The Restoration Impact of Saihanba on Beijing's Sandstorm Resistance

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Abstract: Recent years have witnessed significant positive impacts on ecological conservation constructions. This paper, based on entropy-weight TOPSIS, Interpolation fitting, and so on methods, makes quantitative assessments of Saihanba's current effects both on itself and on Beijing's sandstorm resistance. The total score of Saihanba local ecological environment will increase by 0.7% when the afforestation area of Saihanba is expanded by 1%. TOPSIS model is established first. After normalizing the indexes of different dimensions, the total score of ecological environments increased 140% by year-on-year. This paper also employs Interpolation fitting to complete the missing values, use Cook distance to eliminate outliers, and pass the Pearson's correlation test to ensure the reliability of the conclusion. For every 1% increase in the total score of Saihanba, the sandstorm situation in Beijing will be optimized by 1.08% (correlation coefficient = 0.95). The optimized Entropy weight TOPSIS model is used to affect the evaluation results comprehensively. Thus, the conclusion of Saihanba's promotion effect on Beijing sandstorm resistance is more convincing.

1. Background and Propose

More than half a century ago, the ecological foundation of Saihanba was fragile, and landscapes were barren. However, 369 forest entrepreneurs resolutely embarked on the northern plateau from around China; Saihanba Tree Farm was finally established in 1962[1]. Keeping their initial visions, Saihanba people have successfully built a million mu artificial forests, creating a model in the history of ecological conservation constructions worldwide.

This paper will analyze and assess the ecological ameliorative effect of Saihanba over the years by establishing a series of the reliable mathematical model. This paper also evaluates the impact on Beijing's sandstorm resistance based on the restoration level on Saihanba.

2. Quantitative Assessment of Saihanba's Impact on Local Ecology

2.1 Data processing

Because of the lack of a few year statistics, like the afforestation area of Saihanba in 2005 and 2006, Quintic Polynomial Interpolation Fitting was applied to smooth the statistical data in order to facilitate the establishment of the mathematical model.

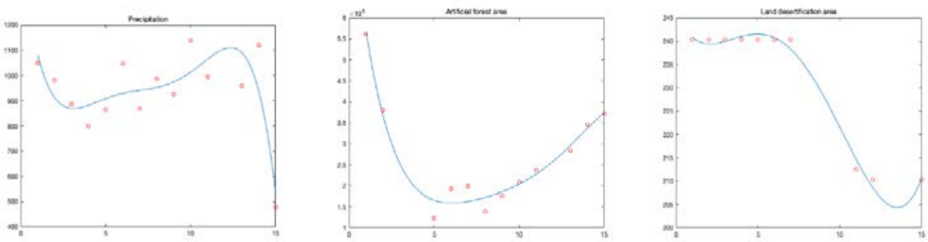

Figure 1 Interpolation of precipitation, artificial forest area, land desertification

Based on the existing data, the Quintic Polynomial method in MATLAB is applied for interpolation, and relevant processing results are as for Figure 1.

2.2 Descriptive Analysis

After 2003 was taken as the first point, according to all known issues, a smooth curve is fitted, and the functional expression of the curve is obtained. Then substitute the year coordinates of unknown points to figure out the missing data.

From 2004 to 2017, the average annual afforestation area in Hebei Province was 0.13-0.25 million hectares, and the afforestation area in 2003 was about 0.56 million hectares, which deviated significantly from the overall afforestation distribution.

The average annual soot emission in Hebei Province is scattered with a low median, which most years are less than 0.8 million tons.

2.3 Model Establishment and Solution

2.3.1 Overview of Topsis Model

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), an efficient way in multi-objective decision analysis, ranks the proximity between the evaluation object and the idealized goal to obtain the relative optimal degree of the existing things.

2.3.2 Index System Construction and Symbol Definition

Combined with the environmental indicator system [2], the ecological environment factors are divided into water resources quality, soil quality, and atmospheric quality. The environmental environment assessment index system is shown in Table 1.

Table 1 Ecological environment evaluation index system

Variable type	Primary index	Secondary index
Variable 1	Restoration of Saihanba	Artificial forest area (HA)
Variable 2	Atmospheric quality	Soot emission (10000 tons)
		Sulfur dioxide emission (10000 tons)
	Soil quality	Land desertification (10000 hectares)
		Water and soil loss control area (1000 HA)
	Water resources quality	Watershed treatment area (1000 HA)
		Total water resources (100 million m3)
		Precipitation (100 million m3)

2.4 Model Solution

TOPSIS method measures the variation of atmospheric environmental quality, water resources quality and soil quality of samples from 2003 to 2017. The model operation results are shown in Figure 2.

