ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0056

Ecological Environment Influence Appraisal Model based on Entropy Weight Method and GE Matrix

Jiyang Liu, Fangtong Sun, Xin Wang, Hanwen Yu, Yuxin Wu

National University of Defense Technology, Changsha, Hunan, 410000, China

Abstract

This paper establishes a two-dimensional model for the ecological environment evaluation of Saihanba by selecting the main indexes such as climate, biology, hydrology, and land. The principal component analysis was used to remove the correlation among the indexes. The current standard and field data are combined to give weight, and the entropy weight method is used to give weight data to amend. A two-dimensional evaluation model of the ecological environment is established by using the GE matrix, and the Stability Index (SI) is introduced to quantitatively express the comprehensive efficiency of the ecological environment in the GE matrix, the distance between the coordinate and the optimum point (1,1) is taken as a quantitative index to evaluate the comprehensive efficiency of ecological environment. Before and after the completion of the Saihanba, the comprehensive eco-environmental efficiency was improved by 77.65%.

Keywords

Two-dimensional Model; Entropy Weight Method; GE Matrix.

1. Introduction

Clear waters and green mountains are mountains of gold and silver. This is the concept put forward by the Chinese government to protect the ecological environment. Generations of young Chinese have been coming to Saihanba, a sandy wasteland since the 1960s to implement a sustainable development strategy and build an ecological civilization. After more than half a century of effort, the Chinese people have built the world's largest artificial forest in Saihanba. Artificial afforestation can conserve water, prevent wind and fix sand, and play a significant positive role in protecting the environment and maintaining the balance and stability of the ecosystem.

2. Ecological Environment Influences Appraisal Model

2.1 Model Establishment

2.1.1 Index Selection

Based on the available data, we found that different countries and regions have established a variety of ecological environment evaluation systems, but the indicators contained in each system are different. To better adapt to the actual situation of China’s Saihanba, we established a new Ecological Environment Evaluation Index (EEEI) and selected the following four types of development indicators: Meteorology, Biology, Hydrology, and Geology. By comparing the environmental conditions before and after the restoration of the Saihanba, we conducted a quantitative evaluation of the environmental impact of the restoration of the Saihanba.

To better reflect environmental changes, we select the corresponding evaluation indicators based on the following principles in response to the requirements of the subject:

(1) Indicators can more intuitively reflect environmental quality;

(2) Indicators have little influence on each other;

Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0056

(3) Index data is easy to collect and can be quantitatively analyzed;

According to the above three principles, we selected 20 indicators and constructed a three-level evaluation indicator system.

