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# Construction of Ecological Conservation and Assessment of Its Impact on Environment

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**Abstract**

In recent years, environmental problems caused by global warming--- melting glaciers, rising sea levels, frequent wildfires and the death of large coral reefs, moved from the pages of the books to reality. To solve the problem, we develop several mathematical models, using both qualitative and quantitative methods, analyzing the importance of each influencing factor, finally build evaluation model of ecological environment and nature reserve.

Firstly, in order to make a comparative analysis of the environmental conditions before and after the restoration of Saihanba, I collect the data of forest coverage rate, water conservation, PM2.5, oxygen release and carbon dioxide absorption of Saihanba in 60 years from 1962 to 2021, establishing Entropy Weight Method and Technique for Order Preference by Similarity to an Ideal Solution model (EWM-TOPSIS). Obtained that water conservation was the index with the largest weight, forest coverage rate is the index with the least weight, and the ecological environment in this area is the best in 2021 and the worst in 1962, indicating that saihanba restoration plays a significant role in improving the environment in this area.

Secondly, I analyze the correlation between saihanba and Beijing's ecological environment, and qualitatively judge the degree of impact between the two. Then I take five ecological environment indexes of Saihanba as independent variables and four indexes of Beijing's anti-sandstorm ability as dependent variables of four Multiple Linear Regression models (MlR), which helps me make quantitative judgment, and finally get the conclusion that the improvement of the ecological environment of Saihanba will promote the anti-sandstorm ability of Beijing.

After modelling, I also conduct sensitivity analysis to experiment the sensitivity of some parameters included in my models. In the end, I summarize strengths and weaknesses and a brief conclusion is also presented.

**Keywords:** Saihanba, ecological reserves, EWM-TOPSIS

## 1. Introduction

### *1.1 Background*

For over a half century, builders from the Saihanba Tree Farm dedicated themselves to creating a miracle of turning desert into forests. With practical action, they forge the spirit of Sekhangba and interpret the concept that lucid waters and lush mountains are invaluable assets.The forest coverage rate of Seyhanba Mechanical Forestry Field has increased from 11.4% at the early stage of construction to 82% nowadays, constructing a green barrier for Beijing, Tianjin and Hebei regions. If the forest trees are arranged at a spacing of one meter, they can circle the earth's equator 12 times. (Liu, Y., 2021)

However, they have encountered new problems on the road of development. Thus, people in Saihanba now own a higher mission of restoring the ecology.

### *1.2 Literature Review*

The recovering of Saihanba Tree Farm from desert to an eco-friendly and green farm is marvelous, which becomes the world’s largest artificial forest. Nowadays, Saihanba plays an important role in planting trees to fix the sand and conserve water resources with the perseverance of several young generations (Zou, C.-N., et al., 2021). General Secretary Xi Jinping (2021) propose six principles for building a community of human and natural life based on the Spirit of Saihanba, pointing out that the precious spirit created by Saihanba Mechanical

Forest farm contributed Chinese wisdom to solving global ecological problems and promoted the construction of a community of shared future for mankind.

Gao Hainan (2019) points out that Saihanba Forest Farm is representative of the evolution of state-owned forest farms, and its ecological evolution reflects the transformation of the relationship between man and nature from "human-centered theory" to "respect for nature and harmonious coexistence between man and nature". Chen Yuanyuan (2019) takes Saihanba Mechanical Forest Farm as the research object and uses AHP to evaluate the sustainable development status of the forest farm. The result shows that the comprehensive evaluation index is 0.810, which is close to the target value of sustainable forest management. Therefore, the forest farm is considered to be in a state of sustainable development.

The positive impact of Saihanba Forest farm on the ecological environment further promotes the goal of carbon neutrality in China.Carbon neutrality means that enterprises, groups, or individuals measure the total amount of greenhouse gas emissions produced directly or indirectly within a certain period, and offset their carbon dioxide emissions by planting trees, saving energy, and reducing emissions, to achieve "zero" carbon dioxide emissions (Zou, C.-N., et al., 2021). Since the 16th Party Congress, the Party Central Committee and the State Council have proposed new ideas and initiatives to establish and implement the scientific outlook on development, build a harmonious socialist society, build a resource-saving and environment-friendly society, make rivers and lakes rest, and promote the historical transformation of environmental protection, etc. (Ministry of Ecology and Environment, PRC.). Based on this problem, this paper evaluates the impact on the environment after the restoration of Saihanba.

