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ROOTS OF RICHES: HARNESSING CARBON-CENTRIC FOREST MANAGEMENT FOR DUAL GAINS IN ENVIRONMENTAL AND ECONOMIC PROSPERITY

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Abstract
With the escalating impacts of climate change on ecosystems, the imperative to mitigate greenhouse gas emissions has gained unprecedented significance. The President of the United Nations Climate Change Conference underscored the urgent need to limit global warming to a maximum of 1.5 degrees Celsius and committed to reducing global CO_2 emissions by nearly 50% by 2030. In light of this global commitment, the focus has shifted from solely reducing CO_2 emissions to enhancing carbon sequestration as a critical strategy for environmental protection.
Historically, the prevailing perspective centered on the necessity of curbing deforestation to achieve increased carbon sequestration. However, this viewpoint requires reevaluation. It is now evident that carbon sequestration can also be bolstered through the growth of mature trees, the establishment of new forests, and the sustainable management of forest products. Moreover, it is essential to recognize the broader impacts of such strategies, including their potential to conserve biodiversity and generate cultural and recreational values. Consequently, the selection of an appropriate forest management plan emerges as a pivotal determinant in maximizing the multifaceted value of forests.
This study delves into the intricate relationship between forest management strategies and carbon sequestration. By exploring the potential of various forest management approaches, including planned deforestation for value optimization, it aims to provide insights into how these strategies can contribute to both mitigating climate change and enriching the ecological, economic, and cultural aspects of our environment.

Keywords: Carbon sequestration, Forest management, Climate change mitigation, Biodiversity conservation, Sustainable deforestation

1. Introduction

With the increasing impact of climate change on ecosystems, people are increasingly concerned about the emission of greenhouse gases in the atmosphere. The President of the United Nations Climate Change Conference at the COP26 summit in December 2021 proposed limiting global warming to no more than 1.5 degrees and committed to cut global CO_2 emissions by nearly half by 2030. [1-2] To accomplish this goal, the consideration of reducing CO_2 emissions alone can no longer fully meet the

needs of environmental protection, and Increasing carbon dioxide reserves - carbon sequestration - has gradually become a national focus.
The dominant view in the past was that reducing deforestation is necessary to achieve more carbon sequestration [3-4]. But we need to consider the growth of new trees and forest products can produce carbon sequestration. In other words, the growth of adult trees, new trees and forest products can produce carbon sequestration, and we also need to consider the impact of other added values on forest management plans such as conserving biodiversity and bringing cultural and recreational values. [5] Therefore, the selection of an appropriate forest management plan plays an important role in maximizing the value of the forest. Planned deforestation of their forests to maximize forest value[6].

2. Framework of carbon sequestration model

In view of establishing the carbon sequestration model, we consider the influence of topography, climate, humidity, tree species, and woodland area on forests. TOPSIS is used to obtain the ranking of tree species, and the logistics curve is used to calculate the number of cuts, intermediate cutting period, and species of cut trees of a forest in a period to determine our cutting plan[7]. Deforestation plan and planting plan interact with each other and constitute forest management plan together with forest products. Analysis flow chart of carbon storage model is shown as figure 1.

