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Research on forest management based on multi-objective planning

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Abstract: *Global climate change is a major problem shared by humankind, and the rate of climate change is exacerbated by excessive carbon emissions. In managing excessive carbon emissions, forests play an important role. But forest ecosystems have not only ecological values, but also economic and recreational values. In order to maximize the value of forests, this paper develops a multi-objective planning model to achieve a balance of various values and maximize benefits, considering numerous factors of forests and providing suggestions for forest management decisions.*

Keywords: *Forest Management Plan, Multi-objective planning, Carbon sequestration*

1. Introduction

At present, global climate change is an urgent problem to be solved in today's world, which concerns the survival and sustainable development of mankind. Carbon emissions are the main cause of climate change, the IPCC, points out that since the industrialization, the concentration of carbon dioxide in the atmosphere has increased by 40%, China and India, two industrial production in recent years, rapidly developing countries increase CO_2 emissions per capita, should actively adjust to the idea, take relevant measures to reduce the occurrence of this phenomenon.

The current status and progress of forest management research at home and abroad in recent years are reviewed. Forest management is the main measure to maximize the benefits of forest production, and firstly, forest quality and efficiency can be carried out by optimizing forest management strategies to obtain maximum benefits[1]. Secondly, through rational selection of harvesting wood, species selection, scientific selection of forest breeding methods, as well as forest road construction and observation sample construction, we can also provide reference for forest management and increase of forest carbon sink[2]. Finally, the forest management and management level should be improved by steadily increasing the accumulation and growth per unit area of the forest, and by using afforestation and reforestation measures to achieve effective forest renewal[3].

Forests can affect climate change through carbon sequestration[4]. Growing forests have a large volume to absorb sufficient amount of carbon and increase the carbon storage of forests. According to statistics, China's forest coverage rate is 23%, and the area of artificial afforestation is 79.542,800 hectares, which has great potential to increase forest carbon sink. Forest management and public policy can strongly affect the sequestration process. How to balance the relationship between forest economic value, biodiversity and carbon sequestration is an important part of forest management and management. In order to design a reasonable forest management plan, this paper discusses three natural forest types to achieve a balance of various values and maximize benefits by selecting the appropriate natural forest type and cutting plan.

Considering the value of forests in other ways, the value of biodiversity is just as important as the value of wood production. For the scope of the study, we selected three forest types in The Lesser Khingan Mountains and performed subsequent calculations based on their growth patterns. The comprehensive wood has the highest economic value[5][6], the highest carbon sink value[7] and the highest biodiversity value.[8] A multi-objective planning model is established, and five cycles are set, one planning period is set every 8 years, to conduct detailed research on the operation and harvesting plans of different forest types.

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2. Forest Management Plan of Natural Forest

Forests, because of their longevity and their considerable size, can sequester large amounts of carbon dioxide and play an important role in combating global climate change[9]. In addition to increasing carbon sinks, forests play an important role in other aspects of timber production, biodiversity conservation and economic value. In forest management, multi-objective planning can achieve the balance of various values and maximization of interests, and design a reasonable forest management scheme.

2.1 Growth model

According to the public information of The Lesser Khingan Mountains, the forest type of The Lesser Khingan Mountains is mainly mixed coniferous and broad-leaved forest, which can be divided into the following three forest types and their growth patterns are shown below

Natural coniferous and broad-leaved mixed forest:

$$V = 158.4\left(1 - e^{(-0.2A)}\right)^{195.9} \quad (1)$$

Natural coniferous mixed forest:

$$V = \frac{179.1}{1+265.2e^{-0.1A}} \quad (2)$$

Mixed broad-leaved forest:

$$V = \frac{152.2}{1+145.7e^{-0.1A}} \quad (3)$$

Where, A is the stand age, and V is the volume of stock per hectare.

2.2 Multi - objective programming model

In the establishment of multi-objective programming model, planning period, planning stages, harvesting methods, harvesting period should be considered, and objective function and constraint conditions should be defined[10]. According to the regulation of the interval of intermediate and harvesting and selective cutting, 8A is taken as the interval of intermediate and selective cutting, and a total planning period of 40 years is set. Among them, intermediate is used for young age and middle age, and selective cutting is used for near maturity and maturity.

