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Mathematical Models on Forest Logging and Carbon sequestration

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Abstract

In this article, we explore the relationship between carbon sequestration and the age of forests and their products, and evaluate the effectiveness of various forest management strategies in sequestering carbon dioxide. Our analysis suggests that moderate logging, when carefully conducted, can rejuvenate forests and provide a range of benefits including ecological, economic, and social benefits. These findings suggest that moderate logging be a useful tactic in forest management plans.

Keywords: carbon sequestration, multi-linear regression, Pearson correlation, time series.
2010 MSC: 93A30, 97M10, 00A71.

1. Introduction

Climate change poses a grave threat to all aspects of life (see, for instance, [1] and [2]). The United Nations Framework Convention on Climate Change (UNFCCC), adopted in 1992, recognized the role of carbon sinks in mitigating climate change (see, for example, [3]). Carbon sequestration refers to actions that increase the amount of carbon stored in carbon pools other than the atmosphere (see, for example, [4] and [5]). In recent years, there has been a growing emphasis on nature-based solutions, and biological carbon sequestration is considered the most promising approach to mitigating global warming (see, for example, [6] , [7] and [8]). Biological carbon sequestration uses photosynthesis in plants to convert carbon dioxide into carbohydrates, which are stored as organic carbon in the plants or soil (see, for example, [9] , [10] and [11]). Synthetic and systems biology techniques, such as DNA or genome editing in plants, may also offer possibilities for reducing greenhouse gas concentrations and promoting environmental sustainability and adaptation (see, for example, [12] , [13] and [14]). Forests, being the most prevalent vegetation type worldwide, are crucial to study in terms of their carbon sequestration

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capabilities in order to achieve carbon equilibrium (see, for example, [15]). Forests absorb and store significant amounts of carbon dioxide from the atmosphere through their growth, and their storage capacity depends on the type of forest vegetation, tree biomass, stand volume, and age of the forest (see, for example, [16] and [17]). Artificial intervention, particularly through balancing the carbon sequestration capacity of forests and wood products under various factors such as rotation period and the proportion of new planting, is crucial in achieving a higher level of carbon sequestration (see, for example, [18] and [19]). Mathematical models have also been utilized in competitions or contests (see, for example, [20] and [21]) and research programs to simulate, predict, and propose solutions to deforestation and carbon sequestration. In addition, the authors in [22] considered a fractional dynamics-based measles outbreak model. In [23], a mathematical model was used to study corruption among students in Nigerian tertiary institutions and found that it is likely to persist unless root causes are addressed. The model demonstrated threshold dynamics and the presence of both corruption-free and endemic equilibrium points. Additionally, in [24], a model is presented to study anemia in children under five and the impact of a control measure on the disease. Results suggest that the control measure can reduce the number of child patients and yearly deaths from anemia, but the disease may not be fully eliminated. The effectiveness of the control measure depends on timing and duration.

Grossman and Krueger's (see [25]) empirical findings indicate that economic growth often leads to environmental degradation, and Panayotou et al. (see [26]) argue that as economies develop, the relationship between economic growth and environmental quality shifts from positive to negative as people's incomes reach levels where they can afford and demand a cleaner environment. The inhibiting effect of financial development on carbon emissions can be reversed through the promotion of green finance, such as green loans and green bonds, which facilitate low-carbon technological progress. Therefore, it is crucial to strike a balance between economic and environmental considerations. In recent years, there has been a growing emphasis on studying carbon balance and sequestration due to concerns about carbon dioxide emissions and global climate change.

This article presents the following key contributions:

1. Development of a model to quantify the long-term carbon sequestration potential of forests and forest products. The model incorporates strategies for managing living plants and forest products to maximize carbon sequestration.
2. Construction of a decision-making model that takes into account the ecological and social benefits of forests. This model allows for a balanced evaluation of various forest values and identifies optimal forest utilization, unlocking their full potential.
3. Application of the decision model to diverse forest scenarios and evaluation of its effectiveness.
4. Explanation of a management plan involving moderate tree cutting, highlighting the validity of this approach.

In recent years, with increasing carbon dioxide emissions and global climate change, there has been growing attention on the study of carbon balance and sequestration (see, for example, [27] and [28]). To address the impacts of climate change, we must both reduce greenhouse gas emissions and sequester carbon. Carbon sequestration can be

