

# Original Research Article

## A Comprehensive Evaluation Model Based on the Environmental Impact of Saihanba

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### ABSTRACT

China Saihanba Forest Farm has become an ecological green farm with stable sand control function, and an ecological environmental impact assessment model is constructed according to the ecological model of Saihanba Forest Farm. According to the seven data indicators collected, this paper uses principal component analysis to objectively evaluate the great impact of the restoration of Saihanba forest farm on the ecological environment. At the same time, in order to establish ecological regions more accurately and extend the ecological protection model to the whole country, based on the AHP method and TOPSIS method, we calculated the comprehensive evaluation indicators of the ecological environment in Liaoning, Ningxia and Shanxi provinces, and then determined that Ningxia and Shanxi provinces should pay attention to the establishment of ecological zones.

*Keywords: AHP method; principal component analysis method; TOPSIS method*

### 1. INTRODUCTION

With the help of the Chinese government, China Saihanba Forest Farm has recovered from the desert and become an ecological green farm with stable sand control functions. Therefore, it is analyzed that those areas also need to pay attention to the establishment of ecological regions, practice China's concept of sustainable development, and give priority to protecting the ecological environment. In recent years, the comprehensive evaluation of the ecological environment mainly adopts the AHP method, TOPSIS method, and factor analysis method [1-5], which shows that the comprehensive evaluation of the ecological environment is meaningful.

In this paper, we use principal component analysis to objectively assess the great impact of the restoration of Saihanba forest farm on the ecological environment. Taking Liaoning, Ningxia and Shanxi provinces as examples, we calculate the comprehensive evaluation indicators of the ecological environment of the three provinces based on the AHP method and the TOPSIS method, and divide the ecological environment of each province.

### 2. ECOLOGICAL ENVIRONMENTAL IMPACT ASSESSMENT MODEL

In order to study the impact of the restoration of Saihanba forest farm on the ecological environment, we used principal component analysis, which is a statistical analysis method that converts multiple indicators into a small number of comprehensive indicators. Since different indicators involve large differences in fields, and have different units and orders of magnitude, the accuracy of the results will be affected, so we need to standardize the indicators before analysis.

Note  $x_1, x_2, \dots, x_p$  as the variable indicator, let  $E(x_k) = \mu_k, Var(x_k) = \delta_k$ . After normalizing the original data, we solve the correlation coefficient matrix of the variables as follows:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{21} & r_{22} & \cdots & r_{2p} \\ \vdots & \vdots & \cdots & \vdots \\ r_{p1} & r_{p2} & \cdots & r_{pp} \end{bmatrix}$$

$$\text{Where } r_{ij} = \frac{\sum_{k=1}^n (x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j)}{\sqrt{\sum_{k=1}^n (x_{ki} - \bar{x}_i)^2 \sum_{k=1}^n (x_{kj} - \bar{x}_j)^2}}$$

Then to solve the eigenvalue of  $R$ , the corresponding eigenvector and the corresponding variance contribution rate, here we commonly use to solve the eigenequation  $|\lambda I - R| = 0$  to use the Jacobian method to find the eigenvalues, arrange the solved eigenvalues  $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_p \geq 0$  in order of size, and extract the common factor according to the eigenvalues greater than 1, so that the utilization rate of data information is higher. Then, the eigenvector  $a_i (i = 1, 2, \dots, p)$  with the eigenvalue  $\lambda_i$  is found

$$a_1 = \begin{bmatrix} a_{11} \\ a_{21} \\ \vdots \\ a_{p1} \end{bmatrix}, a_2 = \begin{bmatrix} a_{12} \\ a_{22} \\ \vdots \\ a_{p2} \end{bmatrix}, \dots, a_p = \begin{bmatrix} a_{1p} \\ a_{2p} \\ \vdots \\ a_{pp} \end{bmatrix}$$

Finally, the linear expression of the principal component is found

$$F_i = a_{1i}x_1 + a_{2i}x_2 + \dots + a_{pi}x_p \quad i = 1, 2, \dots, p$$

According to the linear expression, the score of each component factor is calculated, and the variance contribution rate is used as the weight, and the comprehensive score is obtained and then evaluated.

