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Ecosystem evaluation model based on hierarchical analysis

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Abstract

Taking the ecological environment of Saihanba, Beijing and Mongolia as the main research object, according to the requirements of the topic, this paper establishes the relevant analysis model of Saihanba's anti dust ability to Beijing and extending Saihanba to Mongolia in the whole country and the Asia Pacific region, discusses the influencing factors on the ecological environment of the three regions, and studies the role of Saihanba's ecological model on Beijing and Mongolia, The scale and quantity of Saihan dam in these two regions are determined, and the extent of the extension of Saihan dam ecological protection model to the whole country and the Asia Pacific region to achieve carbon neutralization and reduce greenhouse effect is evaluated. The main work of this paper is as follows: Firstly, according to the variable data before and after the restoration of Saihan dam, the hierarchical structure of the impact of Saihan dam on the ecological environment is established. Then the judgment matrix is constructed to obtain the positive reciprocal matrix. Through MATLAB language, the consistency of positive reciprocal matrix is tested and the combined weight vector is calculated.

Keywords

Saihan dam, analytic hierarchy process, correlation analysis, entropy weight method, Particle Optimization.

1. Problem Restatement

1.1. Topic Scenario

Saihanba forest farm in China is an important ecological barrier in Beijing and Tianjin. With the development of time, the ecological environment of Saihanba area has been significantly improved, which explains the concept that green water and green mountains are Jinshan and Yinshan. Through struggle, the forest coverage in Saihanba area has been significantly improved, with 747000 tons of carbon sequestration and 545000 tons of oxygen release. It is conducive to the realization of carbon peak and carbon neutralization goals.

1.2. Problems to be solved

Question 1: use analytic hierarchy process, correlation analysis, principal component analysis and normalization to analyze the relevant statistical data and evaluate the impact of Saihan dam on the environment after repair.

Question 2: establish a mathematical model of the impact of Saihan dam on Beijing's anti sandstorm ability and evaluate the effect of Saihan dam on Beijing's anti sandstorm ability.

Question 3: in the above mathematical model, China needs to establish the scale, geographical location and quantity of ecological areas and evaluate their impact on achieving the goal of carbon neutralization.

Question 4: other countries in the Asia Pacific region need to establish the geographical location, quantity and scale of ecological areas to assess their impact on absorbing greenhouse gases and reducing carbon emissions.

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Question 5: according to the established mathematical model and data analysis, put forward feasible schemes and suggestions for the construction of ecological reserves.

2. Model Hypothesis

According to relevant research and mathematical statistical analysis, the following assumptions are made for the model in this paper:

1 Suppose that the data we count and analyze are objective and true;

2 The errors of all experimental data are relatively independent and follow the normal distribution n $(0,\sigma)$, and the influence on the data can be ignored;

3 When considering the impact of the establishment of Saihan dam on the ecological environment, it is assumed that there is a progressive structure in the three levels, and only the impact of seven indicators on the ecological environment is considered; Similarly, when considering the scale and quantity of ecological areas, only the given index factors are considered;

4 It is assumed that the entropy weight method only considers the environmental indicators in recent 20 years when standardizing the overall indicators of Beijing and Saihanba.

5 it is assumed that the migration rate is not considered in the population statistics; 6) The assumption does not include human factors, such as the environmental impact of epidemic situation and mountain fire on Beijing and Mongolia;

3. Symbol Description

Symbol	Definition
Xi	Elements of judgment matrix
Xj	Elements of judgment matrix
CI	Consistency index
RI	CI size of consistency measure
CR	Consistency ratio
λ	Maximum eigenvalue
W_i	Weight of each indicator after planning processing
Y_{ij}	Data value after data standardization
P_{ij}	Probability matrix
E_j	Information entropy
σ	variance
Other unlisted symbols shall be explained separately in the text	

4. Problem Analysis

4.1. Overal Analysis

According to the conditions and information given by the topic and the five problems required to be solved, generally speaking, the first four are evaluation and optimization problems. In order to solve these problems, we need to determine the evaluation indicators through analysis and determine the index weight according to the relevant data.

