Research on Eco-efficiency of Saihanba Based on Comprehensive Evaluation Method

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Abstract. Saihanba plays an important role in preventing wind and sand, protecting the environment, and maintaining ecological balance and stability. The miracle of turning "desert" into "forest" has had a profound impact on the surrounding areas. In order to explore the environmental impact of the restoration of Saihanba Dam, we used AHP and entropy method to improve the weighting process of EI index, and combined with TOPSIS method to establish a MEI evaluation model that fits the local conditions of Saihanba Dam. We obtained the conclusion that the local ecological environment quality in general showed a positive trend after the restoration of Saihanba.

Keywords: Saihanba, Nature reserve, AHP-entropy method, TOPSIS evaluation method.

1. Introduction

The prosperity of ecology leads to the prosperity of civilization, the decline of ecology leads to the decline of civilization [1]. With economic development, the ecological environment is deteriorating, and the importance of ecological civilization construction and sustainable development is self-evident [2].With the help of the Chinese government, after more than half a century of struggle, the world's largest plantation was built on the land of Saihanba. China's Saihanba Forest Farm has recovered from the desert and has now become an eco-friendly green farm with a stable sand prevention function. Today, the forest coverage in Saihanba area has reached 80%. It provides 137 million cubic meters of clean water to Beijing and Tianjin every year, sequesters 747,000 tons of carbon, and releases 545,000 tons of oxygen [3-4]. On the barren plateau 400 kilometers north of Beijing, builders have expanded 1.12 million mu with more than 400 million trees, creating a sea of green. The so-called lucid waters and lush mountains are invaluable assets, and Saihanba has played an inestimable role in the process of environmental protection. In order to explore the environmental impact of the restoration of Saihanba Dam, we used AHP and entropy method to improve the weighting process of EI index, and combined with TOPSIS method to establish a MEI evaluation model that fits the local conditions of Saihanba Dam [5].

2. Building the model

2.1. Building the MEI model

In 2006, the Ministry of Environmental Protection issued the "Technical Specification for Ecological Environment Condition Evaluation (for Trial Implementation)", which provides the standard for ecological environment condition evaluation. The ecological environment condition index EI is widely used, but its index weights need to be set artificially, and there is a large influence of subjectivity [6], In order to enhance the accuracy of evaluation, we used AHP and entropy method to improve the assignment process of EI index, combined with TOPSIS evaluation method was used to establish the MEI evaluation model which is consistent with the local conditions of Saihanba.

2.2. Constructing the index system of the ecological environment of the Saihanba

Ecological Environment Status Evaluation Index is shown in table 1.

Table 1 Ecological Environment Status Evaluation Index

Target layer	Index layer	Indication layer	Nature
Ecosystem status of Saihanba CMED	Index of biological abundance B1	Forest area a1	+
		Water area a2	+
		Grassland area a3	+
		Other area a4	-
	Index of vegetation coverage B2	Forest land area a5	+
		Grassland area a6	+
		Farmland area a7	+
	Index of water system density B3	Length of river a8	+
		Lake (offshore) area a9	+
		Water Resources al0	+
	Index of Land degradation B4	Area of light erosion a11	-
		Area of moderate erosion a12	-
		Area of severe erosion a13	-
	Index of Pollution load B5	Emission of SO2 a14	-
		Emissions of solid waste al5	-
		Emissions of COD a16	-

2.3. Establishment of weights

In this paper, we use the combination of hierarchical analysis and entropy method to calculate the weights[7], hierarchical analysis can provide rational reference for decision makers to make subjective decisions, entropy method can make objective quantitative analysis of its evaluation factors, the combination of the two can make the calculation of weights more accurate and persuasive, the subjective and objective weights will be integrated and optimized using the mean method, the model building process is as follows.

a. Hierarchical analysis

The hierarchical analysis method requires calculating the mutual importance between elements layer by layer, and solving for the weight of each indicator relative to the criterion layer using the indicator layer as an example. For n elements, Saaty's scale method of 1 to 9 levels is used to construct the judgment matrix C for two comparisons.

$$C = (c_{ij})_{m\times n} = \begin{vmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{vmatrix} \quad (1)$$

Where C_{ij} is the importance value of evaluation indicator i compared to evaluation indicator j for the criterion layer, and $C_{ij} > 0$, $C_{ij} = 1$, $C_{ij} = 1/C_{ij}$.

