

Research on forest management plan based on forest ecosystem carbon sequestration model (FCSM) and forest value assessment model (FVM)

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Abstract: Firstly, a model for measuring carbon sequestration is established based on vegetation, soil and forest products. Due to the influence of different forest geographical characteristics, climate and tree growth cycle, the model is modified. The time series prediction model is used to predict China's forest carbon sequestration in 2030. Finally, the FVM model is developed. The combination weighting method is used to calculate the weight vector. The specific score of forest value is calculated by GCA (grey correlation analysis). Then the evaluation criteria are obtained by using k-means clustering algorithm.

Keywords: Carbon sequestration, time series prediction, GCA, k-means clustering algorithm

1. Introduction

In recent years, as people are increasingly worried about climate change caused by the increase of carbon dioxide concentration in the atmosphere, reducing the amount of greenhouse gases in the atmosphere has aroused great interest.

It is precisely because some wood products live longer than trees themselves and absorb more carbon dioxide. Therefore, on a global scale, moderate logging is conducive to carbon sequestration, while excessive logging is the opposite. Therefore, forest managers need to consider all aspects and find a balance between the development of forest products and the sustainable growth of forests.

2. Establishment Model

2.1. Establishment FCSM

The biosphere sequesters carbon dioxide in plants (especially large plants such as trees), soil and water environment. In order to determine the carbon sequestration capacity of forest and its products, the carbon sequestration capacity was calculated from three aspects: forest vegetation, soil and forest products.

Define the formula for calculating carbon emissions (in years):

$$CS_t = P_t + S_t + FP_t \quad (1)$$

Where, P_t is the total carbon sequestration of vegetation in forests in year t ; S_t is the total carbon sequestration of soil in the forest in year t ; FP_t is the total carbon sequestration of forest products in year t .

The calculation formula of vegetation carbon sequestration is as follows [1]:

$$P_t = \frac{\sum_{i=1}^n PC_{i,t} \times Area_{i,t}}{\gamma} \quad (2)$$

Where, $PC_{i,t}$ represents carbon sequestration density of arbor layer vegetation in forest of i age in year t . $Area_{i,t}$ represents the area of vegetation of i age in year t . γ represents ratio of tree layer biomass to total biomass.

The calculation formula of soil carbon sequestration is as follows [2]:

$$S_t = \sum_{i=1}^n SC_{i,t} \times Area_{i,t}, SC_{i,t} = \alpha T \rho \quad (3)$$

Where, $SC_{i,t}$ is the carbon storage per area of i soil type in year t . $Area_{i,t}$ is the area of soil type in the region in year t . α is conversion factor. T is mean soil thickness. ρ is average bulk density of soil.

If the amount of wood carbon stored by forest products is greater than that released in a certain year, forest products will become an important carbon sink and coping strategy to reduce greenhouse gas emissions [3].

$$FP_t = \sum_{i=1}^n FPC_{i,t} \times Vomult_{i,t}, FPC_{i,t} = Input_{i,t} - Output_{i,t} \quad (4)$$

Where, $FPC_{i,t}$ is net carbon sequestration of forest product i in year t . $Vomult_{i,t}$ is the amount of forest product i in year t . $Input_{i,t}$, $Output_{i,t}$ represents the carbon absorption or emission of forest product i in year t .

Managed forests have greater carbon benefits than unmanaged forests [4], because we can take corresponding management measures to improve the carbon content in vegetation, soil and forest products, so as to increase the carbon sequestration of forest ecosystem. The forest management strategy is shown in Figure.1.

