Forest efficiency decision-making model based on linear weighted multi-objective genetic algorithm

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Abstract. It can not be negligible that climate change is a dire threat to countless people due to the development of our society and technology.To draw the applied range of the decision-making model of forest management plan, we set up Linear-weighted multi-objective genetic algorithm according to the ecological, economic and social factors of the forest ecosystem and determine the different weight of each factor through the entropy weight method.finally, we select the Pennsylvania Forest as an example to test our model.

Keywords: Ecological economic and social factors, The length of the optimal rotation model, Genetic algorithm.

1. Introduction

It can not be negligible that climate change is a dire threat to countless people due to the development of our society and technology [1-2].

Besides reducing greenhouse gas emissions, Carbon Sequestration, which means stock up on carbon dioxide from atmosphere [3], is an indispensable resort to mitigating climate change. On account of the excellent capacity of sequestering carbon dioxide, forest systems and the forest products the produce create a magnificent carbon sink globally [4-5]. To optimize forest management decisions, forest managers want to get a considerate management plan [6].

How to locate serviceable data from numerous reviews and design a forest management strategy to balance these effectiveness and enable managers to maximize the comprehensive benefits through the harvesting and maintenance of forest resources? [7-8]This is a very meaningful and challenging scientific question [9-10].

2. Pre-preparation

2.1. The multi-goal-oriented decision model

Given other ways of forest value, dividing forest value into use and non-use value, the optimal forest management plan in the carbon sequestration model is not necessarily the most social fit. Based on this, we need to obtain the value evaluation of the forest ecosystem, namely, establishing a multi-goal-oriented decision model.

At present, the business purpose of forest management has shifted to a more extensive value production.Forest ecosystems are intertwined with social, economic, natural systems and, and therefore, multiple operational objectives of forest ecosystems include economic, social, and ecological objectives,as show in figure 1.

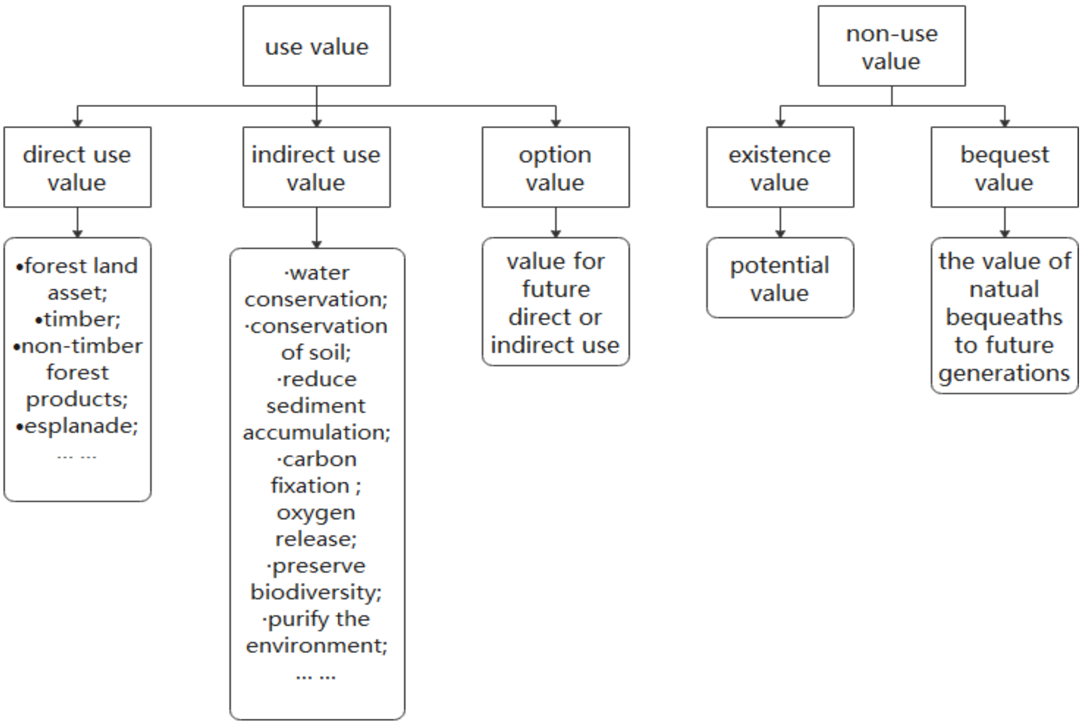

Figure 1. The total economic value of forest ecosystems

The scientific and operable index system and evaluation method of the sustainable development of forest ecosystem are not only the necessary standard and evaluation scale for the sustainable operation of forest ecosystem, but also an important tool for the sustainable management and the sustainable development strategy of forest ecosystem.

