Forest Value and Management Plan: A Development Guidance Report for Forest in Different Countries

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Abstract. Forests are an important part of natural resources. Forest management is a management science integrating ecological, social and economic benefits. To tackle the problem of calculating carbon sequestration,the Forest Volume Method and InVEST model are good choices.Firstly, we collected forest data of 35 countries and carried out data pre-processing. After calculating carbon sequestration, we used a more intuitive world map to show the result. For the purpose of determining optimal forest management plan, we introduce a new indicator: Characteristics and Location of Forest index(CLF) to represent the characteristics of the country's basic forest resources. We use the coordinate (FVI, CLF) and the distance d to reflect the level of forest resources and forest management capacity.

Keywords: Carbon Sequestration, Transition strategy, Grey Model.

1. Introduction

The greenhouse effect caused by human activities and the impact of the global climate change on the global ecological environment are attracting more and more attention. Enhancing forest carbon sequestration capacity is one of the goals of sustainable development of forest resources, and it is of great significance in achieving global climate change goals [1].

Forest is the most widely distributed vegetation system on land, accounting for about 31% of the global land area, and about 77% of the carbon in the global terrestrial carbon pool is stored in forest ecosystems. Various ecological functions of forests play an irreplaceable role in slowing down global warming [2]. Forest management is an important factor affecting forest carbon sequestration [3], and forest harvesting management is one of the core contents of forest resource management. A good forest logging management system can effectively promote sustainable forest management, protect forest resources, and arouse the enthusiasm of forest managers [4].

2. Assumptions

In order to simplify the model, we make the following assumptions:

- **Assumption 1:** Carbon sequestration range
- **Assumption 2:** When GM (1,1) grey forecasting model and power function model are used for forecasting, the influences of external factors such as economic development and policy changes are not taken into account.
- **Assumption 3:** There will be no super-large forest fires or large-scale human activities destroying the environment.
- **Assumption 4:** The overall forest value is only related to our evaluation indicators.
- **Assumption 5:** The data we collect is accurate.

3. Carbon sequestration model

3.1. Forest carbon stock calculation

The calculation methods of forest carbon stock include biomass method, stock volume method[5], carbon density method, and carbon balance method [6]. Considering the practicability and operability of the calculation method, this study mainly uses the Forest Volume Method to measure carbon storage. The method is scientific to a certain extent, and the calculation results are very close to the actual carbon storage monitoring data of the Food and Agriculture Organization of the United Nations (FAO). It has certain accuracy and credibility. This method is mainly used in this research to measure carbon stock.

The specific calculation formula of stock volume method is:

$$TC_F = S_i C_i + \alpha S_i C_i + \beta S_i C_i \tag{1}$$

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

In the formula: TC_F is the carbon stock of forest resources, S_i is the area i th forest, C_i is the i th carbon density of forest, V_i is the stock volume per unit area of the type i forest, α is the carbon conversion factor understory plants, β is the carbon conversion factor of forest land, δ is the biomass expansion factor, ρ is the biomass volume converted to biomass dry mass factor, scilicet Bulk Density, γ is the coefficient of converting biomass dry mass into carbon sequestration, namely the carbon content rate. And $V_f = S_i V_i$ is the total stock volume.

Therefore, the above formula (1) can be further transformed into:

$$\begin{aligned} TC_F &= S_i C_i + \alpha S_i C_i + \beta S_i C \\ &= V_f \delta \rho \gamma + \alpha V_f \delta \rho \gamma + \beta V_f \delta \rho \gamma \\ &= (1 + \alpha + \beta) V_f \delta \rho \gamma \end{aligned} \tag{3}$$

Generally, the formula for calculating forest carbon stock is:

$$TC_W = V_f \delta \rho \gamma \tag{4}$$

3.2. Introduction of new indicator: CSC

Based on the above model, we introduce a new indicator: Carbon Sequestration Coefficient per unit area (CSC) to represent a country's level of forest management.

Formula (5) can be used to calculate the Carbon Sequestration Coefficient per unit area (CSC).

$$\rho_c = \frac{TC_F}{S_i} \tag{5}$$

In the formula: p_c is the carbon sequestration coefficient per unit area; TC_F is the carbon stock of forest resources; and S_i is the area of the forest.

CSC is the premise and key of forest management decisions. Increasing CSC is an effective way to improve forest carbon sequestration under the condition that forest area is not easy to change. Through the improvement of effective forest management level, it is feasible and necessary to further

increase forest carbon sequestration per unit area and expand carbon sequestration supply capacity. Therefore, in this paper, forest carbon sequestration per unit area (CSC) is used as the measure of current forest management level and carbon dioxide sequestration.

Based on carbon sequestrations, we calculate carbon sequestration coefficients per unit area for 35 countries located in three temperature zones.The figure below gives a more intuitive picture of the CSC.

