Forest Management Plan Based on Forest Carbon Sequestration

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Abstract. As the phenomenon of global warming intensifies, human beings pay more and more attention to environmental protection, and the requirements for carbon reduction and carbon sequestration are getting higher and higher. Forest carbon sequestration is particularly important. In order to achieve the maximum carbon sequestration, we select two representative trees respectively and make them represent the whole forest through the weighted average method. Through a large amount of data collection, the existing data and carbon storage calculation formula can be used to obtain the forest carbon sequestration. Finally using MATLAB programming to draw separately, the change map of the amount of carbon sequestration in forests and forest products over time under the influence of the factors of felling trees is obtained.

Keywords: Forestry Carbon Sequestration, Weighted Average Method, MATLAB.

1. Introduction

As we all know, the effects of climate change on life are devastating. To reduce the impacts, we need to implement the process of carbon sequestration. Trees are one of the most important plants for storing carbon dioxide. Therefore, the management of forests became the focus of our research.

However, unlike our normal thinking, cutting down trees is not necessarily bad, products made from felled trees also absorb carbon dioxide, such as furniture, lumber, plywood, paper, and other wood products. Compared to the forest with no trees cut down the sum of the carbon absorbed by some long-lived tree products and regenerated trees may be greater over time. Thus, appropriate logging policies are good for carbon sequestration. We are asked to find a balance between harvesting and carbon sequestration and find out the optimal solution.

Due to the existence of a variety of forests in the world, the differences between forests can lead to different calculation results. Therefore, we have adopted the most extensive classification method dividing the world's forests into two categories: coniferous forests and broad-leaved forests [1], and respectively selected the two tree species that occupy the largest forest area as representative trees. Then using the carbon storage calculation formula to synthesize the age of tree, the carbon sequestration of trees and forest products can be obtained. By enumerating assumptions, taking into account the time of felling, the number of felling and the amount of trees felled, a graph of the change in the amount of carbon sequestration in forests and forest products over time under the influence of the factors of felling trees, then we can obtain the best forest management plan finally.

Then, we need to consider many other aspects of forest value on the basis of question one, and continue to seek the best forest management plan under this condition. Therefore, we selected five different aspects that can reflect the value of forests, and based on the information and data we collected, we used the AHP method to assign weights to these five indicators. The indicators were then normalized by the topsis model in MATLAB, resulting in a score for the forest management plan under each harvesting interval condition. From the final score, we know that whether it is for coniferous forest or broad-leaved forest, taking 40 years as the logging interval can maximize the comprehensive social value of the forest.

2. The establishment and solution of model

2.1. Model analysis and assumptions

In order to determine how forests can achieve the maximum carbon sequestration. We divide the forest into two types: coniferous forest and broad-leaved forest, select two representative trees respectively, and make them represent the whole forest through the weighted average method. In order to facilitate the analysis, the following assumptions are made for the model.

(1) Assuming the maturity of the tree is 20 years;

(2) Assuming that the area of trees to be harvested is equal each time;

(3) Assuming that each cut is at the same time interval.

2.2. Establishment and solution of coniferous forest model

For coniferous forests, masson pine and fir is the two trees that occupy the largest coniferous forests area in China. Among them, the masson pine forest covers an area of 14.34 million hectares and the fir forest is 9.11 million hectares [2]. From this, we can calculate the proportion of these two trees in the total number of coniferous forest trees.

Masson pine: $\frac{1434}{1434+911}$:0.612

Fir: $\frac{911}{1434+911}$:0.388

We used the biomass equation method recommended by IPCC2006 to calculate the carbon storage of Masson pine and Chinese fir respectively. The formula for calculating carbon storage is:

$$S_{c,t} = V_t \cdot F_{e,b} \cdot \pi\left(1+R\right)C_c \tag{1}$$

Where, $S_{c,t}$ is the carbon storage when the tree age is t, V_t is the accumulation per unitarea when the age of the tree is t, $F_{e,b}$ is the biomass expansion factor, π is the density of wood, R is the ratioof belowground biomass to aboveground biomass, C_c is the carboncontent.

