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Carbon Sequestration Analysis of Forest Management Summary

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Abstract

Forest plays an irreplaceable role in reducing carbon dioxide in the atmosphere. Investigating the balance between the value of forest products obtained from logging and the value of allowing forests to continue to grow as living trees to sequester carbon is not only a major issue of contemporary forest science management, but also an important research significance. Based on the improved forest volume method, we propose a carbon sequestration model and an improved forest value evaluation system, and obtain some results under some statistical data. First, by using the original method of calculating carbon sequestration and forest savings, we establish a carbon sequestration model based on the improved forest volume method. This model solves the relationship between deforestation rate and forest carbon sequestration well. Then, we establish a forest value evaluation system based on the entropy weight method. The comprehensive value of any forest in the world can be reflected by the Forest Value Index (FVI) obtained by the evaluation system, which effectively solves the previous problem that the comprehensive value of forests is difficult to be evaluated intuitively. Next, using the collected data, we put forward three critical points of "Pass", "Good", and "Excellent". Further, according to these three critical points, the comprehensive value of the forest is divided into four grades: "Fail", "Lower-middle", "Above average" and "Excellent". Thus, we give the detailed policies for felling and non-cutting corresponding to each state. Finally, Changbai Mountain is selected as the research case. We use GM(1,1) to predict the forest savings in Changbai Mountain and calculate the carbon sequestration and economic benefits in 100 years. Our model solves the problem of forest management, and provide a valuable reference for the solution of global warming and forest management in the future.

Keywords

Improved Forest Volume Method; Carbon Sequestration Model; FVI; Entropy Weight Method; Forest Economic Benefit; GM (1,1).

1. BACKGROUND

In today's world, the impact of greenhouse gases on the global climate has become a major challenge for all mankind. In order to reduce the impact of greenhouse gases, carbon dioxide is the most abundant greenhouse gas in the atmosphere, and controlling the content of carbon dioxide in the atmosphere has become the main measure to solve the greenhouse gas problem.

In order to reduce the content of carbon dioxide, it is not enough to reduce its emissions. The use of carbon sequestration can effectively reduce carbon dioxide storage. Forests are the main reservoir of terrestrial carbon, storing 80% of the organic carbon in the above-ground part of the terrestrial ecosystem and 40% of the organic carbon in the bottom part of the terrestrial

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ecosystem. Therefore, increasing the amount of carbon sequestration in forests can effectively reduce the carbon content in the atmosphere and solve the problem of greenhouse gases.

In terms of forest carbon sequestration, the forest products produced by rationally felling trees and the carbon sequestration of young trees in the forest will have more carbon sequestration over time than not cutting down trees at all. Therefore, finding a reasonable forest management model plays a huge role in addressing greenhouse gases.

2. CARBON SEQUESTRATION MODEL

2.1. Proposition of the Formula for Carbon Sequestration

The calculation methods of forest carbon sequestration mainly include biomass method, stock volume method, carbon density method, and carbon balance method. Scientific but complicated. From an economic and policy perspective, if the research scale is too small, the calculation process is too complicated, and its operability is limited to a certain extent. Considering the practicability and operability of the calculation method, and according to Reference [1], our model mainly uses forest stock to calculate carbon sequestration.

Forest carbon sequestration generally includes tree carbon sequestration, understory plants and humus carbon sequestration, forest soil carbon sequestration, and forest product carbon sequestration.

To simplify the model, we divided forest carbon sequestration into three parts: forest carbon sequestration, forest land carbon sequestration, and understory carbon seque stration; forest land carbon sequestration and understory carbon sequestration correspond to the understory conversion coefficient α and forest land conversion coefficient β, respectively. At the same time, considering that there is no single tree species in any forest, Ci is the carbon density of the i-th type of tree species, V_i is the stock volume per unit area of the i-th type of forest, and S_i is the coverage area of the i-th type of tree species. In reference [1], the specific calculation formula of forest carbon sequestration is:

$$TC_F = S_iC_i + \alpha S_iC_i + \beta S_iC_i. \tag{1}$$

The formula for calculating carbon density is

$$C_i = V_i\delta\rho\gamma, \tag{2}$$

Where, δ is the biomass expansion coefficient, ρ is the mass coefficient of biomass accumulation into biomass dry matter, that is, bulk density; γ is the coefficient of converting biomass dry matter mass into carbon sequestration, that is, carbon content rate.

The total stock volume of the i-th type of forest is

$$V_f = S_iV_i. \tag{3}$$

Therefore, combined (1) (2) with (3) can be further converted into:

$$TC_F = (1 + \alpha + \beta) V_f\delta\rho\gamma. \tag{4}$$

The formula for calculating forest carbon storage is:

$$TC_W = V_f\delta\rho\gamma. \tag{5}$$

In model(5), each coefficient is set according to the default parameter values of the Intergovernmental Panel on Climate Change (IPCC), that is, δ is the conversion of forest stock

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into forest-based biological stock, and the general value is 1.90; The density ρ is generally taken as 0.45~0.5 t/m3, and our model is taken as 0.5; the carbon content rate γ is generally taken as 0.5; the conversion coefficient of understory vegetation carbon sequestration is 0.195, and the conversion coefficient of forest land carbon sequestration is 1.244.

2.2. The Impact of Deforestation on Forests

When formulating our policy on deforestation and utilization of forests, we define the deforestation rate as x%, that is, when x in the formula below represents our deforestation rate per unit area of forest at this time x%. Considering that when the forest is cut down, the original ecological environment in the forest will be affected, and the understory conversion coefficient α and woodland conversion coefficient β in the model will be affected by the logging. In order to explore how these two coefficients change, we refer to the reference [2] and related literature, obtained some of the effects of α and β with the deforestation rate x, as shown in the Table 2.

In order to get the complete curves of α and β and x, we use the cftool toolbox in matlab to perform polynomial fitting, and get the curves of α and β and x as shown in Table 3.

And we make their images as shown in Figure 1 and 2.

