Forest management plan based on TOPSIS analysis method

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Abstract. Climate change poses a huge threat to life, especially climate change caused by greenhouse gas emissions. Positive actions should be taken to reduce greenhouse gas emissions. But simply reducing emissions is not enough. It is necessary to increase carbon dioxide reserves through biosphere or mechanical means. Forests in the biosphere can store carbon dioxide. Moderate deforestation can increase the amount of fixed carbon dioxide and have little impact on society. For this issue, this article selects Saihanba Forest Farm as the research object. By establishing a mathematical model, the impact of different forest management schemes on the carbon dioxide absorption capacity of Saihanba Forest Farm was analyzed. This paper selected four main variables to reflect their impact: forest coverage, forest volume, forest volume at different ages, and water conservation. The entropy method and TOPSIS comprehensive evaluation method are used for the data in the variables. The results showed that near mature and mature forests contributed the most to carbon dioxide absorption, while over mature trees contributed the least to carbon dioxide absorption. Based on the results, this paper presents the optimal forest management plan, and suggests that managers should appropriately cut down over mature forests to increase the stock of near mature and mature forests.

Keywords: Entropy Method; TOPSIS; Forest Management Plan.

1. Introduction

With the crisis brought about by the worsening greenhouse effect, countries are realizing that climate change is a major global challenge facing humanity today and that there is a high urgency to implement multi-scale sustainable development responses in the context of climate change [1]. The Paris Climate Agreement, signed by 197 countries, and the Sustainable Development Goals (SDGs) put forward a consensus on carbon neutrality, and there is a growing recognition of the potentially important role of continental carbon sequestration in climate change mitigation and adaptation.

Under the vision of carbon neutrality, enhancing the carbon sequestration and sink function of forests is the most economical and effective way to offset and absorb carbon emissions. Accurate assessment of forest carbon sinks and prediction of forest carbon sequestration potential can help quantify the contribution of forests in addressing climate change and achieving the vision of carbon neutrality [2].

It is generally accepted that the ecological functions of forest ecosystems such as carbon sequestration and biodiversity conservation are not in absolute opposition to the harvesting of forest resources. The carbon absorbed by some forest products, together with the carbon absorbed by the regeneration of young forests, has the potential to absorb more carbon over time than the carbon sequestration benefits of no deforestation at all, and a properly harvested forest management strategy can benefit carbon sequestration.

Therefore, the key to sustainable development of forestry lies in scientific management of forests, which is the basis of sustainable management and a key element to obtain sustainable development of society [3]. Currently, the focus of forest ecosystem management in China is changing from a single management objective to a multi-objective approach, with the goal of improving forest quality and maximizing ecosystem service benefits [4]. In this context, forest managers must not only focus on carbon sinks and forest products, but also make forest management decisions based on many aspects of forest values. In the industry, forest ecosystem carbon sequestration and forest value assessment are often analyzed together [5]. It has been pointed out that forest management plan preparation should start from the concept of forest landscape restoration, comprehensive analysis of forest resources, forest landscape, ecosystem and management needs, and use this to determine management objectives and management targets and develop management measures according to local conditions [6]. That is, the dominant role of forest landscape restoration (FLR) and sustainable forest management (SFM) concepts in the preparation and implementation of new forest management programs is clarified [7].

Traditional forest management programs only make general descriptive descriptions [8]. Most of the past papers use GIS technology (Geographic Information System) as the basic method for forest management programming [9] and use ArcGIS software for data processing in forest management programs [10], although the data are more accurate, but the perspective is too homogeneous. The paper from Zhongyang Hu et al. used Matlap language to provide a new way of thinking for forest management management, and the program can complete the work in forest management plan preparation precisely, process, and batch, which greatly improves the efficiency of forest management plan preparation [11], and its shortcomings are that it lacks the synthesis of multiple methods and does not portray the forest management system in detail. This paper is characterized by adopting the ideas proposed by industry scholars and innovatively combining the entropy value method and TOPSIS algorithm from a unique Chinese forest site to arrive at a set of forest management plans that are both accurate and comprehensive.

