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Forest Value Model based on carbon sequestration theory

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Abstract

Carbon sequestration is a biosphere method to sequester carbon dioxide, and forests are indispensable carbon sequestration carriers. Carbon dioxide is sequestered in live plants and forest products. Forest managers must strike a balance between the value of forest products and the carbon sequestration capacity of living plants. We use the relationships among the tree growth law, carbon sequestration,According to different types, we choose two forests: the Shirakami Mountains in Japan and the Lesio-louna Forest in Congo. A forest value model is established. We determine the weight of indicators using the Combination Weighting Method. Two aspects, ecology and climate change, are taken as environmental indicators, and the other two are taken as social indicators. The value of the Shirakami mountain forest in Japan is 0.7651, while the value of the Lesio-louna forest in Congo is 0.6351. When the social index is higher than 0.5, the forest is in a state of uncutability. When the environmental index is higher than 0.5, the forest ecological state is stable and can be harvested.

Keywords

Carbon sequestration; Forest value index; Combination weighting method.

1. Overview

With the continuous change of the global climate, it has brought many impacts that cannot be ignored. The biggest impact is the production of many greenhouse gases, such as the carbon dioxide produced by the Australian fires, which poses a serious threat to the safety of human and other life [1] . The continuous increase in the concentration of CO2 in the atmosphere has also led to an increase in the average temperature of the earth's surface year by year. Compared with 1986-2005, the global average surface temperature is expected to increase by 0.3-0.7C in 2016-2035, and it will increase in 2081-2100. High 0.3-4.8C [2].

In order to slow down the destructive effects of climate change on human society, the United Nations adopted the United Nations Framework Convention on Climate Change in 1992, and formulated a series of strategies to reduce carbon emissions, among which carbon sequestration is the most effective. As the largest carbon pool in terrestrial ecosystems, forest carbon storage accounts for about 46% of the total global terrestrial carbon storage [3], and plays an extremely important role in maintaining global carbon balance and responding to global changes. However, the value of forests is not only reflected in carbon sequestration, but also in the use of soil and water conservation, sand and dust prevention, etc. that are beneficial to human beings. Therefore, in order to maintain the balance of forest resources in carbon sequestration, wood product processing, environmental protection and bio-diversity, how to develop a good forest management plan is very important and urgent.

2. Establishment of the Model

2.1. Carbon Sequestration Model

The so-called carbon sequestration refers to the technology that replaces the direct emission of CO2 into the atmosphere by capturing carbon and safely storing and using it. There are various

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carbon sequestration technologies, and this article discusses the role of forests in carbon sequestration. To determine which forest management plans are the most effective at sequestering carbon dioxide, that is, in which way the forest and its products will sequester he most carbon. By consulting the literature [4], the model of carbon sequestration obtained is:

$$CF = CF_1 + CF_2$$
$$C = D \times \delta \times \rho \times \gamma \tag{1}$$

Where, CF is the total amount of carbon sequestration, CF_1 is the forest carbon sequestration amount, CF_2 is the carbon sequestration amount of wood products, D is the stock volume per unit area of forest,and C is the carbon density of the forest biomass. The international IPCC default value is used when calculating C, δ is the biomass expansion coefficient, ρ is the volume coefficient, γ is the carbon content.And δ =1.9, ρ = 0.5, γ = 0.5.[5] For simplicity, we assume that only the trees in the above-ground part of the forest are considered and other organisms are ignored.

2.2. Forest Value Model

Based on the carbon sequestration model, a forest value system model is established. The forest value system model includes interactions between societies, activities and the outcomes of activities. Since a forest is affected by many factors, we use social, ecological, carbon storage and climate change as the main influencing factors to measure the other forest values of a forest.

The forest ecosystem has brought enormous material wealth and spiritual wealth to human beings, and its rise and fall not only directly affects the ecological environment, but also affects the economic and social development [6]. Therefore, the value of forests is particularly complex, and this complex network is affected by many factors. We use four superior indicators, including society, ecosystem, carbon sequestration and climate change. To facilitate subsequent calculations,

we use the set I to describe these superior indicators:

$$I = \{Soc, Eco, CaS, ClC\} \tag{2}$$

Where, Soc, Eco,CaS,and ClC represent Society, Ecosystem, Carbon Sequestration and Climate Change. Each superior indicator consists of several inferior indicators, which are discussed in detail in the next section.