(1) Economic value of timber

The economic value of timber is expressed by taking the net value of timber harvested during the planning period minus the associated costs and discounting it. The average yield of coniferous wood and broadleaf wood was taken as the mixed yield, and the cost was forest cutting cost and management cost.

The economic value of intermediate timber is:

$$Ear_{ik}^{t-time} = \frac{v_{tik}s_{tik}x_{ik}d_i p_{tik}}{(1+p_0)^{n_k}} \quad (4)$$

The economic value of selectively cut wood is:

$$Ear_{ik}^{s-time} = \frac{v_{sik}s_{sik}y_{ik}d_i p_{sik}}{(1+p_0)^{n_k}} \quad (5)$$

Among them, i= 1,2,3 represents the forest type, k= 1,2, …, 5represents 5 stages.

(2) Biodiversity value

Taking the investigated area as the research unit, the wood stock of each planning period was calculated first, and then the biomass of each planning period was obtained through the biomass conversion equation.

The biomass estimation model is:

$$B = 0.207V^{1.746} \quad (6)$$

The biological value of intermediate wood is:

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$$Bio_{ik}^{t-kind}=\frac{B\left(V_{ik}^{t}-V_{i(k-1)}^{t}-H_{ik}^{t}\right)}{(1+p_0)^{n_k}}(7)$$

The biological value of selectively cut wood is:

$$Bio_{ik}^{s-kind}=\frac{B\left(V_{ik}^{s}-V_{i(k-1)}^{s}-H_{ik}^{s}\right)}{(1+p_0)^{n_k}}(8)$$

(3) Carbon sequestration value

The carbon sequestration value of intermediate and selective cutting is:

$$CB_{ik}^{carbon}=CF*\left(Bio_{ik}^{t-kind}+Bio_{ik}^{s-kind}\right)(9)$$

The carbon sequestration value of forest products is:

$$CB_{ik}^{product}=CF*(H_{ik}^{t}+H_{ik}^{s})/(1+p_0)^{n_k}(10)$$

(4) Multi - objective business planning model.

The study took 40 years as the planning period, and divided into 5 stages every 8 years. There are three objective functions, namely, economic value of wood, biodiversity and carbon sequestration.

The objective function is:

$$\begin{cases}MaxZ_1=\sum_{i=1}^{3}\sum_{k=1}^{5}\left(Ear_{ik}^{t-time}+Ear_{ik}^{s-time}\right)\\ MaxZ_2=\sum_{i=1}^{3}\sum_{k=1}^{5}\left(Bio_{ik}^{t-kind}+Ear_{ik}^{s-kind}\right)\\ MaxZ_3=\sum_{i=1}^{3}\sum_{k=1}^{5}\left(CB_{ik}^{carbon}+CB_{ik}^{product}\right)\end{cases}(11)$$

The constraints are as follows:

The amount of logging is not greater than the amount of growth:

$$\sum_{k=1}^{5}H_k\le H(12)$$

The cutting constraints were balanced in each stage:

$$\sum_{k=1}^{5}(V_{ik}^{t}+V_{ik}^{s}y_{ik})=H_k(13)$$

In order to prevent over-cutting and avoid not cutting, the intensity constraints of intermediate and selective cutting were set:

$$0.01\le x_{ik}\le 0.15(14)$$

$$0.01\le y_{ik}\le 0.35(15)$$

2.3 Business planning and result analysis

(1) Forest management planning

Table 1: Planning of forest harvesting intensity(%)

Period	Method	Broadleaf mixed plantations	Natural coniferous and broad-leaved	Natural coniferous	Subtotal	Total
1	Intermediate	1.90	1.56	2.56	6.02	36.14
	Selective	2.34	16.63	11.15	30.12	
2	Intermediate	1.90	3.14	2.39	7.43	34.60
	Selective	4.61	3.31	19.25	27.17	
3	Intermediate	1.86	2.81	2.02	6.69	35.47
	Selective	2.44	13.41	12.93	28.78	
4	Intermediate	2.03	2.14	1.81	5.98	35.75
	Selective	2.47	20.42	6.88	29.77	
5	Intermediate	2.81	2.08	1.93	6.82	37.96
	Selective	2.49	15.7	12.95	31.14	
	Total	26.46	78.39	73.87	178.72	178.72

