ISSN: 2688-9323

Study of Exclusive Customization of Forest

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Abstract

With the change of global climate, it is of great significance to formulate appropriate forest management plans to increase the carbon sequestration and oxygen release capacity of forest ecosystems. Therefore, we need to establish a new value evaluation system to measure the value of ecological and economic benefits.

Keywords

CO2FIX Model; Ecosystem Benefit; Carbon Sequestration.

1. Introduction

1.1. Problem Background

With the development of society, the amount of carbon dioxide emitted into the atmosphere is increasing day by day. To this end, we need to increase the amount of carbon dioxide sequestration through the biosphere or mechanical means. This process is called carbon sequestration. Forests are an important carrier for mitigating climate change, and forest ecosystems are one of the largest carbon sinks in the terrestrial landscape. Forests sequester carbon dioxide in living plants or wood products, and in order to maximize carbon sequestration levels, forests need to be properly harvested.

1.2. Model Assumptions and Rationality of Assumptions

To simplify our model, we make the following assumptions in the paper.

1) It is assumed that the data we collect is accurate, reliable, and true.
2) Because our data sources are domestic authoritative websites and websites of international organizations, we have reason to believe that these are real, high-quality data.
3) In model validation, it is assumed that the trees in the forest, in addition to the indicators that make changes, always have the optimal environment for their growth. In order to control variables, get accurate simulation results.
4) In the model verification, it is assumed that there will be no natural disasters such as earthquakes and hurricanes, and no human-induced environmental pollution. To avoid large-scale shifts in prediction results.
5) In model validation, it is assumed that team behavior is in line with the laws and policies of the relevant country.

2. Carbon Sequestration Model based on CO2FIX Model

2.1. Model Overview

Forests sequester carbon dioxide through photosynthesis in living plants and in products produced by trees, including furniture, lumber, plywood, paper, and other wood products, so when we calculate carbon sequestration in forests, we need to focus on forest ecosystems in addition to The internal carbon cycle process also needs to consider the carbon circulation process of forest products after the forest vegetation is cut down.

CO2FIX V.2 is a hectare-level forest ecosystem carbon metering model capable of simulating the carbon stocks and fluxes of individual forests on an annual scale($t \cdot hm^{-2}$). Since the model

ISSN: 2688-9323

was developed, it has been experimentally verified by many scholars, which proves that the model is suitable for natural forest and plantation ecosystems, pure forests or mixed forests of the same age or different ages, and multi-level agroforestry complex ecosystems. There are good results in the carbon cycle simulation of climate zones and different types of forest ecosystems [1].

The main feature of the carbon sequestration model based on the CO2FIX model established by our team is that the forest product module is added on the basis of considering the forest biomass carbon pool and soil carbon pool, which makes it possible to systematically study the carbon flow of plantation from planting to harvesting and utilization.

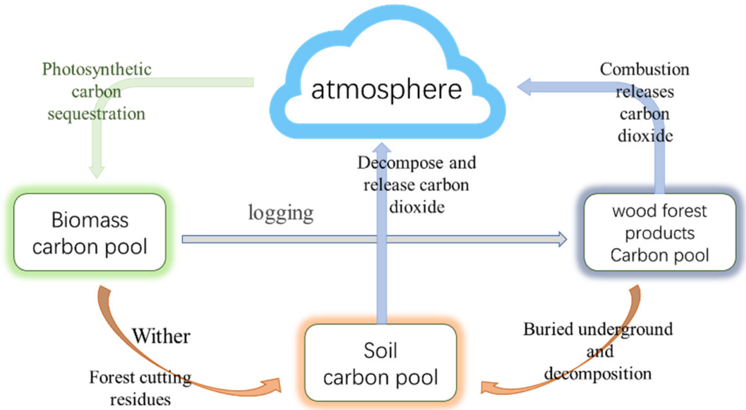

Figure 1. Carbon storage and carbon circulation in forest ecosystems

2.2. Model Analysis and Related Results

The biomass module mainly considers the impact of tree growth, competition, death, management measures (such as harvesting) on forest carbon storage. The most important factor affecting forest biomass is the growth of tree trunks, and we will give two methods to describe the growth of tree trunks. One is suitable for tropical forests whose forest age is not easily determined, and the expression is:

$$\alpha_i = A(\alpha_{\max} - \alpha)\alpha^k \tag{1}$$

α_i is the stand biomass increment, α is the actual biomass, $\alpha_{\max}$ is the maximum biomass that the stand can achieve, A , k is the parameter to be estimated.