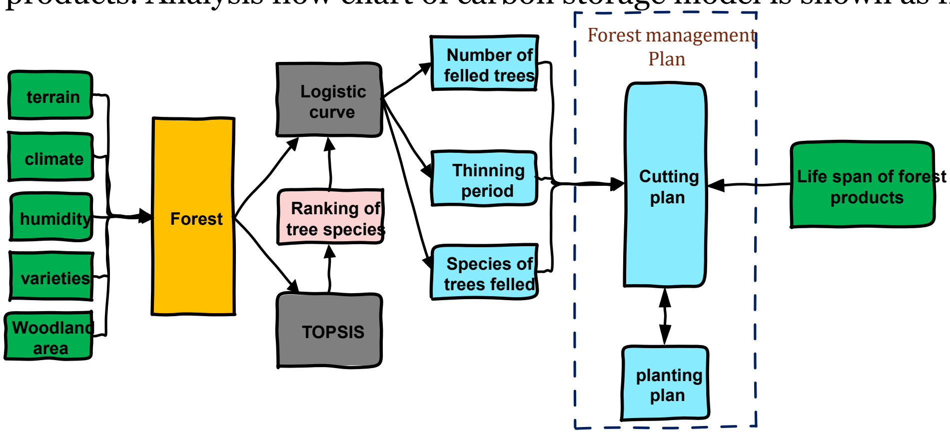

Figure 1: Analysis flow chart of carbon storage model

3. Establishment of carbon storage model

3.1 Calculation of carbon storage

There are many calculation formulas about forest carbon storage, such as $CO\ FIX_2$ model method, carbon balance model method, biomass conversion method, vortex correlation method, box method. Each method has its characteristics, In the carbon cycle study, we try to choose a more straightforward and more suitable calculation method. This can simplify other processes as much as possible and carry out the more suitable calculation[8]. We first adopted the biomass expansion factor (BEF) method to process the original data before cutting.
Calculation formula for carbon sequestration without considering logging

$$C=\sum_{i=1}^{n}\sum_{j=1}^{m}\{A_{ij}\cdot V_{ij}\cdot BCEF_{ij}\cdot(1+R_{ij})\cdot CF_{ij}\} \qquad (1)$$

Where is the carbon storage of arbor forest and sparse forest; i is the climate type; n is the total number of climate types; j is the dominant tree species; m is the total number of dominant tree species; A_{ij} is the forest land area; V_{ij} is the accumulation amount; $BCEF_{ij}$ is the conversion and expansion coefficient from the accumulation amount to aboveground biomass; R_{ij} is the ratio of root to stem of tree species; CF_{ij} is the carbon content coefficient of biomass.

Then, we consider the number of deforestation trees to build a deforestation plan for carbon sequestration of forest products and tree cultivation :

Assuming that a forest has the number of m species of trees, the ratio of each tree is $\alpha_i (i = 1, 2, \cdots, m)$, the ability of each tree to fix carbon is $\beta_i (i = 1, 2, \cdots, m)$, the total number of trees in the forest is ω, x_{ik} is the number of deforestation of the first tree in the kth year, and σ is the ratio of saplings to adult trees to convert carbon.

Carbon storage in natural conditions:

$$y_k = \sum_{i=1}^{m} \alpha_i \beta_i \omega \quad (2)$$

Assuming that logging and production of crops and products commenced in the first year, the system's carbon sequestration in the p year with logging is

$$y_p = \sum_{i=1}^{m} \sum_{k=1}^{p} (\alpha_i - x_{ik}) \beta_i w + \sum_{k=1}^{h} \sum_{i=1}^{m} x_{ih} \beta_i \sigma + \sum_{h=1}^{k} x_{ih} \beta_i c_i w \quad (3)$$

Where $\sum_{i=1}^{m} (\alpha_i - \sum_{k=1}^{p} x_{ik}) \beta_i w$ is the carbon storage of adult trees after cutting, $\sum_{k=1}^{h} \sum_{i=1}^{m} x_{ih} \beta_i \sigma$ is the proportion of carbon storage of young trees, and $\sum_{h=1}^{k} x_{ih} \beta_i c_i w$ is the proportion of carbon storage of forest products.

Then, we use TOPSIS to identify tree species ranked for carbon sequestration capacity TOPSIS is an objective weighting method that determines the weights based on the correlation between the indicators. The specific steps are:

Step1: Use nonlinear transformation or other methods in attribute specification to resolve the nonlinear relationship between certain objectives and attributes and the incomplete compensability between objectives.

