Forest System Comprehensive Evaluation Model

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Abstract. In this paper, we developed a new forest system evaluation model, calculated the weight of each index through the EWM, and then evaluated the relative merits of these indexes by the TOPSIS. Finally, polynomial regression was carried out to obtain a function related to the forest area and these indexes. Forest managers only need to substitute the local related indicators into the function, and then they can get the area with the highest comprehensive benefit of the local forest, and then they can fully manage and utilize the forest through cutting and planting strategies.

Keywords: Forest assessment model, Carbon sequestration model, EWM, TOPSIS.

1. Introduction

In recent years, with the increasing concentration of CO2 in the atmosphere, it is evident that reducing CO2 emissions alone cannot meet the need to curb this trend. Therefore, more and more researchers have begun to pay more attention to CO2 capture technology [1]. For example, we sequester carbon dioxide stored in the atmosphere through biosphere or mechanical means, which is known as carbon sequestration. Both forests and forest products sequester CARBON dioxide, and the combination of the carbon absorbed by some forest products with the carbon sequestrated by the regeneration of young forests has the potential to generate more sequestration benefits than would come from not cutting forests at all

Globally, a good forest management plan may be suitable for carbon sequestration, but forest managers need to balance the value of cutting down trees to make products to keep them alive to absorb carbon. Therefore, they need to consider various factors, such as tree species, forest structure, and geographical location. In addition, forest managers also need to balance the various values of forests, such as ecological and economic benefits, to maximize the use of forests.

Given the wide variation in forest composition, climate, socio-economic interests, and people's values worldwide, a one-size-fits-all approach to forest management is not feasible. Moreover, the best forest management plan for carbon sequestration may not be the best plan for society, and many factors, such as different national policies, geographical distribution, and climate, need to be taken into account. Therefore, according to the above requirements, a carbon sequestration assessment model is developed to determine how much forests and their products can sequester CARBON dioxide and study which forest management plans are most effective at sequestration.

2. Literature Review

As the main body of the terrestrial ecosystem, the forest is an important part of the earth's biosphere and the main body of the regional and even global carbon cycle [2,4]. Compared with other vegetation types, forests have the widest distribution area, the highest productivity, and the most considerable biomass accumulation and play an essential role in the terrestrial carbon cycle[5]. During the growth of forests, Coz is fixed by photosynthesis respiration, and it is fixed in the forest ecosystem in the form of photosynthates. Therefore, forest carbon storage can eliminate the increasing amount of C02 in the atmosphere, which plays a role in stabilizing the global climate and mitigating the greenhouse effect[3,5]

Li Liuyu [2] studies that we want the characteristics, function, and benefit of forest quantitatively based on a specific set up and a corresponding number of forest distribution structures. The number of forest distribution structures reflects the embodiment of the complete system and a quantitative description of the distribution structure's characteristics, features, function, and efficiency to establish a dynamic equation to achieve the goal of description. According to results from Liu Xiying and Song Wenchao [7], the index of Average Forest Carbon Sequestration (AFCS) can be reflected in Forest ecosystems. The ability of photosynthesis to absorb ATMOSPHERIC CO2 per unit area can more accurately reflect the long-term carbon sequestration capacity of forests, thus improving the sensitivity range of carbon footprint calculation.

Gu Shoukuan [8] pointed out that urban forest is of great significance to the living environment of urban residents, and effective management and accurate assessment of urban forest can make more effective use of and play the ecological, economic, and social role of the urban forest.

3. Forest Management Decision Models

3.1. Problem analysis

There are many indicators to measure the integrated value of forests, and this paper will evaluate eight indicators of climate change, environmental protection, and ecological balance, namely precipitation, average temperature, relative humidity, total water resources, days with excellent air quality, area of forest diseases, forest pests and forest fires. Then a comprehensive evaluation system of forest area on the region's ecological environment was obtained.

In this paper, the entropy weight method and ideal solution will be used to calculate the comprehensive benefit score of a selected forest in the past ten years to compare the relative maximum value of the forest ecosystem benefit from 2012 to 2021 with the relative optimal solution. By referring to the specific forest area value of the forest in the ten years from 2012 to 2021, the annual forest area value and the ecological benefit score value of the year were fitted by the polynomial regression method several times, and the corresponding function with small fitting error and the closest reasonable degree was obtained. Finally, how should the forest area change by calculating the corresponding index changes of forests in different years to guide forest managers to control the forest area (through cutting and planting trees) to maximize the total value of forests. In addition, it is only necessary to put different forest impact indicators and areas into the function for different types of forests to get the corresponding weight score and regression equation parameters and then get the most suitable area of different types of forests to guide the forest managers.

3.2. Entropy weight method

In this paper, the Komi forest in Russia is selected for research, and eight variables of the forest in 10 years are assigned weights:

1) Data standardization:

An indicator $y_{ij}$is developed in the equation, the j index value after dimensionless processing. x_{ij} is the i unit and j index data raw value.

$$y_{ij}=\frac{x_{ij}-x_{jmin}}{y_{jmax}-x_{jmin}} \quad (1)$$

2) Definition standardization:

$$y_j = \frac{y_j}{\sum_{i=1}^{m} y_j} \quad (2)$$

3) Entropy of information:

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} Y_{ij} \ln Y_{ij} \quad (3)$$

Information utility value:

$$d_j = 1 - e_j \quad (4)$$

4) Weight of evaluation indicators. The larger the information utility value is, the more important the index is and the more important it is to the evaluation.

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (5)$$

Comprehensive evaluation value:

$$F = \sum W_j Y_{ij} \quad (6)$$

According to the corresponding index and forest area data of Komi forest in Russia in the past ten years, it gets each year's final comprehensive evaluation value.