My work mainly includes the following:

1) select the forest coverage rate, the conservation of water, the amount of oxygen release, the amount of carbon dioxide absorption and the concentration of PM2.5 as the environment indicators and then build EWM-TOPSIS Model to evaluate the impact on the environment after the restoration of Saihanba.

2) Based on relevant data of the anti-sandstorm ability of Beijing (i.e., the monthly data of the average air quality index, the proportion of bad weather, the extreme low temperature and the extreme high temperature in 2017-2021.), analyzing the correlation of the ecological environment of Saihanba and the anti-sandstorm ability of Beijing, then establishing Regression Model to estimate the effect of Saihanba to the anti-sandstorm ability of Beijing.

## 2. Assumptions and Justifications

Aiming to realize the discussion of the employment of college graduate, we could comprehensive consideration which needs appropriate assumptions for better simplified and understood. The assumptions are as follows.

1. Carbon emissions only refer to carbon dioxide.

In addition to carbon dioxide and carbon monoxide, the carbon-containing gases in the air are ignored because of their low concentrations.

2. Hypothesis of linear regression model:

The residual of the constructed regression model follows a normal distribution with zero mean and homoskedasticity.

The independent variables are exogenous explanatory variables, and there is no perfect multicollinearity between independent variables.

The residuals are not correlated with the independent variables

3. It is assumed that air quality and water quality are defined by the same standard across all regions and countries.

eg: air quality index AQI 0-50 is excellent, 50-100 is good...

Water quality index 0-5 is excellent, 5-10 is good...

4. The number of divisions in each nature reserve is proportional to the size of the whole reserve.

In reality, the number of subdivisions in each nature reserve is restricted by local administrative divisions, and it is normal for them to vary in size. But to simplify models, we assume that the regions are evenly divided.

5. Species are evenly distributed in the certain nature reserve, and all types of vegetation have the same carbon fixation capacity, so the size is proportional to the carbon fixation capacity.

In reality, each reserve has its own unique natural conditions, and the carbon fixation capacity must be different.

## 3. Model I: EWM-TOPSIS Model

*3.1 Entropy Weight Method (EWM)*

Entropy is a concept in information theory, which is the measure of uncertainty. The greater the amount of information, the smaller the uncertainty, the smaller the entropy, and vice versa. Accordingly, the entropy values can be used to measure the forest coverage rate, water conservation, PM2.5, oxygen release, and carbon dioxide absorption. The smaller the entropy value, the greater the dispersion degree of the indicator, and the greater the influence (i.e., weight) of the indicator on the local ecological environment.

Step 1: The data for the five indicators (m) of forest cover, water content, PM2.5, oxygen release, and carbon dioxide uptake were selected for a total of 60 years (n),from 1962 to 2021, i.e., the value of the jth indicator in the ith year (i = 1, 2 ... n; j = 1, 2 ... m)

Step 2: Data pre-treatment

For positive indicator (the forest coverage rate, water conservation, PM2.5, oxygen release, and carbon dioxide absorption):

$$x_{ij}' = \frac{x_{ij} - \min(x_{1j}, \ldots, x_{nj})}{\max(x_{1j}, \ldots, x_{nj}) - \min(x_{1j}, \ldots, x_{nj})} \tag{1}$$

For negative indicator (PM2.5):

$$x_{ij}' = \frac{\max(x_{1j}, \ldots, x_{nj}) - x_{ij}}{\max(x_{1j}, \ldots, x_{nj}) - \min(x_{1j}, \ldots, x_{nj})} \tag{2}$$

Step 3: Calculate the percentage of the ith year of the jth index

$$p_{ij} = \frac{x_{ij}'}{\sum_{i=1}^{n} x_{ij}'}, i = 1, \ldots, n; j = 1, \ldots, m \tag{3}$$

Step 4: Calculate the entropy value of the jth indicator

$$e_{ij} = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \tag{4}$$

$$k = \frac{1}{\ln(n)} \tag{5}$$

Step 5: Calculate the redundancy value of the jth indicator

$$d_j = 1 - e_j \tag{6}$$

Step 6: Calculate the weight of 5 environmental indicators. The higher the weight indicates the greater the impact of the indicator on the ecological environment.