Step2: Constructing the weighted canonical array, we decide the weights according to the different properties of the tree species

Step3: By calculation, we obtain the positive ideal solution and the negative ideal solution

Step4: Bringing in the positive and negative ideal solutions, we determine the distance of each solution to the positive and negative ideal solutions

Step5: We calculate the ranking index values of carbon sequestration capacity of various trees and the advantages and disadvantages of the scenarios ranked from the largest to the smallest according to the comprehensive evaluation index for further explanation. List Differential Equations for Logistic Models

$$\frac{dN_i}{dt} = rN_i \frac{(K_i - N_i)}{K} \quad (4)$$

Where N is the number of trees, r is a constant, and K is the environmental suitability of the forest,

N_i represents the current number of forests. It is influenced by the climate, temperature, and other forest conditions. The Logistic curve needs to take into account that r is related to climate, temperature, and other conditions, and indicates the number of trees in the current forest.

We obtained its image and growth rate using the differential equation listed in the logistic model, see Figures 2 and 3

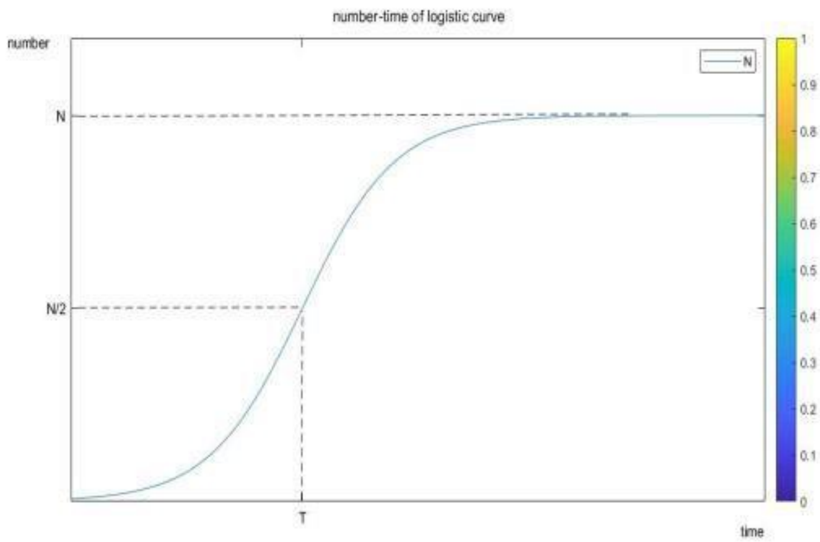

Figure 2: Logistic curve

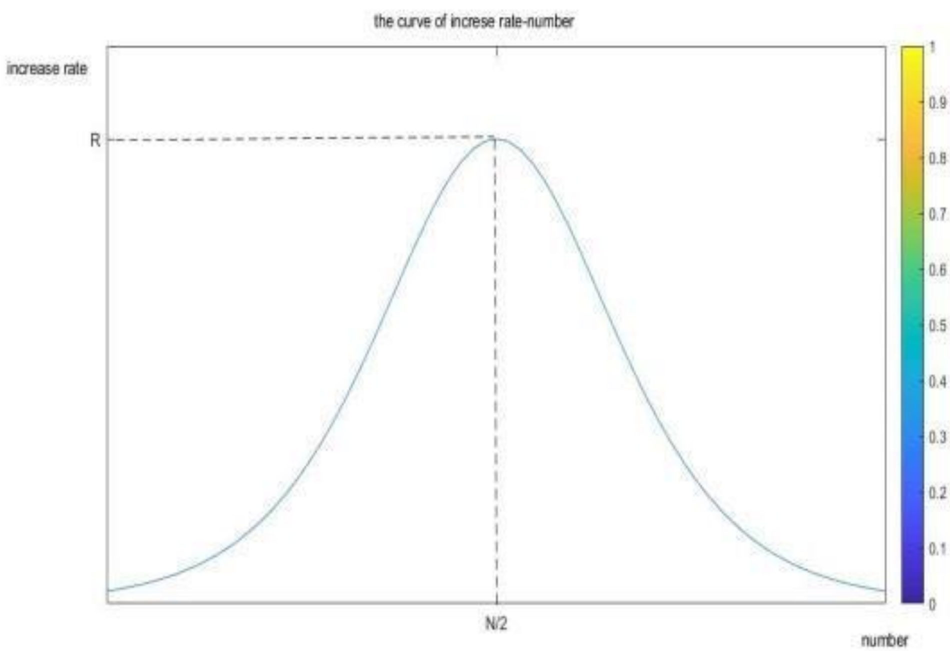

Figure 3: Logistic curve growth rate From the analysis of the above graph, we can get:

$$N = \frac{K}{\,},\ \left(\frac{dN}{\,}\right)_{max} = \frac{rK}{\,} \qquad (5)$$

2 dt 2

Therefore, we control the number of numbers to one-half of the population appropriate amount after cutting, so that we can get the maximum amount of carbon sequestration.

Suppose the initial value of N(t) is $\frac{K}{2}$, then the change of the population number with time is

