis

According to the analysis of the results of Model 2 and Model 3, we obtained the ranking of ecological benefits of cities in Shanxi Province. Taking into account the subjectivity and uncertainty of expert scoring, we further optimized and improved the eco-cost-benefit model. In order to expand the scope of research again, we selected 31 provinces as the research object, based on the applicability of the model research objects and the improvement of the model method, the principal component analysis method was used to evaluate the ecological cost benefits of 31 provinces nationwide[18][19].On the basis of fully considering the authenticity and applicability of the indicators. Finally, we selection of 13 indicators such as power consumption, construction land area, industrial pollution control completed investment, and total water consumption.

3.2. Model preparation

Principal component analysis is a statistical analysis method that turns the original multiple variables into a few comprehensive indicators. From a mathematical point of view, it is a dimensionality reduction processing technique. According to the basic principle of principal component analysis, the steps of calculating the weights can be summarized as shown in the following figure.

3.3. Model establishing and solving

3.3.1. Model establishing

(1)Descriptive statistics of variables

We enter the 13 indicator data selected into SPSS and get the following variable statistics table .

Table 8. Variable description statistics

	Average	Standard deviation	cases
Urban electricity consumption	1599.72	1172.080	31
Per capita net income of rural households	8495.29	3339.759	31
Urban construction land area	1475.83	1046.063	31
Per capita daily water consumption	164.14	43.217	31
Urban drainage pipe length	14163.87	13041.577	31
	441.71	395.608	31
Urban green area	76382.00	78578.308	31
Green coverage rate in built-up areas	38.45	3.826	31
Total water use	198.12	147.180	31
Total wastewater discharge	220890.71	181034.326	31
Sulfur dioxide emissions	68.31	43.046	31
Total afforestation area	180079.29	166593.277	31
Industry investment in pollution control	16.14	13.625	31

(2)KMO and Bartley spherical test

Table 9. KMO and Bartlett spherical test results

KMO test value		0.788
	Approximate K^2	422.419
Bartlett puerility test	Degree of freedom	78
	Significant	0.000

According to the above table, the KMO test value is 0.788<1, so the test is performed. Meanwhile, when the significance level is 1%, the sig value is 0, so the model is suitable for factor analysis.

3.4. Model solving

3.4.1. Calculate the principal component contribution rate

The principal component number extraction principle is the first n principal components whose feature values corresponding to the main component are greater than 1. The eigenvalue can be regarded as an index indicating the magnitude of the influence of the principal component to some extent. According to the eigenvalue selection principle, if the eigenvalue is less than 1, it indicates that the explanatory intensity of the principal component does not directly introduce the average explanatory strength of a primary variable. Large, so the eigenvalue is generally greater than 1 as the inclusion criteria.

Table 10. Eigenvalue and principal component contribution rate

Ingredient	total	variance	Cumulative	total	variance	Cumulative	total	variance	Cumulative
1	7.009	53.912	53.912	7.009	53.912	53.912	5.988	46.062	46.062
2	2.369	18.224	72.135	2.369	18.224	72.135	2.328	17.909	63.972
3	1.171	9.006	81.141	1.171	9.006	81.141	2.232	17.170	81.141
4	0.812	6.244	87.385						
5	0.543	4.180	91.565						
6	0.366	2.813	94.378						
7	0.299	2.298	96.675						

8	0.134	1.029	97.704							
9	0.107	.823	98.527							
10	0.076	.587	99.114							
11	0.061	.467	99.581							
12	0.036	.279	99.860							
13	0.018	.140	100.000							

According to the principle that the eigenvalue is greater than 1, the first, second and third principal components are selected, and the cumulative contribution rate reaches 81.14%, which has a good interpretation of the variables.