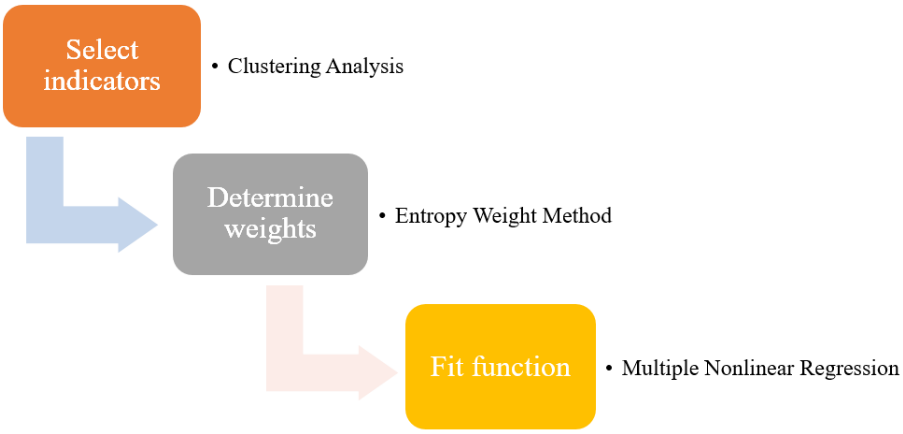
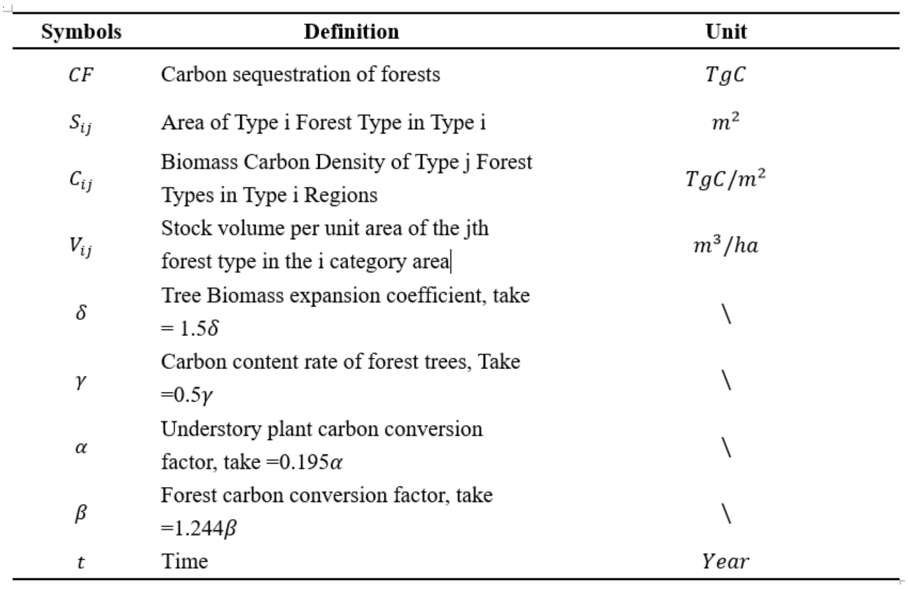


Figure 1: Parts and Processes of the Work

achieved through the use of plants, soils, and water bodies, and network decomposition and analysis using probabilistic methods can be employed (see, for example, [29]). Forests play a crucial role in carbon sequestration, and the age of forests and their products can significantly impact this process. In this study, we focused on Saihanba Forest Farm and analyzed the relationship between carbon sequestration and forest age. Our analysis included multiple linear regression models that accounted for carbon sequestration from various sources such as trees, plants, forest land, and products. We used SPSS to obtain a nonlinear fitting result and applied principal component analysis and the Pearson correlation coefficient method to identify the optimal forest management plan for carbon sequestration.

To balance the various ways of valuing forests, we considered both ecological and socio-economic factors to develop a decision model for optimal forest use. We used the operator of weighted arithmetic mean to express the comprehensive benefit of the weighted mean and determined the weighting rate of forests for industrial construction, forest health industry, and carbon sequestration through multiple nonlinear regression analysis. Our decision model identified the optimal resource allocation mode and was tested for accuracy in other forests. Furthermore, we extended the model to a time prediction model by using a time-series model to predict carbon sequestration over 100 years.

Our study demonstrated that moderate logging is a sound decision in forest management plans. Both living plants and forest products can sequester carbon dioxide, and balanced management of these resources can renew and rejuvenate forests, generating ecological, economic, and social benefits. In conclusion, we recommend integrating moderate logging into forest management plans as a strategy for carbon sequestration. Tree growth directly increases carbon dioxide storage and effectively removes excess emissions, while moderate logging leads to carbon sequestration. Our decision model can help balance the ecological and socio-economic values of forests and guide optimal forest use for carbon sequestration and other benefits.



Symbols	Definition	Unit
CF	Carbon sequestration of forests	TgC
S_{ij}	Area of Type i Forest Type in Type i	m^2
C_{ij}	Biomass Carbon Density of Type j Forest Types in Type i Regions	TgC/m^2
V_{ij}	Stock volume per unit area of the jth forest type in the i category area	m^3/ha
δ	Tree Biomass expansion coefficient, take = 1.5δ	\
γ	Carbon content rate of forest trees, Take =0.5γ	\
α	Understory plant carbon conversion factor, take =0.195α	\
β	Forest carbon conversion factor, take =1.244β	\
t	Time	$Year$

Figure 2: Symbol table

2. Assumptions and Notations

2.1. Symbol table

The symbols utilized in this study are defined in fig:infmax.

2.2. Assumptions

Our models are based on the folllowing assumptions:

1. Large and unpredictable man-made environmental damage is assumed to be excluded;
2. Suppose that every region has a complete ecological civilization system;
3. Resources are assumed to be abundant and will not be used up in the short term.

3. Model I: Carbon sequestration model

3.1. Overview of our approach

We propose the development of a carbon sequestration model that predicts the long-term sequestration of carbon dioxide by forests and their products. Specifically, we will focus on Saihanba Forest Farm, situated in Weichang Manchu and Mongolian Autonomous County, Chengde, Hebei, China. This forest farm is located at the intersection of the northern Hebei Mountains and the Inner Mongolia Plateau, characterized by a plateau terrain.