One is the Chapman-Richards model, which is suitable for stands with a certain age, and the expression is:

$$\beta = \mathcal{B}/(1 + e^{-(\varphi + kt)/v}) \tag{2}$$

β is the biomass of the stand at time, $\mathcal{B}$ is the maximum attainable biomass of the stand, φ 、 k and v is the parameter to be estimated. Through this method, we can obtain the annual biomass carbon storage and increase of the stand. After the annual growth of the trunk is determined, the annual growth of other organs (branch, bark, leaf, root) can be calculated according to a certain distribution coefficient. For example, the main tree species in Saihanba Forest Farm, the distribution of growth per plant of different ages of larch is shown in the table [2]:

Table 1. The biomass distribution ratio of larch with different leaf ages in Saihanba Forest Farm

Lin age/year	Trunk/%	Bark/%	Branches/%	Leaves/%	Root/%	Total/%
6	28.07	15.13	34.28	11.43	11.09	100
12	37.15	11.47	31.41	8.39	11.58	100
24	50.63	11.23	19.65	6.41	12.08	100
36	55.21	8.75	18.29	5.29	12.46	100

The data source of the carbon pool of wood forest products is to track the whole process of biomass carbon from being harvested to being decomposed. We need to consider the various products formed after forest trees are felled and the proportion of each product, and classify the various products according to the service life. It can be roughly divided into long-lived products, medium-lived products, and short-lived products, and it is assumed that each product is discarded exponentially according to its service life. In the end, there are only two ways for the product to "release" carbon, one is released into the atmosphere after burning, and the other is decomposed and transferred to the soil carbon pool.

This paper selects Saihanba Mechanical Forest Farm in Chengde City, Hebei Province, China, and collects relevant data of Saihanba Mechanical Forest Farm from 1962 to 2021. The CO2FIX V.2 model can simulate and calculate the carbon storage and carbon flux of Saihanba over the years, and then calculate the amount of carbon dioxide that the Saihanba Forest Farm can absorb each year. The formula is:

$$m_c = (M_c / M_{total}) \times m_{total} \tag{3}$$

M_c represents the relative atomic mass of carbon, M_{total} Indicates the relative atomic mass of carbon dioxide, and the value is 44; it can be estimated that the amount of carbon dioxide sequestered by Saihanba Forest Farm in 2021 is 860,300 tons, and the rest of the results are as follows:

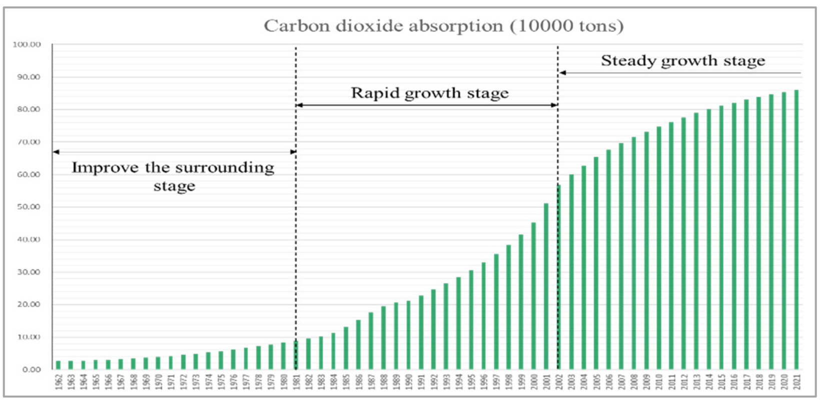

Figure 2. The amount of carbon dioxide absorbed by Saihanba Forest Farm over the years

ISSN: 2688-9323

The team assumes that only mature wood will be harvested during the harvesting process, and that only 15% of the forest volume will be harvested each time, and the saplings will be replanted in time after harvesting.

$$cut = str \times S \tag{4}$$

cut indicates the amount of harvesting in the gap year,str represents the cutting intensity,S Indicates the volume of trees in Saihanba Forest Farm until the time of mining.

According to the cutting volume and the corresponding cutting interval, the age composition and proportion of forest tree species can be known. A forest management plan with an interval of 25, 35, 45, 55 and 65 years, simulates the calculation of carbon storage and carbon flow within 300 years, and compares and analyzes the optimal cutting interval suitable for Saihanba Forest Farm. As shown in Figure 3, we found that the forest management plan with a cutting interval of 45 years has the largest amount of carbon sequestration, which is 2.531 million tons. Therefore, we have reason to believe that if only considering the most effective carbon dioxide absorption The optimal cutting interval of the forest management plan is 45 years, and the error is not more than 10 years.

