Ecological Research of Saihanba Based on Pearson Correlation Coefficient Fuzzy Comprehensive Model

ZhangMing Zhao [1], ZhangKai Zhao [2], Zhanguo Zhang [3, *]

[1] Northeast Agricultural University School of Economics and Management Heilongjiang, Harbin, China, 150038

[2] Harbin University of Commerce School of Accountancy Heilongjiang, Harbin, China, 150028

[3] Northeast Agricultural University College of Science Heilongjiang, Harbin, China, 150038

* Corresponding Author Email: zhangzhanguo210@163.com

Abstract. This article mainly studies Saihanba's ecological model's advantages and characteristics and extends it to the whole country. Firstly, this article constructs a comprehensive evaluation model of fuzzy mathematics and evaluates that the impact on the environment before and after the restoration of Saihanba is very obvious. Secondly, the Pearson correlation coefficient model is established to obtain the correlation coefficient matrix between 10 indicators. Finally, the hypothesis test results deeply analyze the weak correlation between Saihanba and Beijing's ability to resist sandstorms. Then, perform the TOPSIS score evaluation of each province to complete the preliminary screening. The pixel overlay is used to analyze the domestic reasonable ecological area site selection for secondary screening. Finally, establishing an ecological protection area location model based on the immune algorithm determines that 9 regional ecological areas can be built, accounting for about 24.3% of the country's land area. It can absorb approximately 388.608*105KG of carbon dioxide and release 291.456*105KG of oxygen

Keywords: Fuzzy mathematics model; Pearson correlation coefficient; TOPSIS; Immune algorithm.

1. Introduction

Saihanba site is in eastern China at the Inner Mongolia Plateau and the northern mountain of Hebei. Saihanba in history used to be a place where water grass was abundant, and poultry was frequent. However, the pristine forests of the Saihanba were rippled and eventually degraded to a high altitude wasteland due to predatory harvesting and ravaging by successive mountain fires. In order to restore the once ecological picture of Saihanba, the Chinese government has taken a series of measures for the environmental remediation of Saihanba and constructed Saihanba mechanical stands. This initiative provides valuable experience for repairing damaged ecosystems and concrete examples for future environmental remediation engineering.

Afforestation is an important measure in the desertification control project. Saihanba has leading experience in afforestation, wind prevention, and sand fixation and plays an important role in wind resistance and sand fixation, environmental protection, and maintaining ecological balance and stability. The evaluation model of Saihanba's impact on the ecological environment is established, quantitatively evaluating the impact of Saihanba's restoration on the environment. Through the comparative analysis of the environmental conditions before and after the restoration of Saihanba, the importance of sand control engineering can be reflected [1]. This article mainly studies Saihanba's ecological model's advantages and characteristics and tries to extend it to the whole country. Fuzzy mathematical model, Pearson correlation coefficient, TOPSIS evaluation, screening method based on pixel superposition, and immune algorithm debugging model are adopted. In this paper, by establishing an evaluation model and analyzing the correlation coefficients [2], it finally established an ecological protection area location model and determined the buildable ecological reserve.

2. Evaluation Model of Fuzzy Mathematics

2.1. The specific analysis

The entropy weight method is an objective weighting method. Compared with the general weighting method, it is more objective and reliable. The principle is that the smaller the index's variation degree, the less information it reflects, and the lower its corresponding value [3].

Based on the data collection on the changes in environmental conditions before and after the restoration of Saihanba, a total of 60 years (1962-2021) are used as the Evaluation object. The positive matrix X is composed of six evaluation indexes: forest coverage rate, coverage area (10^4 mu), forest volume (10^4 m^3), water conservation (10^9 m^3), carbon dioxide absorption (10^4 tons), and oxygen release (10^4 tons):

Table 1. Weight of each Indicator.