The possible marginal contribution of this paper is that, in terms of research intention, it links forest management scenarios with carbon sequestration, analyzes the relationship between "carbon sequestration in forest systems and forest management scenarios", expands the understanding of carbon sequestration from the perspective of microstructure subjects, and enriches the understanding of forest management and forest values; in terms of research data, based on the Lagrangian In terms of research data, based on the Lagrangian interpolation method, the entropy method and TOPSIS algorithm analysis were used to characterize the weight of forest stock and the advantages and disadvantages of carbon sequestration based on the data from the official websites of the Seyhanba Forestry Reserve and the National Bureau of Statistics of China, which provide useful reference for assessing forest management plans; in terms of research paradigm, a research framework of "data collection - model development - comprehensive analysis" was provided. In terms of research paradigm, it provides a research framework of "data collection-model development", especially based on the data of "forest cover and forest stock" and "storage and water content of different age species", which opens up the gap between forest management and carbon sequestration. In terms of research content, we highlight the basic conditions required to improve forest carbon sequestration as a result of changes in forest management practices in the context of climate change, and examine the important external support for forest carbon sequestration driven by changes in forest management concepts, and verify them through effective empirical tools. We also validate this by effective empirical means.

2. Data Acquisition and Variable Setup

2.1. Data Acquisition and Variable Setup

Research and establish a carbon absorption model to determine the optimal business plan. This paper selects the data of Saihanba from 1962 to 2022: forest area, coverage rate of different types of trees, forest water conservation, etc. The data in this article comes from the official website of Saihanba Machinery Forest Farm in Northern Province and the National Bureau of Statistics of China, in order to determine the amount of carbon dioxide absorbed by Saihanba. Obtaining comprehensive and real data is a prerequisite for solving problems. This paper pays attention to the following two aspects in the selection of variables: first, it can reflect the impact of each variable on the amount of carbon dioxide absorbed. It should be noted that both short-term and long-term effects should be considered for carbon dioxide absorption. Therefore, a large amount of data is the basis for the success of the experiment; second, there are many factors that affect forest carbon sequestration. On the basis of relevant literature, the team summarized four important variables: forest coverage, tree stock, water conservation and different types of tree stock. Variable settings are shown in Table (1).

Table 1. Variable setting.

Forest cover rate	Forest stock	Conservation of water	young forest stock	Middle-aged forest stock	near mature forest stock	mature forest stock	overmature forest stock

2.2. Data preprocessing

By checking the obtained data, it was found that some variables were missing. In general, data interpolation is mainly used to deal with missing data. Data interpolation can not only improve data quality, but also improve the accuracy of model fitting and prediction. The commonly used interpolation methods are mean interpolation method, median interpolation method, linear interpolation method, Lagrange interpolation method, and EM algorithm and regression interpolation method. This paper uses Lagrangian interpolation to fill in missing values. The basic steps of the Lagrange interpolation method are as follows:

Step 1: It is known that there are given n points: $(x_0, y_0)\ \cdots(x_n, y_n)$, among them, x_j corresponds to the position of the independent variable, and y_j corresponds to the value of the function at this position. Assuming that any two different x_j are different from each other, then a polynomial of degree n-1 can be obtained: y=$a_0 + a_1x_1 + a_2x_2^2+\ldots+a_{n-1}x_{n-1}^{n-1}$, the curve of the polynomial passes through these n points, and the n points are brought into the polynomial in turn to obtain:

$$y_1 = a_0 + a_1x_1 + a_2x_1^2+\ldots+a_{n-1}x_1^{n-1} \tag{1}$$

$$y_2 = a_0 + a_1x_2 + a_2x_2^2+\ldots+a_{n-1}x_2^{n-1} \tag{2}$$

$$y_n = a_0 + a_1x_n + a_2x_n^2+\ldots+a_{n-1}x_n^{n-1} \tag{3}$$

Step 2: Solve the Lagrangian polynomial:

$$\mathrm{L(x)} = y_1\frac{(x-x_2)(x-x_3)\ldots(x-x_n)}{(x_1-x_2)(x_2-x_3)\ldots(x_1-x_n)} + y_2\frac{(x-x_1)(x-x_3)\ldots(x-x_n)}{(x_2-x_1)(x_2-x_3)\ldots(x_2-x_n)} + \ldots\ldots + y_n\frac{(x-x_1)(x-x_2)\ldots(x-x_{n-1})}{(x_n-x_1)(x_n-x_2)\ldots(x_n-x_{n-1})} \tag{4}$$

Step 3: The approximate value of the missing value L(x) can be obtained by replacing the missing value x in the original data with the calculation result of the Lagrange polynomial. Taking carbon dioxide emission data as an example, the data interpolation effect is shown in Table (2).