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We collected the sand dust weather outbreak in Beijing over the years, the restoration of Saihanba over the years, and the distribution map of desertification degree in various regions of Mongolia. According to the available reliable data, we established different optimization models and studied their solution algorithms to solve the corresponding problems given by the problem.

4.2. Solution Ideas

Aiming at problem 1, collect the variable data before and after the restoration of Saihan dam, calculate the dependent and independent variables, screen the forest coverage rate and afforestation evolution rate by principal component analysis, and establish the forest environment assessment system.

In view of question 2, according to the existing data, the weighted summation idea is used to obtain the environmental assessment value of Beijing over the years, and then the SPSS correlation analysis is carried out with the overall environmental assessment value of Saihanba area. If there is a positive correlation, it shows that the change of environmental status in Saihanba area plays a positive role in promoting environmental pollution in Beijing.

Problem 3 is a multi-objective decision optimization problem. In order to minimize the cost and maximize the ecological benefit, the constraints are determined according to the data, and the particle swarm optimization algorithm in the simulation optimization algorithm is used to solve it.

For problem 4, priority should be given to countries with low density and poor environment. Analytic hierarchy process is used to determine the index factors to be evaluated. Similarly, the maximization of ecological benefits is pursued, and particle swarm optimization algorithm is used to determine the scale to be established.

5. Model Establishment And Solution

5.1. The Price Type of Environmental Shadow

5.1.1 The Structure of the Impact of Lihan Dam on the Environment

Firstly, the seven indicators are layered, and the decision-making problem is divided into three levels: target level, criterion level and scheme level. Each level has several elements, as shown in Figure 1:

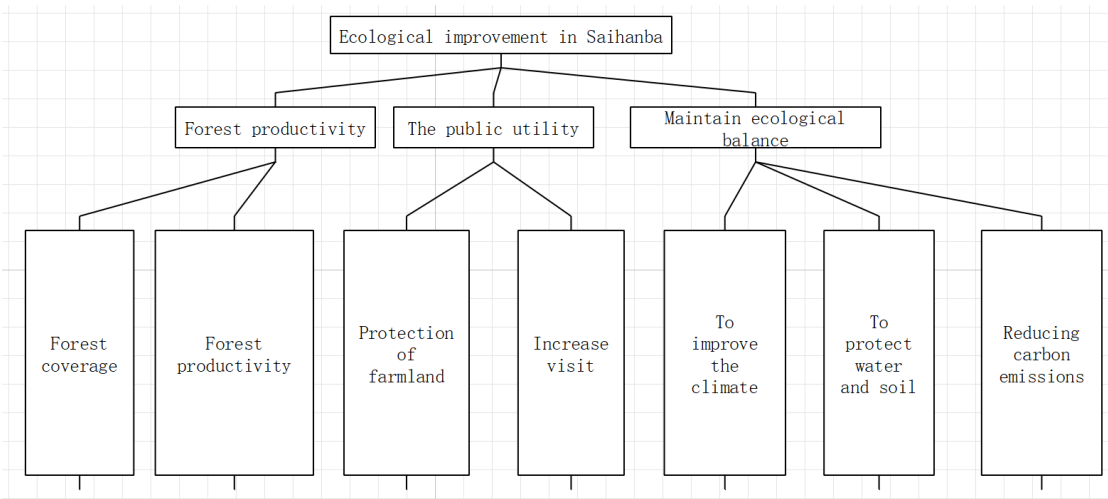

Figure 1 Analytic hierarchy process indicators

Target layer: Saihan dam;

Criterion level: forest productivity, public welfare utility and maintaining ecological balance;

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Scheme level: forest coverage, forest productivity, farmland protection, increased tourism, climate improvement, water and soil protection and carbon emission reduction