We collected 11 basic data indicators forest coverage, coverage area (10,000 mu), forest accumulation (10,000 cubic meters), water content (100 million cubic meters), carbon dioxide absorption (10,000 tons), oxygen release (10,000 tons), tourist number (10,000 tons), tourism revenue (100 million), urban air quality compliance days, PM2.5 concentration (micrograms/cubic meter), surface water quality compliance rate (%) were recorded as  $x_1, x_2 \dots x_{11}$  respectively, and the original data indicators were standardized first. Then, SPSS is applied to principal component analysis to solve the following results:

**Table 1. The total variance of the interpretation**

	Initial Eigenvalues	Extraction Sums of Squared Loadings				
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %

According to the solution results in Table 1 above, we can see the initial eigenvalues, variance contribution rate and cumulative contribution rate of each component, and we extract the common factor by following the principle that the eigenvalue is greater than 1. From the results of the above table, it can be seen that there are 2 data indicators with feature values greater than 1, so we mainly extract 2 common factors, and the variance contribution rate of the first common factor is 81.916%; The variance contribution rate of the second common factor was 12.599%, and the cumulative variance contribution rate of the

extracted two common factors reached 94.515%. When the cumulative variance contribution rate of the common factor is larger, it means that the extracted common factor reflects more information about the original data, and the 2 common factors we extracted this time can reflect 94.515% of the information of all original indicators, which can be seen that the extracted common factor has been able to reflect the information of the original data well, and we will extract the common factor to  $F_1, F_2$  respectively.

We then proceed to factor analysis to obtain a matrix of principal component coefficients, which illustrate the loading of each principal component on each indicator. In order to analyze the correlation between the index and the component more clearly, the maximum variance method is selected to rotate the factor to obtain the factor rotation matrix, as shown in Table 2 below

**Table 2. Rotate the component matrix**

	Component	
	1	2

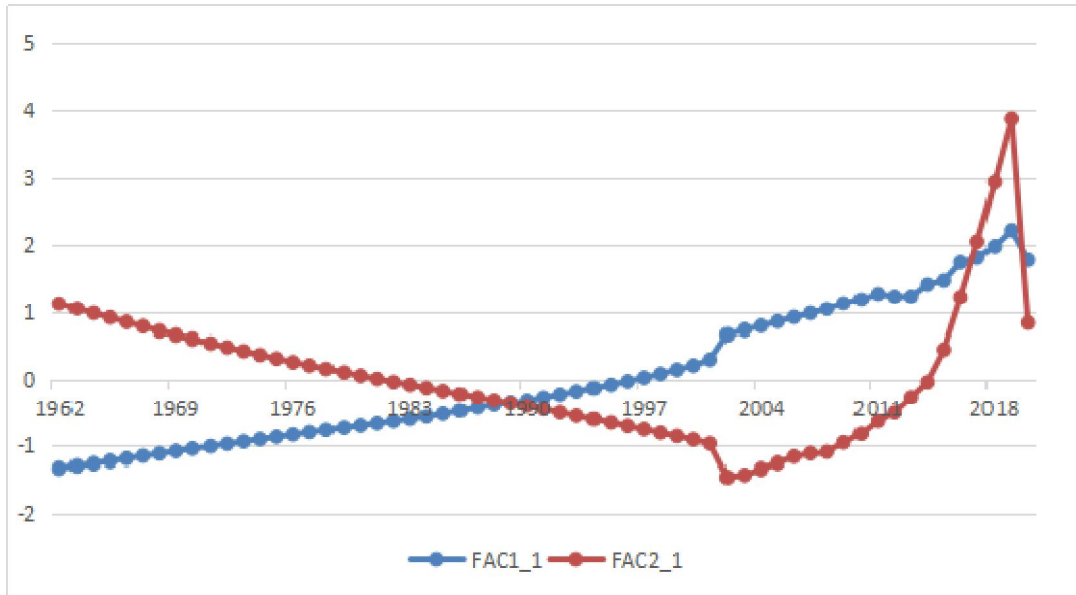
The rotational component matrix in Table 2 is the main content of factor analysis, and none of the 11 indexes have a factor load greater than 0.5 on the first principal component and the second principal component, indicating that the 11 indicators do not need to be deleted and the components are clearly divided. It can be seen that the first factor  $F_1$  mainly includes nine indicators: forest coverage, cover area, forest accumulation, water content, carbon dioxide absorption, oxygen release, urban air quality compliance days, PM2.5 concentration and surface water quality compliance rate, reflecting the impact of tree conditions. The second factor  $F_2$ , mainly includes the number of tourists and tourism revenue, reflecting the impact of the tourism industry.