$$N(t) = \frac{K}{1+e^{-n}}, \quad t = \frac{1}{r}\ln\frac{N}{K-N} \tag{6}$$

If the number before cutting N_1 and the number after cutting N_2 are determined, then the cutting interval should be

$$t_1 - t_2 = \frac{1}{r}\ln\frac{N_1}{K-N_1} - \frac{1}{r}\ln\frac{N_2}{K-N_2} \tag{7}$$

The above logistic model analysis can be used to obtain the total amount of felling, and the intercutting period, i.e., the number of trees is controlled at one-half of the appropriate amount for the population. By using TOPSIS and logistic model, we can obtain the cutting volume of each tree, and thus get the maximum carbon sequestration volume.

3.2 Forest product flow

During a rotation cycle, part of the tree enters the soil and the other part is processed into various products such as wood. As an important carrier of carbon sequestration, forest products play an important role in the carbon sequestration process of forests. Among the forest products, the carbon sequestration of short-term products has been mentioned in the equation. For medium-term and long-term forest products, carbon sequestration can exist as a constant, so it will not be explored in the forest products. The details are shown in Figure 4.

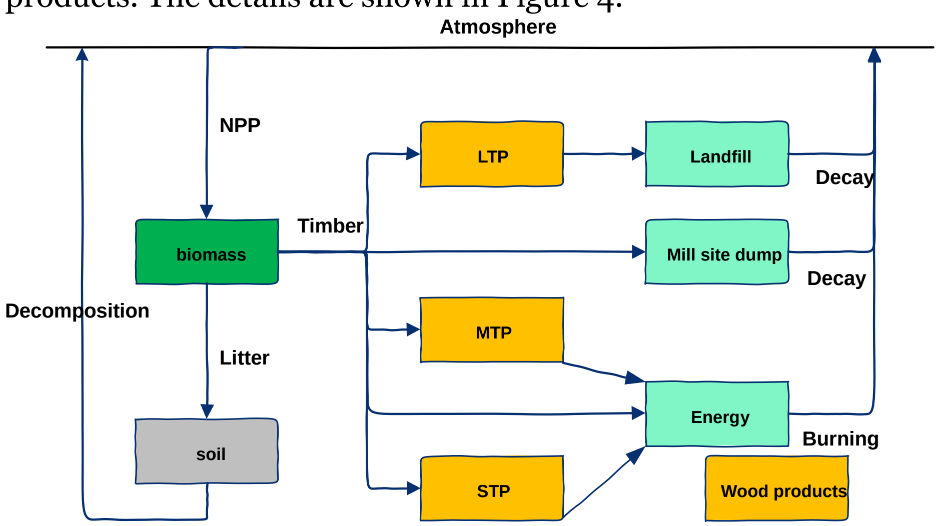

Figure 4: Carbon fluxes in the forest during a rotation cycle

3.3 Ziwuling Forest Indicator Selection

Ziwuling is a natural secondary forest that has been naturally restored after abandonment by chaotic warfare and plays an important role in the climate of western China. The vegetation of the Ziwuling forest area in Gansu is a warm temperate deciduous broadleaf forest region with natural secondary forest areas, including temperate coniferous forest, mixed evergreen coniferous deciduous broadleaf forest, and deciduous broadleaf forest.