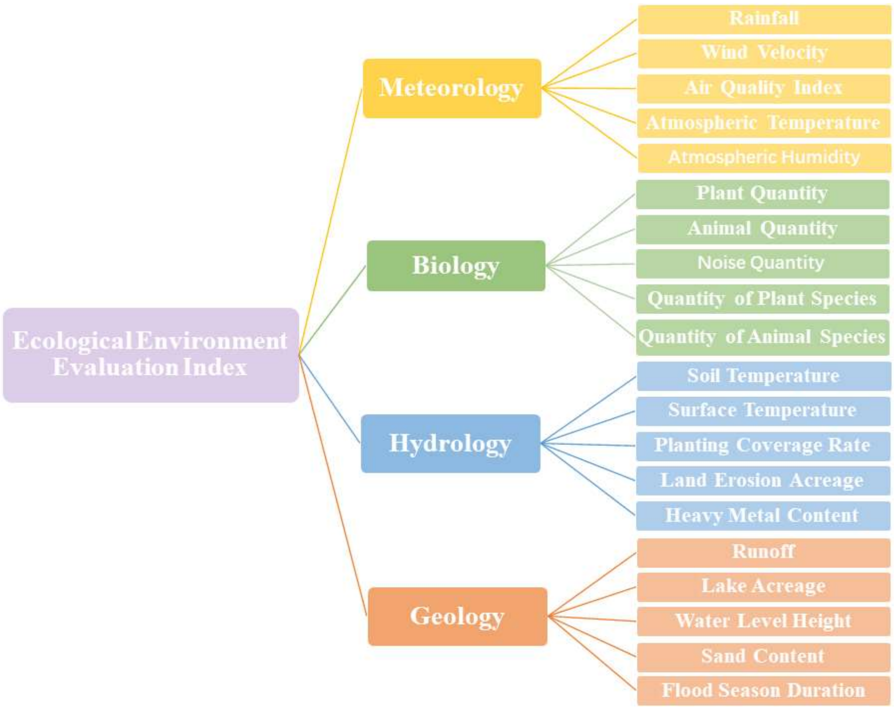

Figure 1. Ecological Environment Evaluation Index

2.1.2 Standardized

Since each index data is selected based on different scales, they must be standardized to the same scale. Standardization processing is required when using all index data.

The selected 20 indicators are divided into three categories, the ones that have a positive effect on the ecological environment efficiency are positive indicators, and the ones that harm the ecological environment efficiency are negative indicators. In addition, the indicators that are neither proof indicators nor negative indicators are balance indicators.

Assuming that n indicators and m different ecological environments are considered, $x_{ij}(x_{ij} > 0)$ is the initial value of the indicator to the ecological environment j, among $i = 1,2,\cdots,n; j = 1,2,\cdots,m$. Use $\bar{r}_{ij}$ to represent the standard value of x_{ij} in all samples.

For all positive indicators, the larger the value, the better the indicators.

$$\bar{r}_{ij} = x_{ij}/\max(x_{ij}), i = 1,2,\cdots,n; j = 1,2,\cdots m \tag{1}$$

On the contrary, for negative indicators, the smaller the absolute value, the better the indicators.

$$\bar{r}_{ij} = \min(x_{ij})/x_{ij}, i = 1,2,\cdots,n; j = 1,2,\cdots m \tag{2}$$

Therefore, the standardized value f_{ij} of the positive or negative index i of the sample ecological environment j is:

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0056

$$f_{ij} = \bar{r}_{ij} / \sum_{j=1}^{m} \bar{r}_{ij}\,, i = 1,2,\cdots,n; j = 1,2,\cdots m \tag{3}$$

In addition, for balance indicators, such as atmospheric temperature, rainfall, etc., the higher is not the better, nor the lower the better, but there is an optimal value for the stable existence of the ecosystem. We deal with such indicators as follows:

$$\bar{r}_{ij} = x_{ij} / x_{ij_b}\,, i = 1,2,\cdots,n; j = 1,2,\cdots,m \tag{4}$$

2.1.3 Determine the Weight

Since each evaluation index has different contributions to the ecological environment efficiency, and the contribution direction is different, if the quantitative efficiency of the ecological environment is to be given, it is necessary to assign weights to each index to obtain the comprehensive efficiency of the index. In the weight distribution, we adopt the method of combining existing standards and real data. On the one hand, by consulting the weights of various indicators of the ecological environment under China's current standards, on the other hand, combining the specific data of Saihanba and cooperating with the entropy method. Determine the weight of each index together, and finally calculate the comprehensive performance of the index.

Table 1. Current standards in China

Types of indicators	Points indicator	Points indicator	Weight	Type
Ecological status indicator	Ecological function index	Vegetation cover index	0.24	Positive
		The area ratio of protected areas	0.10	Positive
	Ecological structure index	Forest and grassland coverage	0.22	Positive
		The water area ratio of wetlands	0.20	Positive
	Ecological stress index	The ratio of cultivated land to construction land area	0.14	Negative
		The area ratio of desertified land	0.10	Negative
Environmental status indicator	Pollution load index	The emission intensity of major pollutants	0.45	Negative
		The emission rate of pollution sources meets the standards	0.10	Positive
		Rate of centralized urban sewage treatment	0.10	Positive
	Environmental quality index	Water quality compliance rate	0.15	Positive
		Air quality compliance rate	0.15	Positive
		Water quality standards of centralized drinking sources	0.05	Positive

2.1.4 Entropy Weight Method

The entropy method is an objective weighting method, which determines the weight of the indicator by calculating the information entropy of the indicator and determining the weight of the indicator according to the influence of the relative change degree of the indicator on the overall system. An index with a large relative degree of change has a larger weight, and an indicator has a larger weight.