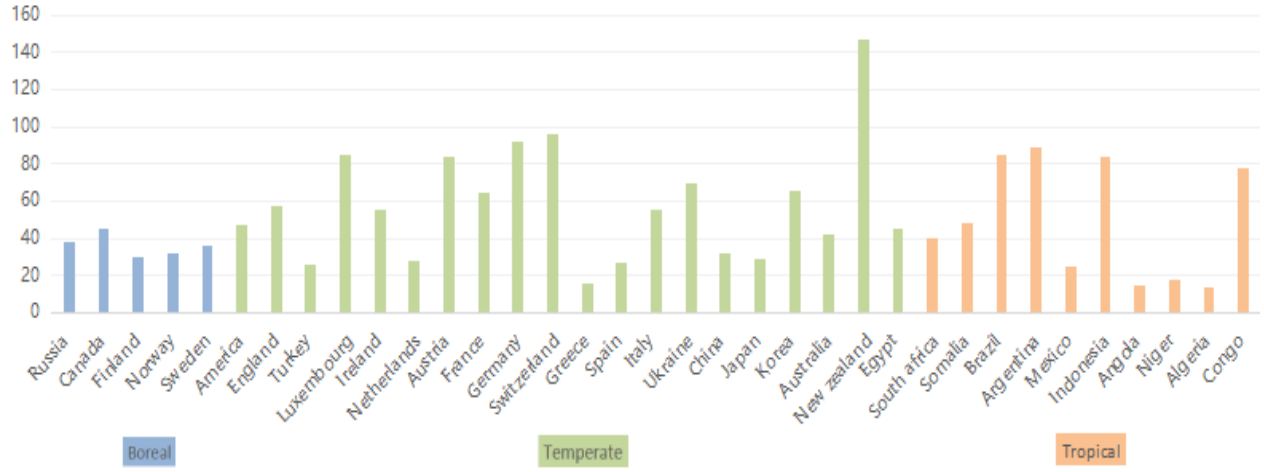


Figure 1. CCS of 35 countries

3.3. Prediction model

Grey model can establish grey differential prediction model through a small amount of incomplete information, and make a fuzzy long-term description of the law of development of things [7]. Considering the uncertainty of external factors, the GM (1,1) grey model is adopted in the study. Meanwhile, in order to make the results of the model more reliable, the "S" of the biological growth process is studied according to the data scatter diagram.Curve, construct Power Function Model ($y = ax^b$) for prediction and comparative analysis.

The basic principle of GM (1,1) grey prediction model is to construct the differential equation of first order of variables to time, and its corresponding differential equation is as follows:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \tag{6}$$

In the formula: $x^{(1)}$ is the sequence generated by the original data $x^{(0)}$ after one accumulation; t is the time variable; a and u are called evolution parameter and gray action respectively. The steps are as follows.

Let the raw number be listed as: $x^{(0)} = \left(x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \cdots, x^{(0)}(n)\right)$;do a cumulative, generate accumulative sequence $x^{(1)}$. $x^{(1)}(t) = \sum_{m=1}^{t} x^{(0)}(m) \quad t = 0,1,2,\cdots,n$.

To solve the mean value sequence, formula $z^{(1)}(t) = \frac{1}{2}\left[x^{(1)}(t) + x^{(1)}(t+1)\right]$ was used to calculate the mean value sequence, and the first-order linear differential equation $\frac{dx^{(1)}}{dt} + ax^{(1)} = u$ was established. The least square method was used to solve it, and the undetermined coefficients a and u of the grey GM (1,1) model were estimated to obtain the time response function of grey GM (1,1):

$$x^{(1)}(t+1)=\left(x^{(0)}(1)-\frac{u}{a}\right)e^{-at}+\frac{u}{a} \tag{7}$$

The predicted value is solved by the back time response function:

$$x^{(0)}(t+1)=x^{(1)}(t+1)-x^{(1)}(t), t=0,1,2,\cdots n \tag{8}$$

Model test, residual test and a posteriori test. Relative error is generally considered satisfactory within 5%, qualified within 10%, and unqualified above 10%. Generally speaking, a posteriori C (variance ratio) is considered to be less than 0.35 for good prediction accuracy, less than 0.5 for qualified, less than 0.65 for basically qualified, and greater than or equal to 0.65 for unqualified.

4. Forest Value Assessment Model

The inferior indicators need to be normalized into the range of [0,1]. Meanwhile, the inferior indicators need to be transformed to the benefit-type indicators which means that the larger the better. We use different normalization methods to normalize different kinds of indicators according to their characteristics. These methods include the logistic function, the maximum normalization method, the moderate normalization method, the minimum normalization method and the subordinate function of fuzzy mathematics. We are going to show the applications of each method we use.

- **Logistic function**

$$y=\frac{1}{1+e^{-b(x-x_0)}} \tag{9}$$

Where is y the normalized indicator; x is the original indicator; x_0 is the minimum standard of the indicator; b is a parameter to control the climbing speed of the normalization function. The value of b will be determined in the solution of model.

- **Maximum normalization method**

$$x'=\frac{x}{x_{\max}} \tag{10}$$

Where $x_{\max}$ is the maximum of the indicator.

- **Minimum normalization method**

$$x'=\frac{\left|x-x_{op}\right|}{\max\left\{\left|x_{\max}-x_{op}\right|,\left|x_{\min}-x_{op}\right|\right\}} \tag{11}$$

Where x_{op} is the optimal value of the indicator.