From 1 and 2, with the increase of x, both α and β decrease with the trend of quadratic function, that is, as the deforestation rate x increases, both the understory conversion coefficient α and the woodland conversion coefficient β decrease.

Table 2. The change trend table of α and β with x

x	0	5	10	15	20	25	30	35	40	45
α	0.195	0.193	0.19	0.185	0.175	0.168	0.156	0.142	0.125	0.112
β	1.244	1.103	0.972	0.873	0.778	0.636	0.509	0.416	0.283	0.178

Table 3. Function of x and α, β

Location	Conversion factor	Goodness of fit
α	$\alpha=-1.727e^{-5}x^2-0.0003661x+0.1962$	0.9897
β	$\beta=-1.727e^{-5}x^2-0.02423x+1.232$	0.9987

2.3. Balance between carbon sequestration and deforestation rate

We stipulate that we will clear the forest every 10 years, and because the forest is an extremely stable ecosystem, we think that the forest will return to the state before it was not cut in ten years after each cut. And according to our statistics, the average lifespan of wood products is 12.32 years. In order to simplify the model, we substitute the average lifespan of 10 years to calculate, and the increase in carbon sequestration in 10 years is:

$$TA = (1 + \alpha + \beta)\, V_f\, \delta\rho\gamma x - V_f\, \delta\rho\gamma x = (\alpha + \beta)\, V_f\, \delta\rho\gamma x. \quad (6)$$

Take the forest stock volume of Changbai Mountain in 2022 as an example, as shown in Figure3:

It can be seen from the image that with the change of x, Tz increases first and then decreases.

When x=28%, T_z increases to the maximum. When x > 55, T_z < 0 that is, when 28% of the forest is cut down, the maximum carbon sequestration benefit can be obtained, and when more than 55% of the forest is cut down, the conversion rate of forest land and understory will decrease, and the carbon sequestration will be irreversible. decrease, the ecological environment of this forest will be greatly damaged. Since the maximum value of x has nothing to do with the coefficient V_f at this time, we know that no matter any forest, when the deforestation rate is 28%, the increase in carbon sequestration in the next 10 years will reach

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the maximum, so we set 28% as the golden deforestation. If there is no other explanation later, the deforestation rate is 28%.

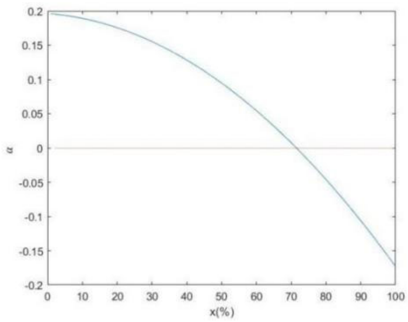

Figure 1. α change with the cutting rate x

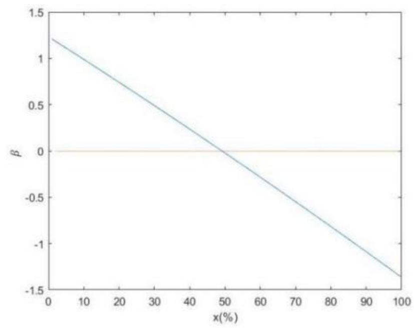

Figure 2. β change with the cutting rate x

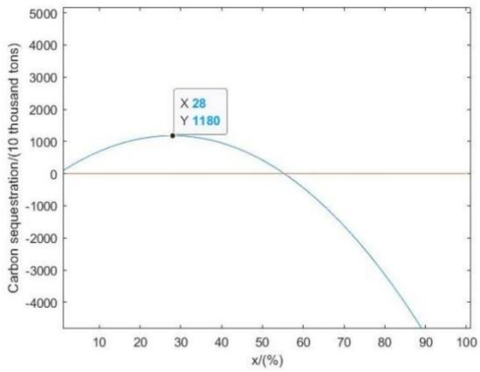

Figure 3. Growth rate curve

2.4. Economic Benefit Analysis

From reference [3], it can be seen that the economic benefits of forests are obviously related to the deforestation rate x and the forest savings Vf. We list the calculation formula of the economic benefits as follows:

$$W_e = 0.857 V_f \rho_w W_w, \tag{7}$$

Where, ρ_w is the density of wood, which is generally the average density of wood, usually 0.4~0.75 t/m^3, and W_w is the average price of wood. We take the average of wood prices in China in recent months, 894.22 yuan/t for calculation.

2.5. Other Benefit Analysis

Other benefits of forests are often related to carbon sequestration, conservation and biodiversity aspects, recreational and cultural uses, and we list the other benefits WO calculated as follows:

$$W_o = (T_{cf} + T_A)\, W_w + W_r \tag{8}$$

Where, T_{cf} is the carbon sequestration amount, TA is the increased carbon sequestration amount, and W_w is the cost of fixing one ton of carbon. Here we refer to [4] to take the comprehensive cost of capturing carbon dioxide as 180 yuan/t ,W_r takes the tourism income near the forest location as a reference.

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2.6. Model Conclusion

We comprehensively considered the relationship between the understory conversion rate α, the forest land conversion rate β and the deforestation rate x, and further considered the impact of carbon sequestration, economic benefits and other benefits, and optimized the original carbon sequestration calculation method. The formula for forest carbon sequestration is as follows:

$$T_{cf} = (1 + \alpha + \beta) V_f \delta \rho \gamma x$$

$$\alpha = -3.328e^{-5}x^2 - 0.0003661x + 0.1962 \tag{9}$$

$$\beta = -1.727e^{-5}x^2 - 0.02423x + 1.232$$

And determine the optimal cutting rate x is 28%, when we cut at the optimal cutting rate, the carbon sequestration increased by 10% every 10 years compared with the previous 10 years.

3. FOREST VALUE EVALUATION SYSTEM

3.1. Indicator Establishment

In order to measure the comprehensive value of a forest more scientifically, we decided to establish a forest value system, and use the forest value system to comprehensively measure a forest to help forest managers make better use of and provide guidelines for managing forests.