2.3. Methods of Normalization

Because some of the data we are looking for are not available every year, but we need continuous data for several years, we interpolate those missing data to supplement the missing data. In order to make the data dimensionless, we need to take the data normalization method to process the data. Different data have different normalization methods. In order to meet the requirements of precision, we list different normalization methods below: It should be noted that the data normalization values of these methods are all between [0, 1].

Z-score normalization method

This method can be used for some indicators that approximate a normal distribution, and requires standardization when it comes to covariance. such as lumber price. The specific expression is as follows:

$$X_n = \frac{x - \mu}{\sigma} \tag{3}$$

Where, X_n is the normalized index, x is the original index. μ is the mean in all sample data, and σ is the standard deviation of all sample data.

min-max normalization method

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This method, also known as linear normalization or dispersion normalization, is divided into two types: benefit index and cost index. The larger the index value, the better the benefit. The expression is as follows:

$$X_n = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{4}$$

Where, min(x) is the minimum value among all index values, and max(x) is the maximum value among all index values.

For cost line indicators, such as crime rate, virus fatality rate, etc., the smaller the indicator value, the better, the expression is:

$$X_n = \frac{\max(x) - x}{\max(x) - \min(x)} \tag{5}$$

For some indicators with optimal values, we use the median normalization method. When the original value of the indicator is closer to the optimal value, the normalized value is larger, Such as average temperature, average humidity, etc.The specific expression is :

$$X_n = \frac{|x - x_0|}{\max\{|x_{\max} - x_0|, |x_{\min} - x_0|\}} \tag{6}$$

Where, x0 is the index optimal value,that is the median.

Improved Logistic function (sigmoid function) method

The interval of the original Logistic function method is [-1, 1], but this paper needs to normalize the data to [0, 1], so according to the literature, it can be seen that this normalization method does not have a fixed index for the index. limit. Such as population, per capita grain output, per capita CO2 emissions, etc. For such indicators, when the original indicator is close to 0, the standardized indicator is judged to be 0. Conversely, when the original index tends to infinity, the standardized index is judged to be 1. For such metrics, we choose a logistic function for normalization:

$$X_n = \frac{1}{1 + e^{-k(x - x_{\min})}} \tag{7}$$

Where, k is the normalization coefficient, and xmin is the minimum value among all index values.

Subordinate function method

This normalization method is a method for that discretization index. Indicators for which there is little variation between countries or where specific data cannot be found are suitable, and these indicators can be divided into several intervals with discrete levels. First, these metrics are graded and then normalized by membership functions. This paper divides these indicators into five levels. They are: bad, bad, normal, good, very good. The higher the level, the greater the value of the indicator. The specific calculation formula is as follows:

$$X_n(x) = \begin{cases} \dfrac{1}{1 + \dfrac{a}{(x-b)^2}} & 1 \le x \le 3 \\ c \ln x + d & 3 \le x \le 5 \end{cases} \tag{8}$$

It should be noted that: k=b.

Here, we assume Xn(5)=1, Xn(3)=0.8, Xn(1)=0.01, therefore, a = 1.1086, b = 0.8942, c =0.3915, d = 0.3699. The normalized quantitative values of these five grade indicators are {1.1086, 0.8942, 0.3915, 0.3699}, respectively.

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Using these normalization methods, all poor quality indicators can be normalized. Here we do not list the specific normalization steps for each indicator.

3. AHP–EWM Determines the Weight

Since AHP is a scientific decision-making method that combines qualitative and quantitative organically, decision-makers rely on subjective experience to judge qualitative issues for quantitative evaluation, and it is a relatively mature method in the world. We will not repeat them here.

The basic principle of the entropy method is that the greater the change of a certain index value of all evaluation objects, the greater the weight of the index, and vice versa. The specific calculation steps are as follows:

Step 1: Calculate the information entropy r_{ij} of each evaluation index x_{ij} :

$$r_{ij}=\frac{x_{ij}}{\sum_{i=1}^{m}x_{ij}} \tag{9}$$

Step 2: Calculate the entropy value of the index j according to the information entropy:

$$e_j=-\frac{1}{\ln m}\sum_{i=1}^{m}r_{ij}\ln r_{ij} \tag{10}$$

The range of ej values is between [0,1]