As the vertical distribution of vegetation in Ziwuling is not apparent, the horizontal distribution is affected by the topography showing complexity. The distribution of vegetation varies due to the difference in temperature humidity. The more humid shady and semi-shady slopes have more distribution of sapodilla and birch. In comparison, the arid, sunny slopes and semi-sunny slopes have more distribution of sapodilla and sapodilla. The specific indicators and their influence degree are shown in the following table.

Table 1: Indicators and their influence degree

Indicators	Influence degree
The type of tree	larger
The vegetation distribution	big
Climate type	larger
Woodland area	larger
The life span of forest products	small

3.4 BEF method was used to standardize the Ziwuling data

We used the biomass expansion factor method (BEF) to calculate the carbon storage, selected the dominant tree species in the Ziwuling forest, and standardized and normalized the data on the ratio of root to stem, carbon content coefficient of biomass, and the conversion and expansion coefficient of stock to aboveground biomass (BECF), so that the data were between 0 and 1. The carbon storage capacity of tree species in the Ziwuling forest can be obtained by ranking the carbon storage capacity of dominant tree species and calculation parameters. The carbon storage capacity of broadleaf mixed forest with the highest carbon storage capacity is as high as 4.316 million tons in this forest, the carbon storage capacity of birch in this forest is 961,900 tons, and the carbon storage capacity of elm is only 0.39 million tons. The calculation parameters of dominant tree species in Ziwuling Forest region of Gansu Province are shown in Table 2. Then, we rank the dominant tree species to obtain the proportion and quantity of felling.

Table 2: Calculation parameters of dominant tree species

Serial number	Edge species	BECF/(t m. after)	Tree species root to stem ratio	The coefficient of Biomass carbon content
1	larch	0.6513	0.188	0.5137
2	Pinus tabulaeformis	0.6452	0.208 0	0.5184
3	Mourning cypress	0.6885	0.219	0.5088
4	Quercus species	0.7991	0.289	0.4798
5	brich	0.7061	0.253	0.5055
6	elm	0.6661	0.2504	0.4803
7	acacia	0.8396	0.241	0.4901

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8	Other broad categories	0.8396	0.241	0.4901
9	poplar	0.508	0.185	0.4502
10	Other soft board trees	0.5375	0.215	0.4502
11	Mixed Coniferous forest	0.5325	0.2086	0.5168
12	Broad-leaf mixed	0.6692	0.2351	0.4796
13	Coniferous broadleaf	0.629	0.2218	0.4893

4. Solution of carbon storage model

4.1 Ranking of carbon sequestration capacity of tree species

Using TOPSIS, we determine the weights. w= (0.4,0.3,0.3) Through calculation, we get the positive ideal solution and the negative ideal solution. w^{+} = (0.2032,0.0555,0.1555)

w^{-} = (0.33,0.087,0.135)Then the distance between each scheme and the positive and negative ideal solution is determined