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{7}$$

*3.2 Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS)*

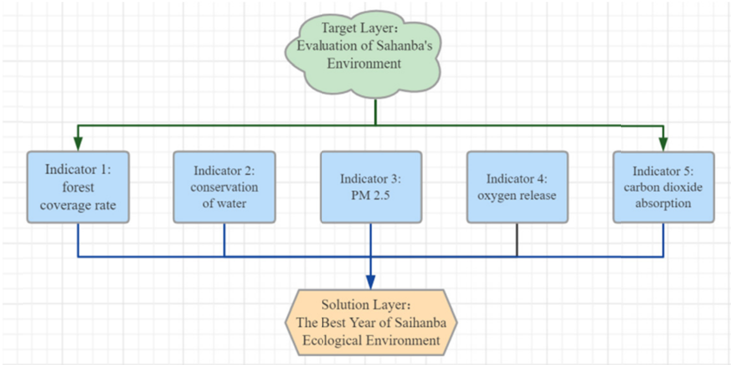


Figure 1. Target Layer, Indicator Layer, Solution Layer

Step 1: Data for the five environmental indicators of the Saihanba from 1962 to 2021 were gathered, converged and normalized.

For positive indicator (the forest coverage rate, water conservation, PM2.5, oxygen release, and carbon dioxide absorption):

$$Z_{ij}' = \frac{x_{ij} - \min(x_{1j}, \dots, x_{nj})}{\max(x_{1j}, \dots, x_{nj}) - \min(x_{1j}, \dots, x_{nj})} \tag{8}$$

For negative indicator (PM2.5):

$$Z_{ij}' = \frac{\max(x_{1j}, \dots, x_{nj}) - x_{ij}}{\max(x_{1j}, \dots, x_{nj}) - \min(x_{1j}, \dots, x_{nj})} \tag{9}$$

The matrix formed by $Z_{ij}$ is denoted as $Z_{n\times m}$

Step 2: Figure out the optimal and inferior matrix vectors

The optimal matrix vector $Z^+$ is the vector formed by combining the largest values of the above five environmental indicators; the inferior matrix vector $Z^-$ is the vector formed by combining the smallest values of the above five environmental indicators.

$$Z^+ = (\max Z_{i1,} \max Z_{i2}, \dots, \max Z_{im}) \tag{10}$$

$$Z^- = (\min Z_{i1}, \min Z_{i2}, \dots, \min Z_{im}) \tag{11}$$

Step 3: Calculate the distance between the evaluation object and the positive ideal solution $D_i^+$ or the negative ideal solution $D_i^-$, i.e., the proximity of the environmental indicators of Saihanba in each year to the best and worst years of their ecological environment indicators expressed by distance, is calculated separately. We have to use the weight $w_j$ here derived from EWM in the previous section.

$$D_i^+ = \sqrt{\sum_{j=1}^{m} w_j (\max Z_{ij} - Z_{ij})^2} \tag{12}$$

$$D_i^- = \sqrt{\sum_{j=1}^{m} w_j (\min Z_{ij} - Z_{ij})^2} \tag{13}$$

Step 4: After calculation, it indicated that the distance values are close to the program value $G_i$, which are the integrated environmental index of Saihanba in different years. The larger this index is, the better.

$$G_i = \frac{D_i^-}{D_i^+ - D_i^-} \qquad 0 \le G_i \le 1 \tag{14}$$

$G_i$ takes values from 0 to 1, dividing the intervals into multiple levels equidistantly, and thus determining the years with the best and worst ecological conditions.