The entropy value Hi of the i-th index can be obtained from Equation (5) as:

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0056

$$H_i = -k\sum_{j=1}^{m} f_{ij}\cdot \ln f_{ij}, i = 1,2,\cdots,n; k = 1/\ln m \tag{5}$$

Calculate the redundancy of information entropy.

$$d_i = 1 - H_i \tag{6}$$

Correspondingly, we can determine the weight of the i-th indicator.

$$\omega_i = \frac{1 - H_i}{\sum_{i=1}^{n}(1 - H_i)}, i = 1,2,\cdots,n \tag{7}$$

Therefore, the comprehensive effectiveness of n indicators for the sample ecological environment can be expressed as:

$$F_j = \sum_{i=1}^{n} \omega_i f_{ij}, j = 1,2,\cdots,m \tag{8}$$

We divide the EEEI into four aspects: meteorology, biology, hydrology, and geology, $F_{j(me)}, F_{j(bi)}, F_{j(hy)}, F_{j(ge)}$ are used to represent the comprehensive effectiveness of the ecological environment in meteorology, biology, hydrology, and geology.

2.1.5 Development Index and Stability Index

The ecological environment is an overall concept that not only needs to meet existing standards but also needs to exist stably. Here, we use the Development Index (DI) to represent the overall development status, and the Stability Index (SI) to represent the stability of the ecological environment. These indexes are based on comprehensive performance in all aspects. When the DI and SI are both high, the ecological environment is considered to be good and stable. For this reason, the development index is defined as:

$$DI = \boldsymbol{CF}, \boldsymbol{C} = [\gamma_1, \gamma_2, \gamma_3, \gamma_4], \boldsymbol{F} = [F_{me}, F_{bi}, F_{hy}, F_{ge}] \tag{9}$$

The parameters $\gamma_1, \gamma_2, \gamma_3, \gamma_4$ respectively represent the weight of $F_{me}, F_{bi}, F_{hy}, F_{ge}$.

The stability index is defined as:

$$SI = 1 - S/\bar{F} \tag{10}$$

$$S = \sqrt{\left[(F_{me} - \bar{F})^2 + (F_{bi} - \bar{F})^2 + \left(F_{hy} - \bar{F}\right)^2 + \left(F_{ge} - \bar{F}\right)^2\right]/4} \tag{11}$$

$$\bar{F} = \left(F_{me} + F_{bi} + F_{hy} + F_{ge}\right)/4 \tag{12}$$

S is the standard deviation of the four performance indicators, $\bar{F}$ is the average of the four.

ISSN: 2414-1895
DOI: 10.6919/ICJE.202207_8(7).0056

2.1.6 Calculation of Eco-environmental Efficiency Coefficient with GE Matrix

The GE matrix is a management model for business portfolio analysis of the company's strategic business units. It is used to evaluate the company's attractiveness and stability in a two-dimensional framework. Although the ecological environment is different from the company, an appropriate analogy can still be made. On the one hand, the attractiveness of a company indicates a company's operating profitability. Accordingly, the development index of the ecological environment describes the efficiency of environmental protection; On the other hand, the company's cooperation ability represents a company's sustainable ability. Accordingly, the stability index of the ecological environment describes the stable and sustainable ability.

Therefore, GE Matrix is introduced here, as shown in Figure 2, and the indicators DI and SI are divided into three levels according to the actual situation in

Table **2**.