Table 2. Example of Lagrangian Interpolation.

Raw data		Interpolated data	
year	Carbon dioxide absorption/ton	year	Carbon dioxide absorption/ton
2000	45.18	2000	45.18
2001	missing	2001	51.05
2002	56.72	2002	56.72
2003	59.96	2003	59.96

2.3. Model overview

In order to explore the most effective forest management plan for carbon dioxide absorption, this study established a directional assessment model, which selected forest coverage, different types of forest stock, water conservation and forest stock as variables, calculated weights, and studied the impact on carbon dioxide absorption. In this paper, the entropy value method + TOPSIS comprehensive evaluation method is used to measure the influence of the set variables. Finally, the comprehensive evaluation of each annual forest management plan is discussed, and based on the annual carbon emissions, the carbon sequestration effect of different forest management plans is evaluated.

2.4. Calculate the weight of each variable based on the entropy method

The entropy value method is an objective weighting method, which draws on the idea of information entropy. It calculates the information entropy of the index and determines the weight of the index according to the impact of the relative change degree of the index on the overall system. The degree of weighting is carried out to obtain the corresponding weight of each index. The index with a relatively large degree of change has a larger weight. The larger the entropy, the more chaotic the system, the less information it carries, and the smaller the weight; Orderly, the more information it carries, the greater the weight.

In order to calculate the weight of each variable, this paper uses the entropy method to calculate, and the specific calculation principle is as follows:

Normalizing the data results in a normalized matrix as shown below, where n are the rows and m are the columns. i is row i and j is column j.

$$\mathrm{N} = \left[\mathrm{x_{ij}}\right]_{\mathrm{n*m}} \tag{5}$$

The proportion of the i-th sample value under the j-th variable to this indicator is:

$$\rho_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, (i = 1,2,3,\ldots; j = 1,2,3,\ldots,m) \tag{6}$$

The information entropy of variable J is:

$$e_j = -k \sum_{i=1}^{n} \rho_{ij} * \ln(\rho_{ij}), (j = 1,2,3,\ldots,m) \tag{7}$$

It should be noted that, in general, the value of k is:

$$\mathrm{k} = \frac{1}{\ln(\mathrm{n})}, (0 \le \mathrm{e_j} \le 1) \tag{8}$$

The coefficient of variance for the item j variable is:

$$d_j = 1 - e_j \tag{9}$$

Finally, the variable weight of item j can be obtained as:

$$\omega_j = \frac{d_j}{\sum_{j=1}^{m} d_j}, (j = 1,2,3,\ldots,m) \tag{10}$$

2.5. Calculation result of entropy method

Table 3. Calculation result of entropy method.

item	Information entropy value e	Information utility value d	Weights
Forest cover rate	0.969	0.031	0.028
Forest stock	0.879	0.121	0.109
Conservation of water	0.872	0.128	0.115
young forest stock	0.901	0.099	0.089
Middle-aged forest stock	0.896	0.104	0.093
near mature forest stock	0.758	0.242	0.217
mature forest stock	0.639	0.361	0.324
over mature forest stock	0.972	0.028	0.025

Table 3 reports the results calculated using the entropy method. The weight calculation results of the entropy value method show that, in ascending order of age, the weights of forest stock of different ages are 8.9%, 9.3%, 21.7%, 32.4% and 2.5%, among which the weight of mature forest (32.4%) is the largest, and the weight of over-mature forest Forest weight (2.5%) is the smallest.

Calculate the weight of each variable based on the entropy method, and analyze its carbon dioxide absorption capacity according to the weight of each variable. It can be intuitively found that mature forest and near-mature forest contribute more to carbon sinks, while over-mature forest contributes less.

2.6. Comprehensive Analysis Based on TOPSIS Algorithm

In this paper, the panel data is used for comprehensive scoring. TOPSIS is a commonly used comprehensive evaluation method, which can make full use of the information of the original data, and the results can accurately reflect the gap between the various evaluation schemes.