Step 3: Calculate the coefficient of variance of the first indicator:

$$d_i=1-e_j \tag{11}$$

Step 4: Calculate the weight of the indicator x_{ij}

$$w_j=\frac{d_i}{\sum_{j=1}^{n}d_i}=\frac{1-e_j}{\sum_{j1}^{n}1-e_j} \tag{12}$$

Among them， $j=1,2,\cdots\cdots,n$

Although this method has objective advantages, it cannot reflect the degree of people's attention to different indicators, and will have a certain weight, which may be contrary to reality to a certain extent. Therefore, in order to obtain a more reasonable index weight, we use the combination of Analytic Hierarchy Process (AHP) and Entropy Weight Method (EWM) to make up for the shortcomings of the single-weight method.

$$W_{ae}=\frac{\sqrt{w_i w_j}}{\sum_{i=1,j=1}^{n}\sqrt{w_i w_j}} \tag{13}$$

Where, w_i is the weight calculated by AHP, and w_j is the weight calculated by EWM.

Finally, the weights of the four comprehensive evaluation indicators of society, ecosystem, carbon sequestration, and climate change can be calculated. From these calculated weights, we get the following expression for the forest value indicator:

$$\begin{cases} Soc = Cul \times \alpha_1 + Pop \times \alpha_2 + Eoc \times \alpha_3 + Ent \times \alpha_4 \\ Eco = APC \times \beta_1 + BiD \times \beta_2 + DiI \times \beta_3 + SCC \times \beta 4 \\ CaS = StV \times \gamma_1 + Are \times \gamma_2 \\ ClC = AvT \times \lambda_1 + AvH \times \lambda_2 + AvP \times \lambda_3 \end{cases} \tag{14}$$

Where α, β, γ, and λ respectively represent the coefficients of each index and the forest value can be expressed as:

$$FV = Soc \times \omega_1 + Eco \times \omega_2 + CaS \times \omega_3 + ClC \times \omega_4 \tag{15}$$

We get the final weight results as shown in Table 1 below:

Table 1: The Weights of Forest Value Index Indicators

Sociology 0.2685	Ecology 0.3198	Carbon sequestration 0.2691	Climate change 0.1426
Culture 0.3023	bio-diversity 0.4387	Storage volume 0.5137	Average humidity 0.2938
Population 0.2312	Air purification capacity 0.2116	Coverage area 0.4863	Average temperature 0.3209
Economics 0.2713	Disease incidence 0.1211		Average precipitation 0.3853
Entertainment 0.1952	Sand control capacity 0.2286		

4. 4.Situation Analysis in Shirakami and Lesio-louna

we apply our model to the lesio-louna forest in Congo and the shirakami mountain forest in Japan and calculate the value index of these two forests, as shown in Table 2 below:

Table 2 :value index of these two forests

Index Indicators	Lesio-louna	Shirakami-Sanchi
Sociology	0.3737	0.2093
Ecology	0.2339	0.3682
Carbon sequestration	0.2281	0.2371
Climate change	0.1643	0.1854
FV	0.6351	0.7651

When the forest value index is higher than 0.4, the forest is in a stable state, and when it is higher than 0.6, the forest is in an exploitable state.

From Figure 2, it is more intuitive to show that the Lesio-louna forest in Congo has the highest social index, while the Shirakami mountain forest in Japan is the highest in terms of ecosystem, indicating that the main purpose of the Lesio-louna forest is to produce wood for human use, while the Shirakami mountain is mainly used for human use. is to protect the environment.

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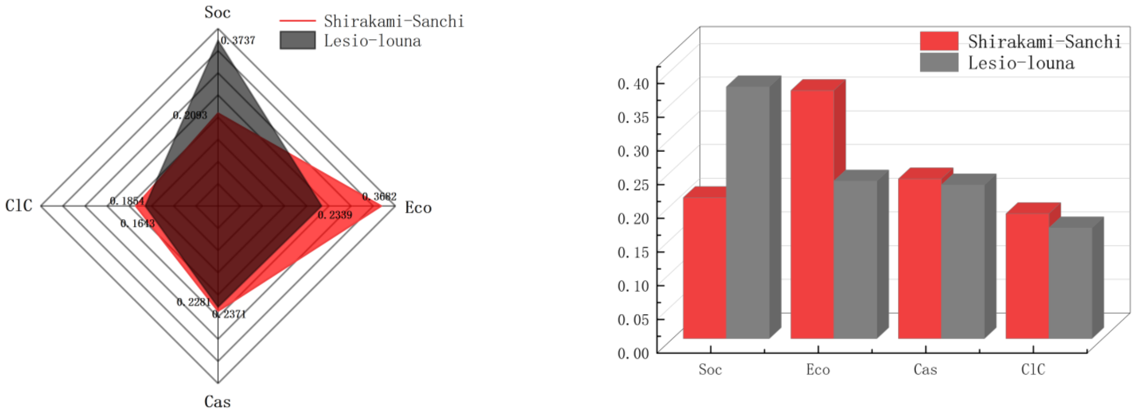