- **Normalization of Inferior Indicators**

$$\{Awful, Bad, Normal, Good, Excellent\}=\{1,2,3,4,5\} \tag{12}$$

The partial large Cauchy distribution membership function is determined as:

$$f(x)=\begin{cases}\dfrac{1}{1+\dfrac{a}{(x-b)^2}} & ,1\le x<3\\ c\ln x+d & ,3\le x<5\end{cases} \tag{13}$$

We set that when the grade value is 1, the membership grade should be 0.01; when the grade value is 3, the membership grade should be 0.8; when the grade value is 5, the membership grade should be 1. Here, the parameters of the partial large Cauchy distribution membership function can be determined as:

$$\begin{cases}a=1.1086, b=0.8942\\ c=0.3915, d=0.3699\end{cases} \tag{14}$$

Using these normalization methods, all the inferior indicators can be normalized. The normalized data form a Y matrix. Here we omit the detailed methods for each inferior indicator.

We selected 35 countries with different continents and different development situations as research objects to calculate their FVI.

We use TOPSIS comprehensive evaluation method to evaluate FVI of 40 countries, and obtain the FVI scores of 35 countries. The higher the score, the more abundant the forest ecological system. We collect data from 35 countries and calculate.

From the above calculations we can get a standardized Y matrix, and now we determine the optimal scheme and the worst scheme for each indicator:

$$\begin{aligned}Y^+&=\left(\max\left\{y_{11},y_{21},...,y_{n1}\right\},\max\left\{y_{12},y_{22},...,y_{n2}\right\},...,\max\left\{y_{11},y_{21},...,y_{n1}\right\}\right)\\&=\left(Y_1^+,Y_2^+,...,Y_m^+\right)\end{aligned} \tag{15}$$

The worst scheme Y^+ composed of the maximum value of each column element in the Y :

$$\begin{aligned}Y^-&=\left(\max\left\{y_{11},y_{21},...,y_{n1}\right\},\max\left\{y_{12},y_{22},...,y_{n2}\right\},...,\max\left\{y_{11},y_{21},...,y_{n1}\right\}\right)\\&=\left(Y_1^-,Y_2^-,...,Y_m^-\right)\end{aligned} \tag{16}$$

Calculate the proximity of each indicator to the optimal scheme and the worst scheme:

$$D_i^+=\sqrt{\sum_{j=1}^{m}w_j\left(Y_j^+-y_{ij}\right)^2} \tag{17}$$

$$D_i^-=\sqrt{\sum_{j=1}^{m}w_j\left(Z_j^--z_{ij}\right)^2} \tag{18}$$

Calculate the closeness of each indicator to the optimal scheme:

$$FVI_i=\frac{D_i^-}{D_i^++D_i^-} \tag{19}$$

The higher the FVI_i score, the more effective and sustainable the country's forest management plan.

5. Forest management plan

5.1. Spectrum of optimal forest management plan

In order to make pre-established forest management plans fully effective, we have considered in depth the scope of application of best forest management plans.

In the 35 countries we selected, the least forested country was Congo, with 44,980 hectares; The country with the largest forest area is Russia, whose forest area is 8,153,116,000 hectares. It can be seen that the forest management plan we studied is more suitable for larger forests. Forests are too small to design long-term forest management plans as a whole.

The tree species involved in the optimal forest management plan are mainly conifers and broad-leaved trees with a large number, which can provide human beings with a common number of forest products and forest by-products, and trees with great ornamental value, cultural value, and tourism value, such as the millennium ginkgo. Trees etc. are outside the scope of the discussion of the best forest plans we have studied.

5.2. Rotation

Rotation is the management cycle of same-age forests. In terms of a business unit, rotation period refers to a depleted after the whole business unit mature forest, to test the time required for cutting mature forest branch office again for a stand, rotation period is refers to afforestation, forest, deforestation[8], the time required to update and wheel generation period is the same age Lin operating cycle: suitable operation method to clear cutting operation: update the way for artificial regeneration; The stand formed is still the same age stand. The rotation period is determined mainly on the basis of forest maturity and regeneration. The rotation period of timber stands is based on technological maturity and focuses on economic maturity and gives proper consideration to quantitative maturity.

Adopt appropriate rotation period, have the following two main benefits. The first is that proper logging can not only provide forest products and forest by-products for human beings, but also forest products have better carbon sequestration function [9], so that the number can grow better. The other is that wood can replace plastics, steel and concrete, which use a lot of fossil fuels and emit a lot of carbon dioxide in their manufacture [10]. Banning logging is therefore counterproductive, not only in helping to tackle global warming, but also in increasing carbon dioxide emissions in the long run. The scientists suggest cutting down timber from economic forests that have not been attacked by pests and diseases. At the same time, new trees are planted so that the new ones absorb the carbon dioxide released by the dead ones, thereby balancing the forest ecosystem. In general, there are no conditions that can prevent forests from being cut down except for ancient trees with high cultural tourism value.

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