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Forest Planning Model And Decision Based on EWM-AHP

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Abstract: In recent years, the impact of global climate change on people's life and survival has gradually increased. Reasonably calculate the forest carbon sequestration stock, formulate the best forest management plan and improve the forest value. In order to study the carbon sequestration reserves of forest, we established CARFP model. By studying the Longmen River Valley Forest in Chun'an City, the forest production equation was obtained We knew that the carbon sequestration of the forest in recent one year. Compared the forest carbon sequestration stocks under various forest management methods, and defined the optimal management strategy of the forest; Meanwhile, in order to make a comprehensive decision on the best forest management, we establish an AHP-EWM combined evaluation model, establish nine indicators from the three dimensions of economy, ecology and society to evaluate the forest value, and build constraints, establish a single objective programming model, and make decisions on the forest management plan. These models are applicable to any forest and have a wide range of objects, which have great practical value.

Keywords: Carbon Sequestration Model; CARFP Model; AHP-EWM; The Single Objective Programming Model

1. Introduction

Global climate change is a hot environmental issue of widespread concern to the international community. Due to the impact of human activities, the emissions of greenhouse gases such as carbon dioxide, water vapor and nitrous oxide have increased sharply. In order to better reduce greenhouse gas emissions, we need to use carbon capture and storage[1]. In carbon sequestration, the biosphere stores carbon dioxide in plants (especially large plants), soil and water environment. Therefore, forests are an integral part of any effort to mitigate climate change.

Based on this background, many scholars have studied and discussed forest carbon sequestration and forest management plan. These documents clarify the changes of forest trunk cumulative biomass and harvested biomass in China under different climate,CO_2 concentration changes and management measures[2]; The average carbon sequestration rate is different in different places and at different times, which is related to the increase of the length of the growing season[3]; Forest development and wood use should not only meet technical, economic, social or social needs. Therefore, we need to consider various demand conditions when formulating forest management plans[4].

2. The Carbon Sequestration Model

In order to measure the carbon dioxide storage in forests over a period of time, after understanding the framework of CRAFT model[5], we introduced a new index(CA), to measure the carbon storage capacity of forests.

2.1 Calculation of Natural Carbon Sequestration

Taking Masson Pine in Chunan Longmen Valley Forest as an example, we collected the growth data of Masson Pine in the study area.

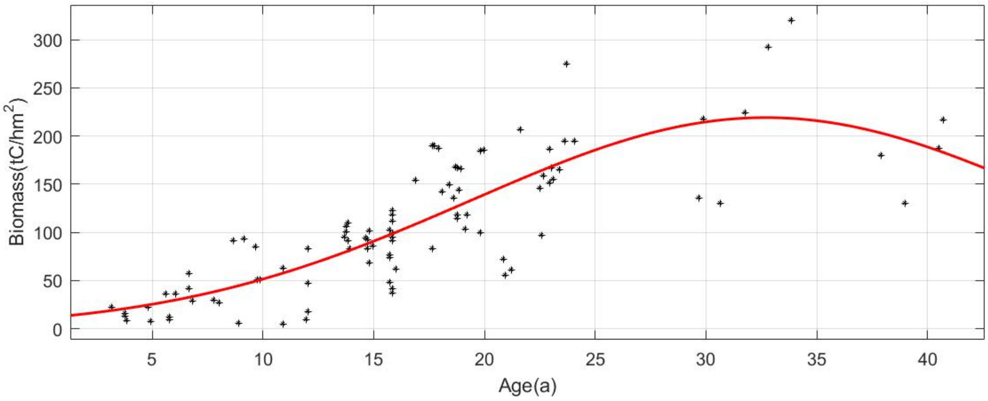

Figure 1: Forest growth model of Masson Pine

- The average tree-age of Masson Pine in this area is as follows:

$$A_m = \frac{1}{S_m}\sum_{n=1}^{5} S_n A_n \qquad \text{* MERGEFORMAT (1)}$$

S_m represents the total area of Masson Pine, S_n is the area of a certain age class of Masson Pine, A_n represents the median value of the corresponding age class.

- The stand density of Masson Pine is as follows:

$$S\% = \frac{B_i}{B} \qquad \text{* MERGEFORMAT (2)}$$

B_i represents the actual biomass estimated based on forest inventory data; B represents the simulated biomass.