3.1.1 Establish Indicators

In order to evaluate a forest more scientifically, we decided to evaluate all aspects of a forest from five indicators: composition, climate, population, interests and values, and under each indicator, the impact of different factors on the indicators was comprehensively considered. These indicators, factors work together to affect the forest value system . The index structure diagram is shown in Figure 4:

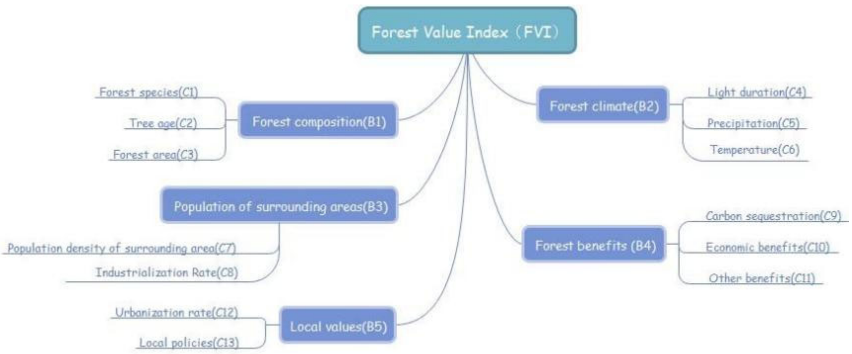

Figure 4. Forest value system

3.1.2 Forest composition (B1)

Forest composition (B1) is divided into three sub-indicators: Forest species (C1), Tree age (C2), and Forest area (C3). This indicator mainly considers the composition of the forest, and the larger the value of the indicator, the more complete the composition of the forest:

a.Forest species (C1) are generally divided into broad-leaved forests, mixed forests, and coniferous forests. Obviously, the carbon sequestration capacity and photosynthesis capacity of broad- leaved forest are the strongest, followed by mixed forest and coniferous forest. Broad-leaved forest is often distributed in low latitudes, mixed forest is distributed in mid-latitude,

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and coniferous forest is distributed At high latitudes, mixed forests and coniferous forests are strongly affected by seasons, while broad-leaved forests are evergreen in all seasons, which is obviously stronger in carbon sequestration and photosynthesis. Therefore, we use a ten-point system to score a forest according to its tree composition and its seasonal nature, with higher scores representing stronger carbon sequestration and photosynthesis capabilities.

b.Tree age (C2) The change process of individual growth and development of various trees in their lifetime, which refers to the whole process from fertilization of egg cells to zygotes and development of embryos, forming seeds, germinating into seedlings, growing into large trees, flowering and fruiting, until senescence, renewal and death . This process is called the life cycle (also known as the age period). Generally speaking, the life of a tree is divided into a juvenile period, a beginning harvest period, a full harvest period, a harvest decline period, and an aging renewal period. Trees in the full harvest period have stronger photosynthesis and carbon sequestration capabilities, while trees in other stages have less strong photosynthesis and carbon sequestration capabilities. Our calculation method is to calculate the average tree age per unit area of the forest. The closer it is to the harvest period, the higher the score. The full score is 10 points and the minimum score is 1 point.

c.Forest area (C3) Obviously, the larger the area of a forest, the stronger its comprehensive capacity.

3.1.3 Forest climate (B2)

Forest climate (B2) is divided into three sub-indicators: sunshine time (C4), Precipitation (C5), and Temperature (C6). This indicator mainly considers the climate of the forest. The larger the value of the indicator, the better the comprehensive benefit of the forest's climate to the forest:

a.Light duration (C4) Light duration affects the photosynthesis intensity of plants in the forest, and the more sunlight, the stronger the photosynthesis capacity of plants.

b.Precipitation (C5) The more rainfall, the more lush the plants will grow. At the same time, the forest will react to the rainfall, forming a positive feedback.

c.Within the normal range of temperature (C6), the higher the temperature, the more active the enzymes in the plant will be, the better the photosynthesis effect of the plant will be, and the stronger the carbon-fixing ability will naturally be.

3.1.4 The population of surrounding areas (B3)

The population of surrounding areas (B3) is divided into two sub-indicators:Population density of surrounding areas (C7) and Industrialization rate (C8). This indicator mainly considers the impact of the population in the surrounding area on the forest. The larger the indicator, the more positive impact the population has on the forest:

a.Population density of surrounding areas(C7)

The greater the population density in the nearby area, the various human actions will have various effects on the forest, usually negative, so the smaller the population density, the better for the forest.

b.Industrialization rate(C8)

The rate of industrialization often reflects the level of industry in a region. The higher the level of industry, the less pollution caused by deforestation or other behaviors.

3.1.5 Forest benefits (B4)

Forest benefits (B4) are divided into three sub-indicators: Carbon sequestration (C9), Economic benefits (C10), and Other benefits (C11). This indicator mainly considers the benefits that forests can bring. The larger the indicator, the more benefits the forests can create;

a. Carbon sequestration (C9)

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Carbon sequestration can reflect the carbon sequestration capacity of a forest. Carbon sequestration is one of the most important ecological values of a forest, and it is also the focus of this paper.

b. Economic benefits(C10)

Economic benefits represent the ability of forests to provide raw materials such as wood. Wood is one of the indispensable raw materials in various industrial constructions. Building buildings and railways are inseparable from wood. Wood is also a raw material for the paper industry, rayon industry and organic synthetic chemical industry, and is one of the most important raw materials in modern society.

c.Other benefits(C11)

Other benefits represent the benefits of forests in terms of biodiversity conservation, climate and ecological protection, as well as recreational use and cultural benefits.