Figure 2: Forest Value Index for two forests

5. Result and Discussion

1. Four indicators of society, ecology, carbon sequestration and climate change were selected to build a model and to provide a forest management plan based on the indicators of a forest in these four aspects; for the weakest indicator among the four indicators, other indicators were considered. Appropriate adjustments are made to make up for weak indicators. The carbon sequestration capacity of trees decreases as the trees mature. A relatively reasonable management plan is to cut down trees that have reached maturity according to their growth years, replant them after felling, and retain trees that have not yet reached maturity. It is necessary to consider the bearing range of the forest ecosystem and the economic benefits generated.

2. Deforestation will have a certain degree of impact on forests and forest ecosystems. When the status of the forest ecosystem indicators is already in jeopardy, it is necessary for managers to consider postponing the felling plan or even not cutting down; until the forest ecosystem is complete and the indicators are normal, managers can then go to the deforestation plan around the economic purpose. The sum of the index values of society and carbon sequestration is determined as the criterion for deforestation. When the index sum is higher than 0.5, the forest has a high level of social aspects and carbon sequestration and cannot be harvested. Additionally, some products have a short lifespan, while others may outlive the trees from which they are produced, such as petrified wood, which is literally fossilized wood.

3. The focus of various types of forests is different. Economic forest focuses on the economy, while natural forest focuses on forest ecology. The biggest difference is whether there is interference from the human cutting plan. If the deforestation of economic forests is appropriately reduced, for natural forests with good ecological conditions, a deforestation plan within the tolerance range of the forest ecosystem should be formulated. The transition point for the management plan is when the two logging plans can be approximated as the same plan. The transition point is the intermediate point between the two states of uncutable and logable. The ecological and climate change index values are used to measure whether the state of the forest ecosystem is stable. When the index value is higher than 0.5, the forest ecosystem is stable and can be harvested.

4. Japan's forest coverage area is as high as 68%, and Congo is the African country with the largest forest area. As shown in Figure 8, we looked for a comparison map of the forest area between the two countries in Google Maps and Google Chrome to analyze our results. It can be seen that both countries are forest powers for Congo.

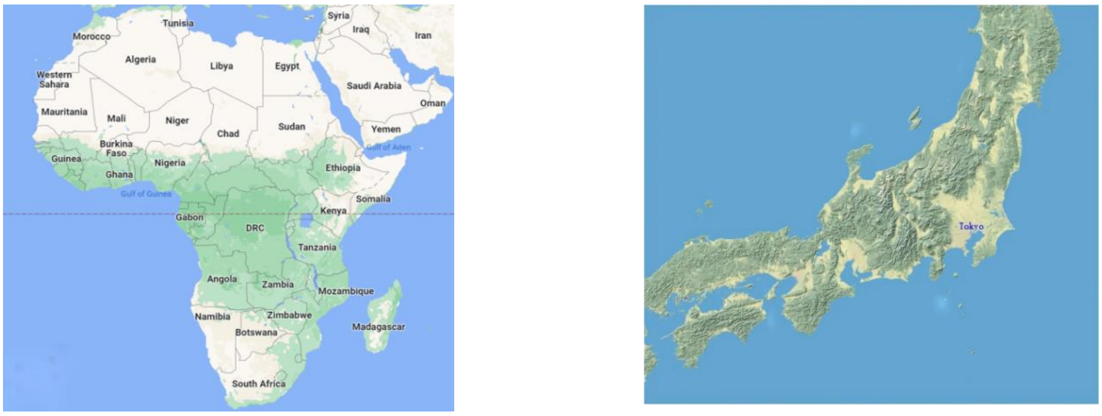

Figure 3: The Percentage of Forest Area in Two Countries

The Shirakami in Japan and the Lesio-louna in Congo were selected. The carbon sequestration potential of Lesio-louna is beneficial for developing African countries to obtain carbon emission credits, which is beneficial to the sustainable management of forests in the long run. In addition, the increase in forest coverage of African savanna is well reflected in Lesio-louna[7]

