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A Forest System Evaluation Model Based on Grey Correlation Analysis and TOPSIS

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Keywords: Grey correlation analysis, TOPSIS, Evaluation model, Forest ecosystem.

1. Introduction

Forests, as the main terrestrial ecosystem, are the most widely distributed, rich in types and complex in structure of the biosphere ecosystem. They not only provide important social, economic and environmental goods and services for human beings, but also play an irreplaceable role in maintaining global ecological balance and biodiversity and supporting human life systems. The study of forest ecosystem health has become a hot topic in the field of forestry, and many scholars are actively exploring the definition, measurement, assessment and management of forest ecosystem health[1]. Many scholars have studied the progress and methods of ecosystem health and found that maintaining forest ecosystem health is still the future direction of forest management. At present, there is no reliable and unified standard for assessing forest ecosystem health, but only qualitative judgement. This paper constructs a forest system evaluation model based on grey correlation analysis and TOPSIS method, and analyses it with examples, in order to provide some reference significance for forest ecosystem assessment.

2. Introduction to the Method

2.1. Grey system

As a practical problem, grey system exists in a large number in the world, and it is also an abstract grey system. Forest composition, population, climate and economy are all factors affecting carbon sequestration, but it is difficult to determine the decisive factors affecting production and the quantitative relationship between forest carbon sequestration and forest carbon sequestration[2]. Therefore, the correlation degree analysis can be used to measure the degree of correlation between factors by the similarity of the development trend among various factors, and these four factors not only affect the amount of carbon sequestration, but also influence each other.

Step1: Select reference sequence.

$$a_0 = \{a_0(t) \mid t = 1,2,\cdots,n\} = (a_0(1), a_0(2), \cdots, a_0(t)) \quad (1)$$

Where t represents the moment, there are four comparative sequences.

$$b_i = \{b_i(t) \mid t = 1,2,\cdots,n\} = (b_i(1), b_i(2), \cdots, b_i(n)) \quad (2)$$

Where i corresponds to a row in the comparison series.

Step2: Dimensionless variables (cannot be expressed and compared because of the different dimensions of the data in the comparison series in the system). Initialize the data (a total of 4 sequences). Adopt the following formula.

$$b_i(t) = \frac{b_i(t)}{b_i(1)}, t = 1,2,\cdots n; i = 0,1,2,3,4. \quad (3)$$

Step3: Calculate the correlation coefficient.

$$\varepsilon_i(t) = \frac{\min_i \min_t |a_0(t) - b_0(t)| + P \max_i \max_t |a_0(t) - b_0(t)|}{|a_0(t) - b_0(t)| + P \max_i \max_t |a_0(t) - b_0(t)|} \quad (4)$$

Then

$$\varepsilon_i(t) = \frac{\min_i \min_t \Delta i(t) + P \max_i \max_t \Delta i(t)}{\Delta i(t) + P \max_i \max_t \Delta i(t)} \quad (5)$$

Correlation coefficient table: (note: P ∈ (0,100), P resolution coefficient, the smaller the P, the greater the resolution. Here take Purge 0.5463)

Step4:Calculate the correlation degree. ξ1 (t) is the correlation degree value between a0 and bi at each time. Because the data are scattered, it is not easy to compare, so ξ (1) is concentrated as a value, and the correlation degree is expressed as the quantity of the correlation degree between a0 and bi.

$$\alpha_i = \frac{1}{n}\sum_{t=1}^{n}\xi_i(t), t = 1,2,\ldots,n \tag{6}$$

Step5:By sorting the correlation degree α1, we can get that the comparison series are more similar to the reference series.

Step6:Calculation of comprehensive correlation degree. Calculate by combining the optimal and the worst correlation degree.

$$\alpha_0 = \frac{1}{\left(1+\frac{\alpha_{\min i}}{\alpha_{\max i}}\right)^2} \tag{7}$$

The situation in which only one correlation degree leads to inconsistent results is avoided.

2.2. Topsis (superior and inferior dissociation method)

There are four samples to be evaluated: black forest in Germany, Amazon rain forest, Xishuangbanna in Yunnan, China, and temperate rain forest in Queensland, Australia[3]. The five evaluation indicators are forest population extreme weather times, economy, carbon sequestration, value. Form the original index data matrix.