3.4.2. Calculate principal component load and principal component score

The extracted principal components 1, 2, and 3 are respectively obtained as feature vectors e1, e2, and e3, and the loads of the respective variableson the principal components are calculated to obtain a principal component load matrix. The degree of influence factor is not used for classification, which makes the result more accurate[20].The maximum variance of the load matrix is obtained. After 11 iterations, the rotation component ma trix is obtained. The results are shown in the following table.

Table 11. Principal component rotation load matrix

	Symbol	Ingredient		
		1	2	3
Urban electricity consumption	X1	0.841	0.376	0.295
Per capita net income of rural households	X2	0.155	-0.211	0.866
Urban construction land area	X3	0.822	0.161	0.460
Per capita daily water consumption	X4	0.497	-0.713	-0.030
Urban drainage pipe length	X5	0.812	0.126	0.491
daily treatment capacity ofurban sewage	X6	0.914	-0.026	0.340
Urban green area	X7	0.878	-0.031	0.335
Green coverage rate in built-up areas	X8	0.277	-0.004	0.556
Total water use	X9	0.821	-0.070	-0.278
Total wastewater discharge	X10	0.919	0.084	0.289
Sulfur dioxide emissions	X11	0.421	0.850	-0.071
Total afforestation area	X12	-0.030	0.710	-0.405
Industry investment in pollution control	X13	0.544	0.594	0.272

From the chart above, we can see that the first principal component has a greater correlation with urban power consumption (X1), urban construction land area (X3), urban drainage pipe length (X5), urban sewage daily processing capacity (X6), urban green space area (X7), and a total of seven indicators. According to the nature of the index, we define the first principal component as the urban social development factor. The second principal component has a greater correlation with the four indicators of per capita daily domestic water consumption (X4), sulfur dioxide emissions (X11), and industrial pollution control completed investment (X13), so we defined the second principal component as energy consumption factor. The third principal component is related to green coverage rate in built-up areas(X8) and X2, thus, the third principal component is defined as the vegetation greening factor.

3.4.3. Determination of indicator weight

After naming the principal component factors, we calculate the weights of the indicators in three principal components, as shown in the following table.

Table 12. Index score coefficient matrix

	Symbol	Ingredient		
		1	2	3
Urban electricity consumption	X1	0.113	0.124	0.032
Per capita net income of rural households	X2	-0.155	-0.020	0.532
Urban construction land area	X3	0.088	0.043	0.126
Per capita daily water consumption	X4	0.211	-0.385	-0.223
Urban drainage pipe length daily treatment capacity ofurban sewage	X5	0.081	0.031	0.146
	X6	0.161	-0.066	0.001
Urban green area	X7	0.153	-0.065	0.005
Green coverage rate in built-up areas	X8	-0.065	0.031	0.311
Total water use	X9	0.296	-0.144	-0.404
Total wastewater discharge	X10	0.164	-0.021	-0.024
Sulfur dioxide emissions	X11	0.046	0.347	-0.062

Total afforestation area	X12	0.023	0.290	-0.193
Industry investment in pollution control	X13	0.018	0.253	0.114

Multiply the obtained feature vector by the normalized data, and then obtain the expressions of the three principal components as follows:

$$F_1=0.113X_1-0.155X_2+0.088X_3+0.211X_4+0.081X_5+0.161X_6+0.153X_7-0.065X_8+0.296X_9+0.164X_{10}+0.046X_{11}+0.023X_{12}+0.018X_{13}$$

$$F_2=0.124X_1-0.020X_2+0.043X_3-0.385X_4+0.031X_5-0.066X_6-0.065X_7+0.031X_8-0.144X_9-0.021X_{10}+0.347X_{11}+0.290X_{12}+0.253X_{13}$$

$$F_3=0.032X_1+0.532X_2+0.126X_3-0.223X_4+0.146X_5+0.001X_6+0.005X_7+0.311X_8-0.404X_9-0.024X_{10}-0.062X_{11}-0.193X_{12}+0.114X_{13}$$