F=[0.68367192,0.5949104,0.56469673,0.37663176,0.55159502,0.35695543,0.34974654,0.52438032,0.56274143,0.4307423]

Table 1. Index weight value

Item	entropy of information	Information utility value	The weight
precipitation	0.833	0.167	0.177
The average temperature	0.921	0.079	0.083
Relative humidity	0.88	0.12	0.128
Total water resources	0.859	0.141	0.149
Days of excellent air quality	0.891	0.109	0.115
Area of forest disease occurrence	0.896	0.104	0.11
Forest insect pest	0.874	0.126	0.134
The forest fire	0.902	0.098	0.104

3.3. Topsis

Based on the values of these eight indices over the past ten years, we can get matrix A and then normalize matrix A to form matrix B. The purpose of normalization is to unify variables that are not dimensionally unified or evaluated by a unified numerical representation. During standardization, the indexes are judged to be cost or benefit variables according to the relationship between each index and forest area.

Precipitation, average temperature, relative humidity, total water resources, and days with excellent air quality are beneficial variables, while forest disease occurrence, insect pests, and forest fire are cost variables.

Positive and negative ideal solutions are selected from normalized data. Let the positive ideal solution of the j property attribute be, the negative ideal solution is C_j^0.

Forward processing of data:

$$c_j^* = \begin{cases} \max\limits_i c_{ij}, j \text{ is the benefit attribute}, j = 1,2,3\ldots,n \\ \min\limits_i c_{ij}, \quad j \text{ is the cost attribute}, \quad j = 1,2,3\ldots,n \end{cases}$$

$$c_j^0 = \begin{cases} \max\limits_i c_{ij}, j \text{ is the benefit attribute}, j = 1,2,3\ldots,n \\ \min\limits_i c_{ij}, \quad j \text{ is the cost attribute}, \quad j = 1,2,3\ldots,n \end{cases}$$

Calculate the distance between each scheme to the positive and negative ideal sets:

$$s_i^* = \sqrt{\sum_{j=1}^n \left(c_{ij} - c_j^*\right)^2}, i = 1,2,3\ldots,m$$

$$s_i^0 = \sqrt{\sum_{j=1}^n \left(c_{ij} - c_j^0\right)^2}, i = 1,2,3,\ldots,m$$

Calculates the sorted metric values for each scenario:

$$f_i^* = S_i^0/(S_i^0 + S_i^*), i = 1,2,\ldots,m$$

3.4. Polynomial regression

According to the corresponding woodland area S in each year:

S= [245.377,240.073,250.01,224.03,257.09,278.0,220.02,230.06,234.08,260.0]

After four times of fittings, the following graph is obtained:

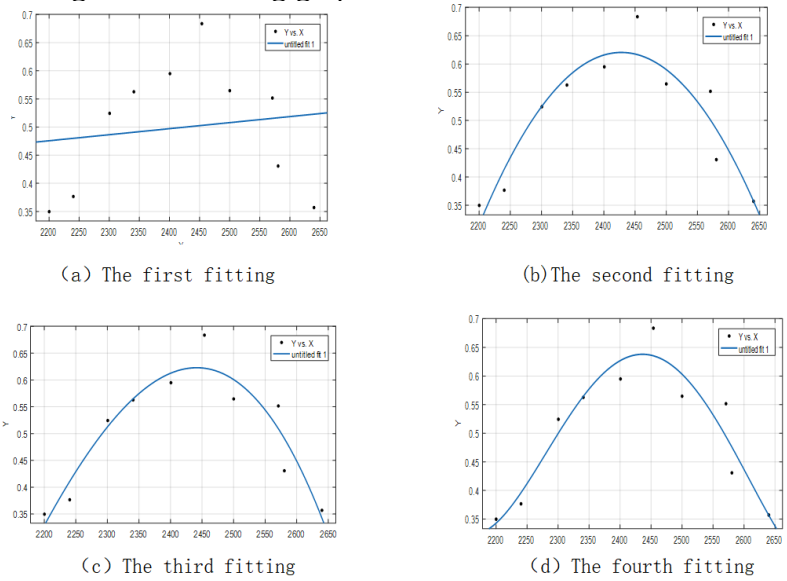


Fig 1. Fourfold fitting of forest area and composite score index

By comparing the fitting errors, the best fitting scheme is a quartic function:

$$f(x) = p1x^3 + p2x^2 + p1x^1 + p4$$

Parameter values are as follows:

p1 = 5.413e-11 (-1.094e-10, 2.176e-10)
p2 = -5.292e-07 (-2.113e-06, 1.055e-06)
p3 = 0.001931 (-0.003817, 0.00768)
p4 = -3.118 (-12.38, 6.141)
p5 = 1880 (-3706, 7466)

According to this function, the optimal effective area of the forest is 24.2550 million hectares

A function related to the two can be obtained through the regression fitting of the forest area and the composite score index, and the area where the forest generates the highest benefit can be obtained by observing the function. The obtained forest area will also guide the logging and planting plan in the following article.

4. Conclusion

Our model considers many factors, such as the amount of carbon sequestration of forests, the interests of forest managers and people who use forest resources, and the impact on society. Moreover, the model is flexible, and it can adopt different indicators according to different needs.

We use the analytic hierarchy process, a hierarchical and multi-level index system. The first level has a wide range of indicators and can take care of many parties. Many hypotheses are used in the model, and their rationality is confirmed by comparison with real-life after substituting data. The model is universal and applicable to all kinds of forests in different states. The abstract forest is embodied, the index value is quantified, and the fitting function is obtained. The specific value can be obtained, and the application area can be expanded with convincing force.

Finally, a complete set of evaluation system schemes is formed, which can obtain specific values, practical and reliable with convincing force.

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