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Ecosystem evaluation and prediction based on Saihanba

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Abstract: This paper selected and sorted out the area, energy consumption, and coal consumption, carbon emissions, and industrial production value, monthly average number of natural disasters, water resources, and environmental emergencies in 30 provinces in China. The number of events and the number of geological disasters are evaluation indicators. The principal component analysis method is used to obtain important principal components and principal component contribution rates (weights). The scale of the ecological area to be built is planned by evaluating the ecological conditions of each province, and the gray prediction model is used to demonstrate the positive impact of the popularization of Saihanba's plantation model on China's carbon emission reduction.

1. Introduction

Since its establishment in 1962, several generations of people from Saihanba have carried forward the Saihanba spirit which contains burdening the mission, hard work and attaining ecological development, struggling hard and dedicating themselves to the desert land, expanding the afforestation area by 1.12 million acres and planting more than 400 million trees. With their youth, sweat and wisdom, they turned the barren mountains and sands into green land, and then turned it into mountains of gold and silver. Today, the forest coverage in the Saihanba area has reached 80%, and is able to provide 137 million cubic meters of clean water, sequester 747,000 tons of carbon, and release 545,000 tons of oxygen every year.

2. Eco-district construction

For China, we selected 30 provinces and cities (except Inner Mongolia) to determine the location, number or size of ecological reserves.

Eight evaluation indicators: energy consumption, coal consumption, $-\frac{100}{Carbon\ Emissions}$, ndustrial production value, average monthly number of natural disasters, $\frac{1}{Amount\ of\ water\ resources}$, number of environmental emergencies, number of geological disasters (the evaluation indicators established have been pre-processed to realize that the larger the specific value of the indicator the more serious the negative impact on the environment).For thirty provinces and cities and eight evaluation indicators, let x_{ij} be the value of the jth indicator of the ith province($0< i \leq 30, 0 < j \leq 8$), then x_{14} is the value of industrial production in Beijing.

2.1 Standardization of raw data

Assume that the sample observation data matrix is:

$$X = \begin{pmatrix} x_{11} & \cdots & x_{18} \\ \vdots & \ddots & \vdots \\ x_{301} & \cdots & x_{308} \end{pmatrix} \tag{1}$$

The raw data were normalized according to the following method:

$$x_{ij}^{*} = \frac{x_{ij} - \bar{x_j}}{\sqrt{\mathrm{Var}(x_j)}} (i = 1,2, \ldots ,30; j = 1,2, \ldots ,8) \tag{2}$$

Among them:

$$r_{ij} = \frac{\mathrm{Cov}(x_i, x_j)}{\sqrt{\mathrm{Var}(x_1)}\sqrt{\mathrm{Var}(x_2)}} = \frac{\sum_{k=1}^{n} (x_{ki} - \bar{x}_l)\left(x_{kj} - \bar{x_j}\right)}{\sqrt{\sum_{k=1}^{n} (x_{ki} - \bar{x}_l)^2 \sqrt{\sum_{k=1}^{n} \left(x_{ki} - \bar{x_j}\right)^2}}} (n > 1) \tag{3}$$

Matrix visualization processing:

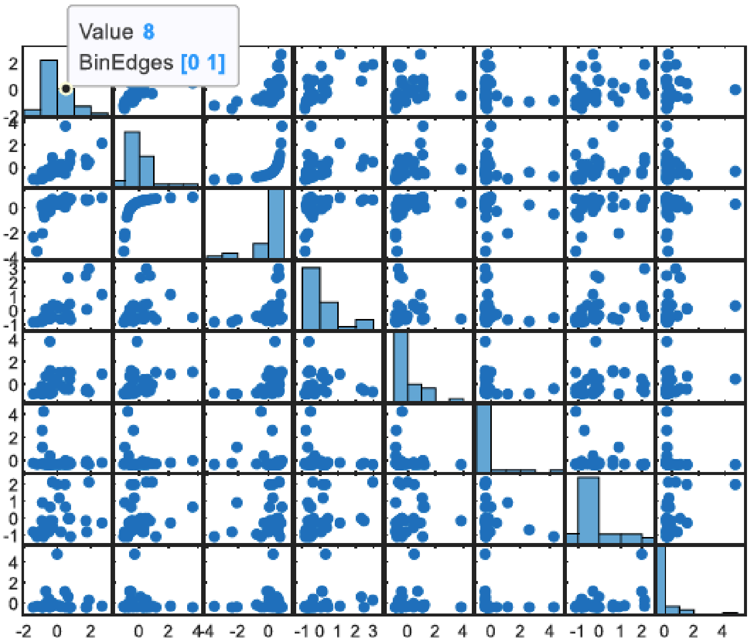

Figure 1: Matrix visualization processing.

2.2 Calculate the sample correlation coefficient matrix

For convenience, assuming that the original data are still denoted by X after standardization, the correlation coefficient of the standardized data is:

$$R = \begin{pmatrix} r_{11} & \cdots & r_{18} \\ \vdots & \ddots & \vdots \\ r_{81} & \cdots & r_{88} \end{pmatrix} \tag{4}$$

Among them:

$$r_{ij} = \frac{\mathrm{Cov}(x_i, x_j)}{\sqrt{\mathrm{Var}(x_1)}\sqrt{\mathrm{Var}(x_2)}} = \frac{\sum_{k=1}^{n} (x_{ki} - \bar{x}_l)\left(x_{kj} - \bar{x_j}\right)}{\sqrt{\sum_{k=1}^{n} (x_{ki} - \bar{x}_l)^2 \sqrt{\sum_{k=1}^{n} \left(x_{ki} - \bar{x_j}\right)^2}}} (n > 1) \quad (5)$$

We give a heat map of the correlation coefficient matrix of eight variables. The darker the color, the stronger the correlation.

2.3 Calculate the sample correlation coefficient matrix

Calculate the eigenvalues (λ_1, λ_2, ..., λ_8) and corresponding eigenvectors of the correlation coefficient matrix R:

$$a_i = (a_{i1}, a_{i2}, \cdots, a_{i8}), (i = 1,2, \cdots, 8) \quad (6)$$

The contribution margin is the proportion of the variance of a particular principal component to the total variance, which is actually the proportion of a particular eigenvalue to the total of all eigenvalues, that is:

$$\text{contribution margin} = \frac{\lambda_i}{\sum_{i=1}^{8} \lambda_i} \quad (7)$$

The larger the contribution margin, the stronger the information of the original variables included in that principal component. Indicators with a cumulative contribution rate of 85% or more were selected to ensure that the composite variables include most of the information of the original variables and we finally obtained 6 principal components.($k = 6$)

2.4 Calculate the principal component score

The new data for each sample under each principal component are:

$$\begin{pmatrix} F_{11} & \cdots & F_{18} \\ \vdots & \ddots & \vdots \\ F_{301} & \cdots & F_{308} \end{pmatrix} \quad (8)$$

Among them:

$$\mathrm{F_{ij}} = a_{j1}x_{i1} + a_{j2}x_{i2} + \cdots + a_{j8}x_{i8}, (i = 1,2, \cdots, 30, j = 1,2, \cdots, 6) \quad (9)$$

2.5 Modeling results and result analysis

We use $P_i=[F_i]+6$ as the number of construction. The scores of 30 provinces are listed in the appendix. Since the area and energy consumption have been considered in the evaluation model, we select cities with more serious pollution or more ecological reserved land in each province, and use MATLAB to pass the latitude and longitude and construction scale of each selected city. The following figure is obtained, in which the size of the blue bubble corresponds to the scale of the ecological zone.