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{25} \\ x_{31} & x_{32} & x_{33} & x_{34} & x_{35} \\ x_{41} & x_{42} & x_{43} & x_{44} & x_{45} \\ x_{51} & x_{52} & x_{53} & x_{54} & x_{55} \end{bmatrix} \tag{8}$$

Step 1:Data preprocessing

Make the five evaluation indicators have the same tendency, and make the data dimensionless, in order to eliminate the dimensional vector and normalize the original data.

$$y_{ij} = \frac{x_{ij}}{\sqrt{\sum i \cdot x_i^2 y}} \tag{9}$$

Analytical matrix

$$y = \begin{bmatrix} y_{11} & y_{12} & y_{13} & y_{14} & y_{15} \\ y_{21} & y_{22} & y_{23} & y_{24} & y_{25} \\ y_{31} & y_{32} & y_{33} & y_{34} & y_{35} \\ y_{41} & y_{42} & y_{43} & y_{44} & y_{45} \\ y_{51} & y_{52} & y_{53} & y_{54} & y_{55} \end{bmatrix} \tag{10}$$

Step 2:The best value and the worst value.

$$\begin{aligned} y^+ &= \max\left(y_1^+, y_2^+, \ldots, y_5^+\right) \\ y^- &= \max\left(y_1^-, y_2^-, \ldots, y_5^-\right) \end{aligned} \tag{11}$$

Step 3:Calculate the distance between the optimal value and the lowest value of the four forests respectively.

$$\begin{aligned} D_i^+ &= \sqrt{\sum_j \left(y_{ij} - y_j^+\right)^2} \\ D_i^- &= \sqrt{\sum_j \left(y_{ij} - y_j^-\right)^2} \end{aligned} \tag{12}$$

Step 4: Calculate the relative proximity between the three evaluation indexes and the optimal value, such as the Black Forest in Germany.

$$J_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{13}$$

Step 5 Get the results and sort them.

The larger the Ji, the closer the forest management is to the optimal value.

3. Results and Analysis of the Result

3.1. Results of grey correlation analysis

According to the grey correlation analysis, the results obtained in this paper are shown in Table 1.

Table 1. Correlation coefficient result

	People (thousand)	Economic (hm)	Climate	Carbon Sequestration (t)
1	0.6970724331734	0.34776815401317	0.9300326227416	0.9700107739291
2	0.8247162872975	0.64805993188848	0.8417873519168	1
3	0.8593288410639	0.51933190396417	0.9956327665976	0.9947846003744
4	0.6741222450111	0.40112391343606	0.8951719908016	0.9749689951625

As can be seen from the above table, the grey correlation degree analysis is carried out for four evaluation items (people (thousand), economic (hm), climate, carbonsequestration (t)) and four data, and year is taken as the "reference value\" (parent sequence) to study the relationship between four evaluation items (people (thousand), economic (hm), climate, carbonsequestration (t) and year (correlation degree)[4].

And provide analysis reference based on the correlation degree, when using the grey correlation degree analysis, the resolution coefficient is 0.5, combined with the correlation coefficient calculation formula to calculate the correlation value, and according to the correlation value, and then calculate the correlation value for evaluation and judgment, the results are obtained as shown in Table 2.

Table 2. Correlation degree result

Evaluation item	Correlation degree	Ranking
Carbon sequestration (t)	0.985	1
Climate	0.916	2
People (thousand)	0.764	3
Economic (hm)	0.479	4

As can be seen from the above table: for the four evaluation items, carbon sequestration (t) has the highest evaluation (correlation degree: 0.985), followed by climate (correlation degree: 0.916). The characteristics of different forests are different, so we can first calculate the correlation degree and weight of each related index of the forest, and then establish the optimal solution by TOPSIS method, that is, the transition point between management plans.

3.2. Results of TOPSIS

This paper calculates the weight of carbon sequestration, extreme weather, population and economy on forest from the correlation degree[5]. In the management range that may be suggested by our decision-making model considering the state of natural resources, economy and market situation, my decision-making model will take environmental safety, ecological harvesting, carbon management, wood safety, environmental security and so on as the future planning direction. (comprehensive consideration of the correlation degree analysis with the best forest management methods)

Intermediate value as shown in Table 3.

Table 3. Intermediate value

Item	D+	D-
People	0.98039182	0.00000196
Economic	0.90452307	0.00003015
Carbon sequestration	0.80177609	0.00002672
Extreme weather	0.61675265	0.00000030

Calculated from Table 3 to obtain the results in Table 4.

Table 4. Results

Index value	D+	D-	Composite score index	Sorting
1.0	0.49487317	0.62041086	0.55628059	2
2.0	0.42923031	0.58611339	0.57725615	1
3.0	0.68252437	0.35019607	0.33910055	4
4.0	0.60783609	0.38585418	0.38830428	3

3.3. Results of the experiment

According to the TOPSIS method, there is an extreme point in deforestation and planting, that is, the optimal solution. Excessive deforestation and overplanting beyond the extreme point are not the optimal scheme. Therefore, there is a transition point between management plans applicable to all forests[6].