According to the information we collected, the following data can be obtained, as shown in Table 1 [3-5].

Table.1. Data sheets for masson and fir

	Biomass expansion factor	Ratio of belowground biomass to aboveground biomass	Density of wood	Carbon content rate	Growth harvest model
Masson	1.47	0.187	0.38	46	$0.684e^{5.8789-11.2616/t}$
Fir	1.64	0.246	0.307	52	$308.64906(1-e^{-0.12163t})^{4.21772}$

Therefore, we wrote a MATLAB program, and the carbon storage at any time node can be obtained by substituting the weighted data of the above two trees into the solution.

In order to find out the optimal forest management plan, i.e. how to harvest trees properly, we make an idealized background assumption. In an identified forest area, we assume that the time horizon is 100 years. At the initial point of the 100 years, we assume that the tree grows from nothing, and based on the available data, it is reasonable to suppose that the maturity of the tree is 20 years, so harvesting starts after 20 years. We divide the forest evenly, assuming that the area of each cut is equal, the time interval of the cutting activities is also the same, and the area that has already been cut is not cut down, and the same number of new trees are planted immediately after each cut, then turn the felled trees into forest products. We aim to eventually experience as much as possible one harvest in each area, so that the time interval between each harvest and the area of each harvest is related. Therefore, due to the different values of the time interval for felling, there may be some trees that have not experienced felling in 100 years.

In the Fig.1 we give an example of setting the interval of harvesting to 25 years.

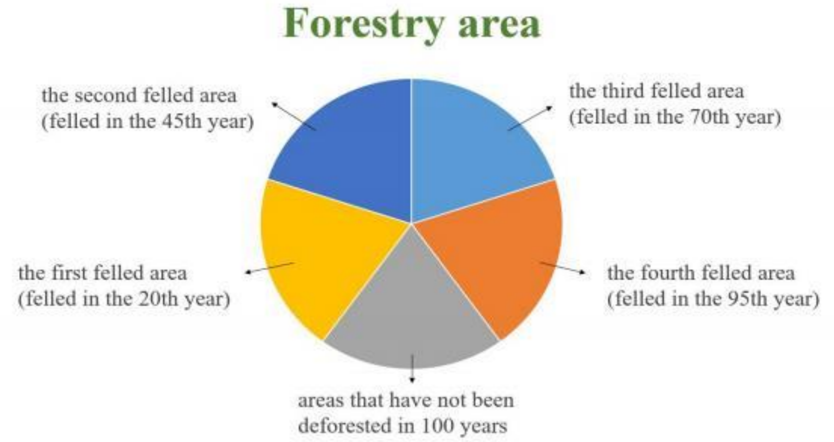

Figure 1. An example of setting the interval of harvesting to 25 years

Based on the complexity of the problem, we need to conduct a classification discussion, considering the carbon storage of trees in various situations with their age, the carbon storage of new trees with their age, the carbon storage of forest products and the carbon stocks of trees that may not have been felled. Then sum them up, and find ways to maximize carbon stocks.

In addition, according to the survey, the carbon storage of forest products is about 4.75%-8.42% of the carbon sequestration of trees in recent decades, with an average of 6%. Due to the increasing trend of this proportion, this value is estimated to be 7% in this study [6-9].