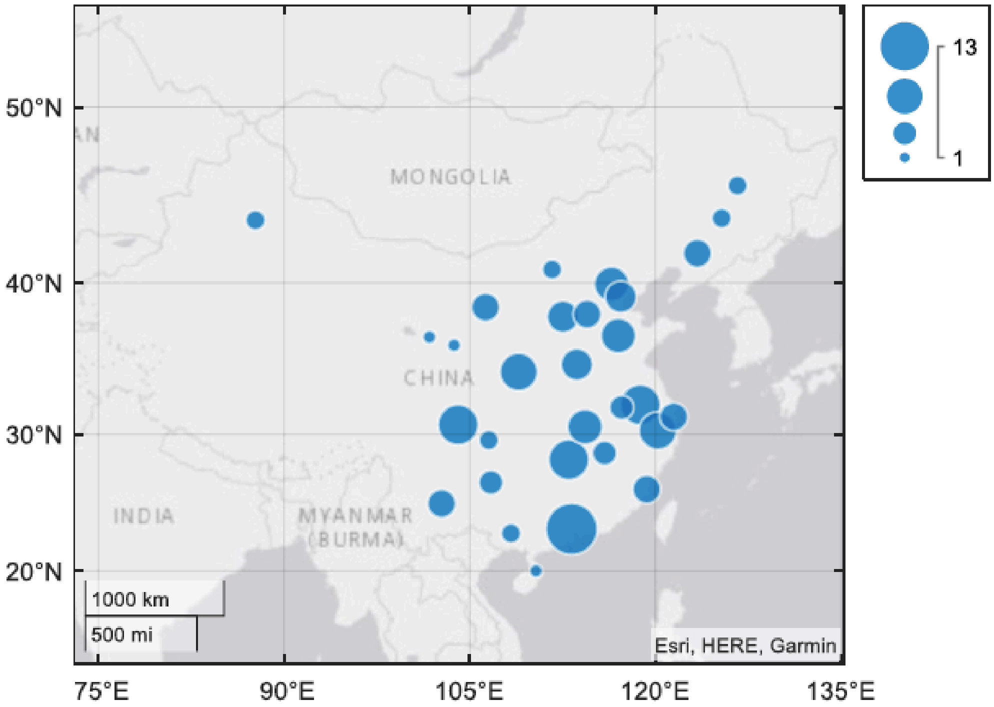

Figure 2: The scale of the ecological zone.

3. Assessing the impact

The original series $x_1^{(0)} = (x_1^{(0)}(1), x_1^{(0)}(2), \cdots, x_1^{(0)}(21))$, $x_2^{(0)} = (x_2^{(0)}(1), x_2^{(0)}(2), \cdots,$ $x_2^{(0)}(21))$, $x_3^{(0)} = (x_3^{(0)}(1), x_3^{(0)}(2), \cdots, x_3^{(0)}(21))$ respectively indicate the actual CO2 emission from Chengde, the actual CO2 absorption from Saihanba and the CO2 emission from Chengde without Saihanba from 1997-2017.

3.1 Using gray projection to get the trend of $x_1^{(0)}$ and $x_3^{(0)}$ in the next 20 years

The original data of $x_1^{(0)}$ are accumulated in order to weaken the volatility and randomness of the random sequence and obtain a new data sequence:

$$x_1^{(1)} = (x_1^{(1)}(1), x_1^{(1)}(2), \cdots, x_1^{(1)}(21)) \tag{10}$$

In the equation, each data in $x_1^{(1)}(t)$ represents the accumulation of the data corresponding to the previous terms:

$$x_1^{(1)}(t) = \sum_{k=1}^{t} x_1^{(0)}(k) \ or \ x_1^{(1)}(t+1) = \sum_{k=1}^{t+1} x_1^{(0)}(k)(t = 1,2, \dots ,31) \tag{11}$$

Create a first-order linear differential equation for $x_1^{(1)}(t)$:

$$\frac{dx_1^{(1)}}{dt} + ax_1^{(1)} = u \tag{12}$$

a, $u$are the coefficients to be determined, called the development coefficient and the amount of gray action, respectively, the effective interval of a is (-2,2) and the matrix formed by a, u is noted as $\hat{a} = \binom{a}{u}$. Only the parameters a, u are required to find $x_1^{(1)}(t)$ and thus the future predicted value of $x_1^{(0)}$.