3.1.6 Local values(B5)

Local values(B5) are divided into two sub-indicators: Urbanization rate (C12) and Local policy (C13). This indicator can reflect the impact of the values of the region where the forest is located on the forest. The higher the score of this indicator, the healthier the local values are for the protection and use of forests;

a. Urbanization rate (C12)

Generally speaking, the higher the urbanization rate, the more civilized the city will be, and the stronger the people in the city will have the values of environmental protection and development balance in the forest, so we choose the urbanization rate as our indicator. The existing conditions of the local forest will be better.

b. Local policy (C13)

Aggressive or conservative local policies can often have a dramatic impact on the comprehensive use of forests. Therefore, in order to scientifically judge the current situation of a forest, we must evaluate the existing policies of the local government on the forest, with a ten-point system. For forest development, a low score is given.

3.2. Use the Entropy Weight Method to Determine the Weight

Typical methods for determining weights include: Analytic Hierarchy Process (AHP), factor analysis weight method, entropy weight method, etc. The AHP is too subjective; the factor analysis weight method cannot guarantee the irrelevance between the various common factors in the data, the irrelevance between the special factors and the irrelevance between the common factors and the special factors, and the entropy weight method is a It is an objective weighting method, which corresponds to the corresponding weight through the degree of variation of the index, and the comprehensive value corresponding to different forests is reflected by the degree of variation of the index. In addition, the application of the entropy weight method is limited, so we choose the entropy weight method.

We first selected the nine most representative forests, Pu'er Forest (PF), Changbai Mountain Forest (CMF), Amazon Rainforest (AR), Tianshan Spruce Forest (TSF), Congo Basin Forest (CBF), Chilean Araucaria Forest (CAF) , German Black Forest (GBF), Vienna Woods (VF), Daintree Forest (DF), and then search for the data of each of their sub-indicators, that is, the data of C-level indicators, and use the entropy weight method to determine the sub-indicators. Then, the existing data is divided into dimensions, and the data of the main indicator, namely B, is calculated according to the obtained weight, and then the weight of the main indicator is determined according to the data of the main indicator, and finally the forest value index can be calculated. Its flow chart is shown in Figure 5.

We select forest climate (B2) as a sub-indicator and determine its weight as follows:

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(1) Forward processing

Forest climate (B2) is divided into three sub-indicators: Light duration (C4), Precipitation (C5), and Temperature (C6). If there are extremely small, intermediate, and interval types, the matrix needs to be forwarded. The forwarding process is implemented by matlab. See the appendix for details;

(2) Standardized processing

There are a total of 9 objects to be evaluated and 3 evaluation indicators, and the data formed after the normalization process is as shown in Table 4:

Table 4. Forwardization data

Forest	C4	C5	C6
PF	2500	877.3	20.5
CMF	2270	550	2.4
AR	3000	2500	27
TSF	3100	1000	0
CBF	1725	2000	26
CAF	3077	200	12
GBF	1500	2200	2
VF	1183	660	9.8
DF	2154	300	14

Importing its data into the matrix we get the following n m order matrix

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{10}$$

xnm represents the nth evaluation object, the data of the mth index .The normalized matrix is denoted as Z, and each element in X is processed as follows to Z:

$$z_{nm}=\frac{x_{nm}}{\sqrt{\sum_{n=1}^{10} x_{nm}^{2}}} \tag{11}$$

Write the data Z into the table to get the following Table 5:

Table 5. Insert data after Z

Forest	C4	C5	C6
PF	0.3509	0.2084	0.4302
CMF	0.3187	0.1306	0.0504
AR	0.4211	0.5938	0.5666
TSF	0.4352	0.2375	0.0000
CBF	0.4352	0.2375	0.0000
CAF	0.4319	0.0475	0.2518
GBF	0.2106	0.5225	0.0420
VF	0.1661	0.1568	0.2056
DF	0.3024	0.07125	0.2938

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The probability matrix P is calculated by the following formula:

$$p_{ij} = \frac{\widetilde{z}_{ij}}{\sqrt{\sum_{i=1}^{n} \widetilde{z}_{ij}^{2}}} \tag{12}$$

Finally, the information entropy table is obtained as shown in Table 6:

Table 6. Entropy table

Entropy	C4	C5	C6
e	**0.9795**	**0.8834**	**0.8405**

The information entropy is processed by the following formula 13 for normalization:

$$W_j = d_j / \sum_{j=1}^{m} d_j (j = 1, 2, \ldots, m) \tag{13}$$

Finally, the weight of each C-level indicator is obtained as shown in Table 7:

Table 7. Entropy table

Index	C4	C5	C6
Weights	0.0690	0.3931	0.5379

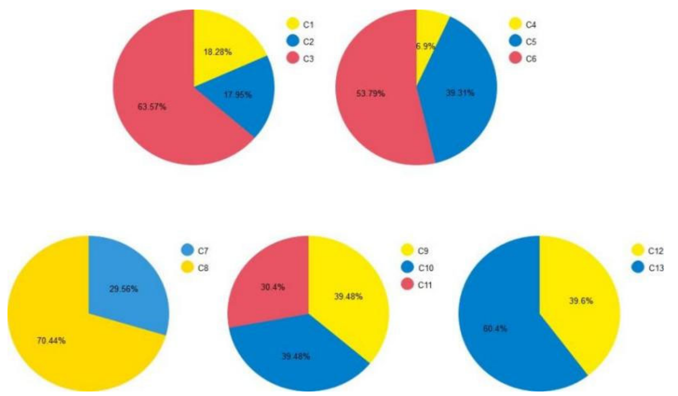

Figure 6. Forest Value Evaluation System

Divide the data into dimensions and multiply the corresponding weights to obtain the final cohesion (B2) data, as shown in Figure 6. Repeat the above steps, and finally obtain the weight of each sub-indicator as shown below:

By substituting the original data into the calculation through the weight of each sub-indicator, the scores Fb1, Fb2, Fb3, Fb4, and Fb5 of each parent indicator can be obtained, as shown in Table 8 below.