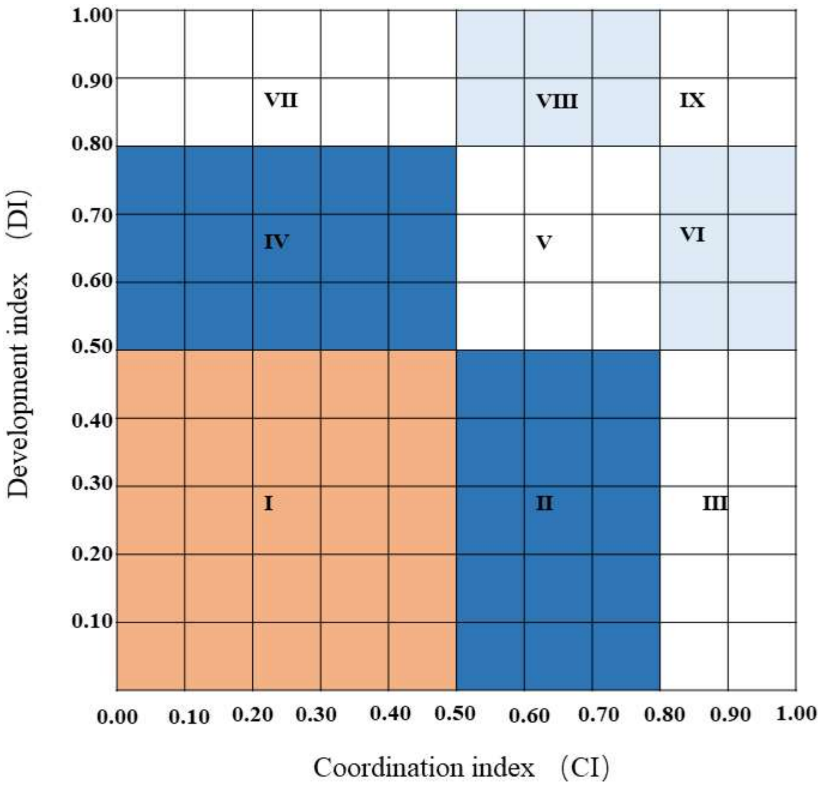

Figure 2. GE matrix for evaluating the environment

Table 2. Classification of indicators SI and DI

Value of indicator	Development level
0~0.5	Weak
0.5~0.8	Medium
0.8~1.0	Strong

According to the values of ecological environment DI and SI, we can determine the coordinate position of the ecological environment in the GE Matrix at a certain time. The coordinate position and the distance from the best point (1,1) can be used to quantitatively evaluate the overall efficiency of the ecological environment. The smaller the value, the better the efficiency of the ecological environment.

DOI: 10.6919/ICJE.202207_8(7).0056

2.2 Model Solution

2.2.1 Finalization of Evaluation Indicators

Due to the relevance of the evaluation indicators, some indicators cannot provide more effective information and make the model complex. After decorrelating, the final selection of the indicators is shown in:

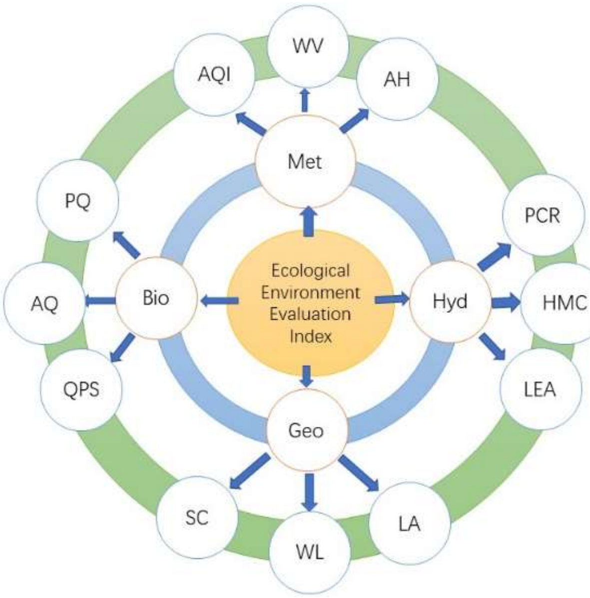

Figure 3. Final indicator of environmental evaluation

The abbreviations in Figure 3 are abbreviations for the indicators in Figure 1.

According to the method of combining the entropy weight method with the current standard, the weight value of each evaluation index is determined.