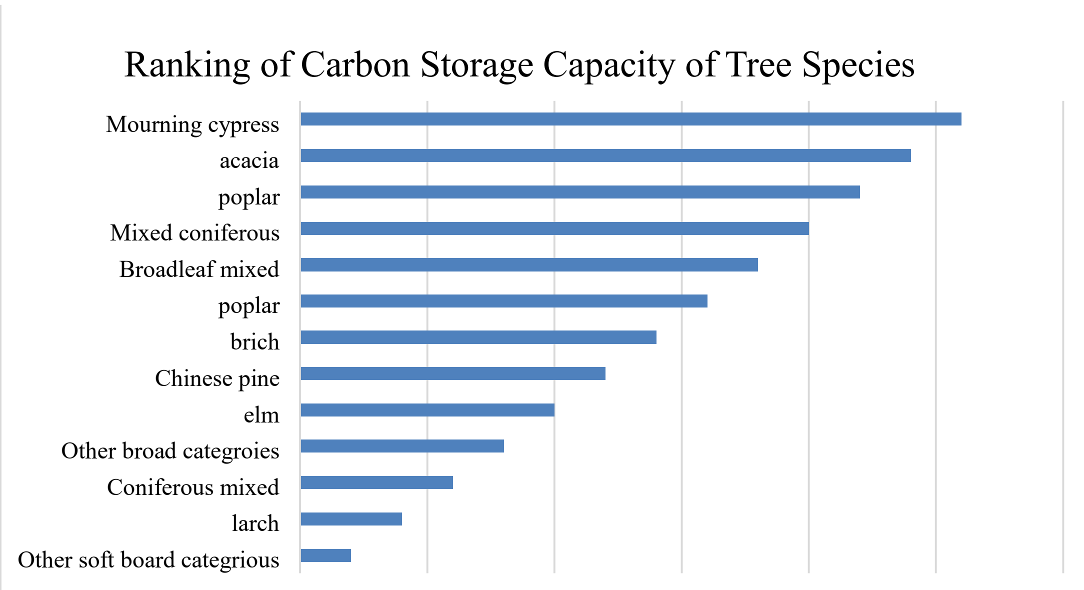

Figure 5: Ranking of Carbon Storage Capacity of Tree Species

d^{+} = (0.082,0.67,0.57,0.73,0.12,0.253,0134,0.021,0.134,0.553,0.504,0.1169,0.067) d^{-} = (0.057,0.071,0.083,0.066,0.127,0.123,0.019,0.136,0.019,0.084,0.087,0.022,0.071)

Finally, we calculate the sorting index values of all kinds of trees and further explain the advantages and disadvantages of the sorting scheme according to the comprehensive evaluation index. The figure 5 below shows that cypress wood has the highest carbon sequestration capacity, followed by Robinia locust, and other soft Broadwood species have the lowest carbon sequestration capacity.

4.2 Carbon storage and cutting quantity of each tree species

Through logistics curve and data[9], we can accurately conclude that the thinning period of Ziwuling is 5-8 years, and the total number of cutting is 1,129,936. Logistic curve and TOPSIS were used to obtain the felling proportion and number of each type of tree, and the total carbon storage of each species. Specific data are shown in Table3.

Table 3: Carbon storage and felling quantity of corresponding tree species in Ziwu Ridge

Tree species	ranking	Total carbon storage/ten thousand tons	Cutting number
brich	7	0.22	308
elm	9	0.39	390
larch	12	0.91	364
Mourning cypress	1	0.99	2574
Mixed coniferous	4	1.17	2340
Other soft board categories	13	4.68	936
acacia	2	13.28	31872
poplar	3	14.07	30954
Other broad categories	10	25.86	20688
Coniferous mixed	11	51.95	31170
poplar	6	72.52	116032
Chinese pine	8	96.19	115428
Broadleaf mixed	5	431.6	776880

5. Conclusion

In order to reduce the impact of carbon dioxide on climate change, carbon sequestration is adopted. Therefore, we establish a carbon sequestration model using the logistics curve and TOPSIS to determine the most effective management plan for carbon dioxide sequestration firstly. This paper considers many factors affecting carbon sequestration and forest value, which is highly adaptable to the forest management decision model and has a good regression effect. In this paper, carbon sequestration, forest value, and the impact of forest management decisions are related. The trade of carbon sequestration and forest value on forest management decisions are integrated through the optimization model to make the range selection and improvement of management plans more efficient.

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