Proposed Forest Carbon Sequestration Management Plan Based on Mathematical Modeling Method

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Abstract. In order to alleviate global warming, reducing carbon emissions has become a common goal for human being. Forests as the largest carbon sequestration site in the ecosystem, they have made a huge contribution to reducing the carbon content in the air. Nowadays, using the carbon sequestration capacity of forests to sequester CO2 has become a trending topic. This study took Yellowstone National Park as an example, using the analytic hierarchy process to extract the forest value with the help of the concept of multivariate elasticity, and the forest stock volume conversion factor method was used to take into account the carbon sequestration capacity and the rotation period to obtain the forest area and structure. Then we got the forest growth rate, biodiversity, he weights of socio-economic factors are 0.35, 0.25, 0.2, 0.1 and 0.1, respectively. Finally, we proposed a forest management plan potential evaluation index model (PCSDPI), and a management plan that is most in line with the forest characteristics of Yellowstone National Park is obtained. In addition, we calculated the balance point of different plans as 3.2 years, 5.1 years, 6.8 years and 9.3 years. This study also applied the model to the whole world, adding two indicators of development degree and climating to the existing management plan evaluation indicators, obtaining the best management plan of four kinds of forests. The results of the pros and cons are 0.6046 and 0.7583. We used a logistic model to predict the annual number of trees planted and felled in the forest. The results showed that the change rates of the felled trees were 2.47%, 2.96%, 2.11%, and 3.14%, The rate of change of the planted were 2.41%, 2.86%, 2.14%, and 3.23%, respectively. Finally, we arrived at a 10-year timeline for forest managers to transition to new decisions. In conclusion, the whole framework of this research will help forest managers to give the most reasonable forest management plan under the premise of ensuring the carbon sequestration capacity of the forest which can fully reflect the forest value.

Keywords: Carbon Sequestration Model · TOPSIS Evaluation Model · Logistic Model

1 Introduction

At present, climate change poses a huge threat to life in the world. In addition to controlling and reducing carbon emissions at the source, we also need to increase the amount of

D. Qiu et al. (Eds.): ICBBEM 2022, AHIS 5, pp. 466–481, 2023.
https://doi.org/10.2991/978-94-6463-030-5_48

carbon dioxide stored in the atmosphere that is sequestered by the biosphere. This process is called carbon sequestration [9]. But the carbon sequestration capacity of forests is reflected not only in living trees, but also in finished products. Some researches have shown that some products have a short lifespan, while others have a lifespan that may exceed that of the trees from which they are produced. The carbon sequestered in some forest products combined with the carbon sequestered because of the regrowth of younger forests has the potential to allow for more carbon sequestration over time when compared to the carbon sequestration benefits of not cutting forests at all. So forest managers must find a balance between the continued growth of the forest and the value of sequestering carbon to maximize carbon sequestration [3].

In the research on forest carbon sequestration capacity at domestic and foreign, most of them focus on the theoretical analysis of forest economic value and carbon sequestration. Yi Fan et al. extracted the stand growth indicators of the two periods before and after the experiment based on the meta-analysis method. They also studied the responses of different tree species and regions to forest management [15]. Hu Yuan et al. used statistical analysis and spatial analysis methods to reveal the main problems existing in the development of forest carbon sinks in China in the basis of analyzing the overall status and typical characteristics of domestic forest carbon sink project development [14]. Donald L. Rockwood et al. applied growth and economic models to study the carbon sequestration potential of Florida, including short-rotation woody crops (SRWC) and windbreaks (WB), to obtain the most economical carbon sequestration policy [10].