Forest cover rate	*Covered area*	*Forest accumulation*	*Water conservation*	*CO_2 absorption*	*O_2 release*
0.0387	0.0387	0.2363	0.2138	0.2362	0.2363

$$X = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{16} \\ X_{21} & X_{22} & \cdots & X_{26} \\ \cdots & \cdots & \cdots & \cdots \\ X_{60(1)} & X_{60(2)} & \cdots & X_{60(6)} \end{bmatrix} \tag{1}$$

Note that the standardized matrix is Z so that each element in Z is $Z_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{60} X_{ij}^2}}$, then obtain the standardized matrix Z:

$$Z = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{16} \\ Z_{21} & Z_{22} & \cdots & Z_{26} \\ \cdots & \cdots & \cdots & \cdots \\ Z_{60(1)} & Z_{60(2)} & \cdots & Z_{60(6)} \end{bmatrix} \tag{2}$$

Then calculate the probability matrix P, each element in the matrix P is:

$$p_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{60} Z_{ij}} \tag{3}$$

For the j-th index, its information entropy $e_j = -\frac{1}{\ln n}\sum p_{ij} \ln\left(p_{ij}\right), (j = 1,2,\cdots\cdots,6)$.Obviously, the greater the value, the less available information of the j-th index and $\sum$ pij = 1. Define the information utility value $d_j = 1 - e_j$ .The greater the information utility value, the more information it opposes.

Calculate the entropy weight wj of the j-th index:

$$W_j = \frac{d_j}{\sum_{j=1}^{6} d_j} (j = 1,2,\cdots\cdots,6) \tag{4}$$

2.2. Fuzzy mathematics comprehensive evaluation model

According to the data collection and analysis of the impact of Saihanba on the ecological environment, the evaluation indicators are selected, and the factor set U is established:

$$U = \{U_1, U_2, \cdots\cdots, U_6\} \tag{5}$$

Then establish an evaluation set to deal with the degree of ecological environment impact:

$$V = \{V_1, V_2, \cdots\cdots, V_4\} \tag{6}$$

According to the calculation results of the entropy weight method, the weight level is established: $A = \{0.0387,0.0387,0.2363,0.2138,0.2362,0.2363\}$

The membership function reflects the "authenticity" of elements belonging to a fuzzy set and is a fuzzy set representing the weight value of each factor evaluation index. It mainly reflects the membership degree of a factor belonging to a fuzzy set. The evaluation set of the six factors is divided into "excellent," "good," "general," and "unqualified," and the membership of each factor to the four rating grades is calculated respectively [4].

$$r_{i1} = \begin{cases} 1, & x \geq \alpha_1 \\ \frac{\alpha_2 - x}{\alpha_2 - \alpha_1}, & \alpha_1 > x > \alpha_2 \\ 0, & x \leq \alpha_2 \end{cases} \tag{7}$$

$$r_{i2} = \begin{cases} 0, & x \geq \alpha_1 \\ \frac{x - \alpha_1}{\alpha_2 - \alpha_1}, & \alpha_1 > x > \alpha_2 \\ \frac{\alpha_3 - x}{\alpha_3 - \alpha_2}, & \alpha_2 > x > \alpha_3 \\ 0, & x \leq \alpha_3 \end{cases} \tag{8}$$

$$r_{i3} = \begin{cases} 0, & x \geq \alpha_1 \\ \frac{x - \alpha_2}{\alpha_3 - \alpha_2}, & \alpha_2 > x > \alpha_3 \\ \frac{\alpha_4 - x}{\alpha_4 - \alpha_3}, & \alpha_3 > x > \alpha_4 \\ 0, & x \leq \alpha_4 \end{cases} \tag{9}$$

$$r_{i4} = \begin{cases} 0, & x \geq \alpha_1 \\ \frac{x - \alpha_3}{\alpha_4 - \alpha_3}, & \alpha_1 > x > \alpha_2 \\ 1, & x \leq \alpha_2 \end{cases} \tag{10}$$

α1, α2, α3, α4 is the gap between the evaluation levels.

For indicators u_i, for fuzzy subsets whose membership degree of each evaluation set is V, the evaluation of indicators u_i is recorded as $R_i = \{r_{i1}, r_{i2}, \cdots\cdots, r_{i4}\}$.$r_{im}$ indicates the membership of indicator u_i to evaluation m.