*3.3 Data Preparation: Min-Max Standardization*

In order to compare the environmental conditions before and after the restoration of Saihanba, we use the forest coverage rate, water conservation, carbon dioxide absorption, oxygen release, and urban PM2.5 concentration as evaluation indicators. The data from 1962 to 2021 are collected from the website of Saihanba Mechanical Forestry in Hebei Province. The data are summarized in the following table.

Table 1. Overview of Environmental Evaluation Indicators

| Year | Forest coverage rate | Water conservation | Carbon dioxide absorption | Oxygen release | Urban PM2.5 concentration |
|---|---|---|---|---|---|
| 1962 | 13.57 | 0.09 | 2.74 | 1.90 | 89 |
| 1963 | 15.94 | 0.09 | 2.76 | 1.92 | 88 |
| … | … | … | … | … | … |
| 2020 | 81.46 | 2.40 | 85.40 | 59.40 | 29 |
| 2021 | 82.21 | 2.84 | 86.03 | 59.84 | 27 |

Before calculating the weights with the EWM Model, the data are min-max normalized by applying equations () and (). The indicator of urban PM2.5 concentration are negative data and ought to be orthogonalized by substituting the data into () to make the normalized variables positive. For the forest coverage rate, water conservation, carbon dioxide absorption, and oxygen release, they are both positive data, and these data are normalized by substituting them into () respectively. The variables after the convergence treatment are not affected by the difference of the magnitude, and the data size can be compared at the same level, which makes the calculation of the weights practically meaningful, i.e., the impact on the environment of restored Saihanba can be analyzed by comparing the weight size.

*3.4 Data Processing*

After data pre-processing, the entropy weight method is used to calculate the weights of each environmental index, so as to evaluate the impact on the environment from different aspects after the restoration of Saihanba by comparing the weight values. The calculation results of the weights are demonstrated in the figure below.

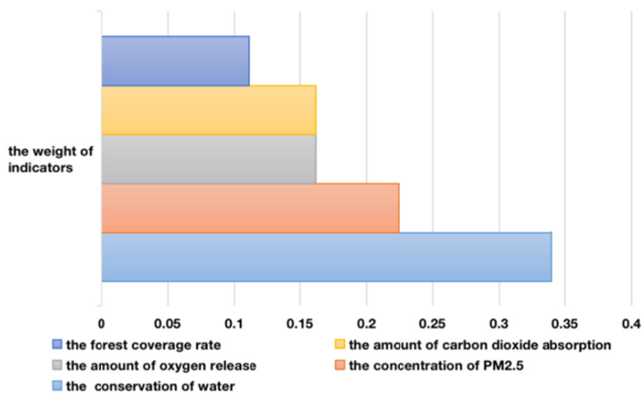


Figure 2. The Importance of Indicators

The weight calculation results of the entropy weight method indicate that the weight of forest coverage rate is 11.149%, the weight of oxygen release is 16.249%, the weight of water conservation is 33.973%, the weight of carbon dioxide absorption is 16.249%, and the weight of urban PM2.5 concentration is 22.381%, where the maximum value of index weight is water conservation (33.973%) while the minimum is the forest coverage rate (11.149%).

Table 2. Positive and Negative Ideal Solution

| item | positive ideal solution | negative ideal solution |
|---|---|---|
| forest coverage rate | 0.29376274 | 0.00000122 |
| oxygen release | 0.25978725 | 5.8e-7 |
| water conservation | 0.54198969 | 0.00002195 |
| carbon dioxide absorption | 0.2597873 | 4e-7 |
| urban PM2.5 concentration | 0.36889207 | 7.7e-7 |

Positive and negative ideal solutions (non-distance) respectively represent the maximum or minimum values of the evaluation index (i.e., optimal and inferior solutions). Using equations () and (), the optimal and inferior matrix vectors can be determined, i.e., the optimal matrix vector Z+ = (0.29, 0.26, 0.54, 0.26, 0.37); the inferior matrix vector Z- = (0.00000122, 5.8e-7, 0.00002195, 4e-7, 7.7e-7)