The judgment matrix C is normalized by the following equation.

$$a_{ij} = \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}} \quad (2)$$

The normalized matrix is summed by rows using the approximation method for the eigenvectors of the judgment matrix.

$$\overline{w_i} = \sum_{i=1}^{n} a_{ij} \quad (3)$$

To the matrix $\overline{w_i} = [\overline{w_1}\ \overline{w_2}\ \ldots\ \overline{w_n}\ ]^T$ normalized to obtain the subjective weight coefficients of each evaluation indicator:

$$\overline{w}_i^1 = \frac{\overline{w_i}}{\sum_{i=1}^{n} \overline{w_i}} \quad (4)$$

Calculate the maximum eigenroot value of the judgment matrix and perform the consistency test.

$$\lambda_{max} = \sum_{i=1}^{n}(C_W)/nw \quad (5)$$

$$CR=CI/RI \quad (6)$$

Where: $(C_w)_i$ is the *i-th* component of the vector; the consistency indicator $CI = (\lambda_{max} - n)/(n-1)$ (see the literature for details on the average randomness index *RI*).

When $CR = CI/RI < 0.1$ When, the judgment matrix is considered to be consistent, that is, the normalized matrix is the weight coefficient of the evaluation index. Otherwise, the judgment matrix is set unreasonably and needs to be adjusted until it passes the consistency test

b. Entropy method

The entropy weighting method is the result of normalization based on entropy, which is now applied to several disciplines and fields. With m elements and n evaluation indicators, the original matrix of evaluation indicators A is constructed:

$$A = (a_{ij})_{m\cdot n} = \begin{vmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{vmatrix} \quad (7)$$

Where: a_{ij} is the original value of the element in row i and column j of the evaluation indicator matrix A.

In order to eliminate the incommensurability of different scales and scale units, the evaluation indexes need to be dimensionless. In this paper, the original matrix A is normalized using the TOPSIS method to form the standard matrix $B = (b_{ij})_{m\times n}$, with the following equation.

$$b_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}}} \quad (8)$$

Find the characteristic weight p_{ij} of the ith factor of the jth indicator, and calculate the entropy value e of the evaluation indicator j_j:

$$P_{ij} = \frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}} \quad (9)$$

$$e_i = \frac{1}{Inm}\sum_{i=1}^{m} P_{ij}\, InP_{ij} \quad (10)$$

Solve for the objective weights of each evaluation indicator.

$$w_j^2 = \frac{1-e_j}{\sum_{j=1}^{n} 1-e_j} \quad (11)$$

c. Synthesis of subjective and objective weights

The weights of the AHP and entropy weighting methods were linearly synthesized to obtain the comprehensive weights of the evaluation indexes. Preserving the expertise of expert decision making and the objectivity of raw data, the linear weighted synthesis was used to obtain the composite weights w_i.

$$w_i = \alpha w_i{}^1 + (1-\alpha) w_i{}^2 \quad (12)$$

Where: α is the proportionality factor, i.e. the proportion of subjective and objective weights in the assignment of weights (α is taken to be 0.4, based on expert advice)

2.4. Construction of a comprehensive TOPSIS evaluation model

(1) Normalization of the normalization matrix

Suppose there are n evaluation objects and m evaluation indicators (which have been normalized) consisting of a matrix $X=(x_{ij})_{m\times n}$, and the X matrix is normalized and denoted as $Z=(z_{ij})_{m\times n}$(i=1,2,...,n; j=1,2,...,m).

(2) Calculate the distance to the ideal point and the negative ideal point distance for each scenario Define the maximum (ideal solution).

$Z^+=(Z^+_1, Z^+_2, ...,Z^+_2, Z^+_m) = (\max\{ z_{11} , z_{21}, ...,z_{n1} ,\}, \max\{ z_{12} , z_{22} , ...,z_{n2} ,\} ..., \max\{ z_{1n}, z_{2n}, ...,z_{nn},\})$

Define minimum (negative ideal solution).