Using the above conditions, we wrote a MATLAB program and obtained a graph of the change of carbon sequestration over time in coniferous forests under the influence of harvesting factors:

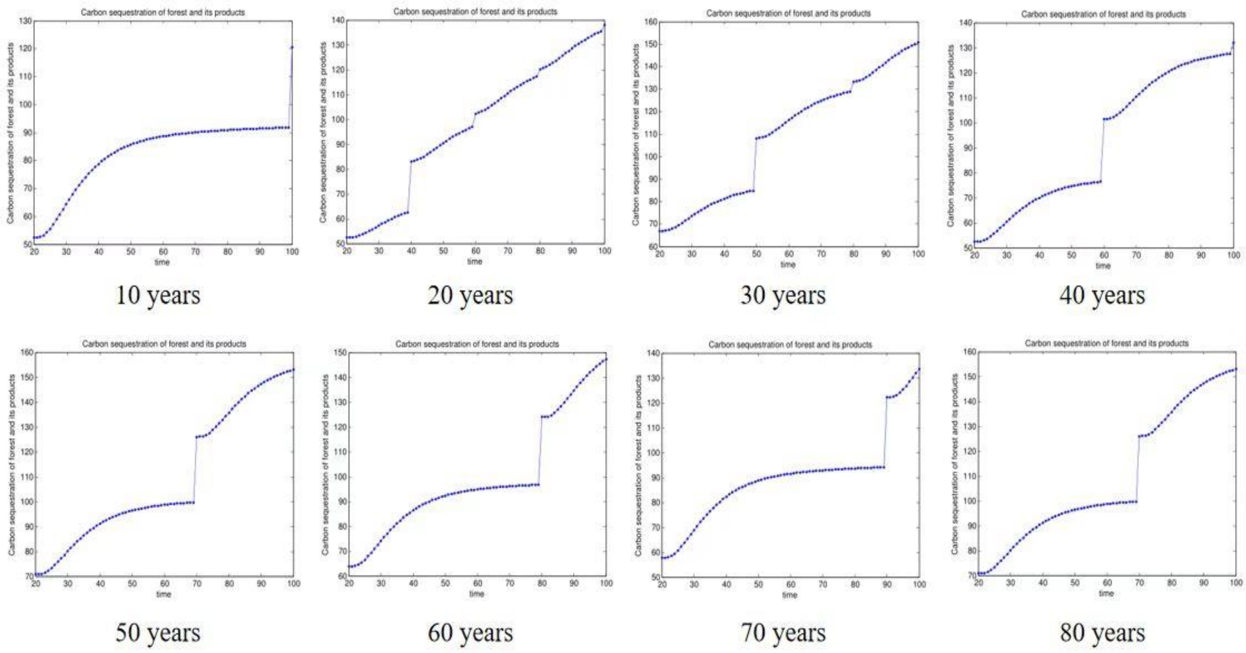

Figure 2. The change of carbon sequestration over time in coniferous forests

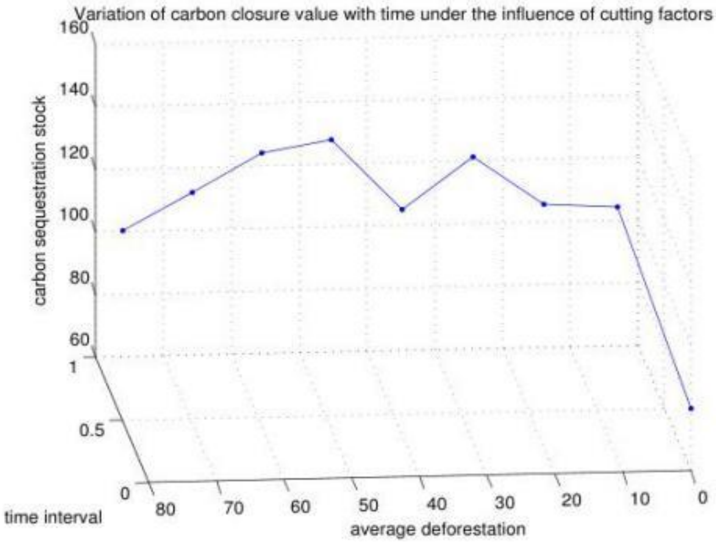

Figure 3. Variation of carbon closure value with time under the influence of cutting factors

From the Fig.2 and Fig.3, it can be concluded that the best forest management plan is to set the time interval for cuttingtrees to be 50 years, so the area of each tree cut is 3/ 15, of the entire forest area. In this way, the maximum amount of carbon sequestered by the entire forest and its forest productscan be achieved, and the most effective carbon sequestration can be achieved.