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Table 8. Insert data after Z

Sequence	Forest	Fb1	Fb2	Fb3	Fb4	Fb5
1	PF	1.3693	5.1749	2.7421	0.0516	6.4147
2	CMF	1.7193	1.2746	3.7370	0.0563	7.1885
3	AR	10.0000	8.6122	2.3373	10.0000	4.1968
...	...	...	...	...	...	...
7	GBF	2.7954	2.3688	10.0000	0.2458	10.0000
8	VF	2.5879	2.6611	4.2735	0.0280	7.6844
9	DF	2.8268	3.3705	1.0094	0.0425	3.5187

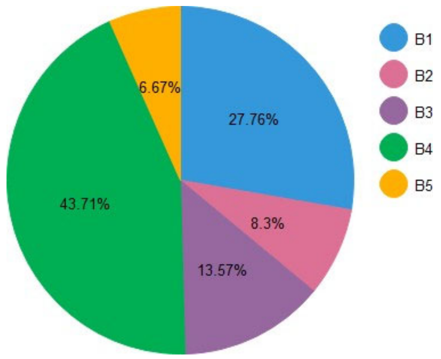

Figure 7. The weight of each B-level indicator

Continue to repeat the above steps, and then use the entropy weight method to calculate the weight of each B-level indicator as shown in Figure 7:

Substitute the weight of each Fb value and B index to get the FVI values of these forests as shown in Table 9:

Table 9. FVI

Forest	PF	CMF	AR	TSF	CBF	CAF	GBF	VF	DF
FVI	1.6315	1.5937	8.4585	1.3448	4.8381	1.9060	3.1031	2.0433	1.4544

Because the forests we select are all representative and typical forests in various places, we use the C-level weights and B-level weights obtained when calculating these forests as the weights in our forest value evaluation system.

Therefore, for any forest, we can use this system to evaluate its forest value index. The evaluation method is to substitute the data of each C-level index of the evaluated forest into the weight of each C-level index, and obtain the value of each B-level index. Score Fb1-Fb5, and then substitute the value of Fb1-Fb5 into the weight of B1-B5, and finally obtain the forest value index FVI. The FVI reflects the combined value of the forest being assessed.

4. ESTABLISHMENT OF FOREST MANAGEMENT PLAN

4.1. Scope of The Plan

The scope of our program is based on our forest value assessment system, which is divided into five areas: forest composition, climate, population, interests and values. Our policies are evaluated by our forest value assessment system. According to our forest evaluation system model, we can obtain the forest value index (FVI) of a forest, and at the same time obtain the scores Fb1, Fb2, Fb1, Fb2, Fb5 of the five indicators of the forest under evaluation. According to the forest value index FVI, we can understand the overall condition of the forest, and through

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Fb1, Fb2, Fb1, Fb2, and Fb5, we can understand the five aspects of forest composition, climate, population, interests and values. Whether the situation is good or bad.

4.2. A condition in Which Forests Are Not Cut Down

To determine when deforestation should or should not be done, we brought a set of forest data we thought was in the "pass" row into our system, resulting in the FVI and scores for each indicator, as shown in Table 10:

Table 10. Score

Index	Fb1	Fb2	Fb3	Fb4	Fb5	Fb5
Pass data	1.0061	1.6276	2.7044	0.0220	2.7917	0.9769

Our passing data are the minimum standards for forests that can be cut down on the basis of referring to a large number of forest-related data. Whether the forest can be cut down is mainly related to the value of forest composition indicators (Fb1) and forest value (Fb4). Forest Value Index FVI. Therefore, we conclude that when any of the forest composition index (B1) or forest value index (FVI) is less than the passing data, that is, when Fb1<1.0061 or Fb4<0.220 or FVI<0.9768, the structure, benefits and integration of forest The index will be in a rather poor "fail" status, and the forest conditions at this time will not be suitable for felling, and should be implemented according to the "fail" status policy in the coping strategy we gave.

4.3. Transition Points Between Forest Management Plans

The same as the "passing group" data mentioned in 3.2, we put a group of data in the "good" state and a group of data in the "excellent" state into our model respectively, and got the "good" and "excellent" data. status, the following table lists the data of Pass, Good and Excellent, as shown in the following Table 11:

These three sets of data are used as transition points to divide the value of FVI into four different intervals, as shown in the following Table 12:

Table 11. Each state corresponds

Index	**Fb1**	**Fb2**	**Fb3**	**Fb4**	**Fb5**	**FVI**
Pass data	1.0061	1.6276	2.7044	0.0220	2.7917	0.9769
Moderate data	2.0586	3.2551	4.7044	0.0580	4.7917	1.8244
Excellent data	4.5422	4.9241	7.0000	0.2201	6.7917	3.1679

Table 12. Insert data after Z

FVI	Condition
FVI<0.9769	Failed
0.9769<=FVI<1.8244	Lower-middle
1.8244<=FVI<3.1679	Above average
3.1679<=FVI	Excellent

4.4. National Forest Value Assessment Index

The National Forest Value Index (NFVI) refers to the average FVI value for each country. We calculate FVI values by plugging globally data-collectible forests into our forest valuation model. These forests were then classified by country and NFVI values were obtained for each country. And use Python to make the image as shown in Figure 8.

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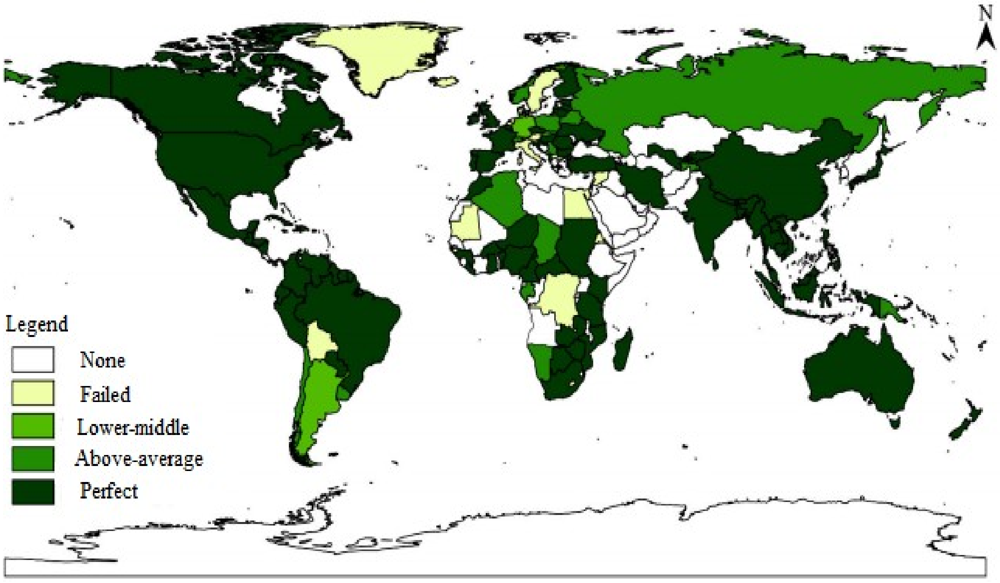