Constraints such as urbanization and climate also affect carbon sequestration in forests. Saleh Shadman et al. conducted an in-depth study of the Zayan Chaduri Playground in Dhakabanani to understand the carbon sequestration potential of existing vegetation and park center lawns. They also listed the top tree species for carbon storage [11]. Weixiang Cai et al. used a forest carbon sequestration model and a field survey method to study the carbon sequestration rate (CSR) of three existing and newly reforestation forests in China from 2010 to 2060 under three climate scenarios [1]. Yan Yan et al. studied the impact of monetary value on carbon sequestration decisions, and established a dynamic monetary valuation perspective by integrating the carbon dynamics model of the ecosystem and the atmospheric carbon cycle model [13]. Kathiresan Kandasamy et al. analyzed the carbon storage and sequestration potential of mangrove stands planted in different age groups, and studied the influence of vegetation and soil characteristics in estuarine systems on the southeastern coast of India [6]. In the context of carbon neutrality in China 2060, Jiandong Chen et al. focused on the regional heterogeneity of CN based on vegetation carbon sequestration from the perspective of convergence, driving and inequality in almost all cities and counties in China from 2000 to 2017, and concluded that the growth of CNI driving factors [2].

Various data showed that forests have a variety of functions, and there are many constraints. It is not comprehensive enough to focus on just one aspect. Therefore, this study focuses on the research of the carbon sequestration capacity, cultural function, biodiversity, economical and recreational functions of forests. We establish a new carbon sequestration model that proposing a suitable forest management plan, and use the TOPSIS model to evaluate the plan. Finally, we propose a forest management plan that is in line with the development of the society. Moreover, this study creatively put the model to global forests in order to test the universality of the model, and propose a forest management plan with a global perspective.

2 Proposing a Comprehensive Forest Management Plan: Taking Yellowstone National Park as an Example

2.1 Establishment of Evaluation Model of Forest Management Plan

2.1.1 Establishment of Evaluation System

When forest managers make decisions on forest management plans, they need to consider many factors to adapt to society. Based on the concept of multiple elasticity of forest resources expounded in forest economics [5], according to the characteristics of Yellowstone National Park, this study comprehensively considers time elasticity, space elasticity, maturity elasticity, structural elasticity, production unidirectional elasticity, utility cross elasticity, and combines forest value as the evaluation target. This study also combines economic thinking, four factors of forest total amount, forest quality, forest health, and ecological function are proposed as primary indicators by using AHP, which are further divided into 11 secondary indicators that are easy to estimate. Among them, the secondary indicators of total forest reserves retain the forest savings, forest area and total forest carbon storage in the most effective forest plan, as shown in Table 1.

Since the forest is a dynamic update process, it is not rigorous enough to only consider static indicators. This study uses the concept of rotation period in forest management and considers the growth function of the iconic tree species in Yellowstone National Park, the fir tree [4] (Eq. 1) to further explain the change process of the forest in order to

Table 1. Evaluation system

Target Layer	First Indicator	Secondary Indicators	Weights
Forest Value	Total Forest	Area	0.1062
		Accumulation	0.0803
		Total carbon storage	0.1300
	Forest Quality	Volume per unit area	0.0737
		Biomass per unit area	0.0883
		Annual growth	0.0672
		Average diameter	0.0863
		Good quality grade	0.0857
	Forest Health	Mixed forest area ratio	0.0789
		healthy forest area	0.0829
	Ecological Function	Good ecological function grade	0.1205

realize the proposal of a comprehensive forest management plan and balance the various values of the forest.

$$Q(t) = b_1 SI^{b_2}\left[1 - e^{(-kt)}\right]^c \tag{1}$$

$Q(t)$ represents the stock volume of Chinese fir when felled in year t; t represents the stand age. According to the stock volume of Chinese fir, the biomass conversion and expansion factor method can be used to calculate the carbon sequestration amount $C(t)$ of the whole forest ecosystem, which represents the carbon sequestration amount in the t year $\left(\mathrm{tC/hm^2}\right)$. The measurement model which includes the biomass that can determine the conversion factor for forest carbon sinks, in order to accurately estimate the calculation formula of the total carbon sequestration of the forest:

$$C(t) = 0.2727Q(t) + Q(t) \times BEF \times (1 + R) \tag{2}$$

2.1.2 Establishment of Potential Model of Forest Management Plan

The construction of the potential model structure of forest carbon sink management plan should be divided into three levels: target level, criterion level and index level [5]. The target layer contains various indicators that affect the development potential index of forest carbon sink. The criterion layer constructs an index system from four aspects: biodiversity, socioeconomics, cultural function, and recreational function. The index layer establishes an evaluation under the above five aspects to form a preliminary comprehensive index, and finally proposes a forest management plan potential evaluation index model (PCSDPI), which is used to calculate the balance of various forest capabilities.