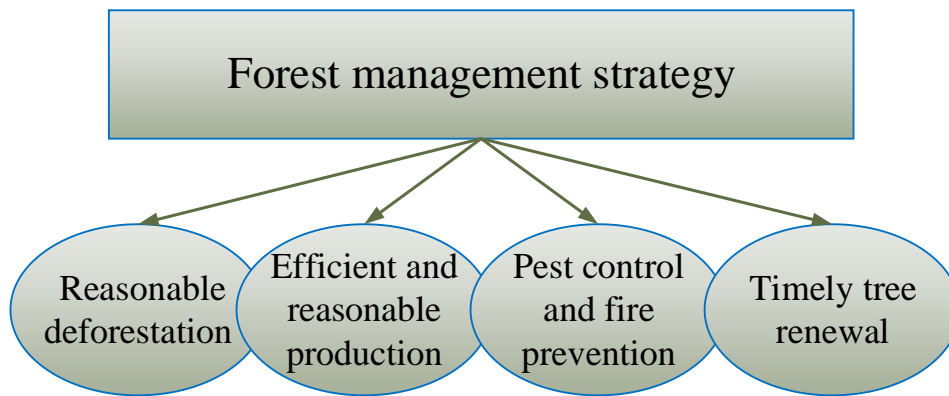


Figure 1: The forest management strategy

Using the above methods, we take the young forest, medium mature forest, near mature forest, mature forest and mature forest in China's forest ecosystem as examples, estimate the carbon fixation density of forest vegetation and the system type of plant carbon storage according to the corresponding forest type area in China's forest ecosystem, and finally obtain the carbon capacity of forest ecosystem of existing plants in China (Figure. 2,3).

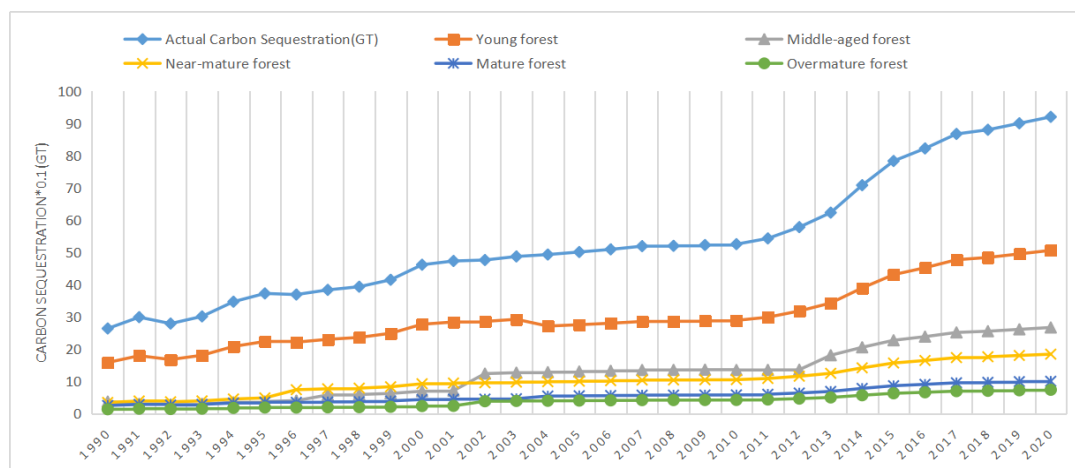


Figure 2: Time series diagram of each tree age and total carbon sequestration capacity



Figure 3: Time series diagram of vegetation carbon sequestration

For carbon sequestration in soil, we first calculate the carbon content of each soil layer of each soil type, and take the area and soil thickness as the weight coefficient to obtain the average thickness and average bulk density. Then, according to (1), the carbon sequestration capacity of forest soil can be calculated (Figure. 4).