5.1.2 Construction of Fault Making Matrix

Table 2 relative importance α Value of ijαij

Relatively important	define
1	If Xi is equivalent to XJ: assign 1
3	If Xi is more important than XJ
5	If Xi is more important than XJ
7	If Xi is more important than XJ
9	If Xi is the most important
2，4，6，8	The importance level is between Xi and XJ
1/2，1/3……1/9	Relationship between Xi and XJ corresponding to the above levels

Firstly, the forest productivity, public welfare utility and ecological balance maintenance of Saihanba are analyzed. Through data comparison and consulting a large number of literature, the positive reciprocal matrix can be approximately obtained:

$$A=\begin{bmatrix} 1 & \frac{1}{2} & 2 \\ 2 & 1 & 2 \\ \frac{1}{2} & \frac{1}{2} & 1 \end{bmatrix}$$

5.1. 3 Times of Discharge and Primary Performance Test

Use MATLAB language to find the maximum characteristic value of matrix A: λ= 3. 0536 consistency index is used to test the consistency of positive reciprocal matrix:

CI=(λ-n)/(n-1)

CI = 0.0268 according to MATLAB language

Consistency ratio: CR = CI / RI = 0.0516 < 0.1, that is, it passed the consistency test.

5.1.4 Calculate the Combination Direction and the Weight Vector

Next, construct the positive reciprocal matrix of each criterion of the scheme layer to the criterion layer

(1) Positive reciprocal matrix B1 of forest coverage and forest productivity to forest productivity:

$B1=\begin{bmatrix} 1 & \frac{1}{2} \\ 2 & 1 \end{bmatrix}$, The maximum features can be obtained by MATLAB language λ Max = 2, consistency CR = 0, CI = 0

(2) Positive reciprocal matrix B2 of protecting farmland and increasing public welfare utility of Tourism:

$B2=\begin{bmatrix} 1 & \frac{1}{2} \\ 2 & 1 \end{bmatrix}$, The maximum features can be obtained by MATLAB language λ Max = 2, consistency CR = 0, CI = 0

(3) Positive and negative moments of improving climate, protecting water and soil and reducing carbon emissions on maintaining ecological balance B3:

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B3=$\begin{bmatrix} 1 & 3 & \frac{1}{2} \\ \frac{1}{3} & 1 & \frac{1}{3} \\ 2 & 3 & 1 \end{bmatrix}$, The maximum features can be obtained by MATLAB language λ Max = 3. 05362, consistency CR = 0. 0515692, CI = 0. 0268108

Similarly, the consistency ratio of the above matrices is processed, and it is found that CR is < 0.1, that is, they all pass the test. The global weights of forest productivity, public welfare utility and maintaining ecological balance are: [0.4934; 0.1958; 0.310]. It can be concluded that forest productivity accounts for a large proportion in the model affecting the ecological environment, and the restoration of Saihanba is mainly to restore forest productivity, so it is concluded that the environmental quality of Saihanba area improves over time.

By consulting a large number of documents, the comparison of conditions before and after Saihan dam restoration can be obtained:

Table 3 Comparison of environmental conditions before and after restoration of Saihan dam

	Before repair	After repair
Gale days	83	53
Average annual frost free period	52	64
Average annual precipitation	410	479
Forest land area	24	115
Forest coverage	11.4%	82%
Water conservation	——	2.84
Forest volume	33	1036
Fixed carbon dioxide	——	74.7 tons
Release oxygen	——	54.5 tons

The comparison shows that the restoration of Saihan dam has a positive impact on the ecological environment.

5.2. The Model of ability to Resist Sandstorms In Beijing is Established

5.2.1Correlation Analysis Method For Correlation Statistics

In view of the correlation between the ecological environment quality of the Sehan Dam and the dust storm data in Beijing over the years, the frequency of sandstorm, the severity of sandstorm and the air pollution situation in Beijing area were determined by consulting a large number of literatures. Using Pearson-related analysis method, the data are analyzed and the following statistics are obtained Thus, the restoration of Sehanba forest field and Beijing's ability to resist sand and dust has a significant correlation.