To sum up, on the basis of the genetic algorithm model established in Question 1, we improved this model for the three goals of ecological benefit, economic benefit and social benefit.

Since the optimal solution after the synthesis of the three objectives is required, and these three objectives conflict with each other, we can build a multi-objective planning model "multi-objective genetic algorithm" to build a forest resource evaluation model for these three objectives.

2.2. Multi-objective genetic algorithm based on linear weighting

The idea of this algorithm is simple, transforming multiple targets into single targets in a linear weighted way, and then being solved by applying a traditional genetic algorithm, the formula is as follows:

$$fitness(I) = \sum_{k=1}^{K} w_k \times f_k(I) \tag{1}$$

From the above formula, the key to the model is how to set the weights. Therefore, we adopt the entropy power method and use the entropy power method model for [ecological benefit, economic benefit and social benefit]to give the weight of each goal.

The three targets were converted into single targets and normalized to (0 – 100), which ultimately yielded a score under a different management plan.

3. Modeling

According to the value theory of natural resources value, utility value theory and sustainable development theory three theoretical basis support, from the forest ecosystem management purpose, build the forest ecosystem influence factor system, establish the forest ecosystem and the relationship between nature, society, human model, provide reference for forest ecosystem management decision.

The final results are shown in the following table:

3.1. The weight derived from the entropy weight method

Table 1. The ecological value of Pennsylvania forests

The Weight	Description
Weight1 = 0.6934	Ecological benefits
Weight2 = 0.2043	Economic benefits
Weight3 = 0.1023	Social benefits

By the entropy method, the ecological value of Pennsylvania forests accounts for about 70%, economic value about 20% and social value about 10%,as show in table 1.(This weight represents Pennsylvania forest parameters of forest asset value with regional locality)

Thus, with the development of productivity and technological progress, the demand for forests is no longer a single timber demand. In terms of social relations are concerned, the employment opportunities provided by the forest, the social equity created and social cohesion, and the religion, culture, knowledge and values related to the forest, will all have an important impact on the forestry production.

In the connection between ecosystem and social system diversity, any overutilization of any level of multiliteracy in a forest ecosystem solely targeting socio-economic interests will weaken the beneficial connection between other levels and socioeconomic systems.

3.2. Optimal round period measurement model

About whether the transition between forest deforestation and management plan, due to ecological value, economic value, social value on the value of forest is different, that is, the maximum benefit of forest operators is different, we established the optimal forest logging period based on economic benefits, as an important basis for operator decision-making.

Economic benefits refers to the economic income available to forest operators, that is, the value of forest products and forest service functions traded through the market. The expected price of forestland is the sum of the net present value of timber income and carbon sink income during multiple rounds of continuous operation of forestland per unit area.

The calculation formula is as follows:

$$\xi = P_w + P_c = \frac{\eta(P_v - C_h)Q(T)(1+r)^{-T} - R + \sum_{t=0}^{T}\left[\Delta b(t)\cdot C_p\cdot(1+r)^{-t}\right] - b(T)\cdot C_p\cdot(1+r)^{-T}}{1-(1+r)^{-T}} \quad (2)$$

In the formula, ξ is the woodland expectation price; P_w is the net present value of timber earnings;P_c is the net present value of carbon sink income; η is the material output rate (fixed value according to forest type); P_v is the wood price (value based on field surveys and timber market prices); r is the discount rate,take the value 3% $Q(T)$ is T years of accumulation; R is the present value of the total forest investment, including the initial afforestation, tending and management and protection; C_h is the acquisition cost; $b(T)$ is the cumulative carbon storage in the T year; $\Delta b(t)$ is the carbon increment in the t year; C_p is the unit carbon price.