Therefore, for 1962, the fuzzy comprehensive judgment matrix of each index can be obtained as follows [5]:

Table 2. Ecological Environmental Impact Assessment Standard.

Excellent		***Good***	***General***	***Unqualified***
Forest cover rate	61.00	54.00	32.00	21.00
Coveredarea	85.40	75.60	44.80	29.90
Forest accumulation	213.50	189.00	112.00	74.76
Water conservation	6.43	0.95	0.06	0.04
CO_2 absorption	56.93	50.40	29.87	19.94
O_2 release	62.34	55.19	32.70	21.83

Table 3. Value of H and P.

H value	0	0	1	1	1	1	1	1	1	1
P value	0.054	0.054	0.030	0.023	0.030	0.030	0.001	0.050	0.010	0.001

$$R = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0.03 & 0.97 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{11}$$

Correspondingly for 2021:

$$R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0.34 & 0.66 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0.65 & 0.35 & 0 & 0 \end{bmatrix} \tag{12}$$

After obtaining the weight of each factor and the membership degree of each evaluation, if there is a fuzzy relationship R = $(r_{ij})_{m\times n}$ from U to V, then the fuzzy transformation F(U)→F(V) can be obtained by using R. The comprehensive evaluation can be regarded as a fuzzy vector on V, which is recorded as B = $\{b_1, \cdots, b_m\}$ (m = 1, 2, 3, 4). B is considered as the score for evaluating each study object.

$$B_{1962} = A \cdot R = [0, 6.414 \times 10^{-3}, 0.2074, 0.7862] \tag{13}$$

$$B_{2021} = A \cdot R = [0.7762, 0.2238, 0, 0] \tag{14}$$

The evaluation result is excellent. Combined with the different performance of six factors in 1962, 2021, it can be considered that the ecological state of Saihanba has changed from unqualified to excellent after restoration. It is proved that the establishment of the Saihanba ecological model has made achievements.

3. Pearson Correlation Coefficient Analysis

Three main factors cause sandstorms: precipitation and thermal conditions, wind sources, and sand sources. The land type, vegetation status, and soil moisture of the underlying surface are the main surface conditions that affect the formation of sandstorms and determine the source of sand. Meteorological conditions are the key element that determines the generation, maintenance, and dissipation of sand and dust storms gave is the fundamental driving factor for the occurrence and development of sand and dust storms. In the case of small changes in the underlying surface, the incidence of sandstorms is closely related to the number of days with strong winds. Precipitation and temperature affect the surface environment and climate change, causing thermal instability and exacerbating the formation of dusty weather [6].

It is selected the monthly temperature and precipitation data in Beijing from 2019 to 2021 to evaluate the correlation between temperature and precipitation and dust weather. Meanwhile, relevant data will be collected from 1962 to 2021, and a mathematical model will be established from Beijing's "sand days," "floating dust days," and "sand storm days" (data source: China Meteorological Administration). To assess the impact of Saihanbas ecological restoration on Beijing's ability to resist sand and quantitatively evaluate Saihanba's role in Beijing's sandstorm resistance.

3.1. JB normal test

Before the Pearson correlation coefficient distribution is performed on the sample indicators, the sample data is required

Table 4. The Value of P.

Forest cover rate		*Covered area*	*Forest accumulation*	*Water conservation*	*CO_2 absorption*	*O_2 release*	*Windy days*	*Sand days*	*Dust days*	*Sandstorm days*
Forest cover rate	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3887	0.0000	-0.2829	-0.4949
Covered area	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.3887	0.0000	-0.2829	-0.4949
Forest accumulation	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.1561	0.0000	-0.2823	-0.3532
Water conservation	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0191	0.0000	-0.3349	-0.3521
CO2 absorption	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.1561	0.0000	-0.2823	-0.3532
Oxygen release	0.8679	0.8680	1.0000	0.9762	1.0000	1.0000	0.1921	-0.6764	-0.2823	-0.3532
Windy days	0.1174	0.1174	0.1921	0.3124	0.1921	0.1921	1.0000	-0.1048	-0.1880	0.3452
Sand days	-0.6535	-0.6535	-0.6764	-0.6544	-0.6764	-0.6764	-0.1048	1.0000	0.4089	0.3193
Dust days	-0.2829	-0.2829	-0.2823	-0.3349	-0.2823	-0.2823	-0.1880	0.4089	1.0000	0.2048
Sandstorm days	-0.4949	-0.4949	-0.3532	-0.3521	-0.3532	-0.3532	0.3452	0.3193	0.2048	1.0000