The ecological quality of Sehan Dam and the dust weather data of Beijing from 2000 to 2019 are shown in the table below:

Table 4 The ecological environment quality and sand and dust weather statistics of Sehan Dam

The ecological environment quality	frequency	Severity	Air conditions

of the Sehan Dam over the years			
2	9	8	5
3	13	9	6
5	11	6	6
6	3	4	6
4	6	7	7
5	5	5	7
4	11	9	8
6	9	8	8
6	9	6	8
6	5	4	9
7	9	6	10
6	4	4	9
6	6	5	10
7	2	4	9
8	3	5	6
7	2	6	5
8	3	4	3
8	1	3	2
9	3	2	2
8	3	3	2

It can be generally seen that the better the ecological environment of the Sehan Dam, the lower the frequency, the less polluted Beijing, the better the air condition. In order to obtain more accurate impact of Sehan Dam ecological environment on Beijing's anti-sand and dust capacity, standardized treatment is carried out.

5.2.2 Entropy Right Method is Standardized

Using the entropy right method, the environmental evaluation value of Beijing calendar year is determined, the data is standardized first, and the data of each indicator are standardized: $X_i = \{X_1, X_{2,} \dots \dots X_n\}$

Suppose the value standardized for each indicator data is$Y_1, Y_2, \dots \dots, Y_K$

$$Y_{ij} = \frac{X_{ij} - min(X_i)}{max(X_i) - min(X_i)}$$

The information entropy of each indicator is determined, and the weight of each indicator is determined

$$E_j = -\frac{1}{lnN}\sum_{i=1}^{n} P_{ij}$$

$$P_{ü} = {Y_{Ü}}\Big/{\sum_{i=1}^{N} Y_n}$$

The weights of each indicator are calculated by information entropy

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$$W_i = \frac{1 - E_i}{k - \sum E_i}$$

The environmental indicators for the Beijing calendar year and the overall environmental evaluation indicators for the Sehanba area are shown in the figure below:

Table 5 Overall environmental indicators for the Sehan Dam area and Beijing

The overall environmental assessment value of Sehan Dam	Beijing calendar year environmental assessment value
2	6
3	5
5	6
6	10
4	11
5	9
4	11
6	13
6	14
6	9
7	15
6	16
6	10
7	15
8	18
7	14
8	17
8	12
9	19
8	17

It can be seen that the higher the overall environmental evaluation value of Sehan Dam, the higher the corresponding Beijing environmental evaluation value, therefore, the overall index of the ecological environment of Sehan Dam occupies a larger weight of the indicators of Beijing environmental evaluation.