In the face of the problem of sorting multiple solutions, TOPSIS's solution is to evaluate the comprehensive distance of any solution in the solution system from the ideal optimal solution and the worst solution through certain calculations. If a solution is closer to the ideal optimal solution and farther away from the worst solution, we have reason to think that the solution is better. It should be noted that the ideal optimal solution is that each index value of the ideal optimal solution is taken to the optimal value of the evaluation index in the system, and the worst solution is that each index value of the ideal worst solution is taken in the system for evaluation worst value of the indicator. The specific calculation principle is as follows:

Standardize the normalized matrix, and record the normalized matrix as Z.

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{11}$$

Compute the optimal solution vector:

$$Z^+ = [Z_1^+, Z_2^+, \cdots, Z_m^+] = [\max\{Z_{11}, Z_{21}, \cdots, Z_{n1}\}, \max\{Z_{12}, Z_{22}, \cdots, Z_{n2}\}, \cdots \max\{Z_{1m}, Z_{2m}, \cdots, Z_{nm}\}] \tag{12}$$

Compute the worst solution vector:

$$Z^- = [Z_1^-, Z_2^-, \cdots, Z_m^-] = [\min\{Z_{11}, Z_{21}, \cdots, Z_{n1}\}, \min\{Z_{12}, Z_{22}, \cdots, Z_{n2}\}, \cdots \min\{Z_{1m}, Z_{2m}, \cdots, Z_{nm}\}] \tag{13}$$

Record Z^+ as Z_{max}, Z^- asZ_{min}, Calculate the distance score formula:

$$\frac{Z_i - Z_{min}}{(Z_{max} - Z_i) + (Z_i - Z_{min})} \tag{14}$$

For the schemeZ_i, calculate its distance d_i^+ from the optimal solution:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (Z_j^+ - Z_{ij})^2} \tag{15}$$

For the schemeZ_i, calculate its distance d_i^- from the worst solution:

$$d_i^- = \sqrt{\sum_{j=1}^{m} (Z_j^- - Z_{ij})^2} \tag{16}$$

Finally, the score of the i-th scheme can be obtainedS_i:

$$S_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{17}$$

In terms of term selection, it was found by reading the literature that when trees become over-mature forests. Its growth will tend to stop. If it is not cut down and replaced in time, it will gradually age or even die, unable to continue to increase carbon sinks, and may even become a "carbon source". In addition, combined with the weight calculation results of the entropy method, it is not difficult to find that overmature forests contribute little to carbon sequestration and have a negative impact on carbon sequestration. Therefore, overmature forest accumulation is regarded as a negative variable in the study.

2.7. Calculation result of TOPSIS algorithm

Table.4. Calculation result of TOPSIS algorithm.

year	optimal solution distance (D+)	worst solution distance (D-)	composite score index	ranking
2021	0.041882	0.337574	0.889626	1
2020	0.04943	0.323173	0.86734	2
2019	0.067801	0.309318	0.820213	3
2018	0.086257	0.29973	0.776529	4
2017	0.097018	0.292879	0.751171	5
2016	0.103552	0.280901	0.73065	6
2015	0.153853	0.225924	0.594885	7
2014	0.184133	.0.201225403	0.522177	8
2013	0.235462	0.180413	0.433815	9
2012	0.257324	0.170479	0.398499	10
2011	0.259338	.0.161204173	0.383324	11
2010	0.260669	0.153516	0.370646	12
2009	0.261355	0.147565	0.360865	13
2008	0.262207	0.143487	0.353683	14
2007	0.265704	0.13181	0.331587	15
2006	0.269862	0.122313	0.311884	16
2005	0.277148	0.111476	0.286848	17

Table 4 reports the results calculated using the TOPSIS algorithm. Due to space constraints, this article only lists some data. The top seven comprehensive rankings are from 2021 to 2015. Combined with the data of Saihanba Forest Farm, the data of forest coverage rate and forest stock, tree species stock of different ages and water conservation in the previous 7 years are shown in Table (5).

Table.5. Data for the first 7 years.