The normal distribution test is performed on the sample data to be normally distributed. Suppose the skewness of the random variable X_i is S_i, and its kurtosis is K_i, and construct the JB statistic:

$$JB = \frac{n}{6}\left[S^2 + \frac{(K-3)^2}{4}\right] \tag{15}$$

Then perform a hypothesis test. Let H_0 be that the random variable does not obey a normal distribution and H_1 that the random variable obeys normal distribution. Use to calculate the corresponding H and P values, as shown in the following table: According to the data in the table, it can be seen that most of the indicators of the sample obey the normal distribution at the 95 % confidence level.

3.2. Pearson correlation coefficient analysis

Use Pearson correlation coefficient to analyze the degree of correlation between sample indicators:

$$r = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})}\sqrt{\sum_{i=1}^{n}(Y_i-\bar{Y})}} \tag{16}$$

r — correlation coefficient
n — sample individual
X_i — the attribute value of sample X
Y_i — the attribute value of sample Y

3.3. Hypothesis test of Pearson correlation coefficient

To observe whether r is significantly different from 0, set the null hypothesis H_0: r = 0, and the alternative hypothesis H_1: r ≠0. Constructing statistics can prove that t is at distribution with 54 degrees of freedom. According to the distribution of statistics, the probability density function is given with a 95% confidence level. It can be seen from the statistical table that the corresponding critical value is 1.96, and the P-value is calculated. When P < 0.05, it means that the null hypothesis is rejected at the 95% confidence level, that is, r is different from 0, and there is a correlation; when P > 0.05, the situation is the opposite.

It can be known that there is a specific correlation between strong wind weather and the number of days of flying sand and sandstorms in Beijing (0 .4419, 0.1653, 0.0092); the general situation of Saihanba forest has a weak correlation with the number of days of floating dust and sandstorms in Beijing (0.0000, 0.0347, 0.0001). It can be considered that the establishment of Saihanba Forest Farm will promote the improvement of Beijing's dust storm situation, but it is not absolute.

4. Analysis of Model Results

In order to screen the areas suitable for the implementation of the Saihanba model across the country, the province is used as a unit for primary screening: the forest coverage rate, desert coverage rate, wetland coverage rate of each province, the richness of treasured animals, the richness of rare plants and the abundance of precious sites Six indicators establish a mathematical model.

To determine which provinces in China need to build ecological zones. Combining the distribution of national ecological red lines, forest distribution, and national ecological zone distribution, the specific locations of the ecological zones that need to be established in each province are subjected to a secondary screening to determine the number and scale of ecological zones to be built.

4.1. TOPSIS preliminary screening

The establishment of ecological reserves is mainly based on three geographical features. Construct forest and desert wetland type ecological zones according to ecological characteristics; establish wild animal and wild plant type ecological zones according to the characteristics of animals and plants; establish natural relic ecological zones according to the types of natural relics. The coverage rates of

forests, deserts, and wetlands in various provinces and cities across the country, the richness of nationally protected animals and plants, and natural relics are selected as evaluation indicators.

To implement Saihanba's characteristic ecological model, the greater the value of the index of forest coverage and wetland coverage, the less necessary it is to establish an ecological reserve. Forest coverage and desert coverage are minimal indicators that require positive treatment. The processing method is:

$$X^* = max - x \tag{17}$$

Table 5. The Topsis Scoring.