Table 3. Sorting Results

| year | Positive ideal distance (D+) | Negative ideal distance (D-) | Integrate score index | rank |
|---|---|---|---|---|
| 1962 | 0.70545728 | 0 | 0 | 60 |
| … | … | … | … | … |
| 1990 | 0.40224062 | 0.02157556 | 0.05293551 | 32 |
| 1991 | 0.39652467 | 0.00733406 | 0.01815998 | 31 |
| … | … | … | … | … |
| 2021 | 0 | 0.402240621 | 1 | 1 |

Using equations () and (), we can obtain the positive ideal solution distance D+ and negative ideal solution distance D-. The smallest value of D+ in 2021 shows that it is the closest to the optimal solution; the smallest value of D- in 1962 indicates that it is the closest to the worst solution. Using equation (), we are capable of calculating the integrate score C value for each year. The C value in 1962 was the smallest and ranked the last; while in 2021 it is the largest and ranks the first.

### *3.5 Results Analysis*

According to the calculation results of the entropy weighting method, the degree of influence of different indicators on the ecological environment can be obtained. The weight of water conservation is the largest, illustrating that the current state of the water environment has the greatest impact on the ecological environment; while from the perspective of economic evaluation of forest resources, the weight of forest coverage rate is the smallest, indicating that the current state of forest environment does not have much impact on the ecological environment. After establishing the importance of different indicators, the ecological environment of different years is considered as the evaluation object and analyzed by TOPSIS. From the ranking results, it is evident that the environmental conditions were the worst in 1962 and the best in 2021. It shows that after the restoration of Saihanba, the ecological environment gradually improved, so the restoration of Saihanba plays an essential role in improving the environmental conditions.

## 4. Model II: Model of Beijing's Ability to Resist Sandstorms

### *4.1 Correlation and Regression Analysis*

Select the five indicators of forest coverage rate, water conservation, PM2.5 concentration, oxygen release, and carbon dioxide absorption to measure the ecological environment of Saihanba. Besides, choose the four indicators of extremely high temperature, extreme low temperature, average air quality index, and percentage of severe weather in Beijing to measure the ability of Beijing to withstand sandstorms.

The Pearson product-moment correlation coefficient between the five indicators of the ecological environment of the Saihanba Forest and the four indicators of the ability of Beijing to resist sandstorms is firstly established, which can be used to measure the strength of the linear correlation between two variables X and Y, whose values range between -1 and +1. The magnitude of the PMCC is used to roughly determine the extent to which the ecological environment of the Saihanba Tree Farm contributes to the protection of Beijing against sandstorms.

Next, establish four multiple regression models with five ecological indicators of Saihanba as independent variables and four indicators of Beijing's sandstorm resistance as dependent variables. Linear regression is a statistical analysis method that uses regression analysis in mathematical statistics to determine the quantitative relationships between variables that are dependent on each other.

Step 1: The PMCC between two variables is defined as the quotient of the covariance of these two variables and the standard deviation of both. Here we use the sample correlation coefficient $r$ because only part of years of data from Saihanba and Beijing were extracted for analysis, and the variable $X_i$ in the equation is the ecological environment indicators of Saihanba and the variable $Y_i$ is the sandstorm resistance indicators of Beijing.

Sample correlation coefficient:
$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \tag{15}$$

Step 2: Suppose the four linear regression model of the random variable $y$ (extreme low temperature, extreme high temperature, average air quality index, proportion of bad weather) and the general variable $x_1, x_2, ..., x_p$ (forest coverage rate, conservation of water, concentration of PM2.5, the amount of oxygen release, the amount of carbon dioxide absorption)

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_p x_p + \varepsilon \tag{16}$$

where $\beta_0, \beta_1, ..., \beta_p$ is $p$ +1 unknown parameters, $\beta_0$ are called the regression constant, and $\beta_1, ..., \beta_p$ are called the regression coefficient. $\varepsilon$ is the random error term, which is required to satisfy the following two assumptions.

$$\begin{aligned} E(\varepsilon) &= 0 \\ \text{var}(\varepsilon) &= \sigma^2 \end{aligned} \tag{17}$$

It is regarded as a mathematical model to evaluate the ability of the Saihanba to resist sandstorms in Beijing, and then quantitatively to acquire the regression relationship between them.