If the forest is not be harvested, that is, when t=100, the carbon sequestration value calculated by the calculation is much smaller than the carbon sequestration value obtained in the above case, from which we can know that the appropriate deforestation is correct.

2.3. Establishment and solution of broad-leaved forest model

For the broad-leaved forest, the two representative trees we selected are oak and poplar. The data collected are as follows [10-11]:

Table.2. Data sheets for oak and poplar

	Biomass expansion factor	Ratio of belowground biomass to aboveground biomass	Density of wood	Carbon content rate	Growth harvest model
Oak	1.42	0.234	0.68	47	$21.23e^{-1.3662e^{-0.0221t}}$
Poplar	1.38	0.243	0.39	55	$43.9822(1-e^{-0.0529t})^{0.9047}$

The modeling method and the idea of solving the problem are the same as the above-mentioned method for solving the coniferous forest problem, but there are changes in the data, which will not be repeated here. Through MATLAB programming, we obtained a graph of the change of carbon sequestration over time in broad-leaved forest under the influence of harvesting factors, an example graph of carbon sequestration by the end of the year that can be obtained at any time under a certain harvesting time interval has been drawn above. It is similar in the classification of broadleaf forests and we will not be listed here:

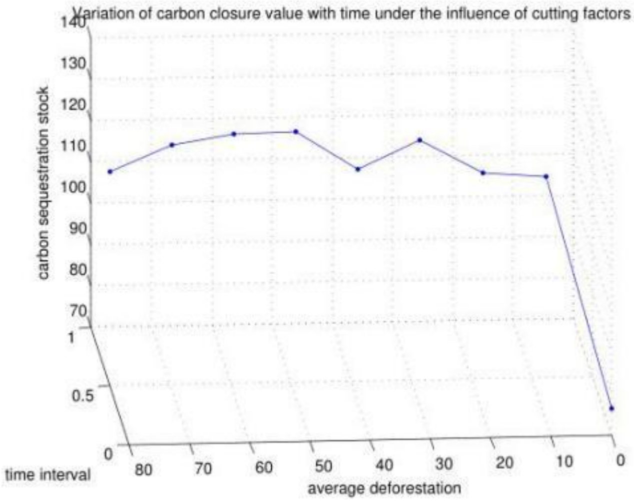

Figure 4. Variation of carbon closure value with time under the influence of cutting factors

Obviously, we find out that setting the time interval for cutting trees to be 30 years, and the area of each tree felling is 3/ 11 of the whole forest area, which is best forest management plan for broadleaf forests.

3. Forest management plan

First of all, for the decision of deforestation, we selected five factors that can measure the social value, namely, the amount of carbon sequestered in the forest, the economic benefits from tree felling, the cost of felling trees, and the impact of the forest after felling on its tourism value, the environmental impact of soil erosion that may result from deforestation.

Then we use AHP to assign proportions to these five factors. In terms of carbon sequestration, we use the data obtained by solving the first question. In terms of economic benefits, we found out the general output and market price of wood that was selected as a representative tree after inquiring about the data. Under the conditions of different felling time intervals, we use the weighted average to obtain the economic benefits of each cutting in a unit area as the economic benefits of this piece of forest. Then, the economic benefits brought by different cutting time intervals are obtained through the frequency of cuttings and the area. In terms of the cost of cutting trees, we assume that the cost of cutting trees is the same each time, so the frequency of cutting trees can be used to replace the cost index. The more times the trees are cut, the higher the cost. In terms of tourism value, since forests will present different landscapes when they encountering different levels of logging, so this factor can also be replaced by the frequency of cuttings. The more cutting times, the higher the tourism value. In terms of environmental factors, the data shows that each cutting will cause a certain degree of soil erosion, so we also use the frequency of cutting to measure this factor. The higher frequency of cutting, the more damage to the environment [12].