During the whole planning period, the logging amount of natural coniferous and broadleaved mixed forest was the largest, followed by natural coniferous and broadleaved mixed forest. This is because the area and stock volume of the first two forest types are relatively large. With the passage of time, the intensity of intermediate in each stage gradually decreases, indicating that the forest is in a process of continuous growth, and appropriate intermediate can promote the growth of trees. The planning of forest harvesting intensity is shown in Table.1.

(2) Wood harvesting, carbon sequestration and biodiversity

In the second stage, the carbon sequestration volume reached the maximum value of 113,300 tons, and then decreased first and then increased, showing a trend from prosperity to decline and then re-growth. Appropriate intermediate and selective cutting are of great significance for sustainable forest growth and carbon absorption. Biodiversity showed a trend of fluctuating growth, which was not significantly related to the change of logging plan, but played a role in promoting the change. The wood harvesting, carbon sequestration and biodiversity is shown in Figure 1.

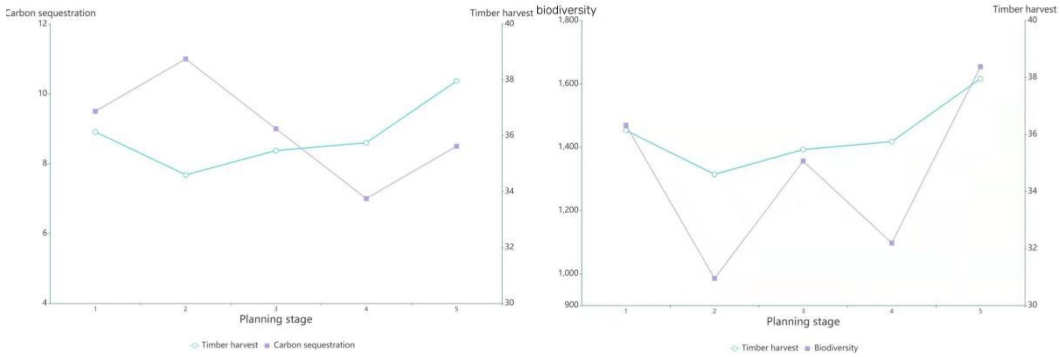

Figure 1: Wood harvesting, carbon sequestration (L) and biodiversity (R)

(3) Analysis of economic value of objective function

As can be seen from the Figure 2, in the objective function, the economic value of wood is 131.239 million yuan, the economic value of carbon storage is 87.326 million yuan, and the economic value of biodiversity.

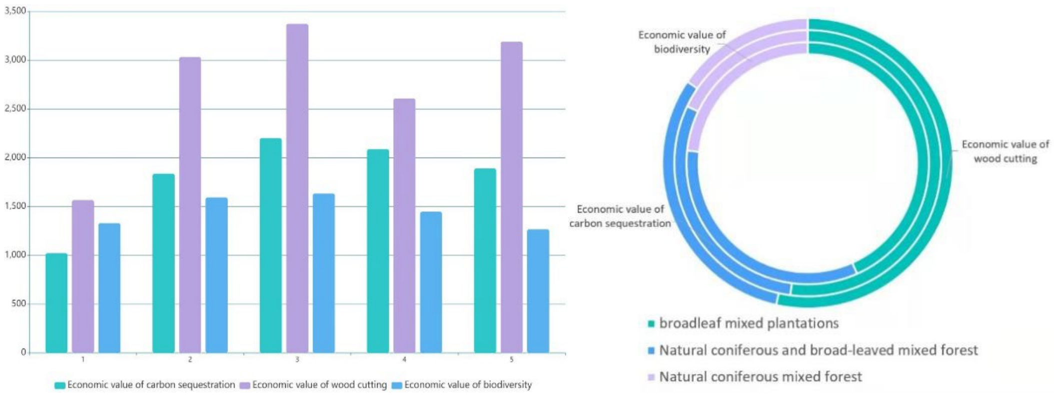

Figure 2: Objective function analysis (L), forest type economic value analysis (R)

The timber economic value, carbon sink economic value and biodiversity value were broadleaved mixed forest, natural coniferous mixed forest and natural coniferous mixed forest. The area and growth rate of coniferous mixed forest are slower, and the economic value of coniferous mixed forest is lower than that of the other two forest types.