1) For a practical problem, we generally have $n$ observed data. At this time, linear regression model equation can be expressed in matrix form as $y = X\beta + \varepsilon$, where:

$$y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \quad X = \begin{pmatrix} 1 & x_{11} & \cdots & x_{1p} \\ 1 & x_{21} & \cdots & x_{2p} \\ \vdots & \vdots & & \vdots \\ 1 & x_{n1} & \cdots & x_{np} \end{pmatrix}$$

$$\varepsilon = \begin{pmatrix} \varepsilon_0 \\ \vdots \\ \varepsilon_p \end{pmatrix} \beta = \begin{pmatrix} \beta_0 \\ \vdots \\ \beta_p \end{pmatrix} \tag{18}$$

To make model parameter estimation more convenient, there exist the following basic assumptions

(Gauss-Markov conditions).

- $X$ is a full rank matrix
- Random error terms own zero-mean-values and homoskedasticity

Therefore,

$$y \sim N(X\beta, \sigma^2 I_n) \tag{19}$$

2) F-tests, t-tests, and identification of any violations of the underlying assumptions (e.g., multicollinearity) were conducted and tackled for the models.

*4.2 Data Preparation: Correlation Analysis*

In order to evaluate Saihanba's role in resisting sandstorms in Beijing, the correlation analysis was performed using the ecological environment quality indicators constructed in the first model of Saihanba and the sandstorm data in Beijing. The ecological environment quality indicators with high environmental impact, i.e., water conservation, urban PM2.5 concentration, carbon dioxide absorption, and oxygen release, are selected, and the monthly time data from 2017 to 2021 average air quality index, percentage of severe weather, extremely low temperature, and extremely high temperature is selected for the Beijing sandstorm data.


Figure 3. Correlation Coefficient Heat Map

From the heat map, it can be clearly seen that $W$ and $H$ are negatively correlated with $\varepsilon$, i.e., the higher the water content of the Saihanba, the lower the frequency of extreme and severe weather, and the better the ability of Beijing to resist the sandstorm. $C$ and $Y$ are both negatively correlated with $\varepsilon$, i.e., the higher the carbon dioxide absorption and oxygen release of the Saihanba, the lower the frequency of severe weather, and the better the ability of Beijing to resist the sandstorm. There is no significant correlation between $\mu$ and the ability of Beijing to resist sandstorms. In conclusion, it is clear that the positive change of the ecological environment of the Saihanba also has a positive effect on improving the ability of Beijing to resist sandstorms.

*4.3 Data Processing: Regression Analysis*


Figure 4. Idea of Building the Regression Model

Multiple linear regression models are respectively established with the indicators of the ecological environment of the Saihanba as the independent variables and the data of the ability of Beijing to resist sandstorms as the dependent variables.

Table 4. Summary of Regression Equation

| The dependent variable | Regression models |
|---|---|
| Extremely high temperature | $y=-3.967W-0.611\mu+0.008Y+0.011C$ |
| Extremely low temperature | $y=-0.29W-0.373\mu+0.011Y+0.016C$ |
| Average air quality index | $y=-21.457W-1.658\mu+0.137Y+0.197C$ |
| Percentage of severe weather | $y=-0.019W-0.003\mu-0.001Y-0.001C$ |

From the regression coefficients, it is obvious that carbon dioxide absorption and oxygen release from the Saihanba have a positive effect on the average air quality index of Beijing, i.e., the increase of carbon dioxide absorption and oxygen release can improve the air quality of Beijing. In addition, the amount of culverted water has a significant negative effect on the extremely high temperature and the average air quality index in Beijing. For the average air quality index, the increase of water conservation reduces the average air quality, which is not consistent with the actual theory. Considering that the model does not pass the significance test or there exists multicollinearity, further analysis will be done in the sensitivity analysis. For the extremely high temperature, the increase of water conservation will reduce the frequency of extremely high temperature and reduce the possibility of sandstorms. Finally, the PM2.5 concentration in the Saihanba urban area has a negative effect on the average air quality index of Beijing. That is, the increase of PM2.5 concentration will deteriorate the air quality in Beijing and increase the possibility of sandstorm weather.