Finally, through figure1 and formula (1) (2), the **natural carbon sequestration** can be calculated as follows:

$$\mathrm{CA_m} = \left[a \cdot e^{-\left(\frac{t+A_m-b}{c}\right)^2} - a \cdot e^{-\left(\frac{A_m-b}{c}\right)^2} \right] \cdot S\% \cdot S_m \qquad \text{* MERGEFORMAT (3)}$$

The main tree species of Chunan Longmen Valley Forest in this area are Masson Pine, Chinese fir, broad-leaved forest and slash pine. After data sorting and calculation, we finally get the following table:

Table 1: Situation of different tree species

Tree species	Average tree-age	Stand density of the tree species	Area (hm^2)	CA
Masson Pine	14	49	378.89	116711
Chinese fir	14	46	257.63	102544
broad-leaved forest	19	57	259.54	175655
slash pine	8	51	287.91	67928

2.2 Influence of Different Management Measures

The common management measures in Chunan Longmen Valley Forest are: **pure forest intercropping, thinning and tending, scientific fertilization**.

By the simulations and calculations, we get that:

Table 2: Effects of different management measures on forest carbon sequestration

The Management Measure	CA of natural carbon sequestration	CA of carbon sequestration of forest products	CA
Pure forest intercropping	138850	20094	158944
Thinning and tending	123619	21099	144718
Scientific fertilization	128726	20094	148820

Therefore, for Masson Pine, it is better to adopt the method of pure forest intercropping, and the ability to increase carbon dioxide sink is the greatest.

3. Single Objective Programming Decision Model based on EWM- AHP Comprehensive Weighting

3.1 Indicator Selection

Based on literature survey and multi-angle thinking of our team, we divided the forest value into three levels: economic value (EMV), ecological value (EGV)and social value (SCV), and constructed evaluation indicators.

Wood Products：

$$V_1 = S \times M - B$$ * MERGEFORMAT (5)

V_1 is the value of wood products. S is the total forest area, M is the average price of trees sold after processing per unit area, B is the total processing cost.

Energy：

$$V_2 = \mu \times S \times P$$ * MERGEFORMAT (6)

V_2 is the value of forest energy, μ is the reclamation rate of forest energy (%), S is the total forest area, P is the price of unit area after reclamation of forest energy.

Species Gene Resources：

$$V_3 = S \times (\sum_i^n N_i \times M_i)$$ * MERGEFORMAT (7)

V_3 is the value of genetic resources of species. S is the total forest area. N_i is the number of a species resource per unit area, M_i is the unit price of a species resource.

Carbon Sequestration：

$$\mathrm{CA_m} = \left[a \cdot e^{-\left(\frac{t+A_m-b}{c}\right)^2} - a \cdot e^{-\left(\frac{A_m-b}{c}\right)^2} \right] \cdot S\% \cdot S_m$$ * MERGEFORMAT (8)

The meanings of the above variables are explained in detail in the carbon sequestration model and will not be repeated here.

Biodiversity：

$$V_5 = \sum S_i \times M_i$$ * MERGEFORMAT (9)

V_5 is the value of biodiversity maintained by forest, S_i is the forest area at grade i,M_i is the value of biodiversity per unit area of Shannon-Wiener index at grade i .

Forest Environment ：

Water Conservation：

$$V_6 = W \times (1 - K) \times S \times P$$ * MERGEFORMAT (10)

V_6 is the value of water conservation, W is the average annual precipitation(mm), S is the total forest area, K is the evaporation coefficient (%), P is the local water price in the assessed area. In the formula, $W \times (1-K) \times S$ is the total amount of water resources retained by forest.

Soil Improvement:

$$V_7 = S \times D \times T \times P \quad \text{* MERGEFORMAT (11)}$$

V_7 is the value of soil consolidation and silting reduction, S is the total forest area, D is the difference of soil erosion modulus between forested and non-forested areas, T is the ratio of sediment transport (%), P is the cost of silting.

Tourism and Entertainment:

$$V_9 = N \times A \times \frac{P}{Q} \quad \text{* MERGEFORMAT (12)}$$

V_9 is the value of tourism and entertainment. N is the number of forest tourists, A is the travel cost of each tourist, P is the number of good comments given by tourists, P is the total number of comments given by tourists.

Employment:

$$V_{10} = V_1 + V_2 + V_3 + N \times (M_1 - M_2) \quad \text{* MERGEFORMAT (13)}$$

V_1.V_2.V_3 is the economic value of forests, N is the number of newly employed people, M_1 is the average consumption level of each person after employment, M_2 is the average consumption level of each person before employment.

Culture:

$$Vg = \sum_{i=1}^{n} Vgt_i \times \alpha_i \times G_i \quad \text{* MERGEFORMAT (14)}$$

Vg is the value of forest culture in garden area within one year (CNY), Vgt_i is the physical quantity of cultural value (CY) of gardens in the region I; G_i is per capita GDP or PCDI(CNY) in the region where the garden is located. α_i is the comprehensive index coefficient of forest cultural value.