$$\zeta_{FCSDPI} = 0.35\zeta_{EAPFDI} + 0.25\zeta_{FSI} + 0.2\zeta_{TGRI} + 0.1\zeta_{BI} + 0.1\zeta_{SAEI} \tag{3}$$

2.2 Proposal and Evaluation of Comprehensive Forest Management Plan

Since the afforestation area of Yellowstone National Park is basically saturated, forest managers have a certain space to plant new trees only after cutting trees. Therefore, when proposing forest management plans, it is more reasonable for us to consider the situation of post-cutting renewal.

For Yellowstone National Park, the iconic tree species are forest, pine and arbor trees. We combine the indicators such as forest rotation period, forest composition, climate, population, interests and values, in order to more comprehensively consider the various characteristics of the forest, get the final plan of cutting tree species, and analyze the law that the index layer affects the forest. The analysis results are shown in Fig. 1.

According to the regular pattern of tree cutting and tree planting, we have summarized 10 forest management plans (Table 2).

The main research object of this study only includes 8 plans, so the number of samples is limited. Moreover, in the index system of forest value, $y_1 - y_7$ are positive indexes, and $y_8 - y_{10}$ are negative indexes, that is, the index system contains both positive

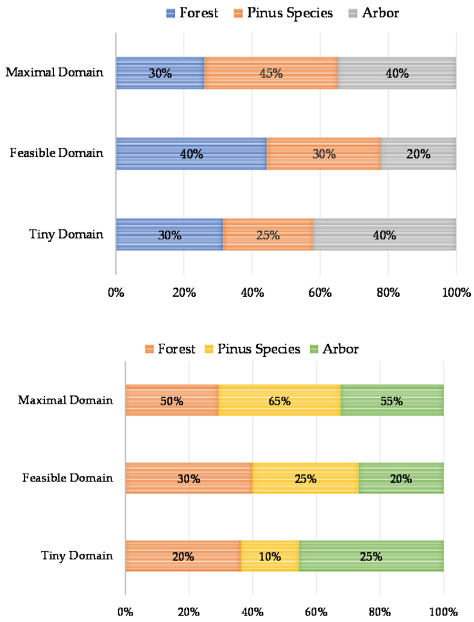

Fig. 1. The boundary between planting and cutting trees

Table 2. Forest management plan

Nu	Tree Cutting plan	Tree Planting plan
A1	Only 70% of forest	Only 50% of forests
A2	Only 55% of pines	Only 35% of pines
A3	Only 60% of arbors	Only 45% of arbors
A4	50% forests and 40% pines	30% forests and 25% pines
A5	50% forests and 50% arbors	30% forests and 30% arbors
A6	40% pines and 50% arbors	25% pines and 30% arbors
A7	30% forests, 25% pines, 60% arbors	20% forests, 10% pines, 45% arbors
A8	70% forests, 25% pines and 40% arbors	50% forest, 10% pines, 25% arbors
A9	30% forests, 55% pines and 40% arbors	20% forests, 35% pines, 25% arbors
A10	Do not cut down any trees	Do not plant any trees

indexes and negative indexes. Based on the above analysis, it is considered to establish a prevention and control effect evaluation model based on the improved Topsis method [12].

The improvement of the method is reflected in two aspects: one is the improvement of the normalization method of the evaluation matrix, and the other is to add weights to each index to form a weighted Topsis method. In order to ensure that all evaluation indicators have the same trend, it is necessary to normalize the indicators of the original data set into benefit-type indicators (positive indicators) and cost-type indicators (negative indicators), so as to obtain the standardized matrix U. We assume that the number of samples is m, the number of indicators is n, and the evaluation matrix of the sample is $Y = \left(y_{ij}\right)_{m\times n}$, denoted $a_i = min_{1\le j\le n}\left\{y_j\right\}$, $b_j = max_{1\le j\le n}\{y\}$, $i = 1, 2, 3, \cdots, m$.