3. Forest Management Plan of Afforestation

Currently, we first plan the management of natural forests through a multi-objective planning model. In order to further explore the feasibility of the forest planning model designed by us, the model is then brought into the study of artificial afforestation. This paper takes Saihanba as the research area. The artificial larch forest and artificial mixed forest in North China have created the miracle of transforming wasteland into forest sea.

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3.1 Human afforestation forest planning model

The growth models of artificial larch and mixed forest were respectively:

$$V = 206.5/(1 + 337.3e^{-0.19A})(16)$$

$$V = 213.7\left(1 - e^{(-0.17A)}\right)^{195.9}(17)$$

Assuming that the interval between harvesting and harvest reaches 10 years, the study takes 100 years as the planning period, and each 10 years is divided into 10 stages.

Objective function changes staging and total forest type:

$$\begin{cases} MaxZ_1 = \sum_{i=1}^{2}\sum_{k=1}^{10}\left(Ear_{ik}^{t-time} + Ear_{ik}^{s-time}\right) \\ MaxZ_2 = \sum_{i=1}^{2}\sum_{k=1}^{5}\left(Bio_{ik}^{t-kind} + Ear_{ik}^{s-kind}\right)(18) \\ MaxZ_3 = \sum_{i=1}^{2}\sum_{k=1}^{10}\left(CB_{ik}^{carbon} + CB_{ik}^{product}\right) \end{cases}$$

The constraints are as follows:

$$\sum_{k=1}^{10} H_k \le H(19)$$

$$\sum_{i=1}^{2}(V_{ik}^{t} + V_{ik}^{s} y_{ik}) = H_k(20)$$

The intensity constraints of intermediate and selective cutting remain unchanged:

$$0.01 \le x_{ik} \le 0.15(21)$$

$$0.01 \le y_{ik} \le 0.35(22)$$

3.2 Results analysis

(1) Carbon sequestration

According to the multi-objective programming solution, the maximum value of carbon sequestration was obtained, and the economic value of carbon sequestration in 100 years was 141.132 million yuan, and the total carbon sequestration was 1.394 million tons. In general, except for stages 4 and 7, the carbon sequestration of artificial larch was higher than that of artificial mixed forest. The first stage showed a low state, and the fluctuation of other stages was small, indicating that the cutting scheme was conducive to the stable growth of artificial forest. The carbon sequestration at each stage is shown in Figure 3.

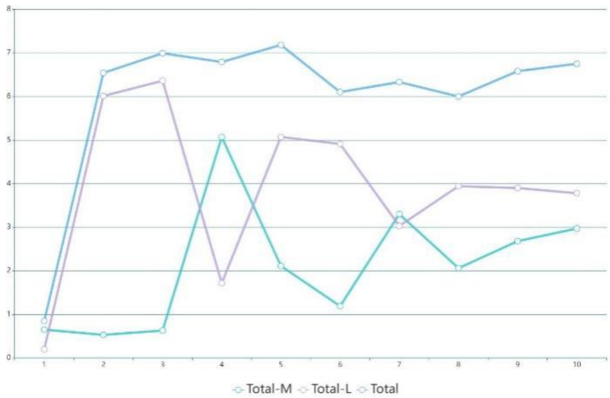

Figure 3: Carbon sequestration at each stage

(2) The economic value

As can be seen from the Figure 4, the three kinds of economic values of artificial forests showed a trend of first increasing and then decreasing, and reached the peak during the 5th to 6th period. For artificial larch, the economic value of wood is 91.831 million yuan, the economic value of carbon storage is 74.125 million yuan, and the economic value of biodiversity is 30.541 million yuan. For the artificial mixed forest, the economic value of wood was 670.07 million yuan, the economic value of carbon storage was 80,251 million yuan, and the economic value of biodiversity was 29.802 million yuan.