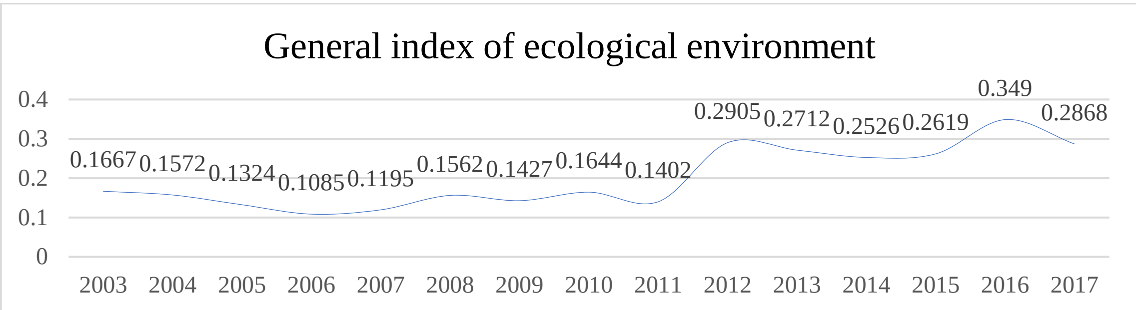

Figure 2 Model operation results

The variation of atmospheric quality of the sample is relatively gentle, with a small range from 2003 to 2010 and then decreased significantly. The index continued to rise during 2011 and 2017. The sample's overall fluctuation of water resources quality is significant, which reached the top point in 2012. The soil quality of the sample did not change significantly before 2011. Yet, it improved significantly and remained at a high level after 2011.

2.5 Person Correlation Analysis

2.5.1 Outlier Test

In order to achieve better correlation analysis results between Saihanba restoration and eco-environmental indicators, we test the samples for outliers before correlation analysis. Finally, the 2013 and 2014 are excluded, based on the Cook Distance.

2.5.2 Correlation Model Operation and Results

The relevant processing results by MATLAB are as Figure 3.

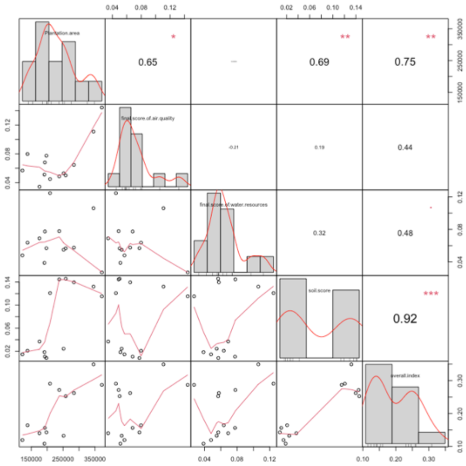

Figure 3 Correlation results

According to the calculation results, the correlation coefficient between the afforestation area of Saihanba and the total score of ecological environment is r = 0.75. It is concluded that there is a significant positive correlation between the afforestation area of Saihanba and the total score of environmental environment.

Between 2007 and 2017, the construction of Saihanba was continuously improved, contributing to the expansion of afforestation from 122,327 hectares to 371,770 hectares.

It can be seen that the ecological environment will be significantly improved by enhancing the restoration degree of Saihanba.

3. Quantitative Assessment of Saihanba's Effect on Beijing's Sandstorm Resistance

In this part, we will improve the previous TOPSIS model. Based on the suitable quantitative indicators and the statistical data of severe pollution days in Beijing [3], this paper will employ the entropy weight method for processing and then take it as the total score to reflect Beijing's wind and sand situation.

3.1 Descriptive Analysis

Firstly, this paper makes a descriptive analysis on the indicators of the restoration degree of Saihanba, which is evident from the restoration degree is getting better and better with time. This is mainly reflected in the annual increase in forest cover. The data increased from 2014 to 2021 from 9.65 million square meters to 10.36 million square meters[4]. In terms of water resources, the forest water storage area of Saihanba has tripled in 8 years (from118 from 284 million m3). The growth rate of carbon dioxide emission and oxygen absorption of Saihanba is slow, but it still keeps rising[5].

Secondly, this paper makes a descriptive analysis of the indicators describing the dust storm situation in Beijing.