Our approach involves selecting and quantifying indicators and weights using the entropy method. By performing regression analysis on data spanning 2010 to 2020, we will establish a model for carbon sequestration in Saihanba Forest Farm, following the guidelines of the United Nations Intergovernmental Panel on Climate Change (IPCC) and the

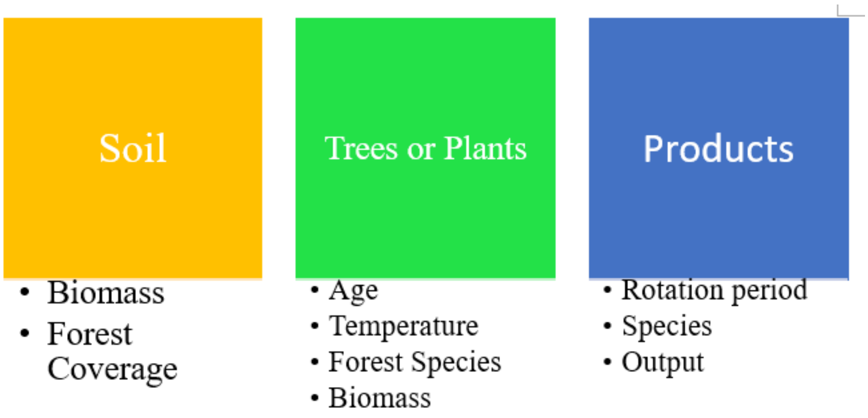


Figure 3: Analysis of carbon fixation stock

Kyoto Protocol. This model will enable us to calculate the forest carbon sequestration stock using a functional equation. Additionally, we will utilize the forest stock conversion factor method, which establishes the relationship between forest biomass and forest stock volume, to calculate the carbon sinks in the forest. To predict the relationship between carbon sequestration and time for forests and their products, we will employ a multivariate nonlinear regression model.

To determine the most effective forest management plan for carbon sequestration, we will employ principal component analysis (PCA), data analysis, and the Pearson correlation coefficient. By analyzing the range of indicators corresponding to maximum carbon sequestration in Saihanba Forest Farm, we can identify the forest management plan that is most effective in enhancing carbon sequestration.

3.2. *Multiple Nonlinear Regression Model*

3.2.1. *Analysis of carbon sequestration*

Forest carbon sequestration consists of four components: forest biological carbon sequestration, forest products carbon sequestration, understory plants carbon sequestration, and soil carbon sequestration. According to literature, soil carbon sequestration is approximately equal to forest product carbon sequestration at the initial stage of a forest farm. As social productivity improves, the carbon sequestration of forest products shows a steady growth trend, while the change trend of soil carbon sequestration is not as noticeable and tends to remain constant. At the same time, the rate of artificial afforestation increases each year, and the forest coverage rate and forest coverage area increase steadily. Therefore, the biological carbon sequestration stock of trees and the carbon sequestration stock of understory plants also increase steadily.

The calculation formula for the forest stock conversion factor method is that the forest stock conversion factor method calculates the total carbon sequestration by adding the contributions of forest carbon sequestration, understory plant carbon sequestration, and woodland carbon sequestration. It provides an estimate of the overall carbon storage capacity of the forest ecosystem.

The carbon fixation stock of a forest includes four components: forest biological carbon fixation stock, carbon fixation stock of forest products, underforest plant carbon fixation stock, and soil carbon fixation stock. According to literature, the soil carbon fixation stock is almost equal to the forest products at the early stage ofa forest farm. As social productivity improves, the soil carbon fixation stock is not as noticeable and reaches a fixed value. Meanwhile, the rate of artificial afforestation increases each year, and the forest coverage rate and forest coverage area increase steadily. Therefore, the forest biological carbon fixation stock and underforest plant carbon fixation stock increase steadily.

The forest carbon fixation stock CF is obtained by adding the forest tree carbon consolidation stock, underforest plant carbon consolidation stock, and forest land carbon consolidation stock:

$$\begin{aligned} CF &= C_t^1 + C_t^2 + C_t^3 \qquad (3.1) \\ &= \sum_{i,j} S_{i,j}C_{i,j} + \alpha \sum_{i,j} S_{i,j}C_{i,j} + \beta \sum_{i,j} S_{i,j}C_{i,j} \end{aligned}$$

where C_t^1, C_t^2, and C_t^3 are the forest tree carbon consolidation stock, underforest plant carbon consolidation stock, and forest land carbon consolidation stock, respectively. $S_{i,j}$ represents the area of the ith grid cell in the jth forest stand, $C_{i,j}$ represents the carbon density of the ith grid cell in the jth forest stand, and α and β are coefficients that account for the carbon sequestration of understory plants and forest land, respectively.

- To calculate the forest tree carbon consolidation stock C_t^1, we use the formula:

$$C_t^1 = \sum_{i,j} S_{i,j}C_{i,j} \qquad (3.2)$$

- To calculate the underforest plant carbon consolidation stock C_t^2, we use the formula:

$$C_t^2 = \alpha \sum_{i,j} S_{i,j}C_{i,j} \qquad (3.3)$$

- To calculate the forest land carbon consolidation stock C_t^3, we use the formula:

$$C_t^3 = \beta \sum_{i,j} S_{i,j}C_{i,j} \qquad (3.4)$$

- Finally, we can supplement the formula for CF by taking into account the amount of carbon fixed and stored in forest products, C_t^4. In 2013, the carbon sequestration of forest land was approximately equal to the carbon sequestration of forest products. Therefore, we can set $C_t^4 = C_t^3$ and use the formula:

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$$\begin{aligned} CF &= C_t^1 + C_t^2 + C_t^3 + C_t^4 \qquad (3.5) \\ &= \sum_{i,j} S_{i,j}C_{i,j} + \alpha \sum_{i,j} S_{i,j}C_{i,j} + \beta \sum_{i,j} S_{i,j}C_{i,j} + \beta \sum_{i,j} S_{i,j}C_{i,j}V_{i,j}\delta\gamma \qquad (3.6) \end{aligned}$$

where $V_{i,j}$ represents the volume of the ith grid cell in the jth forest stand, δ represents the carbon density of forest products, and γ represents the fraction of carbon stored in forest products. Equation 3.6 is the complete formula for forest carbon fixation stock CF.