5.2.3 Correlation Curve

The correlation curve is plotted below using spss correlation analysis

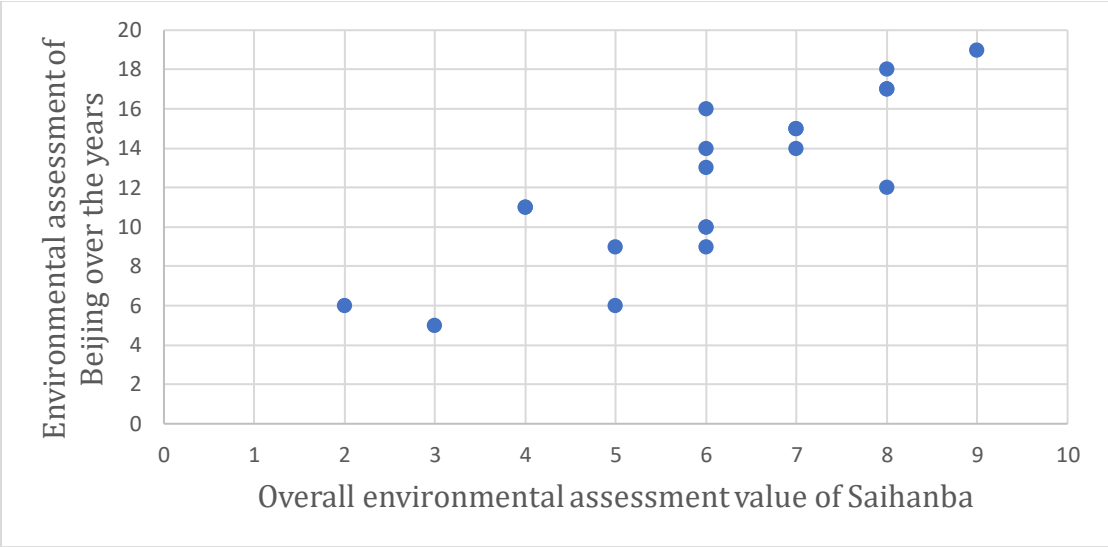

Figure 2 Sehan Dam analysis of environmental evaluation indicators in Beijing

From this, it can be seen that the overall environmental evaluation index of the Sehanba area and the Beijing calendar year environmental evaluation index are positively correlated, indicating that the improvement of the environment in the Sehanba area has a positive impact on Beijing's anti-sand and dust capacity, and the Sehan dam has a positive role in promoting the anti-sand and dust in Beijing, with remarkable results.

5.3. . Based on the Legal Standing Position of Particle Swarm Optimization

5.3.1Construct the Hierarchical Structure

After consulting a large number of documents, the areas with relatively deteriorated ecological environment in China include the Yangtze River Delta economic belt, the Yellow River economic belt, Xinjiang Mongolia Tibet economic zone and the Northern Economic Zone, among which the more serious areas include Shandong, Henan, Shanxi, Shaanxi, Gansu, Qinghai, Xinjiang, western Tibet and Inner Mongolia. The analytic hierarchy process is used to determine the index weight combined with the checked data, analyze and select the location where the ecological area needs to be established.

By consulting the data, it is determined that the indicators are biological richness, water and soil loss, vegetation coverage, plant density and water pollution degree, as shown in Figure 3:

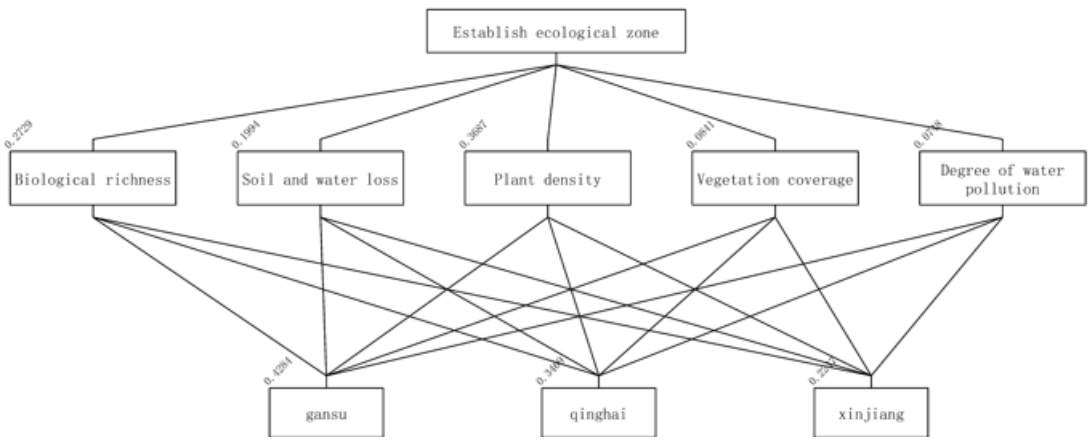

Figure 3:Establish ecological zone

Target layer: establish ecological area criteria;

Layer: biological richness, water and soil loss, vegetation coverage, plant density and water pollution;

Degree scheme layer: Gansu, Qinghai and Xinjiang

Determine the index weight according to the data collected:

Table 6 factors considered for establishing ecological area:

	Gansu province	Qinghai province	Xinjiang province
The annual average temperature is ℃	8.1	6.1	8.7
Annual average precipitationmm	223.7	427.8	194.3
Forest coverage %	11.33	5.82	4.87
Nature Reserve Area (hectares0	671.7	2116.2	1232
Population (people0	25019831	5923957	25852345
Investment in industrial pollution control (ten thousand yuan)	33844	2897	64729
Soil erosion control Area (1000 Ha)	10100	1607.8	2202.3