$Z^-=(Z^-_1, Z^-_2, ...,Z^-_2, Z^-_m) = (\max\{ z_{11} , z_{21}, ...,z_{n1} ,\}, \max\{ z_{12} , z_{22} , ...,z_{n2} ,\}..., \max\{ z_{1n}, z_{2n}, ...,z_{nn},\})$

Define the distance of the i-th (i=1,2,...,n) evaluation object from the maximum value.

$$D_1^+ = \sqrt{\sum_{j=1}^{m} W_j \, (Z_j^+ - z_y)^2} \tag{13}$$

Define the distance of the i-th (i=1,2,...,n) evaluation object from the minimum value.

$$D_1^- = \sqrt{\sum_{j=1}^{m} W_j \, (Z_j^- - z_{ij})^2} \tag{14}$$

Define the relative proximity of the i-th (i=1,2,...,n) evaluation object to the ideal solution.

$$s_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{15}$$

Where, $0 \leq S_i \leq 1$, and ithe larger S the smaller D_i^+, i.e., the closer to the maximum value, representing the better ecological quality, and vice versa, the worse

2.5. Solving the MEI model

(1) The subjective weights are synthesized with the objective weights to finally obtain a combined weight for TOPSIS. As shown in Table 2.

Table 2 The Combined Weights of The Evaluation Indexes of Saihanba's Ecological

Target layer	Index layer	Indicator layer	AHP weights	Entropy method weights	Portfolio Weights
Ecosystem status of Saihanba CMED	Index of biological abundance B1	Forest area a1	0.125	0.0277	0.06662
		Water area a2	0.075	0.0884	0.08304
		Grassland area a3	0.0375	0.0277	0.03162
		Other area a4	0.0125	0.0098	0.01088
	Index of vegetation coverage B2	Forest land area a5	0.1	0.1773	0.14638
		Grassland area a6	0.06	0.0277	0.04062
		Farmland area a7	004	0.0277	0.03262
	Index of water system density B3	Length of river a8	0.066	0.0469	0.05454
		Lake (offshore) area a9	0.066	0.1205	0.0987
		Water Resources al0	0.066	0.1297	0.10422
	Index of Land degradation B4	Area of light erosion a11	0.01	0.0867	0.05602
		Area of moderate erosion a12	0.05	0.0233	0.03398
		Area of severe erosion a13	0.14	0.0098	0.06188
	Index of Pollution load B5	Emission of SO2 a14	0.06	0.0098	0.02988
		Emissions of solid waste al5	0.03	0.1773	0.11838
		Emissions of COD a16	006	0.0098	0.02988

(2) According to the steps of the Topsis method, multiply the combined weights by the corresponding standardization matrix values to determine the weighted standardization matrix, determine the sum, and calculate the results as shown in Table 3.

The distances D_i^+ and D_i^- and S_i relative proximity of each evaluation object to the ideal and negative ideal solutions are calculated as shown in Table 3.

Table 3 TOPSIS Evaluation Calculation Results

Item	Positive idealsolution distance D+	The negative ideal solution distance D-	Relative proximity C	Sort Results
P1	118.373	66.642	0.36	16
P2	113.886	72.158	0.388	15
P3	109.062	78.262	0.418	14
P4	103.765	85.139	0.451	13
P5	98.15	92.825	0.486	12
P6	89.73	105.349	0.54	11
P7	82.074	117.534	0.589	10
P8	79.788	125.179	0.611	9
P9	72.126	131.959	0.647	8
P10	65.143	138.572	0.68	7
P11	59.087	144.883	0.71	6
P12	55.802	150.202	0.729	5
P13	57.235	153.926	0.729	4
P14	45.171	161.003	0.781	3
P15	38.534	167.114	0.813	2
P16	33.485	176.367	0.84	1

Combined with the scoring criteria, evaluation criteria for grading the Eco-environmental Composite Index is shown in table 4.

Table 4 Evaluation criteria for grading the Eco-environmental Composite Index (E)

sports event	0≤E≤0.35	0.35≤E≤0.5	0.5≤E≤0.7	0.7≤E≤0.85	0.85≤E≤1
level	bad	poor	medium	good	Excellent
Explanatory notes	serious environment all pollution backward development	the environment is more polluted	damaged environment is more polluted environment	less environmental pollution	virtually pollution-free environment,
	Chaotic system structure and	Development is relatively backward	consistent development	better development	well-developed,
	Complete loss of service function	The system is structurally faint	changes in system structure	better system structure	well-structured systems,
Explanatory notes		And service are degraded and inadequate	degraded but largely operable services	good service functions	excellent service function

The analysis concluded that the quality of the local ecological environment began to improve year by year after the restoration of Saihanba.