Table 3. Index weight

Indicators	AQI	WV	AH	PCR	HMC	LEA	LA	WL	SC	PQ	AQ	QPS
Weight	0.47	0.24	0.29	0.36	0.25	0.39	0.33	0.42	0.25	0.46	0.22	0.32

2.2.2 Evaluation Indicators Established

Calculate the values of DI and SI for Saihanba over the years, as shown in Table 4. Put it in the matrix, as shown in Figure 4.

Table 4. DI and SI

Time	1995	1999	2003	2007	2011	2015	2019
DI	0.273	0.367	0.443	0.567	0.724	0.716	0.851
SI	0.467	0.521	0.584	0.653	0.702	0.702	0.704

As can be seen from Figure 4, the development index of Saihanba has been on an upward trend, but the stability index has been somewhat deficient because of the deficiency of plantation, pest resistance, and so on, before and after the completion of Saihanba, the comprehensive environmental efficiency has increased by about 77.65%.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0056

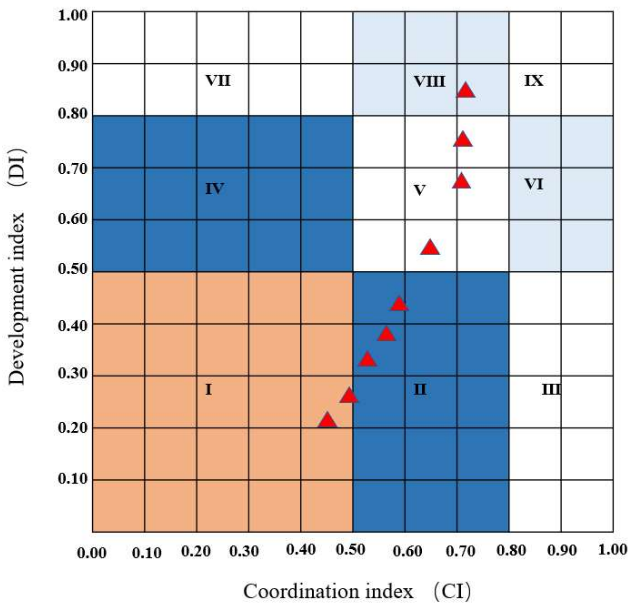

Figure 4. Comprehensive Evaluation of Saihanba over the years

3. Conclusion

The model reasonably selects the index to evaluate the ecological environment quality of Saihanba, removes the index correlation, reduces the information redundancy of the evaluation system, and improves the evaluation efficiency. The method of combining the current theory with the field data and combining the current standard with the entropy weight method can be used to give the weight of each index. Finally, a two-dimensional evaluation system is established by using the GE matrix, and Stability Index (SI) is introduced to overcome the shortcoming of traditional evaluation which only focuses on developing ability but not on sustainable development.

There are many complicated indexes to reflect the quality of the ecological environment, different scholars and institutions have different understanding and understanding, and they also have different emphasis on the selection of indexes. This paper also makes some simplifications in index selection, which may lead to an incomplete analysis of the problem.

Furthermore, we should consider more comprehensively, utilize the knowledge of environmental science, introduce more evaluation standards, consult more information, and select more effective evaluation indexes in the selection of the evaluation indexes of problem-ecological environment, for example, the introduction of ecological footprint, ecological capacity, and other evaluation systems to expand the scope of application of the model to enhance the effectiveness of the model.

References

[1] Research on Saihanba Forest Farm (1962-2017) -- Master's Thesis of Hebei Normal University (CNki.com.cn).
[2] Wind and Weather regularity in Saihanba, Zhang Shushan 25 29 (CNki.net).
[3] Cause Analysis of "3·15" Strong Sandstorm in North China, Duan Bolun (CNki.net).
[4] Dust Storms in US History 35 (CNki.net).
[5] Current Nature Reserves and Their Distribution in China (baidu.com).
[6] A Study on temperature Variation in Saihanba - Docin.com.
[7] Eco-city Environmental Index System (baidu.com).