Province	**Xinjiang**	**Gansu**	**Qinghai**	**Inner Mongolia**	**Yunnan**	**Tibet**	**Ningxia**
Score	0.0524	0.0494	0.0458	0.0447	0.0447	0.0402	0.0389
Province	Henan	Beijing	Sichuan	Shandong	Shanxi	Hebei	Hunan
Score	0.0383	0.0361	0.0349	0.0341	0.0331	0.0322	0.0312
Province	Jiangxi	Guizhou	Jiangsu	Shanghai	Guangxi	Anhui	Liaoning
Score	0.0307	0.0297	0.0291	0.028	0.0274	0.0267	0.0265
Province	Guangdong	Tianjin	Shaanxi	Fujian	Zhejiang	Hubei	Jilin
Score	0.0262	0.0259	0.0258	0.0255	0.0254	0.0253	0.0251
Province	Chongqing	Hainan	Heilongjiang				
Score	0.0243	0.0212	0.021				

Due to the limitation of data collection, this article did not obtain reliable data for Hong Kong, Macau, and Taiwan. Therefore, 31 provinces across the country (except Hong Kong, Macao, and Taiwan) are evaluated, and a positive matrix is formed with six evaluation indicators:

$$\begin{bmatrix} X_{11} & X_{12} & \cdots & X_{16} \\ X_{21} & X_{22} & \cdots & X_{26} \\ \cdots & \cdots & \cdots & \cdots \\ X_{31(1)} & X_{31(2)} & \cdots & X_{31(6)} \end{bmatrix}. \tag{18}$$

Comprehensively consider the impact of forest coverage, wetland coverage, the number of world-class heritage sites, key protected animals, key protected plants, and the proportion of desertified land, and give them the same weight as 1/6, which is recorded as $w_j(j = 1,2,\cdots,6), \sum_{j=1}^{6} w_j = 1$.

For the 31 provinces studied, define the distance between the i-th evaluation object and the maximum value.

$$D_i^+ = \sqrt{\sum_{j=1}^{6} w_j \left(z_i^+ - z_{ij}\right)^2} \tag{19}$$

As shown in the table, this article considers Xinjiang, Gansu, Qinghai, Inner Mongolia, Yunnan, Tibet, Ningxia, Henan, Beijing, Sichuan, Shandong, Shanxi, Hebei, Hunan, Jiangxi provinces, Guizhou Province is worthy of promoting an ecological zone.

4.2. Geographic pixel overlay analysis

In order to increase the rationality of ecoregional site selection, this paper introduces the ecological protection red line, the distribution of national forests, and the distribution of national-level eco-regions to assist in site selection. The red line of ecological protection refers to areas with unique and important ecological functions within the scope of ecological space and must be strictly protected. There is no need to implement the Saihanba ecological model in the densely forested part. The distribution of national ecological zones guides site selection.

In summary, the above three maps are superimposed based on pixel overlap, and the overlapped part is taken as the scope of the specific site selection of the ecological zone.