In summary, forest carbon sequestration is crucial for mitigating climate change, and it consists of four components: forest biological carbon sequestration, forest products carbon sequestration, understory plants carbon sequestration, and soil carbon sequestration. The rate of afforestation and the social productivity affect the carbon sequestration of these components, and the forest coverage and the carbon sequestration stock of trees and understory plants increase steadily over time.

The forest stock conversion factor method provides a calculation formula for estimating forest carbon sequestration and carbon fixation stock. The carbon fixation stock of a forest includes forest biological carbon fixation stock, carbon fixation stock of forest products, underforest plant carbon fixation stock, and soil carbon fixation stock. These components increase steadily with the rate of afforestation and social productivity.

We can use the forest stock conversion factor method to calculate forest carbon sequestration and carbon fixation stock accurately. The formula can be supplemented to include forest tree carbon sequestration, undergrowth plant carbon sequestration, forest land carbon sequestration, and forest land carbon fixation stock of forest products. We can calculate these components using specific formulas for each component.

In summary, proper forest management and afforestation can help mitigate climate change by increasing the carbon sequestration and carbon fixation stock of forests. The forest stockconversion factor method can help estimate and optimize forest carbon sequestration and carbon fixation stock accurately.

3.2.2. Fitting of functions

We used nonlinear regression method to fit the function, and used various index data from 2010 to 2020 to predict the carbon sink potential of Saihanba Forest farm through Matlab and draw the fitting image as shown in fig:-Curve-Fitting: We fit the function using the nonlinear regression method, using various index data from 2010-2020 to predict the carbon sink potential of Saihanba Forest Farm by using nonlinear regression through Matlab and draw the fitted image as shown in fig:-Curve-Fitting.

3.2.3. Result

The above figures show that from 2010 to 2050, forest carbon sequestration tends to show nonlinear growth. The goodness of fit measures, including the sum of squared errors (SSE) and root mean squared error (RMSE), tend to 0, while the adjusted R-squared tends to 1. This indicates that the fitting effect is excellent, and the fitting result has high reliability and statistical significance, presenting a significant level and rejecting the null hypothesis that the regression coefficient is R^2. After integrating the formulas of C_t^1, C_t^2, C_t^3, C_t^4, the relationship between forest carbon sequestration and time T is obtained (in units of TgC, teragrams of carbon):

$$C_f = -0.044t^2 + 178.4t - 180745 \tag{3.7}$$

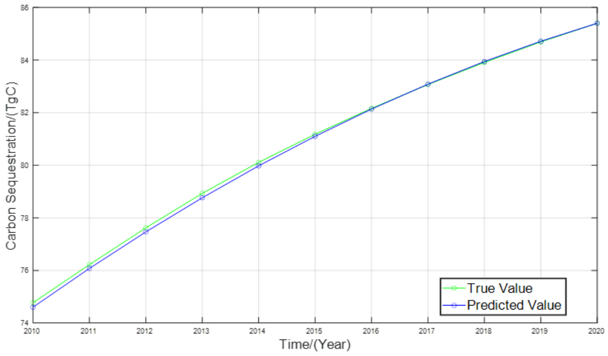


Figure 4: Curve Fitting

Goodness of fit	Value
SSE	0.01309
R^2	0.9999
AdjustedR^2	0.9999
RMSE	0.04046

Figure 5: Goodness of Fitting

This formula predicts how much carbon dioxide a forest and its products can be expected to sequester over time.

3.3. *Principal component and correlation analysis*

3.3.1. *Data analysis*

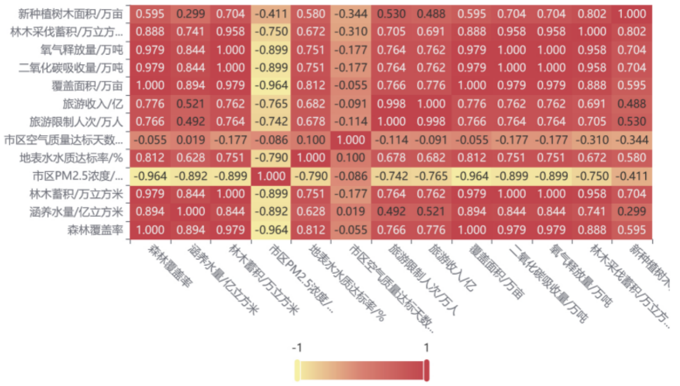
In the field of carbon sequestration in forests, two vital techniques are employed to develop the most efficient carbon storage model: principal component analysis (PCA) and Pearson correlation coefficient analysis. PCA is a powerful statistical tool that transforms a potentially correlated set of variables into a new set of independent, uncorrelated variables through an orthogonal transformation process.