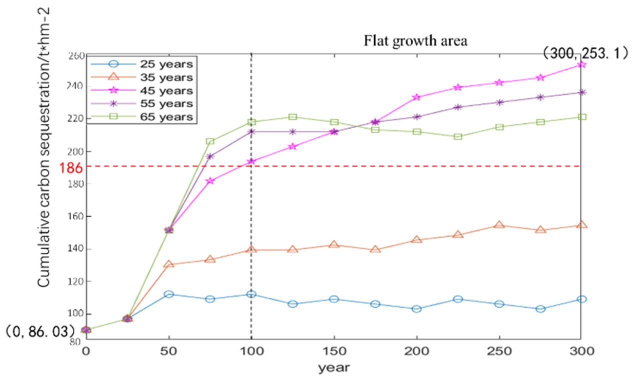

Figure 3. Cumulative carbon sequestration of different forest plans in each year

3. The Best Economic Model

The best forest management plan should reasonably carry out economic activities on the premise of ensuring the sustainable utilization of forest resources and the sustainable development of ecological civilization, so as to maximize the forest ecology and forest economic benefits while obtaining the maximum economic benefits.

Forest ecosystem benefit accounting includes ecological benefit, economic benefit and social benefit. Because the proportion of social benefit is relatively small and the weight influence is small in a long time scale, this paper focuses on ecological benefit and economic benefit.

3.1. Ecological Benefit Accounting

After consulting a large amount of data, it is found that the benefits of water conservation and forest carbon sequestration and oxygen release account for 82.9% of the forest ecological benefits. In order to simplify the model, we only consider these two indicators. The role of forest water conservation mainly includes the regulation of water quantity and the purification of water quality by forest. This paper mainly studies the regulation effect of forest on water quantity. In this paper, from the perspective of water balance, by calculating the increase of water in the forest ecosystem, the total amount of water sources regulated by Saihanba Forest Farm each year is obtained [3]. The formula is as follows：

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$$W_{adj} = 10S(P - T - C) \tag{5}$$

W_{adj} is the amount of water conserved by the forest, and the unit is $m^3 \cdot a^{-1}$;S is the area of forest resources, the unit is hm^2 ;P is the average annual rainfall in the area where the forest is located, in units of $mm \cdot a^{-1}$;T is the stand evapotranspiration in units of $mm \cdot a^{-1}$;C is the surface runoff in units of $mm \cdot a^{-1}$.

(1) Evapotranspiration from Saihanba Forest Farm

Forest evapotranspiration can be calculated from the annual rainfall and evapotranspiration rate of the forest, and the formula is: $T = P \times R$,T is the forest evapotranspiration,P is the annual rainfall,R is the evapotranspiration rate.

(2) Surface runoff of Saihanba Forest Land

We can use the surface runoff coefficient method to calculate the surface runoff. The calculation formula is: $C = P \times \alpha$,C is the surface runoff,P is the rainfall,α is the surface runoff coefficient.

From the above formula and the forest area, rainfall, evapotranspiration rate, and surface runoff coefficient of Saihanba Forest Farm [4], the following table can be obtained:

Table 2. 2014-2019 Saihanba Forest Farm Conservation Water Source

Year	Forest volume/10,000 cubic meters	Conservation water volume/billion cubic meters
2014	965.47	1.18
2015	978.38	1.24
2016	990.18	1.30
2017	1001.10	1.37
2018	1011.29	1.56
2019	1020.70	1.94

As the forest coverage area of Saihanba Forest Farm is getting bigger and bigger, its water culverting capacity is getting stronger and stronger. In 2019, the water culverting capacity of the forest farm reached 194 million cubic meters. From 1962 to 2019, the changes of water culvert in Saihanba Forest Farm over the years are as follows:

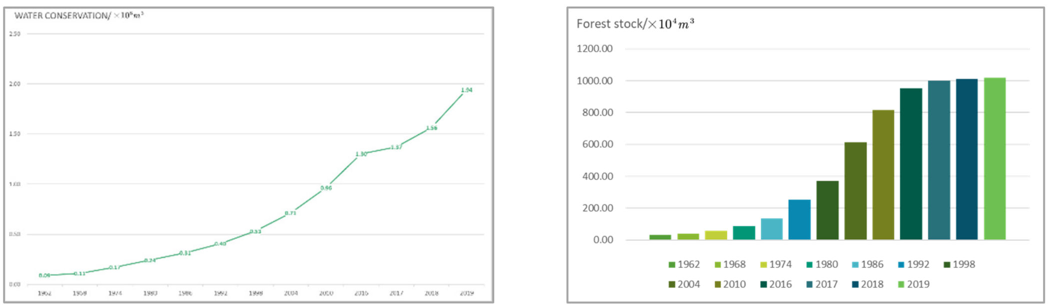

Figure 4. Line chart of water culvert and column chart of tree accumulation in Saihanba Forest Farm in some years

The nature of forest water regulation is similar to that of reservoir water storage, so this paper uses the alternative engineering method to calculate the value of water conservation in

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Saihanba Forest Farm. We transform the estimation of the value of forest water conservation into the water storage cost measurement of the reservoir project, then the value formula of the annual water regulation of the forest ecosystem is: $val_w = W_{adj} \times p$, val_w is the value of forest water regulation, in yuan, p is the investment cost of the reservoir for the construction unit, is $1\ m^3\ need\ 0.9\ yuan$.(It is the reference price for the construction of small and medium-sized reservoirs in China, and the construction cost of large-scale reservoirs is higher) [3] Some data of the value of forest conservation water resources in Saihanba Forest Farm over the years are shown in the following table:

Table 3. The value of forest conservation water source in some years of Saihanba Forest Farm

Year	Forest volume/10,000 cubic meters	Conservation water value/10,000 yuan
1962	33.00	810
1968	40.92	990
1974	58.98	1530
1980	86.60	2172.791
1986	136.78	2824.001
1992	254.50	3641.482
1998	369.84	4783.088
2004	615.18	6406.671
2010	815.64	8670.084
2016	951.22	11731.18
2017	1001.10	12330
2018	1011.29	14072.7
2019	1020.70	17467.36

(1) Forest carbon sequestration value

Carbon Tax

Carbon tax law refers to the method of calculating the value of carbon sequestration function of an ecosystem according to the standard carbon tax selected at home and abroad. We chose to use the Swedish tax rate as the estimation standard. The formula is: $val_c = 1034.94 \times m_c$, val_c is the value of carbon sequestration (yuan), m_c is the total carbon sequestration of the forest farm.

Afforestation cost method

The economic benefits of carbon sequestration can be estimated with reference to the cost of afforestation, that is, the cost of absorbing the same amount of carbon dioxide by forests is used to replace the cost of absorbing carbon dioxide by other means. The cost is approximately equal to 1089.74 yuan in 2019. The formula is: $val_c = 1089.74 \times m_c$.

Robust mean method

For the robustness of the experimental data, the average value of the afforestation cost method and the carbon tax method is 1062.34 yuan as the standard, and the formula is: $val_c = 1062.34 \times m_c$.

In order to compare the above formulas for calculating the carbon sequestration value, different methods were used to calculate the carbon sequestration value of Saihanba Forest Farm in some years, and a bar chart was drawn. The specific relationship is as follows:

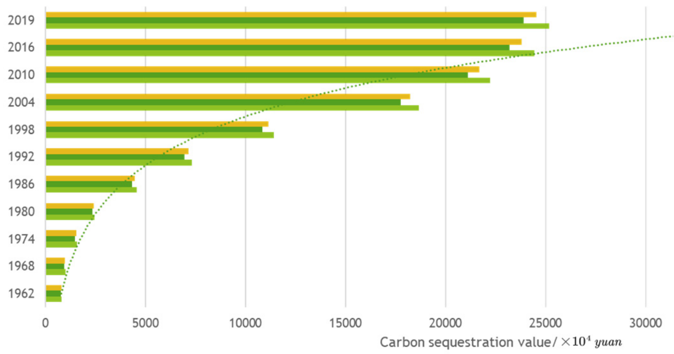

Figure 5. Carbon sequestration value of Saihanba Forest Farm in some years

It can be seen from the figure that the robust mean method has the best fitting degree with the prediction curve.

(2) Oxygen release value of forest

According to the equations of plant photosynthesis and respiration and the ratio of carbon dioxide and oxygen coefficients, it can be known that absorbing 1 gram of carbon dioxide releases 0.7356 grams of oxygen. Therefore, the calculation formula of forest oxygen release is: $m_o = 0.7356 \times m_c$, m_o is the annual oxygen release of the forest, the unit is t. The calculation formula of forest oxygen release value is: $val_o = p_o \times m_o$, val_o is the annual oxygen release value of the forest, the unit is Yuan, p_o is the price of oxygen, in units $yuan\ /\ t$.