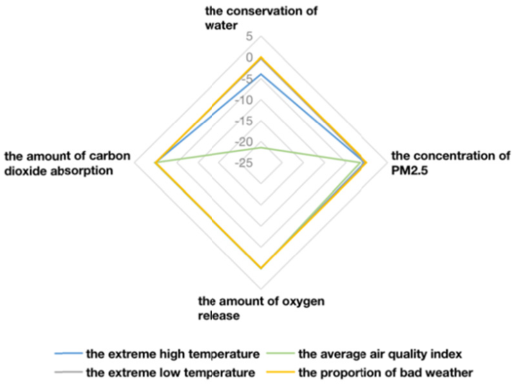


Figure 5. Weights of Independent Variables in the Regression Model

*4.4 Results Analysis*

1) The results of correlation analysis between the ecological environment indicators of Saihanba and the sandstorm data of Beijing from 2017 to 2021 illustrate that the negative indicators of the Saihanba ecological environment and the negative indicators of the sandstorm weather in Beijing show a negative correlation, which means that the positive change of the ecological environment of Saihanba can reduce the possibility of the sandstorm weather in Beijing and improve the ability of Beijing to resist sandstorms.

2) From the results of the multivariable linear regression model between the ecological environment indicators of the Saihanba and the sand and dust storm data of Beijing from 2017-2021, we can learn that the positive indicators of the ecological environment of the Saihanba have a positive influence on the positive indicators of the sandstorm weather in Beijing, while impact negatively on the negative ones, so the improvement of the ecological environment of the Saihanba has a positive contribution to the improvement of environmental pollution and the ability to resist sandstorms in Beijing.

**5. Sensitivity Analysis**

In the second question, when exploring the role of Saihanba on the resistance to sandstorms in Beijing, multivariable linear regression models are developed separately using the Saihanba ecological indicators as independent variables and the data on the resistance to sandstorms in Beijing as dependent variables. We introduce some parameters into our model, and in order to test the rationality and stability of the model better, it is necessary to experiment their sensitivity.

*5.1 Significance Test of Regression Equation: F-test*

The significance test of the multivariable linear regression is to figure out whether the independent variable $x_1$, $x_2$, $\cdots$ $x_p$, as a whole, has a significant effect on the random variable $y$. For this purpose, it is proposed to formulate the original hypothesis:

$$H_0 = \beta_1 = \beta_2 = \cdots = \beta_p = 0 \tag{20}$$

If $H_0$ is accepted, it indicates that the relationship between the independent and dependent variables is not appropriately represented by a linear regression model. To establish the $F$-statistic for testing $H_0$, use the decomposition of the total sum of deviations, i.e.

$$SST = SSR + SSE \tag{21}$$

Construct the $F$-statistic as

$$F = \frac{SSR / p}{SSE / (n - p - 1)} \quad (22)$$

Under the assumption of normality, when the original hypothesis $H_0 = \beta_1 = \beta_2 = \cdots = \beta_p = 0$ holds, $F$ obeys an $F$ distribution with degree of freedom $(p, n-p-1)$.

*5.2 Goodness-of-Fit Test of the Regression Equation*

The goodness of fit is used to test how well the regression equation fits the sample observations. In multivariable linear regression, the sample coefficient of determination is defined as

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \quad (23)$$

The value of the sample coefficient of determination is within the interval $[0,1]$. The closer it is to 1, the better the regression fits; the closer it is to 0, the worse the regression fits.