From the standardized matrix, the optimal vector Z^+ and the worst vector Z^- corresponding to the optimal sample and the worst sample can be obtained as:

$$Z^+ = \{maxu_1, maxu_2, \cdots, maxu_m\} \tag{4}$$

$$Z^- = \{minu_1, minu_2, \cdots, minu_m\} \tag{5}$$

Among them, $maxu_1$ and $minu_i(i = 1, 2, \cdots, n)$ represent the maximum and minimum values of each column of the standardized matrix, respectively.

Since different indicators have different degrees of influence on the evaluation of prevention and control effects, it is necessary to add weights to each indicator. In this study, the analytic hierarchy process (AHP) is used to determine the index weights, but the principle of AHP will not be repeated here, and the calculated weights are shown in Table 1. Therefore, when evaluating the closeness of the sample vector to the optimal vector and the worst vector, it is necessary to calculate the Euclidean distance of the added weight as shown in the formula 6 and 7.

$$D_i^+ = \left[\sum_{i=1}^n \omega_i \left(u_{ij} - z_{ij}^+\right)^2\right]^{\frac{1}{2}} \tag{6}$$

$$D_i^- = \left[\sum_{i=1}^n \omega_i \left(u_{ij} - z_{ij}^-\right)^2\right]^{\frac{1}{2}} \tag{7}$$

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{8}$$

Furthermore, the closeness of the sample to the optimal solution and the worst solution can be obtained (as in Eq. 8). When C_j is closer to 1, it means that the sample is better, otherwise it means that the sample is worse. Finally, we arrange C_j in descending order to get the evaluation result of forest value.

Based on the forest management standards in forest management, data such as forest area, forest biomass per unit area, and average tree diameter at breast height of Yellowstone National Park can be obtained, and then the values of 11 secondary indicators can be obtained. For example, the proportion of mixed forest area, the proportion of healthy forest area, etc.

The standardized matrix can be obtained from formulas 4 and 5 (see Table 3), so the optimal vector should be $Z^+ = (1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0)$, the worst vector should be $Z^- = (0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1)$. We calculate the Euclidean distance between the evaluation vector of the main country and the optimal vector and the worst vector by using the formulas 6 and 7. Proximity is calculated by formula 10 Finally the ranking of the forest management plan is obtained by descending order. The above results are summarized in Table 4.

Table 3. Standardized matrix of primary indicators

P	u_1	u_2	u_3	u_4	u_5	u_6
A1	0.89	0.70	0.22	0.34	0.56	0.09
A2	**0.00**	**0.00**	0.67	0.43	0.76	0.25
A3	0.43	0.96	0.54	0.24	0.35	0.65
A4	0.19	0.23	0.45	0.28	0.98	0.76
A5	**1.00**	0.76	**1.00**	**1.00**	**1.00**	**1.00**
A6	0.62	0.45	0.42	0.63	**0.00**	**0.00**
A7	0.34	0.46	0.85	0.72	0.64	0.91
A8	0.24	0.64	0.26	0.74	0.16	0.21
A9	0.57	0.21	**0.00**	**0.00**	0.45	0.32
A10	0.89	**1.00**	0.85	0.89	0.58	0.34
P	u_7	u_8	u_9	u_{10}	u_{11}	
A1	**0.00**	**0.00**	0.65	0.53	0.16	
A2	0.31	0.69	0.71	**0.00**	0.35	
A3	0.75	0.32	0.15	0.43	0.16	
A4	0.59	0.26	0.61	0.86	0.13	
A5	**1.00**	**1.00**	**1.00**	**1.00**	0.67	
A6	0.27	0.79	0.82	0.41	0.64	
A7	0.33	0.69	0.27	0.71	**0.00**	
A8	0.51	0.94	**0.00**	0.05	0.88	
A9	0.64	0.71	0.52	0.54	1.**00**	
A10	0.24	0.24	0.34	0.03	0.21	

From the ranking results of forest management plan effects in Table 4, it can be seen that among the 10 plans, Plan 7, Plan 6, and Plan 4 have the best forest management effection, ranking the top three, and the forest value is also reflected more comprehensively, Forest trees have the best ability of sequester carbon, so they should be cut less and plant more; Pinus trees are the iconic tree species of Yellowstone National Park, and have good carbon sequestration ability, so they need to be cut less; Arbor species are suitable for wood products, and the carbon sequestration ability and species specificity are both poor, so it is necessary to cut them more and plant them less. The forest management effect of Plan 8 and Plan 5 is the worst among all plans, ranking the bottom two, which shows that these two plans reflect the least comprehensive forest value.