In this paper, the average price of oxygen used in industrial steel smelting is chosen as the oxygen price in the calculation of the oxygen release value, which is approximately 850 $yuan\ /\ t$. The results can be calculated according to the formula. The specific values are as follows. From the table, we can see that the annual oxygen release value of Saihanba Forest Farm in 1962 was 16.1893519 million yuan, and the annual oxygen release value of Saihanba Forest Farm in 2019 was 50074.24334 10,000 yuan, since the average price of oxygen used in industrial steel smelting will change with time and economy, the annual oxygen release value will also fluctuate, but its relative relationship remains unchanged, and the relative change trend remains unchanged.

Table 4. Part of the annual oxygen release value of Saihanba Forest Farm

Year	Annual oxygen release value / $\times 10^4 yuan$	Year	Annual oxygen release value / $\times 10^4 yuan$
1962	1618.93519	1998	22707.56884
1968	2007.43345	2004	37150.76373
1974	3128.02035	2010	44204.82507
1980	4913.33409	2016	48576.96529
1986	9107.71657	2018	49612.67377
1992	14574.35016	2019	50074.24334

The ecological benefit of the forest ecosystem is the sum of the value of forest water conservation and the value of forest carbon sequestration and oxygen release. The total value of the ecological benefits of the Saihanba forest ecosystem in 2019 was 920.7998469 million

ISSN: 2688-9323

yuan, of which the total value of forest water conservation was 174.6736 million yuan, accounting for 18.97% of the ecological benefits of the forest ecosystem; The oxygen value is 746.1262469 million yuan, accounting for 81.03% of the ecological benefits of the forest ecosystem. From the perspective of the ecological benefit value of the forest ecosystem in each year, the ecological benefit value of the forest ecosystem was the largest in 2019, which was 920.7998469 million yuan, followed in 2016, and the ecological benefit of the forest ecosystem was 841.1280053 million yuan. The lowest value is 32.2227816 million yuan.

3.2. Economic Benefit Accounting

The economic benefits of forest ecosystems refer to the value of tangible products provided by forest ecosystems. We divide forest products into two parts for independent accounting, one is the wood part and the other is the non-wood forest products part.

(1) value of forest assets

There are various classification methods for forest trees. We can classify forest trees into timber forest trees, shelter forest trees, economic forest trees and other purpose forest trees according to different management purposes. According to the information, when accounting for forest assets, the forest species can be accounted for as a secondary indicator, and the forest age structure can be accounted for as a tertiary indicator [3].The assessment of forest assets has several commonly evaluation methods: market price inversion method, net present value method of income, present value method of harvest, and replacement cost method.

The market price inversion algorithm is mainly applicable to the forest assets of near-mature forest, mature forest and over-mature forest. The formula is [3]:

$$val_{tree} = W - C - F \tag{6}$$

val_{tree} indicates the value of forest assets, W represents the total sales revenue, C Indicates timber operating costs (including mining and transportation costs, management costs, tax costs, etc.), F Indicates the reasonable profit of timber management. It should be noted that the demand in the log market and the yield rate.

The net present value method of income is applicable to economic forest assets and shelter forest assets. It is necessary to pay attention to the maturity, economic life, and cost differences of economic forests. The formula is [3]:

$$val_{tree} = \sum_{i=n}^{k} \frac{(A_i - C_i)}{(1+P)^{i-n+1}} \tag{7}$$

val_{tree} represents the value of forest assets, A_i represents the annual income in year i, C_i represents the annual cost of the year i, k is the operating period, p is the discount rate, n is the tree sub-age ($n \leqslant k$).

The serial number of labor method is suitable for young trees. The only thing that needs to be paid attention to is the determination of the adjustment coefficient. The formula is [3]:

$$val_{tree} = K \cdot \sum_{i=1}^{n} N_i \cdot B \cdot (1+P)^{n-i-1} + \frac{R[(1-P)^n - 1]}{P} \tag{8}$$

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val_{tree} represents the value of forest assets, K is the stand adjustment coefficient, N_i indicates the number of labor required in the ith year ; B is the production cost calculated in man-days at the time of evaluation, P represents the interest rate; R means rent, n indicates stand age.