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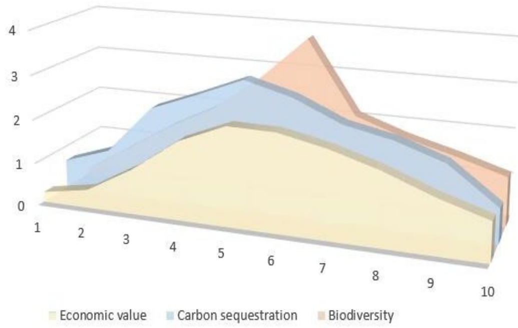

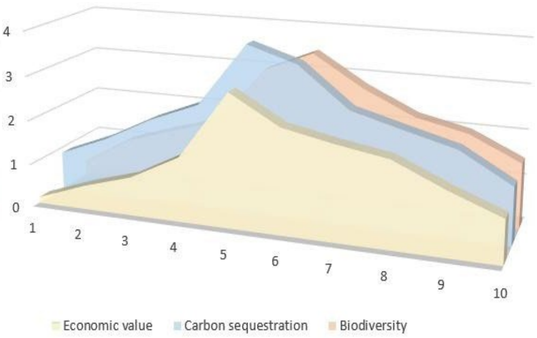

Figure 4: Artificial larch (L) and artificial mixed forest (R)

(3) Afforestation and felling plan

The harvesting interval was extended to 10 years, and the total amount of intermediate and selective cutting in the 100-year planning period was 601,100 tons. Among them, the total cut volume of artificial larch forest is 389,200 cubic meters, the total cut volume of artificial mixed forest is 21,900 cubic meters, the intensity of selective cutting is higher than that of intermediate. The human forestation and harvesting volume planning is shown in Table. 2.

Table 2: Human forestation and harvesting volume planning (10,000 cubic meters)

Period	Method	Artificial larch forest	Artificial mixed forest	Period	Method	Artificial larch forest	Artificial mixed forest
1	Intermediate	0.11	0.29	6	Intermediate	4.89	0.98
	Selective	0.09	0.36		Selective	0.02	0.21
2	Intermediate	5.93	0.21	7	Intermediate	3.02	3.13
	Selective	0.08	0.32		Selective	0.01	0.17
3	Intermediate	6.29	0.32	8	Intermediate	3.94	1.97
	Selective	0.07	0.31		Selective	0.00	0.09
4	Intermediate	1.67	4.78	9	Intermediate	3.90	2.67
	Selective	0.05	0.29		Selective	0.00	0.01
5	Intermediate	5.03	1.85	10	Intermediate	3.78	2.97
	Selective	0.04	0.26		Selective	0.02	0.01

4. Conclusions

In order to design a rational forest management plan, this paper discusses three natural forest types that, this paper expands the research area and divides it into three natural forest types. Combining the value maximization of the three objectives of wood, carbon sequestration and biodiversity, a multi-objective planning model is established to solve the thinning and selective cutting intensity planning of different forest types. During the 40-year planning period, the cutting intensity of natural coniferous and broad-leaved mixed forest and natural coniferous mixed forest were 78.39% and 73.87%, respectively, and there was a fracture transition zone with the cutting intensity of broad-leaved mixed forest of 26.46%.

In order to further verify the feasibility of the planning model, the forest planning model was applied to the planted Saihanba, and the stage was extended to 10 years. A multi-objective planning model is established, and the forest harvesting plan under the new harvesting interval is solved. In 100 years, the total amount of carbon sequestration is 1.394 million tons, and the sum of economic value is 373.557 million yuan. By changing the objective function, the total economic value of the added three schemes is less than that of the multi- objective scheme. Finally, a newspaper article is generated to explain the important basis and significance of moderate cutting planning for forest carbon sequestration and sustainable development.

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