Table 4. Forest management plan ranking

Plan	D^{+}	D^{-}	$D^{+}+D^{-}$	C	Ranking
A7	0.3588	0.9178	1.2766	0.7189	**1**
A6	0.3656	0.6949	1.0606	0.6553	**2**
A4	0.4049	0.6519	1.0568	0.6168	3
A2	0.7220	0.4926	1.2145	0.4056	4
A8	0.7170	0.4343	1.1513	0.3772	5
A1	0.6691	0.3964	1.0655	0.3720	6
A3	0.7348	0.3658	1.1006	0.3332	7
A10	0.7960	0.3913	1.1872	0.3295	8
A8	0.6738	0.3827	1.1826	0.2821	9
A5	0.6363	0.3728	1.0752	0.2653	10

2.3 Proposition of Balance Point of Forest Management Plan

The supply, demand and price of forest resources commodities are two aspects of the circulation of commodity forest resources. The changes in the supply-and-demand relationship of forest resources and the price of forest resources conform to the law of general commodity supply-and-demand and price changes. The balance point between forest management plans can be abstracted as the intersection of supply-and-demand curves based on the concept of forest resource economics. In this study, the supply-and-demand function and supply-and-demand curve of forest resources are constructed according to the specific situation of Yellowstone National Park.

The supply-and-demand relationship of forest resources reflects the commercial forest resources that forest managers can provide or obtain to the society. Since the forest is a complex and huge system with many subjects of forest managers, it is necessary to consider from the individual to the market level. The supply-and-demand relationship in the forest resource market will be discussed separately here.

Quantity supplied of market refers to the total amount of forest resources that all producers (enterprises) in the forest resource commodity market are willing and able to provide, expressed by a functional relationship:

$$Q_S = Q_{S_1} + Q_{S_2} + \cdots + Q_{S_n} = \sum_{i=1}^{n} Q_{S_i} \tag{9}$$

Quantity demanded of market refers to the total demand of forest resource products by all groups or households in the forest resource market, which is expressed by a functional relationship:

$$Q_d = Q_{d_1} + Q_{d_2} + \cdots + Q_{d_n} = \sum_{i=1}^{n} Q_{d_i} \tag{10}$$

Since the quantity supplied of forest resources is affected by many factors besides the market price of forest resources, when one or more of the factors affecting the quantity

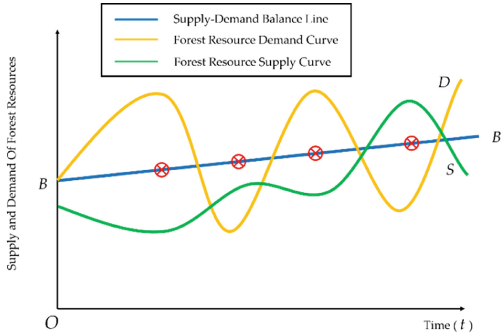

Fig. 2. Supply-and-demand forest resources tend to balance

supplied (or demanded) of forest resources change, the quantity supplied (or demanded) which is only determined by the market price of forest resources will also change, causing the entire supply (or demand) curve to shift.

When the quantity supplied and quantity demanded of forest resource commodities reach a balance, it is the balance point of forest management, as shown in the Fig. 2, the red point in the Fig. 2 is the corresponding transition point of forest management. The supplied and demanded sides are in opposite directions, fluctuating up and down around the balance line of quantity supplied and quantity demanded, while the balance of supply-and-demand relationship of forest resources changes alternately.

It can be seen that the characteristics and location of the forest can be transformed into the market situation of forest resources commodities in the area where the forest is located, and to understand its quantity supplied and quantity demanded of the market. We have to determine the price of the forest resource commodity in Yellowstone National Park first in order to find the transition point. Secondly, it is necessary to clarify the supply and demand situation in the region, and then calculate the balance line of supply and demand according to the function curve involved. Finding the point corresponding to the icon to find the balance point.