3.2 Calculation of Index Weight

3.2.1 Weighted model based on Analytic Hierarchy Process

In order to evaluate the forest value more reasonably, we calculate the corresponding weights of9 indexes determined above through subjective and objective weights (AHP is used for subjective method, EWM is used for objective method).Three secondary indicators were taken as examples for comparison. The comparison matrix is shown in Table 6.

Table 3: comparison matrix

M-P	Economic Value	Ecological Value	Social Value
Economic Value	1	0.5	5
Ecological Value	2	1	4
Social Value	0.2	0.25	1

We can calculate the weight vector V1= [0.329, 0.523, 0.148]. In consistency check, we calculate the consistency index (CI = 0.0416 < 0.10), which means that the weight determined by AHP is reasonable and credible.

3.2.2 Weighted model based on Entropy Weight Method (EWM)

Step 1 Data normalization

$$x'_{ij} = \frac{x_{ij} - \overline{x}_j}{S} \quad \text{* MERGEFORMAT (15)}$$

Step 2 Calculate probability matrix *P*

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} (j = 1, 2, ..., m) \quad \text{* MERGEFORMAT (16)}$$

Step 3 Calculate information entropy

$$e_j = -K \sum_{i=1}^{m} y_{ij} \ln y_{ij} \quad \text{* MERGEFORMAT (17)}$$

Step 4 Calculate the weight of j-th index

$$w_j = \frac{1 - e_j}{\sum_j 1 - e_j} \quad \text{* MERGEFORMAT (18)}$$

3.2.3 Weighted Combination of AHP and EWM

We combine AHP and EWM methods, using the Mon formula, the weighted sum of the results obtained by the two methods. The result is a comprehensive consideration of sub- jective and objective indicators ofthe weight vector.

$$\omega_{\text{total}} = \beta \cdot \omega_{AHP} + (1 - \beta)\omega_{EWM} \quad (0 \leqslant \beta \leqslant 1) \quad \text{* MERGEFORMAT (19)}$$

The weight index results are as following Table X:

Table 4: Index weights

Indicator(Ⅰ)	Indicators(Ⅱ)	Weights	Indicators(Ⅲ)	Weights
FRV	Economic Value (EMV)	0.329	Wood Products	0.453
			Energy	0.317
			Species Gene Resources	0.230
	Ecological Value (EGV)	0.523	Carbon Sequestration	0.462
			Biodiversity	0.395
			Forest Environment	0.143
	Social Value (SCV)	0.148	Tourism	0.463
			Employment	0.170
			Culture	0.367

3.3 Determining optimal forest management plans based on single objective programming model

• **Objective Function**

With the help ofthe weight ofeach index obtained from the evaluation system, the maximization offorest value is the objective function. The formula is as follows:

$$\max \ \alpha_1 \cdot EMV + \alpha_2 \cdot EGV + \alpha_3 \cdot SCV \quad \text{* MERGEFORMAT (20)}$$

- **Constraint Condition**

While maximizing the forest value, we also need to ensure that the income does not de- crease over time. The formula is as follows:

$$\Delta FRV_k \geqslant 0 \qquad \text{* MERGEFORMAT (21)}$$

Where k is the number of years after the implementation of forest management plan, and FRV is the forest value in the evaluation system.

For the amount of felling *x,* the maximum felling area shall not exceed the existing forest area:

$$0 \leqslant x \leqslant S_j \qquad \text{* MERGEFORMAT (22)}$$

To sum up, the decision model of forest management plan based on single-objective programming is established as follows:

$$\max \alpha_1 \cdot EMV + \alpha_2 \cdot EGV + \alpha_3 \cdot SCV$$

$$\begin{cases} \Delta FRV_k \geqslant 0 \\ 0 \leqslant x \leqslant S_j \end{cases} \qquad \text{* MERGEFORMAT (23)}$$

4. Conclusion

By constructing carbon sequestration model, CARFP model, AHP-EWM model and single objective programming model to analyze forest carbon sequestration, we draw the following conclusions:

The carbon sequestration of Longmen River Valley Forest in Chun'an in recent one year is 543403 (TC); Moreover, the forest should implement pure forest intercropping (the proportion of dominant species is about 75%), and the tree age should be maintained between 18-20 years.

Through the weighted decision-making model considering the natural value, economic value and social value of forest, we find that, the total value of forest will have an inflection point. At this time, deforestation will maximize the value of forest, and this inflection point can determine the optimal rotation cycle of forest.

The models considers the diversity of carbon absorption, and makes scientific decision with the help of comprehensive evaluation indicators to ensure the scientific rationality of decision-making. At the same time, the model we built is applicable to any forest and has a wide range of objects, which is of great significance.

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