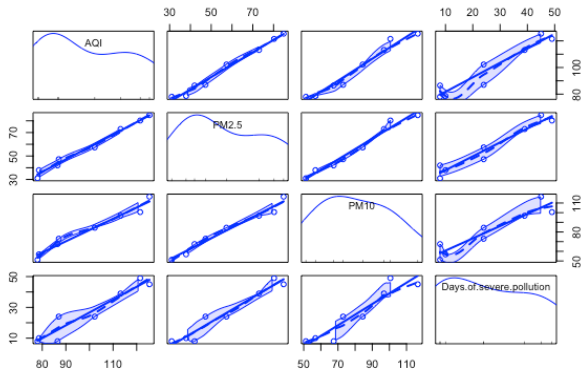

Figure 4 Scatter plot matrix of indicators on dust storm conditions in Beijing

As shown in Figure 4, AQI, PM2.5, PM10 and days of severe pollution showed a significant downward trend from 2014 to 2021, and the correlation between the four indicators was strong. The concentration of PM2.5 decreased by more than twice (84.83 to 31.00), and the days of severe pollution decreased from 45 days in 2014 to 8 days in 2021.

3.2 Model Establishment: Entropy Weight Topsis Overview

The first part does not consider the weight difference between indicators in the evaluation process. Therefore, this paper intends to use the modified entropy weight TOPSIS model to evaluate each index[6].

3.3 Model Solution and Results

3.3.1 Environmental Index Evaluation of Saihanba

Firstly, the entropy weight method is employed to calculate the weight values of the Saihanba environmental index and Beijing sandstorm index. The data are established by weighted index.

Table 2 Summary of weight calculation results by entropy method

Term	Information entropy e	Information utility valued	Information utility value
Forest coverage	0.8917	0.1083	15.99%
Forest volume	0.8912	0.1088	16.07%
Water conservation volume	0.7573	0.2427	35.84%
Oxygen release	0.8914	0.1086	16.03%
Carbon dioxide absorption	0.8912	0.1088	16.07%

The calculation results of Saihanba environmental index weight by entropy weight method are shown in Table 2. The importance of water conservation is the highest, reaching 35.84%; The weight of forest coverage is low, which is 15.99%.

The weight difference of the Beijing sandstorm between each index is slight, and the weight of PM10 and PM2.5 is 20.29% and 26.57%.

3.3.2 Topsis Operation Results

TOPSIS is calculated by the entropy-weight-method- generated data. "*C*" represents the similarity between the evaluation object and the optimal scheme. The greater the value, the closer it is to the optimal scheme.

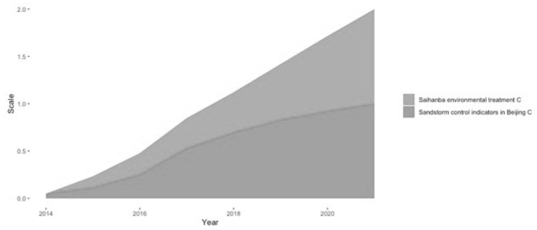

Figure 5 Scatter plot matrix of indicators on dust storm conditions in Beijing

It can be seen from Figure 5 that the environmental construction index of Saihanba and the sandstorm control index of Beijing show a significant upward trend over time.

4. Model Test and Summary

The model operation results are shown in Figure 6.

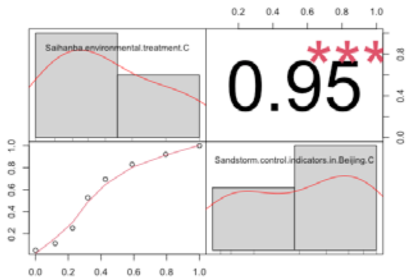

Figure 6 Correlation Matrix

According to the calculation results, the correlation coefficient between the total score of Saihanba restoration progress and the total score of Beijing sandstorm is r = 0.95. It is concluded that there is a significant positive correlation between the restoration progress of Saihanba and the improvement degree of sandstorm resistance in Beijing. Between 2013 and 2021, the restoration of Saihanba has been continuously improved, and the total score of Saihanba has increased from 0.12 to 1; Saihanba forest coverage expanded from 75.5% to 85.5%; During this period, the sandstorm situation in Beijing was also improving, and the total score increased from 0.05 to 1; Beijing's atmosphere quality index dropped from 125.4 to 78; The pollution concentration of PM10 in Beijing decreased from 116.6 μg/m3 to 51.3 μg/m3, a year-on-year decrease of 56%; The number of days of severe pollution in Beijing has been reduced from 45 days to 8 days per year; It can be seen that the higher the restoration degree of Saihanba, the sandstorm resistance situation in Beijing will be significantly improved, that is, the role of Saihanba in Beijing's sand resistance capacity is crucial.

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