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Study on Carbon Sequestration Capacity of ZhangJiajie Forest

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Abstract

The scientific formulation and implementation of forest development planning can improve the quality of forest, promote sustainable development of forestry, reduce the impact of climate change.In this paper, air temperature, precipitation, soil moisture, soil temperature and surface temperature were selected as five indicators to measure the forest carbon sequestration capacity, and relevant index data were collected in Zhangjiajie in recent ten years.In this paper, analytic hierarchy Process (AHP) and entropy weight method were integrated to determine the weight by combination weighting method. Then, the rank sum ratio comprehensive evaluation method was used according to the weight, and the change of carbon sequestration capacity of Zhangjiajie in recent ten years was measured by the final rank sum ratio, and relevant management plans were given respectively.

Keywords

Rank-sum Ratio Comprehensive Evaluation Method; Combination Weighting Method; Forest Management Plan.

1. Introduction

Today, climate change is one of the major challenges facing the world.To mitigate the effects of climate change, we need to take strong action to reduce greenhouse gases in the atmosphere.Forest plants can absorb carbon dioxide and fix it in vegetation or soil, thereby reducing atmospheric carbon dioxide concentrations and mitigating climate change.Therefore, strengthening the carbon sequestration function of forests is the most cost-effective way to offset and absorb carbon emissions.

Forests sequester carbon dioxide in products made by living plants and trees, including furniture and wood, which absorb carbon dioxide throughout their lives.Over time, selective logging of some forest products, coupled with the regeneration of young stands, may absorb more carbon than no logging at all.However, excessive logging limits carbon sequestration.

In view of this, there is an urgent need to develop a model to determine the optimal rate of deforestation and measure the most effective carbon sequestration capacity of forests.

2. Carbon Sequestration Model based on Combination Weighting Method

2.1 Establishment of Evaluation Indicators

The amount of forest carbon sequestration refers to the maximum amount of carbon sequestration accumulated at a certain point in the growth stage of a certain area of forest under specific conditions, without considering the carbon emissions in the process of afforestation or forest management. Through literature review, we selected precipitation, soil moisture, soil temperature, average air temperature and surface temperature as the five indicators affecting forest carbon sequestration in Zhangjiajie, and defined a specific set I for them:

$$I=\{P, M, S, T, L\}$$

Where P, M, S, T and L respectively represent precipitation, soil humidity, soil temperature, average air temperature and surface temperature, as shown in Figure 1.The determination of the weight of each indicator will be discussed later.

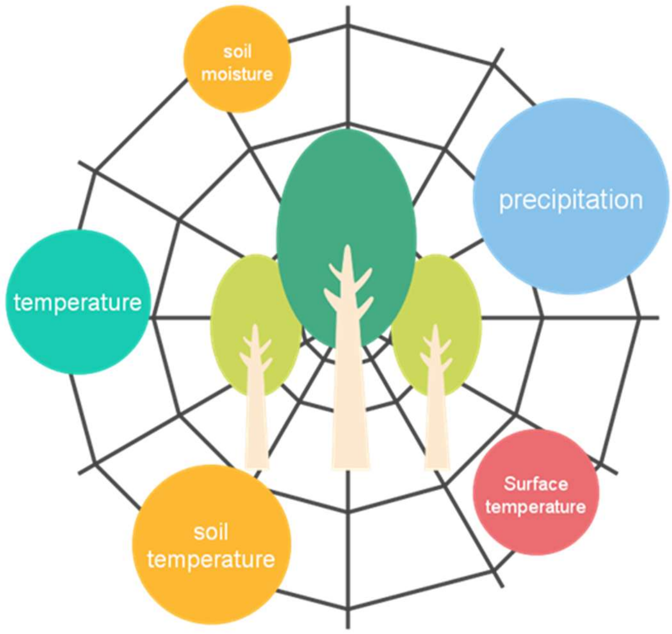

Figure 1. Evaluation index of carbon sequestration model

2.2 Determination of Index Weight

There are many methods to determine the weight of indicators. In order to improve the accuracy of the model, we decided to use the combined weight method to calculate the weight of each indicator.The method combines the analytic hierarchy process (AHP) in subjective weight method with the entropy weight method in objective weight method.

2.2.1 Analytic Hierarchy Process

1) Establish the hierarchical structure model

The decision problem is divided into two layers, which are objective layer N and criterion layer C respectively.The target layer is to select the most appropriate key index to evaluate the amount of forest carbon sequestration, and the criterion layer includes precipitation, soil moisture, soil temperature, average temperature and surface temperature.