Of course, what we pursue is the largest possible amount of carbon sequestration, as much economic benefits as possible, as little cost as possible, as high tourism value as possible, and as good an environment as possible.

Table.3. Control objectives and influencing factors

Factors / Target	Carbon sequestration	Economic benefits	Cost	Tourism value	environment
More cutting	Proper felling required	+	-	+	-
Less cutting		-	+	-	+

We convert all indicators to maximal by forwarding the indicators. Considering the different dimensions of each indicator, in order to eliminate its influence, we normalize it. From this we can use MATLAB to calculate the unnormalized score for each item. Finally, we normalize it to get the final score. Based on coniferous forest conditions, we tabulate it as follows:

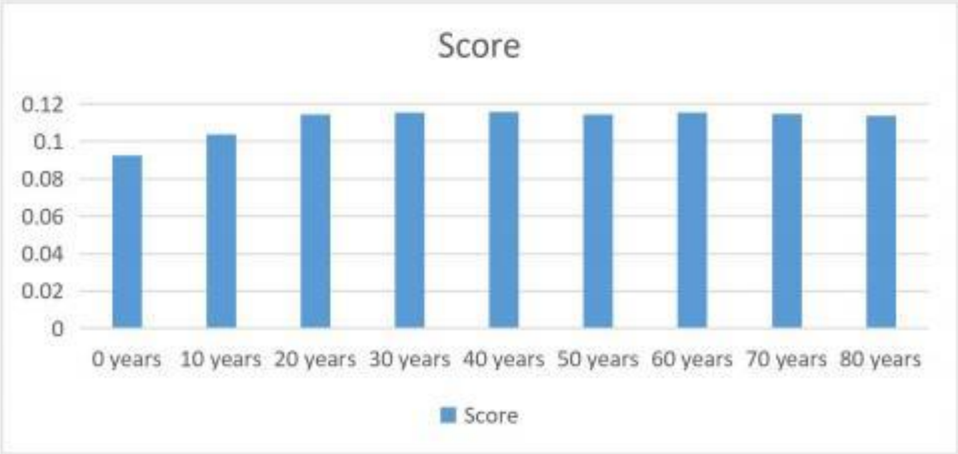

Figure 5. Normalized results 1

We can see from the table that, for coniferous forests, taking into account the five factors, the management plan with the highest score is to take 40 years as the time interval for cutting trees. Therefore, the management plan suggested by our decision model is to conduct harvesting activities every 40 years.

Based on the conditions of the broad-leaved forest, the figure is as follows:

Figure 6. Normalized results 2

Similarly, we can see from the table that for broadleaf forests, the management plan with the highest score also takes 40 years as the time interval for cutting trees. Therefore, the decision-making model we established also recommends a management plan of logging activities every 40 years.

Through the establishment of the model, we found that the comprehensive benefits brought by the forest under the condition that it has not been cut down are not high, so we believe that a certain degree of forest logging is needed, and there is no condition that causes the comprehensive benefit brought by the uncut forest. The benefits are higher than scientifically harvested forests.

For the problem of transition point, the weight of each factor can be flexibly determined by measuring the five factors of forests in different regions, and the best forest management plan can be calculated by the same method.

4. Conclusions

In building the model, we used AHP to weight five metrics that measure the quality of forest management plans. It completely relies on subjective evaluation to make the pros and cons of the plan, the amount of data required is small, and the time spent on decision-making is short. AHP introduces quantitative analysis in the complex decision-making process, and makes full use of the decision-maker's preference information for analysis and decision-making support, so that the decision-making process is highly organized and scientific. At the same time, the evaluation and decision-making model is established in combination with the TOPSIS method, and the best forest management plan is determined. It avoids the subjectivity of the data, does not require an objective function, does not need to pass the test, and can well describe the comprehensive influence of multiple influence indicators. It is suitable not only for small sample data, but also for large systems with multiple evaluation units and multiple indicators.

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