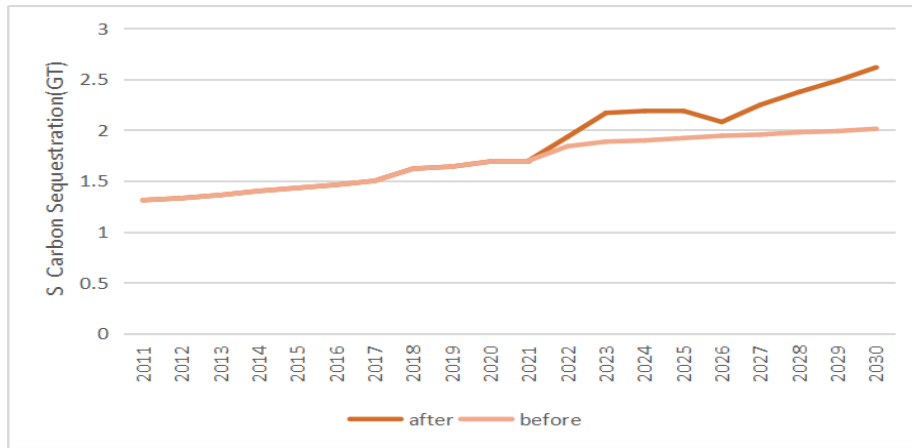


Figure 4: Time series diagram of soil carbon sequestration

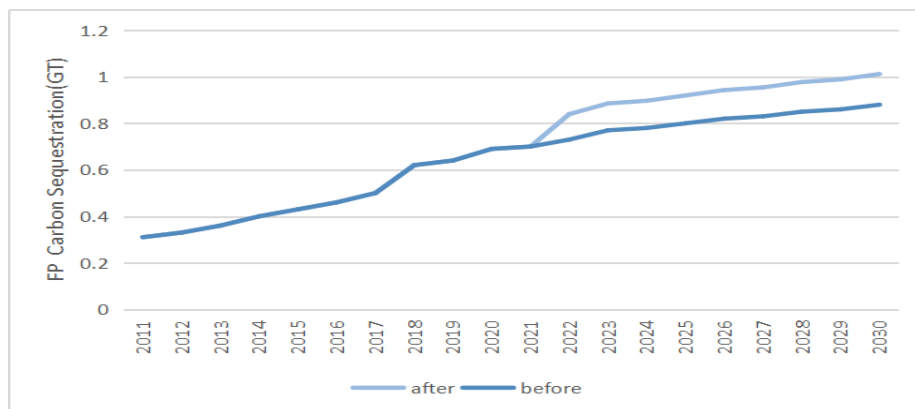


Figure 5: Time series diagram of carbon sequestration of forest products

The time series prediction method is used to predict the carbon sequestration before and after the application of the forest management plan we proposed in Figure. 4. When our plan is applied, carbon sequestration increases faster and more carbon is sequestered than when it is not controlled (Figure. 2,3,4).

The geographical distribution of carbon sequestration in China is mainly concentrated in the Northeast Plain and southern China, where the terrain is mild, the rainfall is sufficient and the soil is fertile, which is conducive to forest growth and carbon sequestration. However, at present, the total

amount of forest resources in China is obviously insufficient, the quality is low and the distribution is uneven. Choosing appropriate forest management strategies can significantly improve this situation (Figure.1).

2.2. Establishment FVM

The combination weighting method is used to determine the weight. The methods to determine the weight mainly include subjective weighting method and objective weighting method (Table 1).

The grey correlation coefficient reflects the closeness of each evaluation object to the ideal object. The larger the correlation coefficient is, the better the evaluation index is [5].

$$U_0 = (u_{01}, u_{02}, \dots, u_{0m}) \tag{5}$$

$$\varepsilon_{ik} = \frac{\min_i \min_k |x_{0k} - x_{ik}| + \rho \max_i \max_k |x_{0k} - x_{ik}|}{|x_{0k} - x_{ik}| + \rho \max_i \max_k |x_{0k} - x_{ik}|} \tag{6}$$

Where, x_{0k} refers to the value of the kth index of the sequence, x_i compares the value of the kth index in the sequence. $\rho \in [0, 1]$ is the resolution coefficient, generally take 0.5, the greater the ρ , the greater the resolution.

The correlation coefficient matrix is obtained:

$$\varepsilon = (\varepsilon_{ij}^k)_{n,m} \tag{7}$$

According to the correlation coefficient and the optimal combination weight, the forest value score *FV* was determined.

$$FV = \varepsilon W_j \tag{8}$$

The K-means clustering method will be used to set reasonable standards, and the forest value standard (FV) will be divided into four levels: excellent, good, medium and poor.