The data generated by the accumulation is averaged to obtain B with a vector of constant terms Y_n, and:

$$B = \begin{bmatrix} 0.5\left(x_1^{(1)}(1) + x_1^{(1)}(2)\right) \\ 0.5\left(x_1^{(1)}(2) + x_1^{(1)}(3)\right) \\ 0.5\left(x_1^{(1)}(30) + x_1^{(1)}(31)\right) \end{bmatrix}, Y_n = \left(x_1^{(0)}(2), x_1^{(0)}(2), \dots, x_1^{(0)}(31)\right)^T \tag{13}$$

To test the established gray model, the steps are as follows:

Calculate the residuals $e_1^{(0)}(t)$ and relative error $q'(x)$ between $x_1^{(0)}$ and $\hat{x}_1^{(0)}$.

$$e_1^{(0)}(t) = x_1^{(0)} - \hat{x}_1^{(0)}(t), q'(x) = \frac{e_1^{(0)}(t)}{x_1^{(0)}(t)} \tag{14}$$

①Find the mean of the original data $x_1^{(0)}$ nd the variance s_1;

②Find the mean $\bar{q}$ of $e_1^{(0)}(t)$ and the variance of the residuals s_2;

③Calculate the variance ratio $c=\frac{s_2}{s_1}$;

④Find small probability error $P = P\{|e(t) < 0.6745 s_1\}$;

⑤ Accuracy check based on the above data: the established gray prediction model has been confirmed to be reasonable.

Forecasting with models:

$$\hat{x}_1^{(0)} = \left[\hat{x}_1^{(0)}(1), \hat{x}_1^{(0)}(2), \dots, \hat{x}_1^{(0)}(31), \hat{x}_1^{(0)}(32), \dots, \hat{x}_1^{(0)}(38)\right] \tag{15}$$

Using the gray prediction model for future 20-year change trend forecasting method the same way can be obtained.

4. Model results and result analysis

We use $T_i=[F_i]*10+6$ as the number of construction. And we similarly define the two series of $x_1^{(0)}$ and $x_3^{(0)}$ to represent China's actual carbon emissions (RED) and the predicted carbon emissions after China's construction of an ecological zone (BLUE). Use gray forecast to show future trends.

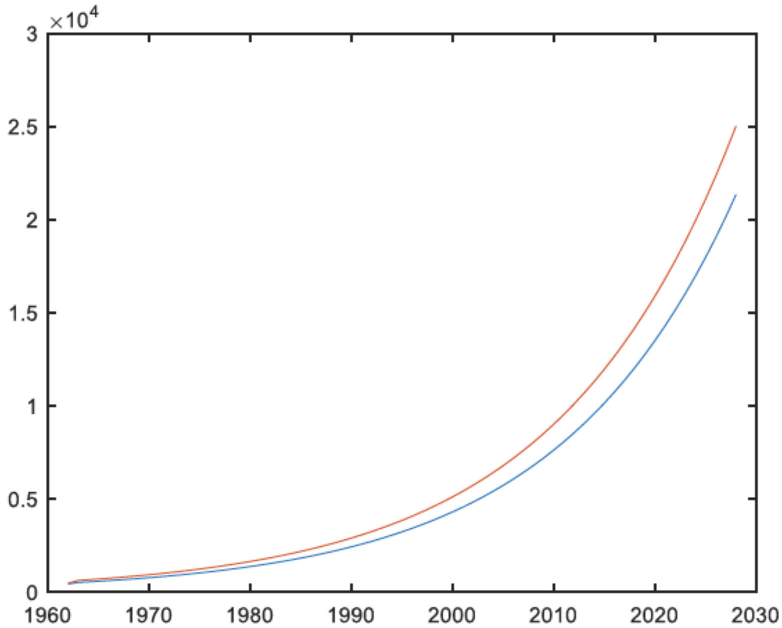

Figure 3: Future trends.

It can be seen that the predicted value (blue) of carbon emissions after the construction of the ecological zone is significantly lower than the original value (red).

References

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