Pearson correlation coefficient analysis, on the other hand, measures the correlation between two variables X and Y. This is done by calculating the ratio of their covariance to the product of their standard deviations. The equation for Pearson correlation coefficient is:

$$\rho_{X,Y} = \frac{\mathrm{cov}(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y} \tag{3.8}$$

Here, $\rho_{X,Y}$ represents the overall correlation coefficient, which is often denoted by the lowercase letter "r". By calculating the covariance and standard deviation of a given sample, we can determine the Pearson correlation coefficient between variables X and Y as:

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \tag{3.9}$$



	森林覆盖率	涵养水量/亿立方米	林木蓄积/万立方米	市区PM2.5浓度/...	地表水水质达标率/%	市区空气质量达标天数...	旅游限制人次/万人	旅游收入/亿	覆盖面积/万亩	二氧化碳吸收量/万吨	氧气释放量/万吨	林木采伐蓄积/万立方...	新种植树木
新种植树木面积/万亩	0.595	0.299	0.704	-0.411	0.580	-0.344	0.530	0.488	0.595	0.704	0.704	0.802	1.000
林木采伐蓄积/万立方...	0.888	0.741	0.958	-0.750	0.672	-0.310	0.705	0.691	0.888	0.958	0.958	1.000	0.802
氧气释放量/万吨	0.979	0.844	1.000	-0.899	0.751	-0.177	0.764	0.762	0.979	1.000	1.000	0.958	0.704
二氧化碳吸收量/万吨	0.979	0.844	1.000	-0.899	0.751	-0.177	0.764	0.762	0.979	1.000	1.000	0.958	0.704
覆盖面积/万亩	1.000	0.894	0.979	-0.964	0.812	-0.055	0.766	0.776	1.000	0.979	0.979	0.888	0.595
旅游收入/亿	0.776	0.521	0.762	-0.765	0.682	-0.091	0.998	1.000	0.776	0.762	0.762	0.691	0.488
旅游限制人次/万人	0.766	0.492	0.764	-0.742	0.678	-0.114	1.000	0.998	0.766	0.764	0.764	0.705	0.530
市区空气质量达标天数...	-0.055	0.019	-0.177	-0.086	0.100	1.000	-0.114	-0.091	-0.055	-0.177	-0.177	-0.310	-0.344
地表水水质达标率/%	0.812	0.628	0.751	-0.790	1.000	0.100	0.678	0.682	0.812	0.751	0.751	0.672	0.580
市区PM2.5浓度/...	-0.964	-0.892	-0.899	1.000	-0.790	-0.086	-0.742	-0.765	-0.964	-0.899	-0.899	-0.750	-0.411
林木蓄积/万立方米	0.979	0.844	1.000	-0.899	0.751	-0.177	0.764	0.762	0.979	1.000	1.000	0.958	0.704
涵养水量/亿立方米	0.894	1.000	0.844	-0.892	0.628	0.019	0.492	0.521	0.894	0.844	0.844	0.741	0.299
森林覆盖率	1.000	0.894	0.979	-0.964	0.812	-0.055	0.766	0.776	1.000	0.979	0.979	0.888	0.595

Figure 6: Predictions

This equation allows us to quantify the strength and direction of the relationship between variables X and Y.

By employing these mathematical techniques in the context of carbon sequestration in forests, we can gain a comprehensive understanding of the factors that affect carbon storage. PCA can help us identify the most important variables that contribute the most to carbon sequestration, while Pearson correlation coefficient analysis can help us determine the relationships between these variables.

For example, we may use PCA to identify that tree species, soil type, and climate variables are the most significant factors contributing to carbon sequestration. We can then use Pearson correlation coefficient analysis to determine the strength and direction of the relationships between these factors, such as how tree species diversity affects carbon storage or how soil moisture levels impact carbon sequestration.

By using these mathematical techniques, we can develop a more efficient carbon storage model for forests, which can help mitigate the effects of climate change by reducing the concentration of carbon dioxide in the atmosphere.

3.3.2. Result

eq:fucnquad is used to obtain the maximum value of the Saihanba carbon fixation stock using Matlab, Which shows that the C F Max will reach the maximum value of 87.724 TgC in 2027 (1TgC= 10 6 t) in 2027, so we will predict the management plan of the Saihanba Forest Farm in 2027 as the most effective scheme in the carbon dioxide storage. Through principal component analysis and Pearson correlation analysis, we identified three forest management indicators, namely, tree harvesting and stock, tourism restriction, and newly planted forest area, and then used the data from 2010 to 2020 to fit the above three forest management indicators to predict their status in 2027.

The most effective scheme for carbon sequestration is to limit tourists to 79.490 million; New Forest area is about 11,100 mu (unit of area, about 66.7 square meters), 25.6%, Larch, Birch and 16.8%, 14.8% and 15.%, And forest Logging accumulation to 167,100 cubic meters, thus this forest management plan is most effective in the carbon dioxide sequestration.

4. Model II: Decision model

4.1. Overview of our approach

In this section, we plan to balance the various ways of assessing the value of forests, take into account the ecological value and social and economic value of forests, and build a decision-making model to provide the best management mode for forest managers.And the scope of the model management plan, the spectrum of management plans, cutting down the situation, the forest management plan between transition points Management plans, a specific forest and its location used to determine transition points between management plans. We get the decision-making model by analyzing the choice of environmental factors, ecological benefits and economic benefits.