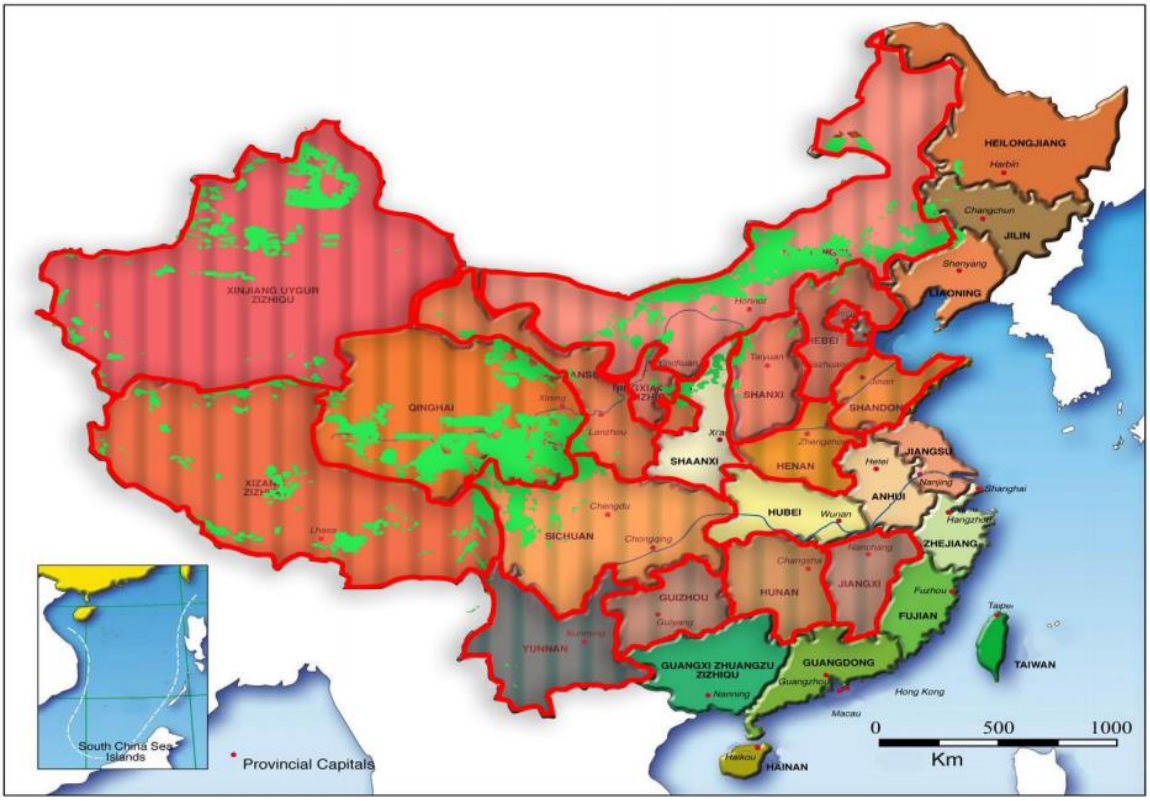


Figure 1. Pixel overlay map.

4.3. Eco-region location model based on an immune optimization algorithm

After upgrading the primary selection and pixel secondary screening, the scope of the ecological area has been reduced for the second time. Finally, we use the immune optimization algorithm to select the location model of the ecological area.