The principal component coefficient matrix is obtained by dividing the principal component load vector by the arithmetic square root of the corresponding principal component characteristic value, and the result is shown in Table 3. The first principal component score and the second principal component score can be used to express the characteristics of the ecological environment, and the dominant expression of the principal component function is calculated as follows

$$F_1 = 0.909x_1 + 0.909x_2 + 0.986x_3 + 0.937x_4 + 0.986x_5 + 0.806x_6 + 0.274x_7 + 0.499x_8 + 0.916x_9 + 0.811x_{10} + 0.989x_{11}$$

$$F_2 = -0.286x_1 - 0.286x_2 - 0.079x_3 + 0.210x_4 - 0.079x_5 - 0.056x_6 + 0.620x_7 + 0.684x_8 - 0.011x_9 - 0.551x_{10} + 0.055x_{11}$$

We substitute 11 standardized data indicators into the above equation, and then perform a percentage conversion. The first principal component score, the second principal component score and the percentage score of each year can be obtained, and the average score of each score in each year can be calculated, and the score graph is obtained as follows:



**Fig. 1. Principal component score**

Figure 1 is the principal component score chart, we can see that in the first principal component score, with the increase of years, the change of ecological environmental factors is gradually increasing, in the second principal component score, although there are ups and downs of changes, but in general, the score of each component in 2019 is higher than in 1962, indicating that with the change of time, the impact on the development of the ecological environment after the restoration of Saihanba forest farm is significant.

### 3. ESTABLISHMENT OF ECO-REGIONS

After Saihanba became an eco-friendly green farm with stable sand control functions, in order to promote the better development of the ecological environment, in order to be able to more accurately determine which geographical locations in China need to establish ecological zones. In the Statistical Yearbook, we collected data indicators from Liaoning, Ningxia and Shanxi provinces, which mainly included five data indicators: average temperature, average relative humidity, total water resources, days of air quality reaching or better than grade II, and forest coverage. We combined AHP with TOPSIS to obtain an evaluation index score to determine whether the three provinces of Liaoning, Ningxia and Shanxi also need to focus on the establishment of ecoregions.

#### 3.1 AHP model establishment

We will use the establishment of ecological zones as the target layer, selecting five data indicators: average temperature, average relative humidity, total water resources, days of air quality reaching or better than level 2, and forest coverage as the criterion layer. Liaoning, Ningxia, and Shanxi provinces will be used as the plan layer.

Paired comparison matrices can be obtained by comparing each criterion layer as follows:

$$A = \begin{bmatrix} 1 & 1 & 5 & 5/7 & 5/3 \\ 1 & 1 & 5 & 7/5 & 5/3 \\ 1/3 & 1/3 & 1 & 1/7 & 1/3 \\ 7/5 & 7/5 & 7 & 1 & 7/3 \\ 3/5 & 3/5 & 3 & 3/7 & 1 \end{bmatrix}$$

Using consistency indicators, random consistency indicators, and consistency ratios for consistency testing:

$$CR = \frac{CI}{RI} = 0.0951 < 0.1$$

Subsequently, construct a combination weight vector

$$B_1 = \begin{bmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/2 \\ 1/3 & 2 & 1 \end{bmatrix}, B_2 = \begin{bmatrix} 1 & 2 & 5 \\ 1/2 & 1 & 2 \\ 1/5 & 1/2 & 1 \end{bmatrix}, B_3 = \begin{bmatrix} 1 & 5 & 8 \\ 1/5 & 1 & 3 \\ 1/8 & 3/8 & 1 \end{bmatrix}$$

$$B_4 = \begin{bmatrix} 1 & 1/2 & 1 \\ 2 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, B_5 = \begin{bmatrix} 1 & 1/3 & 1/5 \\ 3 & 1 & 1/2 \\ 5 & 2 & 1 \end{bmatrix}$$