4.2. Weights to Solve

4.2.1. Selection of environmental factors

Through the analysis of the amount of trees used for carbon sequestration (including the amount of forest carbon sequestration trees and forest products carbon sequestration trees), the amount of industrial production trees, forest health industry.The ecological model economy of Saihanba Nature Reserve reached its maximum value in the range of environmental tolerance (environmental sustainable succession).Considering that economy and environmental protection are reasonable basic quantitative indexes of this model, we set environmental protection factor on the premise of protecting the environment, that is, the amount of wood cut should be less than or equal to 50% of the total amount of trees.Since the carbon sequestration relationship between forest products and forests has been discussed in detail in the first question , considering that the core of the second question is efficiency, the carbon sequestration amount of forest products is equivalent to that of forests.

4.2.2. Analysis of ecological value and social economic value

For the relationship between carbon sequestration and economy, we calculate the economic benefit of carbon sequestration per cubic meter of forest by calculating the price of carbon dioxide per cubic meter.The economic benefits brought by industry are converted by calculating the income of charcoal made from trees, and the negative impact on industrial carbon dioxide is also calculated.Since there is still CO converted from incomplete combustion in the industrial combustion process, it is ignored here.Transport costs in industrial processes are also ignored.Forest health industry can link traditional tourism with different industries such as recuperation industry, culture industry, sports industry, pension industry and tourism industry, quickly realize cluster, base and scale, and cultivate multi-functional industrial complex.There are health industry, pension industry, tourism industry, sports industry and cultural industry.The nature of the protection of the amount of tourism landscape trees is the tourism ticket, the income from the surrounding culture, and the negative impact of its carbon emissions, which we assume is 10% of the negative impact generated by industry.

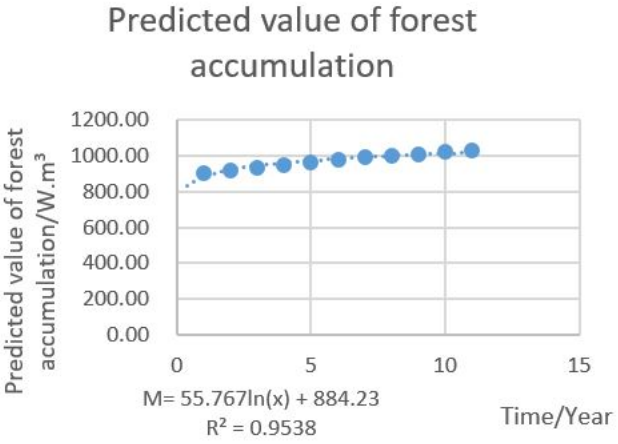


Figure 7: Predicted value of forest accumulation

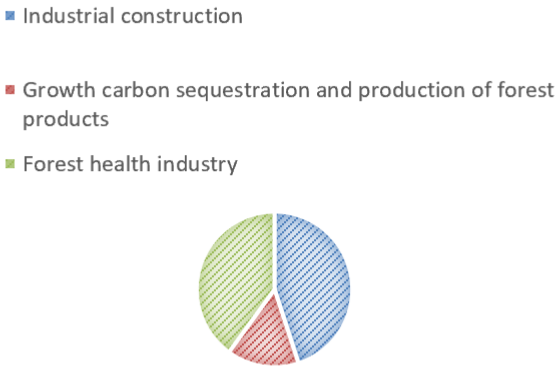


Figure 8: Pie Chart

4.2.3. *Multivariate nonlinear programming*

Scientific studies show that trees absorb 1.83 tons of carbon dioxide and release 1.62 tons of oxygen for every 1 cubic meter of storage they grow.The United Nations Intergovernmental Panel on Climate Change (IPCC) estimates that 1.15 trillion tonnes of the 2.48 trillion tonnes of carbon stored in terrestrial ecosystems are stored in forest ecosystems.

According to the formula of plant photosynthesis via illumination and chloroplast for carbon sequestration,

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2. \tag{4.1}$$

We conclude from the calculation that about 0.21 tons of carbon sequestration per 1 cubic meter of forest.

4.2.4. *Result*

We drew the scatter diagram of forest quantity and fitted it to obtain the expression of M in relation to time as shown in the figure below, where time $t = x + 2$:

According to the fitting image, we estimate the forest reserve in 2022, that is, M= 10,228,000 cubic meters. Calculated by MATLAB: When reach maximum G, a, b, c, re-

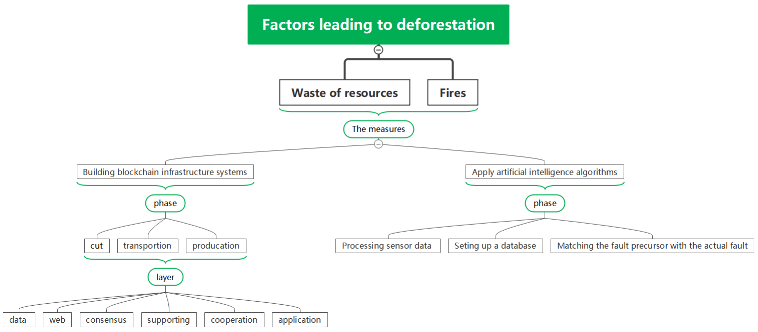


Figure 9: Schemes

spectively, equal to 15, 40, 45, so our allocation of resources for 45% of the trees to the industrial construction of the coal production, 40% of the forest reserves for forest, raising industry operation (i.e. reserved operation ornamental and artificial ecological cultural industry), 15% of the trees to grow carbon and the production of forest products.