Figure 8. National Forest Value Index

None means that there are no forests in the country for which data can be collected; Failed means that the country's National Forest Value Index (NFVI) is in a failing status; Lower-middle means that the country's National Forest Value Index (NFVI) is in the lower middle state; Above-average means that the country's National Forest Value Index (NFVI) is in the upper-middle state; Perfect means the country's National Forest Value Index (NFVI) is in excellent status. With this map, we can easily study the forest landscape of each country and even each continent.

4.5. Forest Management Policy

Each state corresponds to a different solution policy, which is divided into logging and non-logging:

(1) Failed

a Deforestation

Due to its small FVI, the forest composition is very fragile and has low economic value. Therefore, if it is cut down, it may lead to soil erosion in the forest, destroy the ecological environment, and the harvesting income is low, so we do not give it.

b Non-cutting aspects

Strengthen publicity efforts, establish awareness of forest protection, and do a good job in forest fire prevention; combine mountain closure and artificial cultivation to expand forest resources; formulate relevant laws to strengthen forestry management; suspend the development and utilization of forest resources until the forest is out of danger. Carry out reasonable development and utilization.

(2) Lower-middle

a Deforestation

Due to its small FVI, the forest composition is relatively fragile and of low economic value. Therefore, we generally use a relatively conservative logging strategy to cut down such forests. Generally, we will not cut down to the "golden cutting points" described in 4.3. Generally speaking, it is adjusted according to the FVI level of the forest. If the FVI is close to "passing" point, about 5%-10% of the forest is generally cut down; if the FVI is close to the medium point, about 20% of the forest is generally cut down.

b Non-cutting aspects

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For this type of forest, protection is generally the main focus, because its ecological environment is relatively fragile, and the economic value of felling is limited. Appropriate closure of mountains and forests, and relatively conservative policy management to make it reach the "upper-middle" state as soon as possible are the key to the problem.

(3) Above average

a. a Deforestation

For forests in the "moderate to upper" state, the ecological environment has entered a stable state, the composition of tree species in the forest is relatively complex, the impact of surrounding human activities on the forest is small, and local policies have promoted the development of the forest. The economic value of forests is already considerable. Therefore, we can cut it down strictly according to the "golden cutting point" and the cutting rate of 28%, so that while its carbon sequestration increases steadily, we can also obtain considerable economic benefits.

b.b Non-cutting aspects

For this type of forest, because its composition is quite complex, it has a stable state, and its economic benefits are already in a high state. We can use relatively open policies to manage forests, develop forest tourism, increase the economic benefits of forests, tap the value of forest science and education, and provide research materials for scholars.

(4) Excellent

a Deforestation

The FVI index of the forest in the "excellent" state is very high, the ecological environment is quite stable, the composition of tree species in the forest is extremely complex, and generally has a very large forest area, the ability to fix carbon dioxide is extremely strong, and the surrounding environment is often conducive to the development of the forest. Therefore, we can appropriately go beyond the "golden cutting point" to cut down about 30% of the forest, sacrificing part of the carbon sequestration, and pursue higher economic benefits.

b Non-cutting aspects

For such forests, we must give full play to their advantages of high comprehensive value, and on the basis of protecting the forest environment, develop forest tourism, develop forest science and education value, and provide a model for the development of other forests that are not in an "excellent" state. effect.

4.6. Logging Strategy

From the previous calculations in 4.3, when our deforestation rate reaches 28%, the increase in carbon sequestration within 10 years will be the largest. In order to minimize the impact of deforestation on the environment, or even be beneficial to the environment, we decided to adopt the following deforestation policies to deforestation:

(1) Cut down the dense and leave the sparse

In the process of deforestation, we prioritize the deforestation in areas with high tree density, and reduce deforestation in areas with evenly distributed trees and reasonable tree spacing. Because if the density of trees in the same area is too large, it will cause competition among trees for carbon dioxide, water, inorganic salts, light and other growth conditions, which will affect the growth and development of trees and carbon sequestration.

(2) Cut down the old and leave the strong

In the process of deforestation, we preferentially cut down relatively old trees, leaving those relatively strong trees. Because the leaves of senescent trees are relatively scarce, the growth of trees declines, the germination and branching ability of young shoots decline, and the carbon

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sequestration ability is weakened, and its carbon storage is mainly concentrated in the trunk, which is cut off to make products, and the carbon sequestration cycle is longer. , and cutting down old trees will reduce competition among trees, which is conducive to the growth of young trees.

(3) Cut down the bad and leave the good

We give priority to felling trees that have been damaged or tend to be damaged, which can effectively prevent the infection of insect pests and germs, and the damaged trees no longer continue to sequester carbon or their carbon sequestration capacity is greatly weakened. Better nutrients and sunlight can be obtained, which is conducive to the growth of surrounding trees.

(4) Cut down the big and leave the small

We prioritize the felling of relatively large trees, because when competing for growth conditions, the larger trees will be in a relatively dominant position, affecting the growth and development of the surrounding smaller trees. If you cut them down, the surrounding small trees will gain Sufficient growth conditions can create economic and environmental benefits faster.