Calculate the weight vector  $B_k$ , maximum feature root  $w_k^{(3)}$ , and consistency indicators  $CI_k$  and  $CR_k$  of the paired comparison matrix  $\lambda_k$ , as shown in the table below:

**Table 3. Consistency check**

$k$	1	2	3	4	5
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Subsequently, a consistency test was conducted on the combination. According to the table, all combination weight vectors passed the consistency test.

$CI^{(3)} = 0.00232, RI^{(3)} = 0.58, CR^{(3)} = 0.004$  thus  $CR^* = 0.0991$ , Combination consistency test passed.

Finally, calculate the weights of five data indicators on whether to establish an ecological zone, and obtain

$$w = (0.2257, 0.2656, 0.0572, 0.3160, 0.1354)^T$$

### 3.2 TOPSIS method

The entropy weight method determines the weight by using the degree of variation of the indicator itself to determine the size of the information reflected, thereby determining its corresponding weight value. It can objectively determine the weight of the evaluation indicator. When a certain data indicator changes significantly, the more information it reflects, and the greater the weight it occupies.

Here are the three existing evaluation objects and the forward matrix of five evaluation indicators

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

Calculate the final score  $C_i = \frac{D_i^-}{D_i^- + D_i^+}$ , where  $D_i^- = \sqrt{\sum_{j=1}^5 (d_j^- \cdots d_{3j}^-)^2}$ ,

$$D_i^+ = \sqrt{\sum_{j=1}^5 (d_j^+ \cdots d_{3j}^+)^2}$$

Calculate the evaluation scores of the impact of five indicators on the ecological environment  $E_i = C_i \times w$ . So as to sort the ecological environment of each province

**Table 4. Sort Results**

$$D_i^+ \quad D_i^- \quad E_i$$

Using the Rank Sum Ratio (RSR) method to determine the distribution of RSR, the probability unit value Probit corresponding to the cumulative frequency is used as the independent variable, and the RSR value is used as the dependent variable. Using least squares estimation, the parameter values are obtained, and the correlation coefficient  $r$  and linear regression equation are obtained.

$$y = -0.417 + 0.164 \times \text{Probit}$$

From the results of the F-test in the following table, we can see that the significance  $P$  value is 0.000 \*\*\*, the level is significant, the original hypothesis that the regression coefficient is 0 is rejected, and the Goodness of fit of the model is  $R^2$  It is 0.909, and the model performs well, so the model basically meets the requirements. For variable collinearity performance,  $VIF$  is all less than 10, so the model does not have multicollinearity problem, and the model is well constructed.

**Table 5. F-test results**

	Non standardized coefficient	Standardized Coefficient	t	p	VIF	R2	modifyR2	F
B	standard error	Beta						

Finally, based on the normal distribution, the variances of all grades are consistent and the difference is significant. According to the reasonable grading method

**Table 6. Ranking Results**

Tem	RSR Value	RSR Ranking	RSR Fitting value	Level
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From the above table, it can be concluded that Ningxia and Shanxi should pay attention to the establishment of ecological zones, and the scale of the proposed ecological zone should be close to that of Liaoning, the second tier. Only in this way can we better improve ecological civilization and implement sustainable development strategies.

#### 4. CONCLUSION

In this article, we evaluated whether there was a significant impact on the ecological environment before and after the restoration of Saihanba Forest Farm, and found that the restoration of Saihanba Forest Farm had a significant impact on the ecological environment; Subsequently, an evaluation was conducted on whether Liaoning, Ningxia, and Shanxi provinces need to pay attention to the establishment of ecological zones. It was found that Ningxia and Shanxi still need to pay attention to the establishment of ecological zones, and continuous efforts were made to expand the ecological protection model to the whole country and implement sustainable development strategies.

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