The resulting comprehensive modelis:

$$\mathrm{F}=F_1\times\frac{m_1}{m_1+m_2+m_3}+F_2\times\frac{m_2}{m_1+m_2+m_3}+F_3\times\frac{m_3}{m_1+m_2+m_3}$$

The comprehensive model of ecological benefits in all provinces of the country is:

$$\mathrm{F}=0.1065X_1-0.0484X_2+0.0821X_3+0.0290X_4+0.0770X_5+0.0923X_6+0.0876X_7-0.0017X_8+0.1195X_9+0.1016X_{10}+0.1016X_{11}+0.0590X_{12}+0.0814X_{13}$$

3.5. Result analysis

The ranking of eco-efficiencies in the 31 provinces of the country is shown in the table below

Table 13. Ranking of 31 provinces ecological benefit score

Province	Score	Evaluation level	Rank	Gradient ranking
Hubei	90.52	Excellent	1	First gradient
Shanghai	63.10	Better	2	Second gradient
Heilongjiang	55.16	Better	3	
Inner Mongolia	43.39	Good	4	Third gradient
Xinjiang	42.24	Good	5	
Beijing	41.65	Good	6	
Anhui	40.44	Good	7	
Ningxia	39.64	Good	8	
Hainan	35.33	Good	9	
Fujian	35.01	Good	10	
Shanxi	33.76	Good	11	
Hunan	30.61	Good	12	
Guizhou	28.03	General	13	Fourth gradient
Sichuan	25.85	General	14	
Shanxi	25.66	General	15	
Tianjin	24.25	General	16	
Chongqing	24.23	General	17	
Yunnan	23.90	General	18	
Jiangxi	23.00	General	19	
Qinghai	22.96	General	20	
Guangdong	20.92	General	21	
Zhejiang	18.41	General	22	
Guangxi	15.70	General	23	
Hebei	14.58	General	24	
Tibet	12.93	General	25	
Jiangsu	12.28	General	26	
Liaoning	8.07	Poor	27	Fifth gradient
Gansu	7.75	Poor	28	
Shandong	7.23	Poor	29	
Jilin	6.35	Poor	30	
Henan	3.31	Poor	31	

Through the analysis, we can conclude that there are significant differences in ecological benefits among the 31 provinces in China. Among them, Hubei Province has the highest eco-efficiency score, Henan Province has the lowest eco-efficiency score, and the benefit score spans a large extent. In order to more intuitively reflect the ecological benefits of 31 provinces, we divide the benefit scores of 31 provinces into five gradients according to the above analysis, and made the following accumulation maps for the annual data of each province and city with the total water consumption index.