5.3.2 Construction of Fault Making Matrix

As shown in Table 2;

Firstly, the reasons for the establishment of ecological area are analyzed, such as biological richness, soil and water loss, vegetation coverage, plant density and water pollution degree. Through data comparison and consulting a large number of literature, the positive reciprocal matrix can be approximately obtained:

$$C=\begin{bmatrix} 1 & 2 & 1/2 & 4 & 3 \\ 1/2 & 1 & 1/3 & 5 & 3 \\ 2 & 3 & 1 & 3 & 3 \\ 1/4 & 1/5 & 1/3 & 1 & 2 \\ 1/3 & 1/3 & 1/3 & 1/2 & 1 \end{bmatrix}$$

5.3.3Primary Performance Test

Use MATLAB language to find the maximum characteristic value of matrix A: λ= 3. 0536 consistency index is used to test the consistency of positive reciprocal matrix:

CI=(λ-n)/(n-1)

CI = 0.00978967 according to MATLAB language

Consistency ratio: CR = CI / RI = 0.0874078 < 0.1, that is, it passed the consistency test.

5.3.4Calculate Weight Vector

Next, construct the positive reciprocal matrix of each criterion from the scheme layer to the criterion layer:

(1) Positive reciprocal matrix D1 of biological richness in Gansu, Qinghai and Xinjiang:

$D1=\begin{bmatrix} 1 & 1/2 & 3 \\ 2 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{bmatrix}$, The maximum features can be obtained by MATLAB language λ Max = 3. 05362, consistency CR = 0. 0515692, CI = 0. 0268108

(2) Positive reciprocal matrix D2 of water and soil loss in Gansu, Qinghai and Xinjiang:

$D2=\begin{bmatrix} 1 & 1/2 & 4 \\ 2 & 1 & 4 \\ 1/4 & 1/4 & 1 \end{bmatrix}$, The maximum features can be obtained by MATLAB language λ Max = 3. 05362, consistency CR = 0. 0515692, CI = 0. 0268108

(3) Positive reciprocal matrix D3 of vegetation coverage in Gansu, Qinghai and Xinjiang:

$D3=\begin{bmatrix} 1 & 4 & 3 \\ 1/4 & 1 & 1/3 \\ 1/3 & 3 & 1 \end{bmatrix}$,The maximum features can be obtained by MATLAB language λ Max = 3. 07351, consistency CR = 0. 0706861, CI = 0. 0367568

(4) Positive reciprocal matrix D4 of plant density in Gansu, Qinghai and Xinjiang:

$D4=\begin{bmatrix} 1 & 2 & 1/4 \\ 1/2 & 1 & 1/4 \\ 4 & 4 & 1 \end{bmatrix}$, The maximum features can be obtained by MATLAB language λ Max = 3. 05362, consistency CR = 0. 0515692, CI = 0. 0268108

(5) Positive reciprocal matrix D5 of water pollution degree in Gansu, Qinghai and Xinjiang:

$D5=\begin{bmatrix} 1 & 1/2 & 3 \\ 2 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{bmatrix}$, The maximum features can be obtained by MATLAB language λ Max = 3. 05362, consistency CR = 0. 0515692, CI = 0. 0268108

Similarly, the consistency ratio of the above matrices is processed, and it is found that CR is < 0.1, that is, they all pass the test. The global weights of Gansu, Qinghai and Xinjiang are: [0.4284; 0.3469; 0.2247], which shows that Gansu accounts for the largest proportion, that is, it is reasonable to establish an ecological area in Gansu. Considering the cost of establishing the ecological area and other factors, in order to maximize the ecological benefits, particle swarm optimization algorithm is used to determine the scale of establishing the ecological area, which is programmed with MATLAB language:The scale of the ecological area is 32 square kilometers.