5. OUR CASE - CHANGBAI MOUNTAIN FOREST

5.1. The Policies

We choose Changbai Mountain Forest as a case. Changbai Mountain Forest is located in northeastern China, covering an area of about 1,965 square kilometers. We collected various data from Changbai Mountain and substituted it into our forest value evaluation system. The result is shown in Table 13:

It can be seen that all the indicators of Changbai Mountain are above the pass line, and the " Lower-middle" national forest policy proposed in 6.5 (Forest management policy) should be adopted.

Table 13. Each state corresponds

Forest	FB1	FB2	FB4	FB5	FB6	FVI
CBF	1.7193	1.2746	2.7044	0.0220	2.7917	0.9769

5.2. How Much Carbon This Forest and Its Products Will Fix in 100 Years

Here we introduce the prediction model-GM (1,1) to solve, the solving process is as follows.

5.2.1 Smoothness test

GM (1,1) is to use the original discrete non-negative data sequence to generate a new discrete data sequence that weakens the randomness by one accumulation, and then through the establishment of the differential equation model, the solution at the discrete point is obtained after accumulation. Subtracts an approximate estimate of the raw data generated, thereby predicting the subsequent development of the raw data.

From 1992 to 2022, we made statistics on Changbai Mountain's forest stock every ten years, and used every ten years as a cycle to perform GM(1,1) prediction on the data of these six cycles, and obtained Figure 9:

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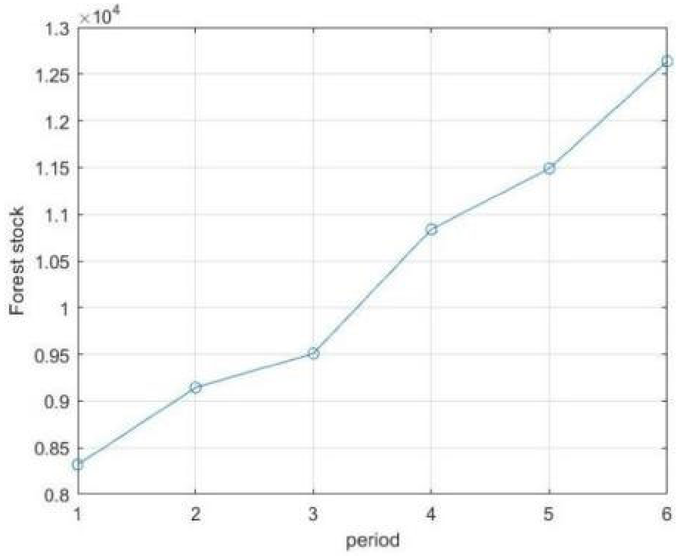

Figure 9. Forest stock in the first six periods

Then, we perform a smoothness analysis on the data, resulting in Figure 10:

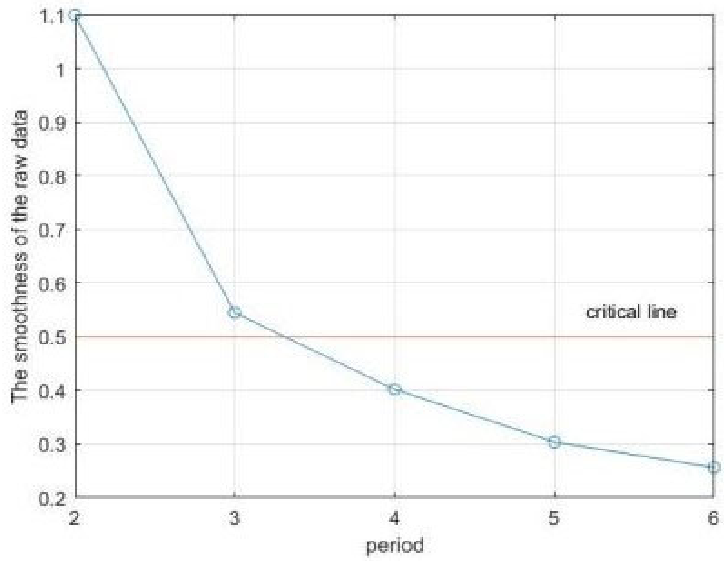

Figure 10. Smoothness Analysis

It is obtained that index 1: the proportion of data with a smoothness ratio less than 0.5 is 85%; index 2: except for the first two periods, the proportion of data with a smoothness ratio less than

0.5 is 100%. Because the proportion of data with a smoothness ratio of less than 0.5 in index 1 is greater than 60%, except for the first two periods of index 2, the proportion of data with a smoothness ratio of less than 0.5 is greater than 90%, indicating a good fit. The raw data can pass the smoothness test and can make GM (1,1) prediction.

5.2.2 GM(1,1) prediction

The basic form of the GM (1,1) model is:

$$x^{(0)}(k) + az^{(1)}(k) = b \quad (k = 2, 3, ..., n) \tag{14}$$

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Among them, b represents the amount of ash action, -a represents the development coefficient. Substituting in the data, the development coefficient is 0.087396, and the ash action is 7863.701.