2) Model solution

Construct the judgment matrix N-C, compare the five elements in the reference layer in pairs to get the pair-comparison matrix, solve the eigenvalues and eigenvectors of N-C, and conduct hierarchical sorting and consistency test to get the relevant results.

By collecting the index data of Zhangjiajie National Forest Park and substituting it into the above model for analysis and calculation, the following results are obtained respectively:

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Table 1. Following results are obtained respectively

Each indicator	precipitation	The average temperature	Soil moisture	Soil temperature	The surface temperature
Weight value	0.2551	0.1961	0.1918	0.1845	0.1725

2.2.2 Entropy Weight Method

1) Data processing

Firstly, the data is normalized to remove the dimensional influence. Since the selected indicators are all positive indicators, the following processing can be done:

$$Z_{ij} = \frac{x_{ij} - min\{x_{1j}, \dots, x_{nj}\}}{\max\{x_{1j}, \dots, x_{nj}\} - min\{x_{1j}, \dots, x_{nj}\}}$$

Normalize each column:

$$\tilde{Z} = \begin{bmatrix} \tilde{z}_{11} & \tilde{z}_{12} & \cdots & \tilde{z}_{1m} \\ \tilde{z}_{21} & \tilde{z}_{22} & \cdots & \tilde{z}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1} & \tilde{z}_{n2} & \cdots & \tilde{z}_{nm} \end{bmatrix}$$

Calculate the proportion of elements in each column in each row as probability, and obtain probability matrix P:

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^{n} z_{ij}}$$

2) Calculate the weight

Calculate the information entropy of each indicator, that is, the information entropy of each column:

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} [p_{ij} * \ln(p_{ij})], j = \{1,2,3 \dots m\}$$

Obtain the information utility value of each indicator:

$$d_j = 1 - e_j$$

The entropy weight of each index can be obtained:

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j}, j = \{1,2,3 \dots m\}$$

Table 2. The entropy weight of each index

Each indicator	precipitation	The average temperature	Soil moisture	Soil temperature	The surface temperature
Weight value	0.222	0.207	0.206	0.187	0.177

3) Final weight value obtained by combination weighting method

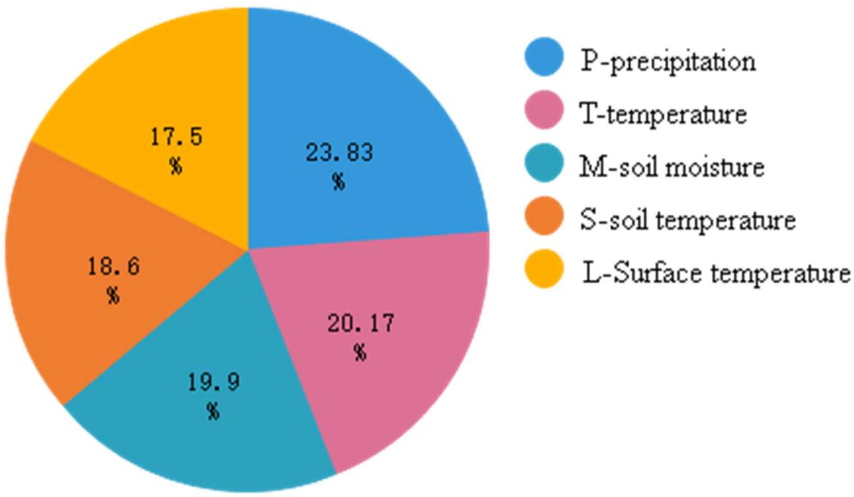

Figure 2. Combination weighting method

2.2.3 Combination Weighting Method

The inherent statistical rules and authoritative values among index data should be considered when assigning weights to indexes.In order to make up for the deficiency of single weighting, a reasonable weighting method is proposed, that is, a combination weighting method combining subjective weighting method (AHP) and objective weighting method (entropy weighting method).A weighting method that combines two weighting methods is called combinatorial weighting.The combination of subjective and objective weights are:

Comprehensive weight of indicators:

$$Q_j = \frac{\sqrt{\alpha_j w_j}}{\sum_{j=1}^{n} \sqrt{\alpha_j w_j}}$$

Among them, α_j Is the weight calculated by analytic hierarchy process, w_j Is the weight calculated by entropy weight method.