4.3. Felling problem analysis

The Blockchain infrastructure system, the purpose of which is to use the Blockchain to improve the scope of services and service standards of the government and organizations. The blockchain technology is very exciting for the development of databases with a variety of assets and participants.For the forestry industry chain of the trees to be cut down, and then to the freight, and then made into wood products.Each stage has the potential opportunities of waste. Blockchain construction can track each stage of the process, ensuring that materials are fully utilized, while waste is converted into different media.

A number of major wildfires are associated with excessive failures in the power system.The establishment of artificial intelligence enables sensors to monitor power lines and establish a database. It can identify different modes and make quality assurance judgments. When a failure occurs, the equipment can give accurate judgment and forecast. According to the analysis, the purposeful, planned and scientific cutting of trees can promote the tree growth, and is of great significance to the sustainable development of the forest.

5. Model III: Time series model

5.1. Overview of our Approach

The problem requires us to apply the model we built to other forests to explore the universality of our model under certain conditions and determine the inclusion of harvesting in management plans.In the exploration of this problem, we chose to study Okara National Forest to predict carbon sequestration after 100 years and test the correctness and sensitivity of our model. We used the time series model to predict the amount of time-related carbon sequestration, and used the combination of AR model and MR model, namely ARMA model, to predict the results through the correlation analysis of the two.The ARMA (AutoRegressive Moving Average) model is a widely used approach for association analysis, combining the autoregressive (AR) model and the moving average (MA) model.

The AR model represents a time series as a linear combination of its past values and an error term, and it can be expressed as:

$$x_t = \phi_0 + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \ldots + \phi_p x_{t-p} + s_t \tag{5.1}$$

Here, x_t denotes the value of the time series at time t, ϕ_i are the autoregressive coefficients, and s_t represents the error term at time t.

On the other hand, the MA model describes a time series as a linear combination of its past error terms, and it can be represented as:

$$x_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \ldots - \theta_p \varepsilon_{t-p} \tag{5.2}$$

In this equation, μ denotes the mean of the time series, ε_t represents the error term at time t, and θ_i are the moving average coefficients.

Combining the AR and MA models, we obtain the ARMA model:

$$x_t = \phi_0 + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \ldots + \phi_p x_{t-p} + s_t - \theta_1 s_{t-1} - \theta_2 s_{t-2} - \ldots - \theta_p s_{t-p} \tag{5.3}$$

To estimate the carbon sequestration of Ocala National Forest over 100 years, we can utilize the information obtained in the previous question, along with the appropriate calculations. By employing the necessary mathematical methods, such as the integration method, we can estimate the carbon sequestration to be 1003.3TgC. This estimation takes into account the specific characteristics of the forest and the time frame under consideration, providing a reliable approximation of the carbon sequestration over the given period.

5.2. *Best forest management Plan*

After extending our model to various forests, analysis and calculation: The most effective scheme for carbon sequestration is to limit visitors to 79.490 million; new forest area to about 11,100 mu, including 25.6%, 16.8%, 14.8% and 15.%; logging to 167,100 cubic meters, which is accurate as the best forest management plan.

5.3. *Sensitivity Analysis*

Even if the time between harvest changes, the carbon sequestration will fluctuate.The original function and the changed function are visualized as follows:

As can be seen from the above analysis, when time changes, the carbon sequestration stock also fluctuates, corresponding to the function that agrees with the abscissa, the corresponding ordinate carbon sequestration stock is also different, and the difference value changes with time.This indicates that the change of time has a certain impact on carbon sequestration, which demonstrates the sensitivity of our model and proves the feasibility of our model.

6. Further on forest production and forest carbon sequestration

Forests play an important role in the global carbon cycle, and their environmental benefits, such as absorbing carbon dioxide, releasing oxygen, conserving water, purifying air, and promoting species diversity, are widely accepted.As governments, businesses, and

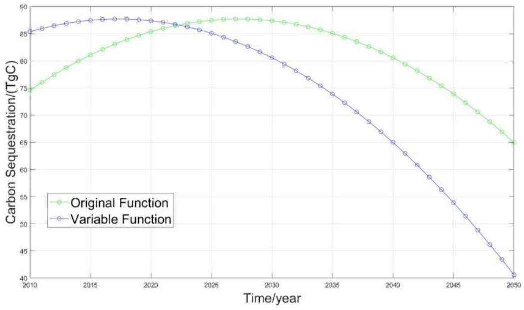


Figure 10: Carbon Sequestration

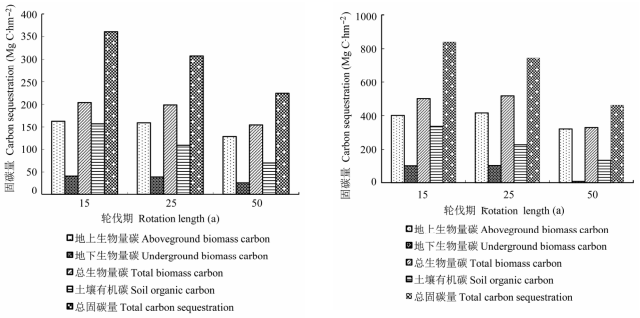


Figure 11: Rotation of logging

nonprofits push for ever more ambitious mitigation plans, we caution against using forests as the only way to combat climate change because they are not well understood.In this report, we will start from Saihanba Forest Farm in Hebei Province, China, and go to Ocala National Forest Farm in Florida, USA, which is also the most famous forest farm in China, to explore the subtle relationship between carbon sequestration of forest products and the carbon sequestration of forests themselves.