As a result, the forest comprehensive score index numbered 2 is the highest, so the best scheme for balanced forest assessment is the Queensland balabala forest selected in the sample, with an annual felling rate of less than 0.054%. If it is higher than 0.054%, it is necessary to suspend felling and plant new trees.

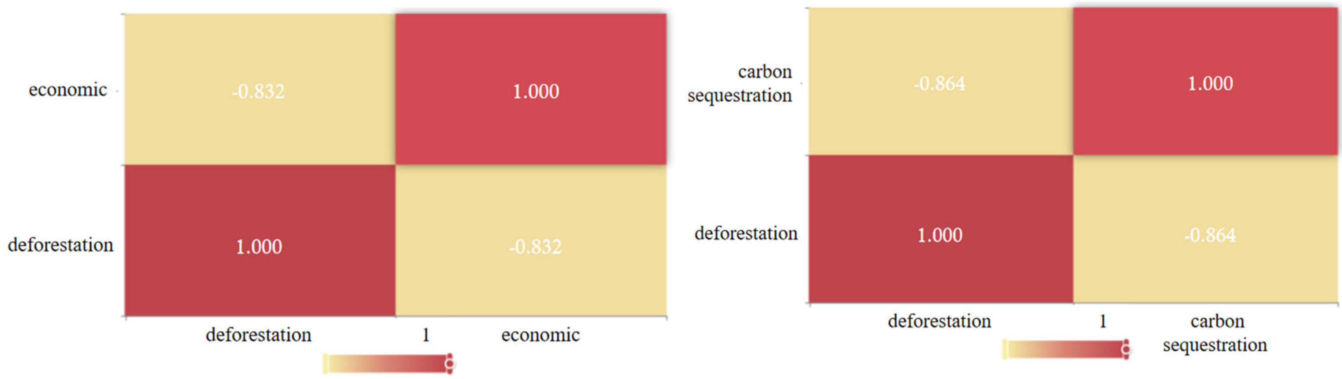

Figure 1. Local display of thermal map of correlation coefficient

Table 5. Correlation degree result

Evaluation item	Correlation degree	Ranking
Climate	0.883	1
Carbon Sequestration (t)	0.836	2
People (thousand)	0.689	3
Economic (hm)	0.459	4

Correlation analysis shows that weather, carbon stocks, economy and population are closely related to deforestation rates.

3.4. Sensitivity analysis

Based on the development of an evaluation model for forest optimization options, sensitivity analyses of important indicators were conducted separately. The results of the sensitivity analysis of the forest management options are derived in this paper, and the impact of these four indicators on the decision model of the upper level indicators is discussed[7]. When one of the indicators changes, the other two keep their initial values unchanged. The overall trend of the curve remains stable, which indicates that the model in this paper is robust.

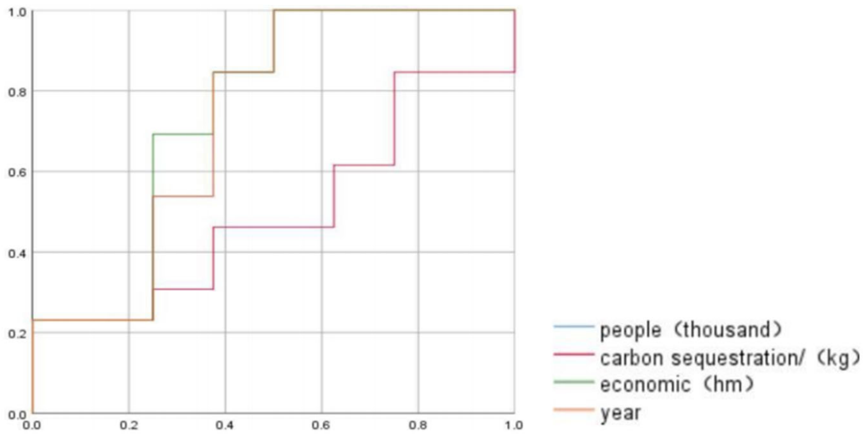

Figure 2. Sensitivity analysis

4. Conclusion

This paper examines the value of multiple aspects of forests and uses grey correlation analysis to determine the specific weights to be given to different indicators of the forest value system. The calculations show that carbon stocks and weather are elevated in priority, but at the expense of economic profit. In order to find the optimal forest management solution, a comprehensive evaluation model was developed and the optimal solution was found using the superior-disadvantageous solution distance method[8]. The results show that the optimal solution is the Queensland wet tropical rainforest selected in the sample, where the annual cutting rate should be less than 0.054% and the planting rate should be greater than 0.098%, which is the transition point for forest management options. According to the different location characteristics of specific forests, after calculating the specific index weights through grey correlation analysis, the optimal scheme was obtained through TOPSIS to construct a forest system evaluation model and analyse it with examples, with a view to providing some reference significance for forest ecosystem assessment.

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