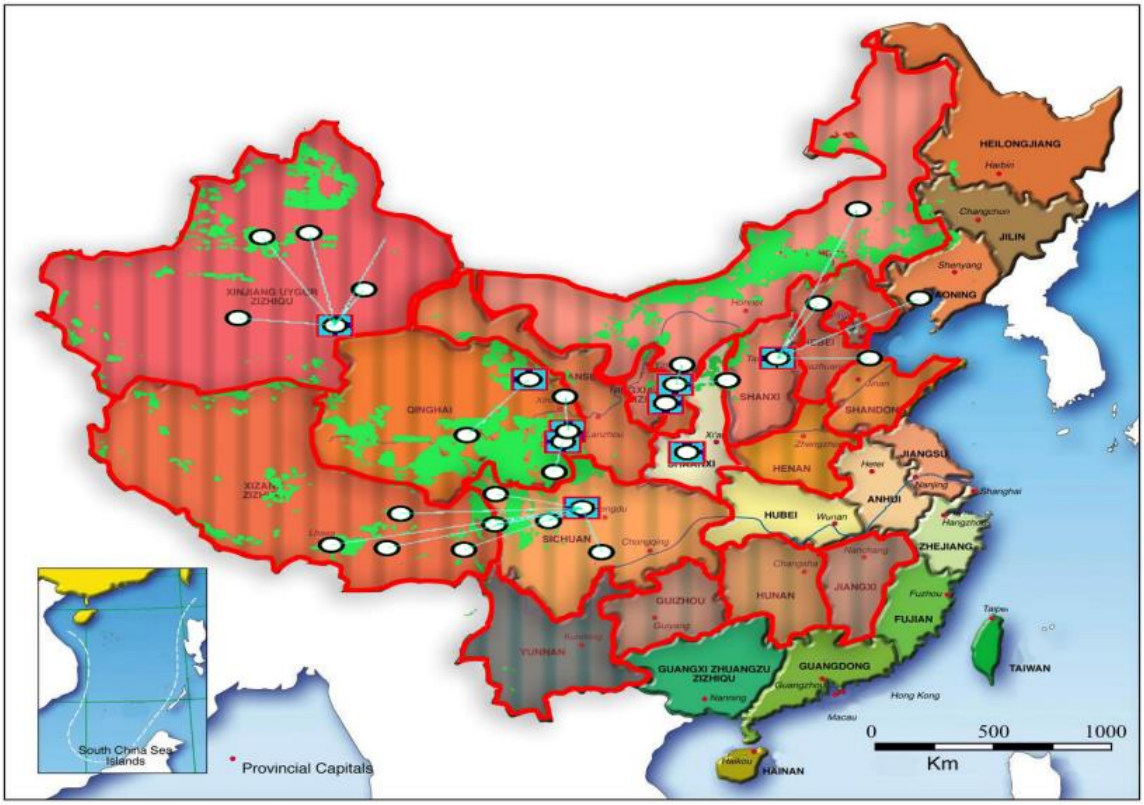


Figure 2. Province screening map.

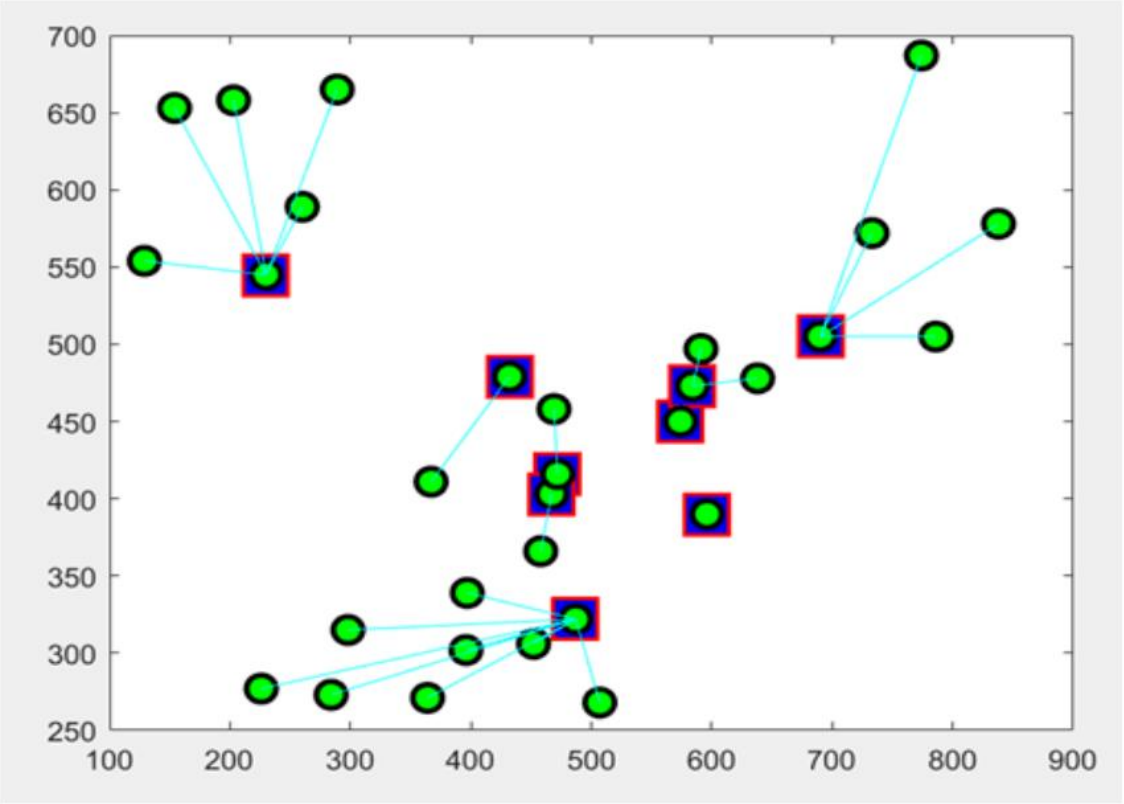


Figure 3. Location map of site selection.

