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Study on ecological protection assessment of Saihan dam based on TOPSIS and principal component analysis

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Abstract: Saihanba plays an important role in protecting the ecological environment. Based on the principal component analysis method, this paper establishes a comprehensive evaluation model based on the ecological protection impact of Saihanba, and analyzes the corresponding ecological problems through the evaluation results. This paper establishes an evaluation model of the impact of the Seyhan Dam on the ecological environment. The comprehensive environmental evaluation score was chosen as the total index, as well as seven sub-indicators such as forest coverage rate and average annual precipitation. The index data of Seyhanba from 1965 to 2017 were studied and queried. Meanwhile, this paper establishes a comprehensive evaluation model of the impact of the Seyhan Dam on Beijing's ability to resist sandstorms. A comprehensive evaluation model based on TOPSIS and Spearman correlation analysis methods was established. The TOPSIS distance method was used to analyze the changes of Beijing's ability to resist sandstorms during the restoration process of the Seyhanba forestry site. The Spearman correlation analysis method was used to demonstrate that the restoration of the Seyhanba woodland was related to the enhancement of Beijing's resistance to dust storms. The absolute value of correlation coefficient was 0.5536, which was close to At 1 and was related.

1. Introduction

1.1 Background

Building a beautiful China and building a modernization in which man and nature coexist harmoniously are the important foundation and main content of socialist modernization with Chinese characteristics. The report of the 18th National Congress of the Communist Party of China regards "beautiful China" as the national development goal, and the Fifth Plenary Session of the 19th Central Committee of the Party clearly stated that by 2035, socialist modernization will be basically achieved and the goal of building a beautiful China will be basically achieved [1]. With the help of the Chinese government, China’s Saihanba has gone from a barren land to a million acres of forests and seas. It delivers 137 million cubic meters of clean water and releases 545,000 tons of oxygen to the Beijing-Tianjin area every year, contributing to the protection of China’s ecological environment. huge contribution. Based on the ecological environment construction of Saihanba, this article will study the construction of ecological protection and the evaluation of its impact on the environment.

1.2 Overview of the problem

In this paper, an evaluation model will be developed to quantitatively analyze the impact of Seyhanba on ecological environment.

First, we determine the evaluation index of the model, determine a total index and seven sub-indexes. The total index is the comprehensive evaluation score. The seven sub-indexes are Saihanba forest coverage, coverage area, forest accumulation, and annual average precipitation. Conservation of water, carbon dioxide absorption, oxygen release[2].

Then, considering that a longer time dimension must be selected to evaluate the impact of the ecological environment, we searched for various sub-indicator data from 1965 to 2017 from websites such as China Environmental Monitoring Center.

Finally, we establish a principal component analysis evaluation model based on the data, calculate the cumulative contribution rate of individual sub-indexes, and calculate the principal component comprehensive evaluation scores for each year on a sub-basis, and quantitatively evaluate the impact of Saihanba on the environment after the restoration of Saihanba based on the scores .

At the same time, this paper establishes a mathematical model to quantitatively evaluate the impact of Saihanba on the ability of Beijing to resist sand and dust storms.

First, we determine the evaluation indicators of the model. Considering that sandstorms mainly affect air quality, we select Beijing's *AQI* value and the concentration of $PM_{2.5}$, PM_{10}, NO_2, CO, SO_2, and O_3 in the air as indicators.

Then, obtain the index data of Beijing from December 2013 to November 2021 from the Beijing Weather Station and other websites.

Finally, we establish a comprehensive evaluation model to evaluate the impact of Saihanba on Beijing's sandstorm resistance. The first step is to analyze the changes in Beijing's ability to resist sandstorms during the restoration of Saihanba Forest Farm based on the TOPSIS method. The second step is to select the data on the number of sand and dust days in Beijing from 1965 to 2017, and do a Spearman correlation analysis with the comprehensive environmental assessment score of Saihanba from 1965 to 2017 calculated in the first question to prove the performance of Saihanba Forest Farm. There is a certain correlation between recovery and the increase in Beijing's ability to resist sandstorms. Furthermore, the two comprehensive quantitative analysis and evaluation of Saihanba's impact on Beijing's ability to resist sandstorms [3].

2. Model Construction

2.1 Principal component analysis evaluation model

2.1.1 Modeling Ideas

First, we standardize the collected sub-index data to obtain standardized index variables. Then, according to the value of the standardized index variable, the correlation coefficient matrix R of the index is calculated, and the eigenvalues of the correlation coefficient matrix R and the corresponding standardized eigenvectors are calculated, and the principal components are determined by the eigenvectors. Next, use formulas to calculate the information contribution rate and cumulative contribution rate of the principal components, and select several principal components with a contribution rate greater than 95% based on this, and we find two principal components based on the results. Finally, using the contribution rates of these two principal components as the weights, a principal component comprehensive evaluation model was constructed to obtain the comprehensive evaluation scores and rankings of each year, and the environmental conditions before and after the restoration of Saihanba were compared and analyzed to establish a principal component analysis[4].