Saihanba eco-environmental area has played a positive role in promoting Beijing's ability to resist wind and sand, and has improved Beijing's overall index evaluation. Through the comparison of a number of data, it can be seen that the extension of Saihanba's ecological protection model to the whole country has a very significant impact on Northwest China and promotes the transformation of economic and social development in Northwest China to an all-round green society, Saihanba ecological protection model releases a large amount of carbon, which should play a positive role in reducing carbon dioxide, reducing greenhouse effect and realizing the goal of carbon neutralization in China.

5.4. Analytic hierarchy process were used to establish themodel

5.4.1TheEestablishment Of Saihanba To Mongolia's Hierarchical Structure

After consulting a large number of literature and collecting the data of various countries in the Asia-Pacific region, we determined the frequency of the occurrence of sandstorms in Mongolia by principal component analysis. Based on the mathematical model of the influence of saihanba ecosystem on the anti-dust ability of Beijing, Mongolia was selected as the mathematical model to be established. After comparative analysis of a large number of data, the ecological environment distribution of eastern, central and western Mongolia is shown as follows:

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Table 7 Distribution of ecological environment in Mongolia:

category	In the west	In the middle	In the east
Vegetation coverage	Forest,forest grassland	Typical grassland and desert grassland	Gobi desert grasslands
The degree of drought	wetter	The drought	The drought
Total precipitation mm	More500	50-500	Less500
terrain	mountains	High and low	The gobi

Through the above data, using analytic hierarchy process, determine the weight index to get the tomographic analysis structure, As shown below:

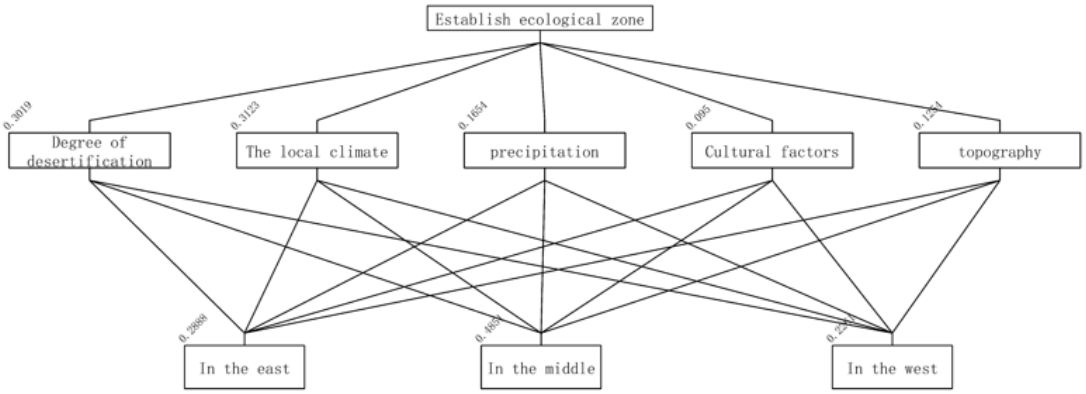

Figure 4 Indicator chart of AHP

Target layer: establish ecological area;

Criteria layer: desertification degree, local climate, precipitation, human factors, landform;

Scheme layer: eastern, central and western;

5.4.2 Constructing Judgment Matrix

As shown in Table 2;First of all, analyze the reasons why Mongolia needs to establish ecological zone, such as desertification degree, local climate, precipitation, human factors, topography and other factors, through data comparison, consult a large number of literature, The positive reciprocal matrix can be approximately obtained:

$$E=\begin{bmatrix} 1 & 1/2 & 3 & 3 & 3 \\ 2 & 1 & 2 & 2 & 2 \\ 1/3 & 1/2 & 1 & 2 & 2 \\ 1/3 & 1/2 & 1/2 & 1 & 1/2 \\ 1/3 & 1/2 & 1/2 & 2 & 1 \end{bmatrix}$$

5.4.3Consistency Test

The value of finding the maximum feature of matrix C using MATLAB language: λ=3.0536;For the consistency test of the reciprocal matrix, the consistency index of T.L.Saaty is adopted:

CI=(λ-n)/(n-1)

according to the MATLAB language, CI=0.0714227

consistency ratio: CR=CI/RI=0.0637703<0.1, which passes the consistency test.