The final weight value obtained by combination weighting method:

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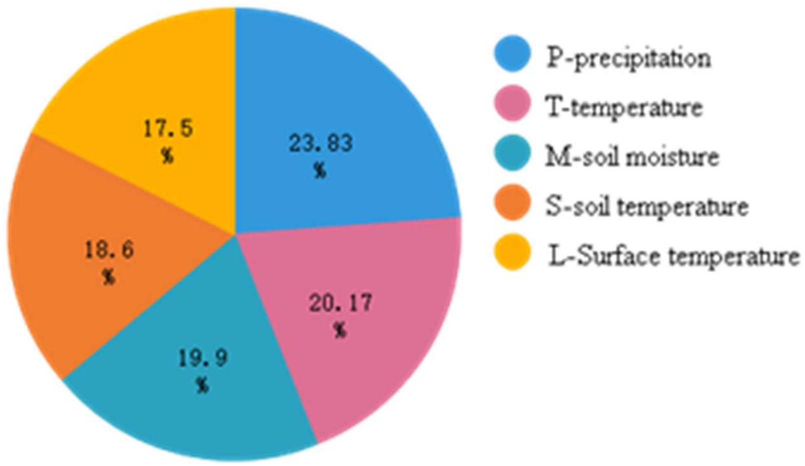

Figure 3. Combination weighting method

Through the combination weighting method, we find that precipitation occupies the largest weight value, and the change of precipitation plays a significant role in the decision of forest management plan in Zhangjiajie.Therefore, we should pay attention to the change of precipitation in different years when we formulate the forest management plan of Zhangjiajie.

2.3 Rank Sum Ratio Comprehensive Evaluation Method

2.3.1 Principle

Its basic principle is to obtain the dimensionless statistic RSR(between 0 and 1) through rank transformation of several index values of samples, and then study the distribution of RSR by using parametric statistical analysis method.The larger the calculated RSR is, the better. The RSR value is used to sort the advantages and disadvantages of the evaluation objects directly or in a hierarchical manner, so as to make a comprehensive evaluation of the evaluation objects.

2.3.2 Algorithm Steps

1) rank

Arrange m evaluation indexes of N evaluation objects into the original data table with N rows and m columns, rank the data of each index column respectively. Since the five indexes selected in this question are all positive indexes, rank the obtained rank matrix in order from small to large is denoted as:

$$\mathrm{R} = \left(r_{ij}\right)_{n\times m}$$

2) Calculate RSR (each index has the same weight =1/m).

3) Compile RSR/WRSR frequency distribution table.

4) Calculate the linear regression equation.

5) Grading and sorting.

The evaluation objects are graded according to the estimated value calculated by regression equation.

Rank sum ratio grading results.

Table 3. Rank sum ratio grading results of Zhangjiajie as an example

The index	RSR_Rank	Probit	RSR Regression	Level
2012	1	6.959964	0.921762586	3
2013	2	6.2815516	0.806561883	3
2014	4	5.5244005	0.677990632	2
2015	8	4.4755995	0.499894519	2
2016	6	5.0000000	0.588942575	2
2017	9	4.1583788	0.446027506	2
2018	3	5.8416212	0.731857644	2
2019	7	4.7466529	0.545921894	2
2020	5	5.2533471	0.631963256	2
2021	10	3.7184484	0.371323267	1

According to the rank sum ratio classification results, the change of forest carbon sequestration capacity in Zhangjiajie in recent ten years is analyzed, among which the carbon sequestration capacity in 2021 is the worst and deforestation should be reduced. According to the overall decreasing trend of RSR Regerssion in recent ten years, we know that the forest carbon sequestration capacity in Zhangjiajie has decreased significantly, indicating that deforestation in Zhangjiajie has been excessive in recent years. Therefore, we suggest that Zhangjiajie should reduce tree felling and gradually restore its carbon sequestration capacity when making forest management plans.

3. Summary

Taking Zhangjiajie National Forest Park as an example, we determined precipitation, soil moisture, soil temperature, mean air temperature and surface temperature to measure forest carbon sequestration capacity.In this paper, a carbon sequestration capacity model based on rank sum ratio comprehensive evaluation model was established by combining subjective ahp and objective entropy method to determine weight.According to the rank sum ratio comprehensive evaluation model, different forest management suggestions were given for different years.

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