2.1.2 Establishment of the model

- Select indicator

Table 1 Selected indicators

Overall index: comprehensive evaluation score	1	Forest cover rate	Refers to the percentage (%) of forest area in total land area. Forest coverage is an important indicator reflecting the forest resources and greening level of Saihanba area.
	2	Covered area	Refers to the area of Saihanba forest (/10,000 mu)
	3	Forest accumulation	The total volume of existing standing trees in a certain area of forest (/10,000 cubic meters)
	4	Average annual precipitation	The mean value obtained by dividing the sum of annual rainfall in Saihanba by the number of years (/mm) The average annual rainfall is one of the important indicators of a place's climate
	5	Water conservation	Ecosystem interacts with water through its unique structure, and the amount of water conserved after intercepting, infiltrating, and accumulating precipitation (/100 million cubic meters)
	6	CO2 absorption	The carbon dioxide content consumed by plant photosynthesis (/10,000 tons)
	7	Oxygen release	Oxygen content released by plant photosynthesis (/10,000 tons)

- Solution steps

Step1: Standardize the values of seven sub-indices from 1965 to 2017. Convert each index value a_{ij} into a standardized index, then

$$\tilde{a}_{ij} = \frac{a_{ij} - \mu_j}{s_j}, i = 1, 2, \cdots, 53, j = 1, 2, \cdots, 7$$

$$\mu_j = \cdot \frac{1}{53} \sum_{53}^{i=1} a_{ij}; s_j = \sqrt{\frac{1}{53-1} \sum_{53}^{i=1} \left(a_{ij} - \mu_j\right)^2}, j = 1, 2, \cdots, 7 \quad (1)$$

Step 2: Calculate the correlation coefficient matrix R. then

$$r_{ij} = \frac{\sum_{53}^{k=1} \tilde{a}_{ki} \cdot \tilde{a}_{kj}}{53-1}, i, j = 1, 2, \cdots, 7 \quad (2)$$

Among them, $r_{ii}=1$; $r_{ij}=r_{ji}$, is the correlation coefficient between the i-th index and the j-th index.
Step 3: Calculate eigenvalues and eigenvectors.

$$
\begin{aligned}
y_1 &= u_{11}\tilde{x}_1 + u_{21}\tilde{x}_2 + \cdots + u_{71}\tilde{x}_7 \\
y_2 &= u_{12}\tilde{x}_1 + u_{22}\tilde{x}_2 + \cdots + u_{72}\tilde{x}_7 \\
&\vdots \\
y_7 &= u_{17}\tilde{x}_1 + u_{27}\tilde{x}_2 + \cdots + u_{77}\tilde{x}_7
\end{aligned} \tag{3}
$$

In the formula: y_1 is the first principal component, y_2 is the second principal component, …, y_7 is the seventh principal component.

Step 4: Calculate the information contribution rate and cumulative contribution rate of the characteristic value. Then:

$$b_j = \frac{\lambda_j}{\sum_{7}^{k=1} \lambda_k}, j = 1, 2, \cdots, 7 \tag{4}$$

And said:

$$\alpha_p = \frac{\sum_{p}^{k=1} \lambda_k}{\sum_{7}^{k=1} \lambda_k} \tag{5}$$

Step 5: Calculate the comprehensive score:

$$Z = \sum_{p}^{j=1} b_j y_j \tag{6}$$

In the formula: b_j is the information contribution rate of the j-th principal component, which can be evaluated based on the comprehensive score value.

2.2 Comprehensive evaluation model

2.2.1 Modeling Ideas

The first part is to use the TOPSIS method to analyze the changes in Beijing's ability to resist sandstorms during the restoration of Saihanba Forest Farm [5]. First, in order to eliminate the influence of different index dimensions, the data is standardized and the index attributes are processed in the same direction. Then, normalize and determine the best and worst solutions. Finally, calculate the closeness C_i between the various indicators we selected and the optimal plan, and rank the results by month. The closer C_i is to 1, the better the overall air quality in Beijing.

The second part is to use Spearman's coefficient correlation analysis to prove that the restoration of Saihanba Forest Farm is related to the increase of Beijing's ability to resist sandstorms.

2.2.2 Establishment of the model

We can see from the relevant sandstorm information: Sandstorm is a general term for both sandstorm and duststorm. It refers to severe wind and sand with strong wind blowing up a large amount of dust on the ground and engulfing it into the air, making the air particularly turbid, and the horizontal visibility is less than 100 meters. Weather phenomenon. Sandstorm refers to a sand-laden storm formed by strong winds blowing a large amount of sand into the near-surface layer; dust storm is a storm formed by strong winds involving large amounts of dust and other fine-grained materials into the upper air.