*5.3 Multicollinearity Test of the Regression Equation*

$$c_0 = c_1 x_{i1} + c_2 x_{i2} + \cdots c_p x_{ip} \approx 0 \quad (24)$$

When the independent variables are related as above, multi-collinearity is presented between the independent variables. The variance expansion factor method is applied to test the model for multi-collinearity. A central normalization is done for the independent variables and noted as

$$C = (c_{ij}) = (X^{*'} X^*)^{-1} \quad (25)$$

Regard its leading diagonal element $VIF = c_{jj}$ as the variance inflation factor $(VIF)$ of the independent variable $x_j$, where

$$c_{jj} = \frac{1}{1 - R_j^2} \quad (26)$$

When $VIF \geq 10$, it means that there is a serious multi-collinearity between the independent variable $x_j$ and the rest of the independent variables, and the multi-collinearity may affect the least square estimates excessively.

Table 5. Regression Model Test Results

| Dependent variable | $R^2$ | Adjusted $R^2$ | $VIF$ | $F$ ( $p$-value) |
|---|---|---|---|---|
| Extremely high temperature | 0.084 | 0.035 | 3.797/1.171 | 0.074 |
| Extremely low temperature | 0.022 | -0.03 | 3.797/1.171 | 0.74 |
| Average air quality index | 0.038 | -0.013 | 3.797/1.171 | 0.53 |
| Percentage of severe weather | 0.268 | 0.229 | 3.797/1.171 | 0.001 |

From the test results of the four regression models, it can be seen that the $R^2$ and Adjusted $R^2$ of the model established by the percentage of ecological environment indicators and severe weather in Saihamba are the largest and best fit, while the $R^2$ and Adjusted $R^2$ of the rest of the models tend to be close to 0, indicating that there is no significant linear relationship between other variables and Beijing sandstorms, so the curve regression can be considered; the $VIF$ of the models are all less than 10, indicating that there is no multi-collinearity among the independent variables There is no multi-collinearity among the independent variables; for the F-test, the $p$ -value of the model statistic $F$ established by the percentage of Saihangba ecological environment indicators and extreme high temperature and severe weather are less than 0.05, so the original hypothesis is rejected, indicating that the Saihangba ecological environment indicators jointly have a significant effect on the extreme high temperature and severe weather in Beijing. For the rest of the models, the $p$-value of the $F$ -statistic was greater than 0.05, so there was no reason to reject the original hypothesis, indicating that the Saihangba eco-environmental indicators combined have no significant effect on extremely low temperature and average air quality index in Beijing.

## 6. Conclusion

In this paper, I use various analytical methods to evaluate different kinds of factors that impact on the ecological environment. Firstly, I gather data of forest coverage rate, water conservation, PM2.5, oxygen release and carbon dioxide absorption of Saihanba in 60 years from 1962 to 2021 and build the EWM-TOPSIS model based on the data. From the model, it is obvious to figure out that water conservation is the indicator with the largest weight, and the restoration of Saihanba hugely influence on the improvement of the environment. Then in the Multivariable Linear model, I apply 4 indicators of Beijing's ability of resisting sandstorms as dependent variables. From the results, it has been concluded that Saihanba plays a vital part in resisting sandstorms in Beijing.

1. When evaluating sandstorm resistance (Model II) and extending carbon emissions from one region to the whole country (Model III), indicators with great impact on ecological environment in the first model are used, which unify measurement standards and facilitate horizontal comparison. In addition, when establishing nature reserves, the analysis is carried out by combining objective indexes and subjective policies, so that the analysis is closer to reality under the premise of science. Pearson correlation analysis was carried out before regression analysis when evaluating the relationship between the anti-sand ability of Beijing and the ecological environment of Saihanba, which can clearly judge the linear relationship between the next two indicators excluding the influence of other variables and supplement the regression analysis. However, in the establishment of regression relationship, four indicators representing sand resistance capacity were used as dependent variables in the four regression models, and then the estimated values of these four indicators were integrated to evaluate sand resistance capacity. The default weight of the four indicators was the same, which was not rigorous enough. And some regression models fail to pass the significance test, indicating that they may be nonlinear regression or have a problem of small sample size. Although we prefer the calculation to be as accurate as possible, owing to the long number of decimal places in the data we used, we had to round off some of the decimals, which may introduce errors into the final result.

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