Based on assumptions, the following location model is established. In the case of meeting the upper and lower limits of the distance, it is necessary to find the most optimal site from the 31 urban sites to be constructed. The objective function is the distance value from each site to the construction site and the construction land ratio. The sum of the products is the smallest.

It is believed that several joint ecological zones will be established in 31 cities in Liancheng blocks, and the rationality of site selection is analyzed and compared, and it is concluded that nine ecological zones need to be established roughly. Its scale covers and radiates to seven provinces.

Imitating the ecological model of Saihanba, in general, the area of ecological zone that can be built across the country is about 242 .88 × 105 km^2. The so-called carbon neutrality, net-zero emissions, refers to the carbon emissions necessary for human economic and social activities, which are captured, utilized, or stored by forest carbon sinks and other artificial technologies or engineering methods the greenhouse gases emitted into the atmosphere are net. The increment is zero. Increasing forest carbon sinks through afforestation is one of the most effective means. Refer to the calculation standard of carbon sink under normal circumstances: each square meter of forest can absorb 1.6 kg of carbon dioxide and release 1.2 kg of oxygen per day. In general, the ecological zone established in this article can absorb 388.608 × 105 kg of carbon dioxide and release 291.456 × 105 kg of oxygen.

5. Conclusion

The impact on the environment before and after the restoration of Saihanba is very obvious. The comprehensive evaluation method of fuzzy mathematics can solve a series of problems such as the complexity of evaluation factors, the hierarchy of evaluation objects, the ambiguity in evaluation standards, the ambiguity or uncertainty of evaluation influencing factors, and the difficulty of quantifying qualitative indicators. It has excellent operability in evaluation.

An ecological protection area location model based on an immune algorithm has been established. The immune algorithm simulates the diversity generation and maintenance mechanism of the biological immune system to maintain the diversity of the group, overcomes the" premature" problem

that is difficult to deal with in the general optimization process, especially the multimodal function optimization process, and finally obtains the overall best Excellent solution.

This paper divides the ecological protection zone throughout the province without prioritizing the ecological zone based on topography and geomorphology.

Compared with the case of prefecture-level cities, the model has some errors. It can be roughly evaluated at the national and provincial levels.

References

[1] Hongbin Xiong, Lingyan Zhou, Research on the Eco-environmental Impact Assessment of Chaohu Lake Flood Control Project Based on PSR-Gray Target Model [J]. Resources and environment in the Yangtze River Basin, 2018, 27(09): 1977-1987.

[2] Wu Yong, Zhou Shan. Eco-environmental impact assessment of land consolidation projects: Taking S Town in Nanchong City as an example [J]. Journal of Southwest Petroleum University (Social Science Edition), 2019, 21(04): 37-42.

[3] Zhang Qi. Evaluation of the impact of land use/cover change on the vulnerability of ecological Environment in Changbai Mountain [D]. Yanbian University, 2019.

[4] Lilei Wang. Fuzzy evaluation model for the impact of cross-basin water transfer on the ecological Environment [J]. Northeast Water Resources and Hydropower, 2020, 38(07): 22-26+72. DOI: 10.14124/j.cnki.dbslsd22-1097.2020.07.008.

[5] Liu Bin, Guoshi Yin, Zhaomei Zhou. Comprehensive assessment of the environmental impact of dam building and reservoir construction based on RBF neural network: Taking Fuling Reservoi r as an example [J]. Hunan Water Resources and Hydropower, 2016(02): 68-71+76. DOI: 10.16 052/j.cnki.hnslsd.2016.02.024.

[6] Yu Wen, Guoxuan Ding, Xiaopeng Fan, Yibing Dong, Bingbing Han, Baofeng Wan, Shanshan Yue. Research on mine geological and ecological environment evaluation based on analytic hierarchy process and fuzzy comprehensive model [J]. Three Gorges Ecological Environment Monitoring, 2021, 6(02): 26-35. DOI:10.19478/j.cnki.2096- 2347.2021.02.04.