P_c varies depending on the carbon subsidy context. Based on the woodland expectation price model, the optimal logging period and carbon sink model under different carbon subsidy mechanisms are constructed, and the corresponding optimal logging period and carbon sink model when the maximum value is reached. It can be seen that the rotation period is an important decision basis for operators in forestry management, which determines the size of forestry management investment risk.

Only considering the value of wood itself, operators tend to cut trees earlier, making the logging period shorter. If the forest carbon fixation benefits are considered, the logging period will be extended, and people tend to cut trees later, which is of great benefit to increasing the forest carbon fixation in China. In addition, forests have many ecological service functions, such as water conservation, wind protection and sand fixation, and biodiversity maintenance. Many studies show that its environmental value has far exceeded its own value.

It can be seen that forest trees need a round logging period, there is no conditions so that they are not cut down.

Find the first derivative of T and make it equal to zero, the optimal logging period T when the expected price is maximum, and T is the transition point between the forest management plan.

3.3. Solution of transition point in specific forest

According to the above optimal round logging calculation model, the specific parameters of the corresponding variables can be determined for the specific forest of Pennsylvania forest.

Using the latitude and longitude of the Pennsylvania forest, the topographic map is viewed through satellite remote sensing technology to determine the specific value of the transportation cost C_h according to the terrain type and terrain characteristics. Since the Pennsylvania forest is a specific type of forest, it corresponds to the unique yield rate n and the wood value P_v .At the same time, the specific value of the discount rate r can be determined by checking the Pennsylvania local governments' forestry policies and attitudes towards forests.

According to the above analysis, if a specific forest and its specific location characteristics are determined, and the corresponding values are replaced into the optimal round logging measurement model, the transition point between management plans can be determined.

Meanwhile, it further reflects the impact of the ecological, economic and social value weight on the forest ecological system obtained by the entropy power method in the value evaluation of the forest ecosystem.

4. Model application

We put year=100 into model 1 to get the carbon sequestration amount of Pennsylvania in the next 100 years, as shown in the figure 2.

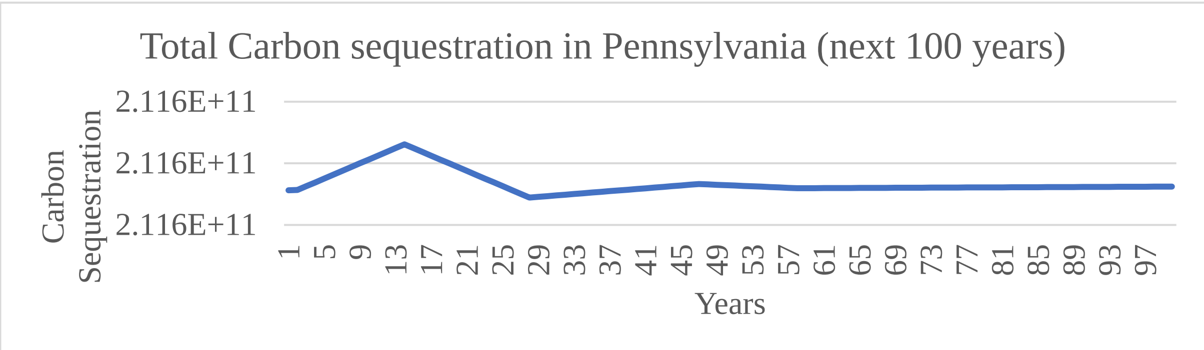

Figure 2. The carbon sequestration amount of Pennsylvania in the next 100 years

4.1. General introduction of the Pennsylvania Forest

(1) Status of the Pennsylvania Forest at present

The most recent USDA Forest Service forest inventory report offers data from 2009, the latest available. The report indicates that the amount of forest cover hovers at about 59 percent of total land area, or about 16.7 million acres.

(2) The envision of Pennsylvania's fores based on the current management plan

Pennsylvania's forest outlook is not entirely rosy, Finley cautioned. Sixty-seven percent of the forestland lost during the inventory period -- which was offset primarily by agricultural abandonment -- was converted to essentially nonreversible uses.

The report also conveys concerns about potential impacts from non-native insects and diseases that increasingly are affecting forests," he said. "Added to this are the rapid invasion and expansion of non-native, exotic plants that are filling our old fields and woodlands with aggressive competitors. That list, too, is long and growing."