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5.4.4 Calculating Weights Calculate Weight Vectors

The reciprocal matrix of each criterion is constructed from the scheme layer to the criterion layer:

(1)Positive reciprocal matrix F1 of desertification degree in eastern, central and western China:

F1= $\begin{bmatrix} 1 & 1/2 & 3 \\ 2 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{bmatrix}$, The maximum feature can be obtained by MATLAB language λmax=3.05362, Consistency, CR=0.0515592,CI=0.0268108.

(2)Positive reciprocal matrix of eastern, central and western regions to local climate F2:

F2= $\begin{bmatrix} 1 & 1/2 & 1/2 \\ 2 & 1 & 2 \\ 2 & 1/2 & 1 \end{bmatrix}$, The maximum feature can be obtained by MATLAB languageλmax=3.05362, Consistency,CR=0.0515592,CI=0.0268108

(3) Forward reciprocal matrix F3 of precipitation in eastern, central and western China:

F3= $\begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 2 \\ 1/2 & 1/2 & 1 \end{bmatrix}$, The maximum feature can be obtained by MATLAB languageλmax=3.05362, Consistency,CR=0.0515592,CI=0.0268108

(4) Positive reciprocal matrix of human factors in eastern, central and western Regions F4:

F4= $\begin{bmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{bmatrix}$, The maximum feature can be obtained by MATLAB languageλmax=3.0092, Consistency,CR=0.00884876,CI=0.00460136

(5) Forward reciprocal matrix F5 of topography and geomorphology in eastern, central and western China:

F5= $\begin{bmatrix} 1 & 1/2 & 1/2 \\ 2 & 1 & 2 \\ 2 & 1/2 & 1 \end{bmatrix}$, The maximum feature can be obtained by MATLAB languageλmax=3.05362, Consistency,CR=0.0515592,CI=0.0268108

Similarly, the consistency proportion of the above matrices was processed and CR was found to be <0.1, that is, they all passed the test.The global weights of eastern, central and western regions are as follows :[0.2888; 0.4851; 0.2261], from which it can be concluded that the central region accounts for a large proportion, and it is more appropriate to choose Middle Gobi Province in the central region to establish the ecological zone after analyzing a large number of data. Considering the impact of cost factors and human factors, to ensure the maximization of ecological benefits, particle swarm optimization algorithm was used to solve the scale of the ecological area, and MATLAB language was used to achieve.

Therefore, the optimal size of the ecological zone is 42.4 square kilometers, and the establishment of this ecological zone has a positive role in the absorption of greenhouse gases and the reduction of carbon emissions.

5.5. Technical Report Non-technical Report

By this model show that the hampshire dam ecological recovery have a positive impact on the ecological environment, and for the resistance to dust and to actively promote in Beijing, can well describe the correlation between them, in order to better protect the ecotope, want to avoid man-made damage, and give corresponding policy encouragement, keep ecological good ecological benefits.

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6. Model evaluation

(1) In establishing the evaluation model of saihanba's impact on the environment and on Beijing's anti-dust ability, the AHP model and entropy weight model are used to simplify the problem and reduce the time complexity.

(2) Many time constraints are simplified to make the problem more simple to solve.

(3) In the multi-objective optimization model, the multi-objective is transformed into a single objective, which makes the model more simplified. Using Matlab software to solve the problem reduces the difficulty of calculation to a certain extent, and can get a relatively optimized solution.

(4) In this paper, in addition to the qualitative analysis of the problem, but also through the calculation of quantitative analysis of the problem, to a certain extent, more research value.

(5) In the whole process of establishing AHP, it may not completely cover all the relevant factors in reality, and the abstraction of reality is bound to cause problems inconsistent with reality. In the specific implementation, it is also difficult to quantify.

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