Next, predict the forest stock volume in the next 100 years, that is, 10 periods, and get the results in Figure 11 below

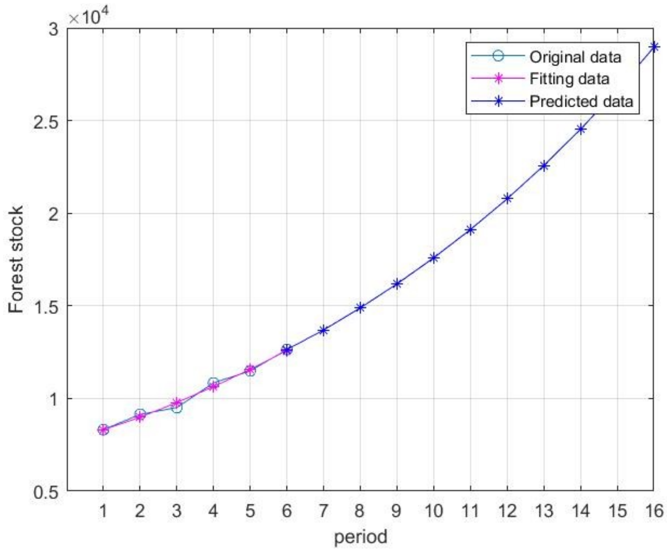

Figure 11. 100-year forest stock forecast

Then we performed the model evaluation and got the average relative residual to be 0.014945; the average grade ratio deviation was 0.027898. The data of relative residuals and mean grade ratio deviation are shown in Figure 12:

From the average relative residuals and average ratio deviations, we can see that the model fits the original data very well. Therefore, the prediction results are credible. We draw the following Table 14:

Table 14. Forecast data

2032	2042	2052	2062	2072	2082	2092	2102	2112	2122
13697	14889	16184	17590	19116	20773	22572	24526	26647	28950

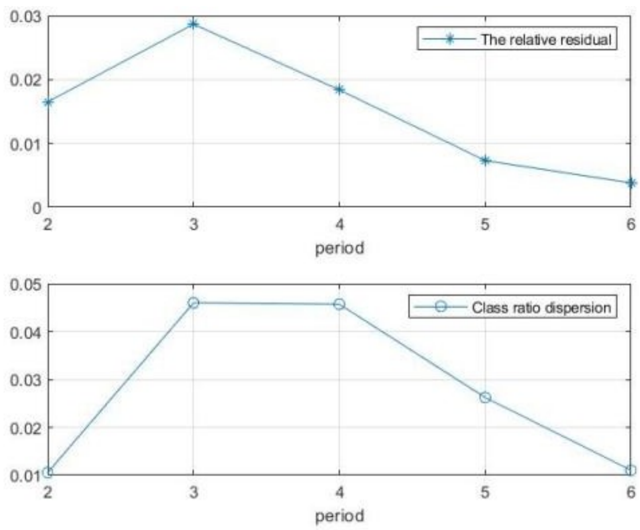

Figure 12. 100-year forest stock forecast

We predict that by 2122, the forest stock of Changbai Mountain will reach 289.501342 million tons. Substituting the forest stock into the forest carbon sequestration formula, the carbon sequestration of Changbai Mountain and its products in 100 years is 375.03958 million tons. The direct and indirect economic value will exceed 50 billion yuan.

6. SUMMARIZE

(1) We improved the original method of calculating carbon sequestration by using forest savings, established a carbon sequestration model based on the improved forest savings method, fitted the relationship between carbon sequestration and deforestation rate, and obtained When the deforestation rate x=28%, the increase in carbon sequestration reaches the maximum.

(2) We use the double entropy weight method to establish a forest value evaluation system, which can evaluate any forest in the world. According to the final forest value index (FVI), the corresponding management plan is given, and the average forest value index (NFVI) of each country is calculated to provide a reference for studying the comprehensive forest situation of each country and region.

(3) Taking Changbai Mountain as an example and substituting it into our model, the forest value index FVI is calculated, and corresponding policies are proposed according to the transition point. Then use GM (1,1) to predict the 100-year forest savings of Changbai Mountain, and use the carbon sequestration model to calculate the total carbon sequestration and economic benefits of Changbai Mountain in the next 100 years. It also explains how the plan should transition smoothly.

7. NON-TECHNICAL ARTICLE

Deforestation = destruction of the environment?

In recent years, global warming has become a problem that all human beings cannot ignore, and forests are a major contributor to suppressing global warming because of their strong carbon dioxide absorption capacity. Therefore, how to protect the forest has been widely discussed.

In our past cognition, it is generally believed that protecting the forest from deforestation means protecting the environment. But have you ever thought that proper deforestation can better protect the environment?

As we all know, the Amazon rainforest is one of the largest forests. But in fact, the early local government did not adopt a good policy to prevent deforestation, and it was not until more and more deforestation people were forced to introduce relevant policies. In fact, the carbon sequestration in the Amazon forest in the early stage has not been reduced, but is steadily increasing, and the surrounding economy is also increasing steadily. Why is this?

In fact, this is closely related to the deforestation rate. After fitting, we obtained the relationship between the deforestation rate and the increase in carbon sequestration. The increase in carbon sequestration first increased and then decreased with the increase of x. When the increase in carbon sequestration was at its maximum, the deforestation rate was 28%, which we call the "golden deforestation rate".

The growth and development of trees requires certain nutrients and natural conditions, and when the forest develops for a long time, the older trees that have grown for a long time will more easily absorb nutrients from the land because of their deep roots; Blocking out the sunlight that other younger trees need, etc., stifles the growth of younger trees. So we need to clear the forest.

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Then some people will wonder, if the living old trees are cut down, doesn't it reduce the carbon fixed in the forest? In fact, not only living trees can fix carbon, but the products derived from the trees themselves are also a way of fixing carbon. The felled trees are not "wasted", but continue to play them in the form of "wood products". carbon sequestration until it is discarded and returned to the atmosphere in the form of carbon dioxide. And because the old trees are cut down, the young trees that get enough nourishment will start to grow vigorously, thus carrying out a new round of carbon sequestration cycle.

In addition, the carbon sequestration capacity of trees gradually declines from the prime period to the old age. If the old trees are cut down, more young trees will grow into the prime-age trees, and the prime-age trees will also receive more sunlight and nutrients. The absorption of carbon dioxide is completed at a faster rate.

Similarly, when trees grow too densely, competition between trees for sunlight, nutrients and other resources will also occur, which in turn affects the growth of trees. At this time, we should cut down the densely growing trees properly, so that the remaining trees can grow better and play a better carbon sequestration efficiency.

Therefore, we cannot simply think that deforestation is destroying the environment. Appropriate deforestation of forests is conducive to the development of forests and is also beneficial to our environment.

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