4.2. Forests regeneration --biological aspects

(1) For forest manager

(A) Retain and plant quality trees of desirable species

Young regrowing forests can be especially vulnerable to being cut down again, because people view them as less valuable or as a temporary land cover.

Developing financial tools to incentivize keeping forests in place and/or planting some commercially valuable trees in naturally regenerating forests represent potential options for encouraging the maintenance of young forests.

(B) Optimize tree species--based on the shade-tolerance classes

Examining the shade-tolerance classes of three valuable timber species in the Pennsylvania Forest, we find they fall into different shade-tolerance classes: black cherry, intolerant; northern red oak, intermediate; and sugar maple, tolerant. Understanding the shade-tolerance characteristics of desirable species forms the basis for developing harvest prescriptions. The results are shown in the table 2.

Table 2. Shade tolerance for common Pennsylvania trees

Species	Tolerance	Species	Tolerance
Black cherry	Intolerant	White oak	Intermediate
White ash	Intolerant	Basswood	Tolerant
Hickory	Intolerant	Red maple	Tolerant
Yellow poplar	Intolerant	Sugar maple	Very tolerant
Northern red oak	Intermediate	American beech	Very tolerant

Shade tolerance for common Pennsylvania trees

For example, if a forest is managed for shade intolerants and intermediates such as yellow poplar, white ash, black cherry, and oak, you have to increase the amount of light across the forest floor to stimulate seed germination and seedling growth. Harvesting activities must consider shade tolerances of the species for which you are managing.

(C) Reduce the damage done by deer

Through preferential browsing, the Pennsylvania Forest has great amount of deer. Deer have the ability to broadly affect forest plant communities. Specifically, they can reduce tree seedling numbers, seed availability, species composition, and seedling height growth.

Hunting is the only management alternative that can address deer numbers and associated impacts at a landscape scale.

Landowners should promote harvest of antlerless deer to attain lower densities several years prior to a harvest designed to start the regeneration process.Based on our experiences on university forest lands, it will take years of sustained hunting pressure and removal of adult does to lower deer densities sufficiently to achieve adequate seedling regeneration.

For all who use the forest:

All stakeholders, including the government, NGOs, the private sector and consumers, can play a role. Government is particularly important, and a strong regulatory framework must be established to drive real change. We have identified six key actions that protect and limit deforestation to protect forest value:

(1) restoration and afforestation to sustainably manage these and more existing forests and increase their productivity for the purpose of protecting wood production;

(2) promoting sustainable and productive agriculture

(3) increasing wood recovery

4.3. Forests regeneration --economic and social aspects

Pennsylvania fores have some of the finest hardwood timber in the world, fueling a $20 billion wood products industry that directly employs 60,000 people.

Pennsylvania is a tourist city. Forest managers should increase the importance of the tourism industry and publicize more on tourist attractions.

Besides, governments need to marry their support of the wood-based products market with policies that drive an expansion of sustainable forestry. They should establish policy and regulatory frameworks that include clear standards for sustainable forestry and trade regulations that favor sustainably harvested wood.

For all who use the forest:

At the same time, reducing meat consumption, promoting non-deforestation production of palm oil, soybean, beef and wood and extending the service life of wood products are the regenerating management plans from economic benefits. Government can look for new, innovative ways to support sustainable forestry. They can, for example, establish schemes such as ecosystem service payments, which provide remuneration to forest owners who use sustainable practices for the public benefits their forests provide. These payments can in some cases be funded by revenues generated by taxes on CO2 emissions.

Tourists should consciously abide by the laws and regulations of the forest, and do not throw garbage and cigarette butts casually.

5. Conclusions

To draw the applied range of the decision-making model of forest management plan, we set up Linear-weighted multi-objective genetic algorithm according to the ecological, economic and social factors of the forest ecosystem and determine the different weight of each factor through the entropy weight method.

It is assumed that 10 years are the length of the optimal rotation, we select the Pennsylvania Forest as an example. First, We obtain the carbon sequestration of the forest and its products in the next 100 years through carbon sequestration model. Second, we figure out three ratios of ecological, economic and social benefits respectively after substituting parameters into the decision model of benefit. Finally, Comparing the past data with total carbon sequestration after our optimization, we find out that our management strategy is better than the past forest management strategy, namely, the optimal management strategy.

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