The standard of FV is obtained. For each index, 20 forest data were first clustered to calculate 4 grade centers. Then the mean value of the index center is taken as the standard boundary. Criteria for forest values are shown in Figure. 5.

The higher the index score, the better the situation. According to the current score, the corresponding forest management strategy can be put forward. If the sustainable value (SU) score is lower than 0.12869 and the economic (EC) and social (SO) scores are good, it indicates that the ecology is extremely deteriorated and does not affect its economic benefits and social value.

From our model, we can find that EC, SU and so values have obvious transition points from poor to medium, from medium to good, and from good to excellent. Obviously, each forest is in different stages, and its management plan will inevitably be different.

Table 1: Weighted graph of evaluation model

Indicator	Primary Indicator and Weight	Indicator	Primary Indicator and Weight
Economic	Value of forest products (33.79%)	Social (28.28%)	Value of scientific research and education (17.21%)
	Value of fuel products (33.36%)		Natural and cultural heritage value (18.30%)
	Annual net growth value of each tree (32.86%)		Commercial tourism value (25.06%)
	Regulating climate function (16.38%)		Carbon fixation and oxygen production (25.08%)
Sustainable (32.97%)	Purification function (15.99%)		
	Maintain biodiversity functions (17.83%)		Protection against natural disasters (24.37%)

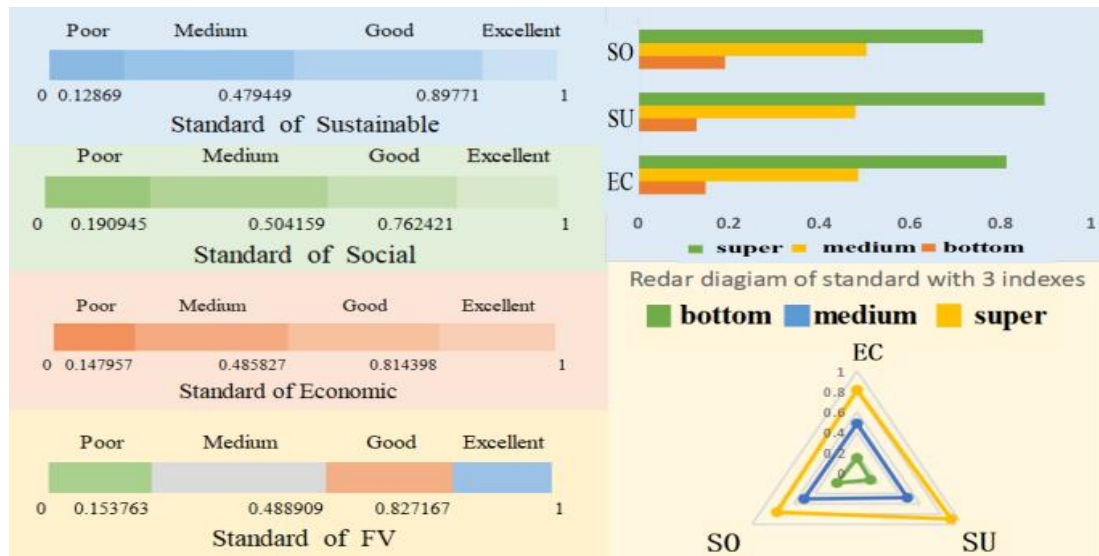


Figure 6: Criteria for forest values

3. Promotion and evaluation of the model

The evaluation index system is complete. We considered 100 factors to determine 13 relatively independent metrics, reducing the impact of redundancy factors. The model is objective. The number of indicators is small, easy to calculate, and the evaluation results are visually represented in grades has integrity.

However, the climate and terrain we considered were relatively simple, without considering the specific characteristics of each forest, and when the model was applied to different forests, the results would produce certain deviations.

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