3 A Forest Management Assessment Planning Model for Global Forests

3.1 Adding Metrics: Thinking Holistically

The forests in different regions of the world have different characteristics due to their different topography and climate, so the required forest management plans are also have huge differences. We will establish a forest management plan model which can be applied to different forests. Since the forest management plan model is based on Yellowstone Park in the United States, we will select the Black Forest in Germany, the Waipowa Forest in New Zealand, the Greater Khingan Mountains in China and the Komoai virgin forest in Africa as the research objects (Table 5).

Table 5. Global research object

Forest Name	Main Species	Tree Growth Rate	Forest Area km^2	Socioeconomic	FCSDPI
Black Forest	pine tree, fir tree	0.6341	6000	0.4953	0.6529
Waipowa Forest	Kauri	0.5782	90	0.2754	0.6264
Daxing'anling	pine tree, fir tree	0.6401	28	0.6811	0.7721
Comoe Forest	cypress, persimmon	0.3785	10000	0.5728	0.6782

Table 6. Four forest carbon sequestration results and potential indices

Forest Name	100 years of carbon sequestration $\left(10^6 m^3/hm^2\right)$	ξ
Black Forest	70473.7	0.6529
Waipowa Forest	68375.6	0.6264
Daxing'anling	84536.6	0.7721
Comoe Forest	74357.7	0.6782

According to the different growth functions of trees and the calculation formula of forest carbon sequestration given in Sect. 2, the carbon sequestration formulas of four kinds of forests can be obtained as follows:

$$C(t) = \xi Q(t) + Q(t) \times BEF \times (1 + R) \tag{11}$$

Among them, ξ is the forest carbon sink potential development index ($FCSDPI$). We can obtain the carbon sequestration of the above four forests in 100 years through the calculation formula of carbon sequestration of different forests.

Therefore, the final simulation results are shown in the Table 6. We believe that in the next 100 years, the carbon sequestration capacity of the Black Forest will be 70473.7 m^3/hm^2, the carbon sequestration capacity of the Waipowa Forest will be 68375.6 m^3/hm^2, the carbon sequestration capacity of the Greater Khingan Mountains will be 84536.6 m^3/hm^2, and the carbon sequestration capacity of the Komoai Forest will be 74357.7 m^3/hm^2.

3.2 Development of a Global Forest Management Plan

Based on the discussion of forest management plans within Yellowstone National Park on a small scale in Sect. 2, we have initially proposed 10 forest management plans, and here we expand our research to a global scale. The climatic conditions of each continent are almost similar, so we select a representative forest in each of the four continents of

Table 7. Best management options for four forests

Forest	Plan	D^+	D^-	$D^+ + D^-$	C
black forest	B3	0.328	0.816	1.148	0.639
Waipowa Forest	C5	0.365	0.957	1.125	0.785
Daxing'anling	D9	0.485	0.836	1.067	0.605
Comoé Forest	E7	0.457	0.794	1.168	0.758

Europe, Oceania, Asia, and Africa for research. We can also eliminate the influence of climate variables on the results.

The small-scale internal reasons are not discussed here. We characterize the world's forests into three types: forest area, dominant tree species, and socioeconomics. It is similarly to the way we considered the forest management plan for Yellowstone National Park, so it can be modified and applied based on the established forest management plan. We have added two indicators of development and climate to improve the forest management plan model.

Our forest resources ecological economic system is controllable. Humans have destroyed the forest, restored forest and created another form of carbon sequestration for the forest [5]. Among them, the practices of developed countries such as New Zealand, Germany and some areas in China have made forests more practical through technological advancement. At the same time, undeveloped regions such as Africa may pay more attention to the economic significance of forests because of their need for money. Therefore, the indicator of the level of development introduced worldwide is meaningful.

Different regions of the world, due to their different climatic environments also have very different forest impacts on their locations. Based on forest management [7], the dense trees in the rainforest have huge leaf areas during photosynthesis, which can absorb more carbon dioxide, and their carbon sequestration capacity is higher than that of temperate trees. Metrics make sense.

We calculate the indicators which affect the four forests. The calculation process follows the explanation in Sect. 2. Finally, we get the plan ranking of the four forests. The best plan and scores of the four trees are shown in the Table 7.