The replacement cost method applies to young trees, commercial forest assets and shelter forest assets. It should be noted that the adjustment coefficient and the reset period are determined, the formula is [3]:

$$val_{tree} = K \cdot \sum_{i=1}^{n} C_i (1+p)^{n-i+1} \tag{9}$$

C_i Represents the production cost calculated in the i-th year based on the current labor price and production level (mainly including the wages, material consumption, land rent, etc. invested in each year), P represents the interest rate, n indicates stand age.

The key to forest value accounting is to determine the price of trees. The main tree species in Saihanba Forest Farm are larch, sylvestris pine, birch, spruce and so on. From the inventory data in the annual report of Saihanba Forest Farm, the forest area and volume of each forest age group can be obtained. Therefore, in this study, each forest age group is used as an indicator variable to achieve the purpose of calculating the value of forest trees. In theory, the replacement cost method is generally used for young forests, and the net present value method is used for middle-aged forests, near-mature forests, mature forests and over-mature forests. Young trees are rarely harvested, so when calculating the tree value of Saihanba Forest Farm, the value of young and middle-aged forests is not considered for the time being.

The timber price is the average price of logs in Hebei Province, China in 2019. The operating profit is the timber price multiplied by the relevant technical parameters. The results are shown in the table:

Table 5. 2019 Saihanba Forestry Asset Value

Year	Near mature forest $/\times 10^8 yuan$	Mature forest $/\times 10^8 yuan$	Overripe forest $/\times 10^8 yuan$	the total $/\times 10^8 yuan$
2019	38.6251	4.8666	0.9241	4.44158

(2) Value of non-wood forest products

According to the nature and use direction of forest products, we can divide forest products into two types: wood forest products and non-wood forest products, and establish a forest product value accounting index system. Since the 21st century, the Saihanba Forest Farm has been gradually transformed from a forest afforestation program that focuses on wood production to an ecological forest farm that focuses on ecological services. The corresponding output value of wood forest products has been calculated in the forest assets, so we won't cover that part anymore. Since the prices of various non-wood forest products fluctuate greatly, the evaluation of their value can be estimated according to the output value of economic forest products in forest assets [3]. The results of 2019 are as follows:

Table 6. 2019 Total value of non-wood forest products in Saihanba Forest Farm

Year	Forest food $/\ t$	Forest beverages $/\ t$	Chinese herbal medicine $/\ t$	prince $/\times 10^4\ yuan$
2019	1641.3	1765.9	2380.7	86369.9503

ISSN: 2688-9323

From the above economic benefit calculation results, it can be seen that the economic benefit value of Saihanba forest ecosystem in 2019 is 5.30527 billion yuan, of which the value of forest assets stock is 4.44158 billion yuan, accounting for 83.72% of the total economic benefit, and the value of forest products is 863.69 million yuan , accounting for 16.28% of the total economic benefits.

3.3. Benefit Accounting

According to the above research, the benefit of the forest ecosystem in Saihanba is equal to the sum of the economic benefit and the ecological benefit of the forest ecosystem. The total value of the forest ecosystem benefit of Saihanba in 2019 is 6.226069 billion yuan, of which the economic benefit of the forest ecosystem is 5.30527 billion yuan. , accounting for 85.202% of the total benefit; the ecological benefit is 920.799 million yuan, accounting for 14.798% of the total benefit; according to the data, it can be clearly seen that the economic benefits of the Saihanba forest ecosystem account for the main part of the total benefit. Therefore, how to formulate forest management plan to obtain greater economic benefits under the premise of ensuring the sustainable development of forests is also a need for forest managers to consider.

4. Evaluation and Promotion of the Model

4.1. Evaluation of Advantages

The carbon sequestration model established with reference to the CO2FIX model has high accuracy and can finally obtain the specific carbon sequestration amount.

In the optimal economic benefit model, various benefits generated by the forest ecosystem are attributed to economic benefits through the conversion of various methods, which achieves the unification of dimensions and provides convenience for obtaining the best results.

4.2. Model Promotion

There are various factors affecting forest carbon sequestration. This paper mainly considers the age and type of trees, the benefits and lifespan of forest products. However, human factors and other natural factors will cause certain deviations in the simulation results. If you want to consider it comprehensively, you can refer to more information to find out how each factor affects carbon sequestration, and establish a more complex model to solve it.

If more complete data are available, a more comprehensive analysis of forests around the world can be carried out, and carbon sequestration models can be revised in time to achieve higher accuracy in determining the optimal harvesting interval.

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