Year	Forest cover rate	Forest stock	Conservation of water	carbon dioxide absorption	oxygen release	young forest stock	middle-aged forest stock	near mature forest stock	mature forest stock	overmature forest stock
2016	77.8	990.18	1.3	82.16	57.15	179.23	301.79	361.23	137.86	10.07
2017	78.9	1001.1	1.37	83.07	57.78	183.39	307.74	351.14	148.11	10.73
2018	79.82	1011.29	1.56	83.91	58.37	192.32	309.69	356.23	149.32	3.73
2019	80.66	1020.7	1.94	84.69	58.91	200.31	310.21	357.13	150.23	2.82
2020	81.46	1029.23	2.4	85.4	59.4	2010.21	311.23	359.38	153.01	4.4
2021	82.21	1036.8	2.84	86.03	59.4	203.2	312.32	361.02	155.21	5.01

It is not difficult to see from the data that the proportion of near-mature forest stock and mature forest stock in the first seven years is significantly higher than that of the lower-ranked years. It can be seen that near-mature forest and mature forest have a significant impact on carbon sequestration. At the same time, the number of super-mature forests in these seven years was also significantly lower than that in other years, confirming the above-mentioned view: super-mature forests played a negative role in the process of carbon sequestration.

3. Conclusions

By establishing the entropy method and the TOPSIS comprehensive evaluation algorithm model, this paper takes Saihanba Forest Farm as an example to discuss the impact of different forest management plans on carbon dioxide absorption. Through empirical research, this paper finds that the carbon dioxide absorption effect of mature forest is the best, that of near-mature forest is second, and that of over-mature forest is the worst. As the cover of near-mature forests and mature forests increases, so does the uptake of carbon dioxide. Therefore, this paper believes that under the condition of controlling the steady growth of forest coverage, increasing the stock of near-mature forest and mature forest, and appropriately reducing the stock of over-mature forest, this forest management plan is the most effective way to absorb carbon dioxide.

References

[1] Wei Y M,Han R, Liang Q M,et al. An integrated assessment of INDCs under shared socioeconomic pathways: an implementation of C^3IAM [J].Natural Hazards, 2018, 92 (2): 585-618.

[2] Li, Haikui. Research progress of forest carbon sink assessment methods and carbon sequestration potential estimation under carbon neutral vision [J]. China Geological Survey, 2021, 8 (04): 79-86.

[3] Li Yinan, Li Zhe, Zheng Lijun, He Xiangyu. Exploration of sustainable forest management in the context of the new era [J]. Forestry Survey and Design, 2020, 49(04):130-132.

[4] Liu ZY, Feng ZK, Chen CH. GEF innovative forest management program: the case of grassland forestry in Fengning County [J]. Sustainability, 2022, 14(13).

[5] Rui LH, Zhao Y,Sheng ZX, Li K,Xu JN. Research on forest management plan based on Forest Ecosystem Carbon Sink Model (FCSM) and Forest Value Valuation Model (FVM) [J]. Academic Journal of Computer and Information Science, 2022, 5.0(7.0).

[6] Liu Jing. New forest management program preparation and implementation [J]. Forest Resource Management, 2020(03):6-10.2020.03.002.

[7] Wang Kexuan, Hu Yue, Hu Lei, Zhang Yahao, Han Zemin, Li Bin, Li Xiaohui, Zhang Zhuowen, Tsukuda Yuan Yong. Preparation and implementation of a new forest management plan based on FLR and SFM [J]. Forest Resource Management, 2022(S1):24-31.

[8] Emmanuel F. Nzunda. 2012-2017 Forest management plan implemented by the REDD+ pilot project in Masito Community Forest Reserve, Kigoma, Tanzania: A general description [J]. Asian Journal of Environment & Ecology, 2021.

[9] Shen Quanlin,Xia Qin,Liu YM. Research on forest management plan preparation under GIS technology application[J]. Rural. Agriculture. Farmer (B), 2021(03):55-56.

[10] Zhou Lifang. Research on the application of ArcGIS-based data processing in the preparation of forest management plan [J]. Gansu Science and Technology, 2020, 36(07):13-15.

[11] Hu C-Y, Liu R-Z, Liu P. MATLAB-based programming of forest management plans [J]. Forest Resource Management, 2019(04):132-136+158.