The Shirakami Mountains are an unspoiled area of virgin forest rich in water resources, and many creeks and rivers originate from this area. It covers approximately one-third of the Shirakami Mountains and consists of steep slopes. and mountain peaks form an intricate terrain. Managers should consider how to adjust the balance between the economy and the environment. If the forest terrain is conducive to human activities and the ecosystem is stable, the forest can be used as an alternative for development; if the forest terrain is not conducive to human activities, the ecosystem is relatively unstable. In this case, human intervention is needed to adjust the forest ecosystem and take corresponding protection measures. Regardless of how a management plan is developed, sustainability should be the primary consideration.

6. Sensitivity Analysis

Based on the forest value model established above, a sensitivity analysis of important variables was carried out. We discuss the impact of these 4 indicators on the superiority indicator of the food system model. When one of the indicators changes, the other three indicators keep their initial values.

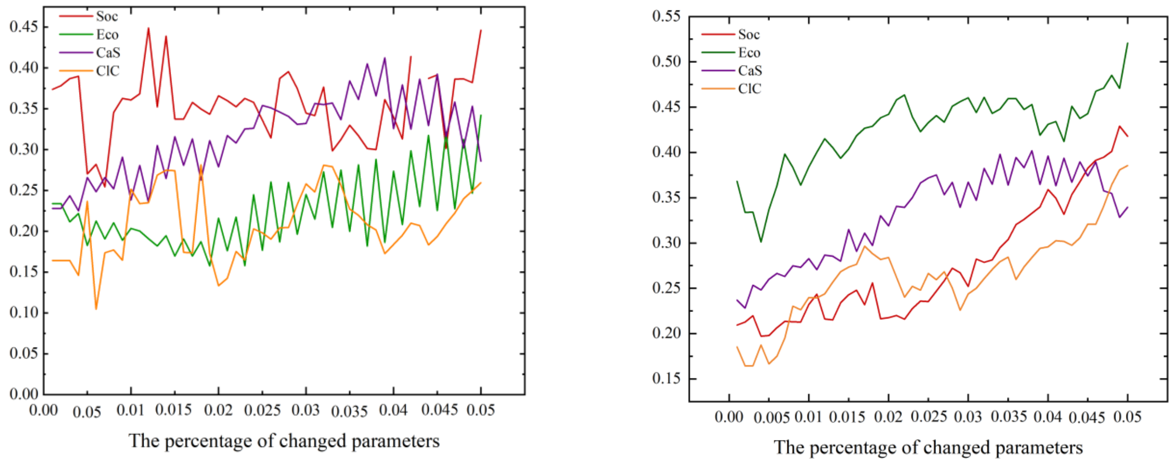

Figure 4 Sensitivity Analysis of the Percentage Change of Indicators

It can be seen from the above figure that Lesio-louna (left) is more sensitive to climate change and society, while Shirakamiyama (right) is relatively stable overall. The 4 indicators are changed from 0.1% to 5%, and the indicator value is calculated every 0.1%. Calculations were performed using normalized data. We can conclude that the forest value indicator has been on an upward trend with the increase of the four parameters. They play an active role in the forest. The fluctuations of the selected parameters have obvious changes in the output value of the model, which indicates that the indicators selected by the model have good representation, and the model has good sensitivity and validity.

7. Summary

In this paper,The carbon sequestration model and the forest value model are discussed, a set of indicators around the four aspects of society, ecology, carbon sequestration and climate change to establish a forest value model are provided for Shirakami Mountains in Japan and the Lesio-louna Forest in Congo. We determine the weight of indicators using the Combination Weighting Method. Two aspects, ecology and climate change, are taken as environmental indicators, and the other two are taken as social indicators. The value of the Shirakami mountain forest in Japan is 0.7651, while the value of the Lesio-louna forest in Congo is 0.6351. When the social index is higher than 0.5, the forest is in a state of uncutability. When the environmental index is higher than 0.5, the forest ecological state is stable and can be harvested.

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