3.3 Logistic Model Establishment and Solution

We set $x(t)$ as the number of trees felled in the t year, $f(t)$ as the number of trees planted in the t year, and $r(x)$ as the rate of change of trees felled of the linear function. Logistic model can be built.

$$\begin{cases} \frac{dx}{dt} = r\left(1 - \frac{x}{x_m}\right)x \\ \frac{df}{dt} = g\left(1 - \frac{f}{f_m}\right)f \\ x(t_0) = x_0 \\ f(t_0) = f_0 \end{cases} \tag{12}$$

Table 8. The rate of change in the amount of trees cut down and planted

country	r	x_m	g	f_m
NE	0.0247	342.5681	0.0241	341.2364
CH	0.0296	321.3649	0.0286	319.2379
GE	0.0211	452.3648	0.0214	462.1862
CO	0.0314	391.4627	0.0323	398.9961

Table 9. Transition timeline for new forest management decisions

Tme	cut down (%)				planted (%)			
	NE	CH	GE	CO	NE	CH	GE	CO
1	41.25	42.18	41.29	43.21	23.45	25.64	21.43	26.53
2	52.12	51.23	44.38	52.14	26.64	25.97	23.94	29.96
3	53.69	41.28	52.89	53.17	31.42	27.75	27.96	33.86
4	58.31	39.34	41.03	48.36	33.52	30.63	31.75	35.95
5	47.33	54.37	39.99	41.74	35.62	33.85	32.85	37.86
6	49.47	49.29	41.26	51.23	38.53	35.96	34.74	38.47
7	52.16	47.35	51.03	49.74	41.64	38.85	36.63	43.86
8	51.23	51.31	55.26	47.36	43.64	40.63	38.72	45.83
9	58.32	47.15	49.68	37.96	50.37	45.27	41.85	48.97
10	59.14	52.11	54.44	51.27	52.64	48.97	45.84	50.95

It is solved as:

$$x(t) = \frac{x_m}{1+\left(\frac{x_m}{x_0}\right)e^{-y(t-t_0)}} \tag{13}$$

$$f(t) = \frac{f_m}{1+\left(\frac{f_m}{f_0}\right)e^{-g(t-t_0)}} \tag{14}$$

We use python to solve the forest data of the four countries in the above question by nonlinear least squares method (Table 8).

We use the resulting solution for taxonomic analysis, a 10-year timeline for forest managers to transition to new decisions was obtained. In order to simplify the model, this calculation only considered the situation of cutting down and planting trees, and did not specifically analyze the types of trees (Table 9).

4 Sensitivity Analysis

Based on the evaluation model of forest management plans for various forests in the world, this study conducts a sensitivity analysis of the range of different indicators.

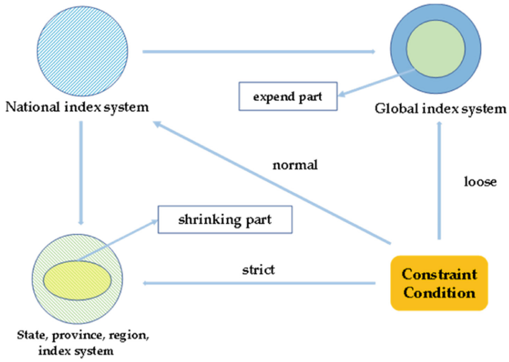

Fig. 3. Principle of sensitivity analysis

Every forest we face in the future will be a completely different ecosystem. To build a large-scale evaluation model of forest management plans on a global scale to meet forests with different characteristics and needs around the world. In this case, it is necessary to adjust the model, including modifying the model indicator system and constraints.

For example, in Sect. 3, we transfer the evaluation model used for Yellowstone National Park to a global scale to evaluate management options for four other forests, taking into account the complexity of the evaluation and including more indicators. But if we want to move to a smaller scale, we need to remove some metrics that are hard to measure, or even impossible to measure. Also, if we want to scale to a larger range, we need to weaken the constraints. If we want to narrow down to a smaller range, we need to tighten the limit. The schematic diagram is shown in Fig. 3.