Using Arcgis software, combining the statistical indicators of MEI and the proportion of area of each grade of ecological index for each time period to obtain the grade transformation map of the Seyhanba area.

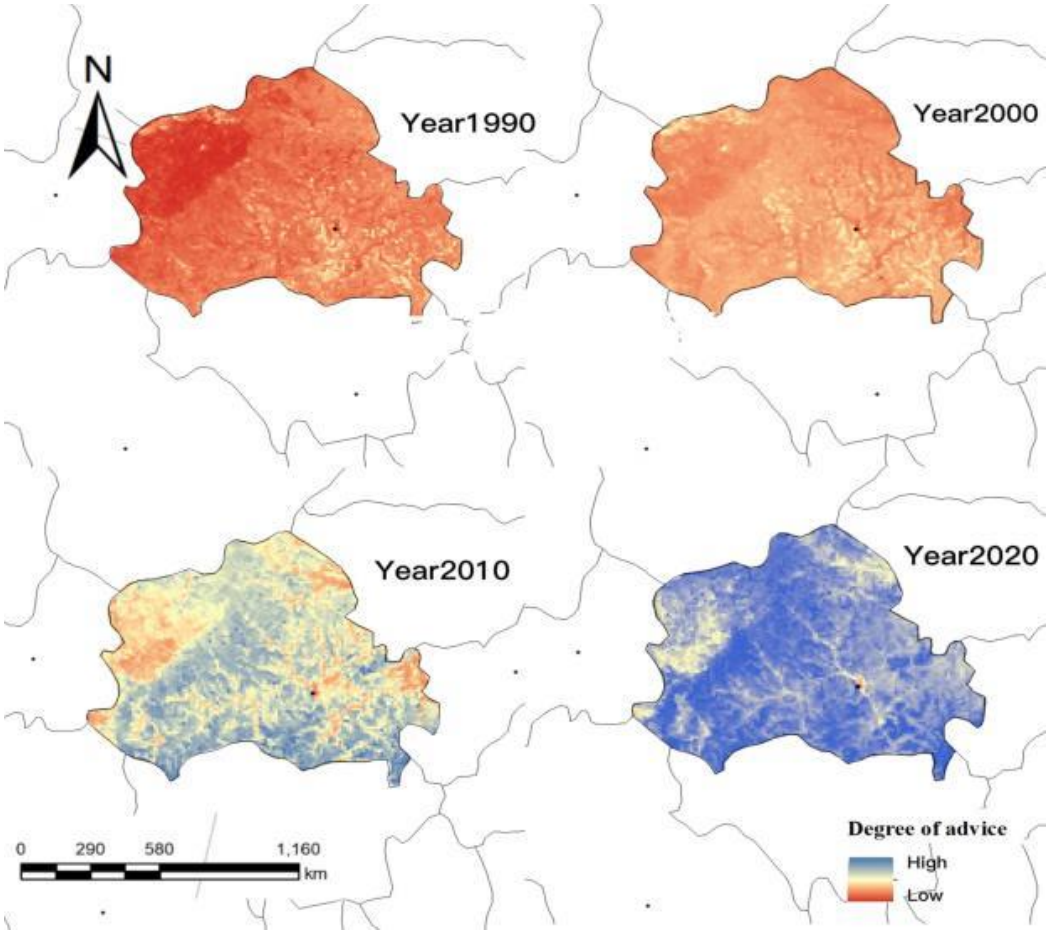


Figure 1 MEI distribution by period in Saihanba

The figure 1 clearly shows that after the restoration of Saihanba, the local ecological quality in general shows a positive trend.

3. Conclusions

Lucid waters and lush mountains are invaluable assets [8].The success of the Saihanba Forestry is a typical example of ecological protection and construction. But there is still a long way to go for ecological conservation. The core objective of this paper is to build an evaluation model with relevant data from the Saihanba woodland and the surrounding areas, and to propose feasible solutions and recommendations for the construction of ecological protection zones [9].

In order to explore the before-and-after status of the restoration of the Saihanba, we selected vegetation cover index, land degradation index and pollution load index as indicators to establish the EI Saihanba ecological environment evaluation index system. In order to enhance the accuracy of evaluation, we used AHP and entropy method to improve the assignment process, and combined with TOPSIS evaluation method to establish the MEI evaluation model which is consistent with the local conditions [10]. We obtained the conclusion that the local ecological environment quality in general showed a positive trend after the restoration of Saihanba.

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