Therefore, we select the monthly average AQI value and the concentration of PM2.5, PM10, NO2, CO, SO2 and O3 in the air from December 2013 to November 2021 in Beijing as the evaluation indicators, as shown in Figure 1 below:

Figure 1 Seven indicators

Step1: TOPSIS-Data Standardization

Standardize the monthly average air quality indicators in Beijing to eliminate the influence of different indicator dimensions.

Step2: TOPSIS-indicator attribute positive

The TOPSIS method uses a distance scale to measure sample gaps, and needs to be processed in the same direction for index attributes. The index attribute is normalized, which means that all types of index types are uniformly transformed into extremely large indexes.

Introduction to indicator types:

- Very small index: the smaller the expected index value, the better
- Intermediate indicators: It is expected that the indicator value should not be too large or too small. It is best to choose an intermediate value appropriately
- Interval indicators: It is best to expect the value of the indicator to fall within a certain interval.

According to the classification criteria of the indicators, the air quality indicators we select can be regarded as extremely small indicators.

Step3: TOPSIS-construct normalized initial matrix

The normalized matrix Z after normalization is obtained:

$$Z=\begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nm} \end{bmatrix} \tag{7}$$

$$n=96, m=7$$

Step4: Z elements:

$$\begin{aligned} Z^{+} &= \left(\max\left\{z_{11}, z_{21}, \cdots, z_{n1}\right\}, \max\left\{z_{12}, z_{22}, \cdots, z_{n2}\right\}, \cdots, \max\left\{z_{1m}, z_{2m}, \cdots, z_{nm}\right\}\right) \\ &= \left(Z_1^{+}, Z_2^{+}, \cdots, Z_m^{+}\right) \end{aligned} \tag{8}$$

Step5: TOPSIS-calculates the distance between each index and the optimal plan and the worst plan:

$$D_i^{+}=\sqrt{\sum_{m}^{j=1} w_j\left(Z_j^{+}-z_{ij}\right)^2}, \quad D_i^{-}=\sqrt{\sum_{m}^{j=1} w_j\left(Z_j^{-}-z_{ij}\right)^2} \tag{9}$$

Step6: TOPSIS-Calculate the closeness of each index to the optimal solution:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{10}$$

Step7: TOPSIS- sorts according to the size of C_i value and gives the evaluation
Step8: Correlation analysis of Spearman coefficient.

$$r = 1 - \frac{6\sum_{n}^{i=1} d_i^2}{n\left(n^2 - 1\right)} \tag{11}$$

3. Model Analysis

According to the selected monthly average air quality index values in Beijing, we draw a line chart of the number of sand and dust storms from 1965 to 2017 (Figure **2**). Then, using the matlab software to solve the problem, using the superior and inferior solution distance method, we get the overall trend of Beijing air quality over time, as shown in Figure **3**:

Figure 2 Annual number of sandstorms in Beijing from 1965 to 2017

Figure 3 Beijing December 2013-November 2021 monthly average air quality index and the close value of the optimal plan C_i

As can be seen from the above figure, the closer the time is to November 2021, the closer the C_i is to 1, indicating that during the Saihanba restoration period, the air quality in Beijing has improved overall over time.

According to the data of the number of sand and dust days in Beijing from 1965 to 2017 and the comprehensive environmental assessment score data of Saihanba from 1965 to 2017 calculated by the first question, the cor function of matlab software is used to solve the problem, and the Spearman correlation analysis is performed to obtain the correlation coefficient. Correlation coefficient:

$$R_s = -0.5536 \tag{12}$$

In summary, with the ecological restoration of Saihanba Forest Farm from 1965 to 2017, the closeness of Beijing's air quality index to the optimal index has been increasing, and the number of dust days has increased from 6th in 2013 to 2nd in 2021. Days, the number of days of sand and dust has gradually decreased, and the air quality has improved overall, which shows that Saihanba plays a major role in Beijing's fight against sand and dust storms.

4. Conclusion

In the principal component analysis method, the weight of each principal component is its contribution rate, which reflects the proportion of the amount of information contained in the original data of the principal component to the total amount of information. It is objective and reasonable to determine the weight in this way, overcoming the shortcomings of certain evaluation methods that consider the determination of weights;

In the comprehensive evaluation model established in the second question, we conducted a Spearman correlation analysis on the number of days of sandstorms in Beijing and the comprehensive evaluation score of Saihanba in the same time period based on the conclusion of the first question and the relevant data in the query , Which proves that the restoration of Saihanba Forest Farm is related to the increase of Beijing's ability to resist sandstorms, making the second question more rigorous;

Principal component analysis (PCA) has certain shortcomings, such as eigenvalue decomposition has some limitations, for example, the transformed matrix must be a square matrix;

The TOPSIS method is difficult to select the corresponding quantitative indicators for the data of each indicator required.

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