In the context of global warming, scientific and systematic decision-making and management of forests is an important way to improve forest carbon sequestration and give full play to forest environmental benefits, among which the most important is the arrangement of rotation. The general public has always had a wrong idea that forests are only allowed to continue "planting", but not "cutting". This idea is one-sided. The following is Figure:

The rotation period is a fundamental aspect of modern forest management and plays a crucial role in adjusting forest structure. It determines the cycle for tree production based on specific objectives related to tree care and growth processes, which in turn influence the distribution of forest structure and age. The distribution of forest age is a critical indicator of forest carbon sequestration. Different age groups of trees exhibit significant variations in their carbon sequestration capabilities, with young and old trees displaying lower sequestration rates compared to medium-aged and old trees.

A short rotation period corresponds to a rapid increase in forest carbon sequestration capacity, but it also leads to ongoing stand differentiation and higher environmental resource consumption. On the other hand, a long rotation period results in a decrease in the forest's carbon storage capacity. However, litter accumulation and understory growth can benefit the restoration of the forest's specific environment. The figure demonstrates the substantial differences in rotation period lengths.

To describe the rotation time within a designated area of sustainable forest development, the concept of "ecological rotation time" is employed, which refers to the minimum rotation cycles required to maintain forest productivity and achieve sustainable high-level carbon sequestration and soil nutrient levels, while focusing on the production of wood and wood products.

When prioritizing economic benefits in forest management, short rotation coppicing is the optimal solution. Conversely, when emphasizing environmental benefits, a long rotation period is preferred. Achieving sustainable forest development necessitates finding a balance between economic and environmental considerations and between the utilization of forest products and the preservation of the forest itself. Based on various models and data studies, the rotation period for logging is determined to be between 14 and 28 years, with the main harvest occurring at around 20 to 24 years of age. This represents one of several forest rotation age management systems currently implemented at the Okara National Forest Farm in the United States.

Apart from establishing the "ecological rotation period" to optimize the industrial structure, the Ocala National Forest Farm in the United States actively promotes the monitoring of forest carbon sequestration capacity. This is achieved through assessing and predicting forest ecosystem functions, making it a leading institution in the United States. Comprehensive quantitative analyses of forest and understory vegetation across various tree species and structures are conducted. Additionally, monitoring forest product carbon sequestration and the overall carbon sequestration process by forests are encouraged to evaluate the temporal and spatial contributions of forest carbon sequestration to mitigating global warming. The development of an ecological accounting and evaluation system for forest carbon sinks will continually enhance forest decision-making and management practices.

The reforestation efforts at the Ocala National Forest Farm are now undertaken with scientific planning in mind. In contrast to mere reforestation, the focus is on "carbon sequestration in the forest" to ensure greater carbon storage. This represents a significant innovation and exploration conducted by the Okara National Forest Farm to mitigate the global warming climate crisis. Nevertheless, these valuable experiences have been attained through continuous practice, as success does not occur overnight.

Balancing forest product carbon sequestration with forest carbon sequestration reflects human wisdom. Realizing our shared purpose and long-standing aspirations is among the best approaches to building a better Earth.

7. Strength Analysis

Calculation model of carbon sequestration in this paper, taking into account the comprehensive factors system, measures to adapt to local conditions to use, such as cluster analysis, the analytical hierarchy process (AHP), and entropy weight method commonly used statistical methods to select indicators to determine the weights, and according to the data characteristics used the multiple regression methods, the adjustment function prototype high precision, good adjustment effect.

1. The carbon sequestration model considering the factor system is comprehensive, according to the local conditions, such as cluster analysis, entropy method commonly used to select indicators to determine the weight, and according to the data characteristics aiming to use a variety of regression methods to fit the function prototype with high precision, the fitting effect is excellent;
2. The calculation model for carbon fixation in this paper is simple, practical and very efficient. The model refers to the calculation method of international mainstream carbon reserves (IPCC and Kyoto Protocol), is based on natural science and existing research results, effectively avoids the segmentation steps in calculation methods based on pure natural science, and greatly improves the calculation efficiency;
3. The process of building the carbon decision model is highly innovative. We have found a new way to study the relationship between the ecological benefits of forest carbon sequestration and the socioeconomic benefits. Based on previous research, we proposed to quantify the economic benefits of forest carbon sequestration with a price of 2 per cubic meter;
4. The strategy for building the models is from simple to complex and from shallow to deep, step by step from several isolated indicators to a general mathematical model, and then apply and test the model.

However, the factors considered in this paper may be slightly different from the real world situation, which makes the model has certain limitations and has a specific impact on the universality and generalization ability of the model.

8. Conclusion

We have explored the relationship between carbon fixation and various indicators, and derive the weights, balance the ecological value and social-economic value, and understand the best use of forests. There may be controversial for cutting, but our research shows that moderate cutting is beneficial to forest management.

Data Availability Statement

The author confirms that the data supporting the findings of this study are available within the article or its supplementary materials.

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