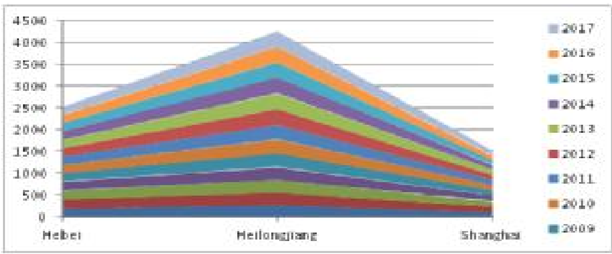

Figure 1. First gradient ecological benefitaccumulation figure

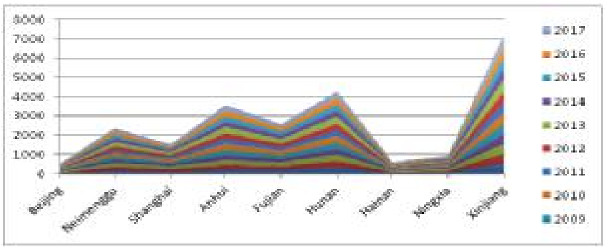

Figure 2. Second gradient ecological benefit accumulation figure

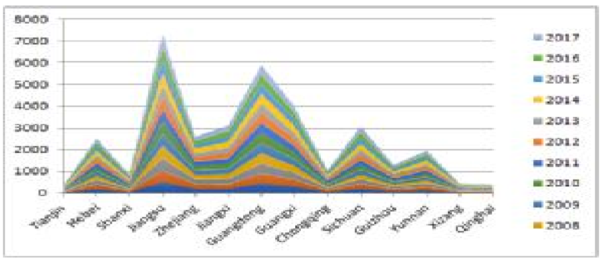

Figure 3. Third gradient province ecologicalbenefit accumulation

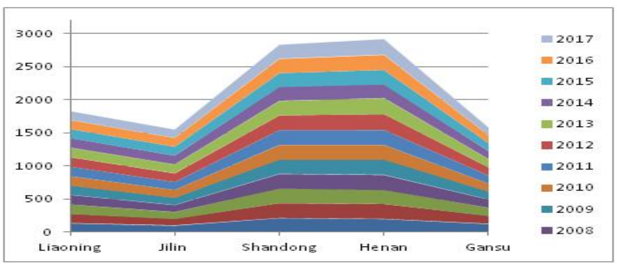

Figure 4. Fifth gradient province ecologicalbenefit accumulation figure

According to the chart, the annual water consumption of the first, second and fifth gradient provinces are on the rise, and there are also some obvious differences in consumption. In the first and second gradient, Heilongjiang Province has the largest amount of water consumption. In the fifth gradient, Hunan Province has the largest amount of it, and Shandong Province is the second. In the second and third gradient, the water consumption fluctuat violently in the horizontal level. The differences in water consumption are massive, but the eco-efficiency scores are relatively close, indicating that the provinces in first and second gradient pay more attention to the input of environmental protection while developing economy, which maintains the balance of economy and environment.

4. Sensitivity analysis

The impact of Cost-effectiveness on ecosystem is achieved through the influence of Cost-effectiveness change on 13 indicators. The model is：

F=0.1065X1-0.0484X2+O.O821X3+0.0290X4+0.0770X5 +0.0923X6+0.0876X7-0.0017X8+0.1195X9+0.1016X10 +0.1016X11+0.0590X12+0.0814X13

First of all, assuming the other conditions remain unchanged, the remaining variables, X_i(i=1,2,...13) are treated as constants, Take the 1.1 times, 1.05 times, 0.95 times and 0.9 times. number to analyze the impact of Security Apparatus Security(x1) on ecosystem is the independent variable and the regression coefficient before x1 is set to k,. The value range is [0,20], y is the dependent variable, and the equation is that:

$$y = 0.1065 X_1 + 42.65$$

According to the different values of k, we use MATLAB to program for sensitivity analysis. The sensitivity of the Security Apparatus to FSI size shown in Figure 5

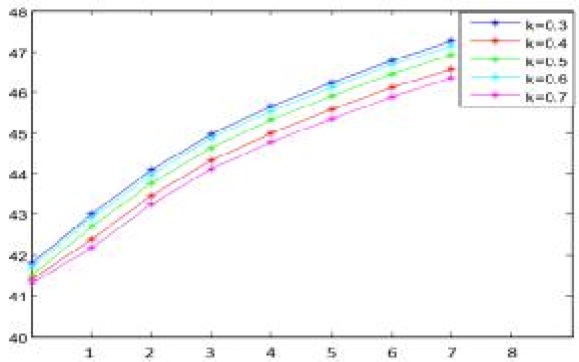

Figure 5. Sensitivity analysis

As can be seen from the sensitivity analysis, when the k value is constant, the Cost-effectiveness value increases with the increase of the security coefficient. At the same time, k increases by 0.05 for different k values. The Cost-effectiveness value increases with the increase of k. That is, the ecological cost increases. Therefore, the effect of this sensitivity analysis is better. Similarly, the sensitivity of the remaining indicators to the Cost-effectiveness can be obtained and the sensitivity of the direct impact of ecosystem to the Cost-effectiveness can also be drawn.

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