We use the model in a smaller scale, integrating with a smaller forest system. We selected the People's Park in Shanghai, China, and removed three indicators of climate, development, and biodiversity. Ultimately, optimal management plans can also be obtained, so the model is also applicable to small-scale forest systems.

5 Conclusions and Recommendations

Taking Yellowstone National Park as an example, this study proposes a forest management plan evaluation model that comprehensively considers the carbon sequestration capacity of forests and other potential capacities of forests, and is used to propose optimal forest management plans for various forests around the world. How to effectively reduce carbon emissions is one of the hottest issues that the world is most concerned about. State Council of China has proposed one-vote veto system in many aspects [8]. Therefore, we must do every effort in many aspects in order to properly reduce carbon emission. The main role of forests is ecological carbon sequestration, effectively sequestering carbon dioxide in the atmosphere, but the contribution of forests in other aspects cannot be ignored just because the carbon reduction capacity of forests should be fully utilized. This study provides some systematic approaches for obtaining the weights of various functions of forests and fully carrying out research on forests according to local conditions. In addition, an integrated method for evaluating plan effectiveness based on the TOPSIS evaluation model is proposed, which will help to obtain optimal forest management plans and can change with the forest managers' focus on forest value. When researching the world's forests, we get the following results:

1. The B3 forest management plan is to cut down 30% of pine trees and 45% of fir trees, and plant 15% of pine trees and 25% of fir trees. Since the Black Forest is located in the southwest of Germany and has a subtropical climate, pine is its characteristic tree species, and its carbon sequestration ability is better than any other tree species. The fir trees also have high economic value. In addition, the tourism and cultural value of the Black Forest in Germany is higher than other value of the Black Forest. Germany is a country which has powerful ability in snow sports. Appropriately cutting down more trees is also conducive to the construction of more ski resorts and promotes the national sports culture.
2. The C5 forest management plan is to cut 65% of kauri and plant 25% of kauri. Kauri is a rare tree species that can show the special point of New Zealand. Its carbon sequestration capacity is not good, but its economic value is significant. The carbon sequestration capacity of its wood products is much higher than that of logs, and its maturity period is short. Considering the small land area of New Zealand, the planting scale does not need to be too large.
3. The D9 forest management plan is to cut down 35% pine trees and 45% fir trees, and plant 30% pine trees and 25% fir trees. The Daxing'anling is one of the most important forestry bases in China, and its biodiversity is the most important forest value. Moreover, the Daxing'anling is located in the cold temperate zone, and the growth cycle of trees is long. So, protecting the tree species is the best forest management plan.
4. The E7 forest management plan is to cut down 65% of cypress trees and 35% of persimmon trees, and plant 45% of cypress trees and 15% of persimmon trees. Komoai Forest is located in Africa, and its economic value is the most important forest value. Moreover, the growth cycle of cypress trees is short, and there are many kinds of wood derivatives, so cutting more kinds of trees is the best management plan; the carbon sequestration ability of persimmon trees is better. Well, the fruit of persimmon trees can also reflect certain cultural characteristics and economic value, so the plan of cutting down trees and planting trees appropriately is the best.

Since this study covers the Americas, Asia, Africa, Europe, and Oceania, the results of the study will be helpful for the formulation of forest management plans in most regions of the world. It also will counterpoise the forest carbon sequestration capacity, economic value, cultural value, the value of biodiversity conservation and recreational value according to the characteristics of different forests. This study can contribute to the world's carbon emission reduction and forest protection.

Since this model is a potential prediction model of forest management plan established according to the current forest growth trend, the management plan is also in line with the current form. The forest manager should formulate a new forest management plan according to the actual situation when encountering some special circumstances in the future. Forest managers can focus on tree species. Carbon emission reduction is big problem human beings in the world. We need to take various measures to control carbon emissions. We must grasp the carbon regulation capacity of forests, and we can not damage the sustainable development of forests in pursuit of a certain aspect. In the future, forest managers should pay more attention to forests in order to further explore the relationship between forest values, try to explore new forest values, and then plan them into forest management plans according to the actual situation. This allows the forest to realize its full value.

Appendix A. Nomenclature

Abbreviations

MST: Ministry of Science and Technology
MEP: Ministry of Environmental Protection

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