Forest management plans based on carbon sequestration models

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Abstract. Carbon sequestration is one of the most important ways to sequester carbon dioxide from the atmosphere to reduce the amount of greenhouse gases in the atmosphere, and forests play an indispensable role in the carbon sink. This paper will use time series prediction model (ARIMA) to Iceland, France and Italy is located in three different latitude, different climatic zone of European countries for predicting the forest carbon sequestration, change model perfectly through stationarity test sequence, and the predicted results are the residual analysis, and finally use AHP to construct a judgment matrix, obtain the weight vector through normalization, conduct consistency test, and establish an evaluation model to measure the five aspects of carbon sequestration, water and soil conservation, biodiversity, wood product profits and benefits, and social services. In the end, this paper gains the weight of the main factors affecting forest value. This paper explains to community dwellers the need for moderate deforestation of forest trees based on the above model and conclusions.

Keywords: Forest, Carbon sequestration, AHP, ARIMA.

1. Introduction

Nowadays, climate change has brought about a very negative impact on human life, such as the melting of glaciers and the increase in extreme weather, which have posed a great threat to human beings[1]. It is necessary to take some measures to reduce the effects of climate change. In addition to reducing greenhouse gas emissions, we also need carbon sequestration -- capturing carbon in a way that can be stored safely. And plants (especially large plants like trees), soil and water environments are very important for carbon sequestration[2,3]. Therefore, we must pay attention to the important role of forests in mitigating climate change. In addition to living plants, forest products can also sequester carbon dioxide, and some products can absorb carbon dioxide during production cycles that extend beyond the life of the trees that produce them. So, the carbon sequestration in some forest products plus the carbon sequestration from the regeneration of young forests may produce a better effect than not cutting forests at all[4]. However, it should also be noted that excessive deforestation will also be detrimental to carbon sequestration. It is important for forest managers to weigh the value of forest products gained from logging against the value of allowing forests to continue to grow and absorb carbon. In addition to carbon sequestration and forest products, forest managers also make the most appropriate forest management decisions based on the multiple values of the forest. In this paper, we mainly need to solve three problems: to establish an appropriate estimation model of forest carbon sequestration, to evaluate the main factors affecting forest value, and to formulate the optimal forest management plan.

2. Materials and methods

2.1. Data sources

Using data collected from the Food and Agriculture Organization of the United Nations (FAO) European database, it is forests in each of the three countries that was analyzed, representing three different climate zones (https://www.fao.org/faostat/zh/#data/GF).

2.2. Methods introduction

1. When using AHP to construct judgment matrix, the consistency test has been passed and the matrix construction has referred to many literatures and experts' suggestions.
2. In the time series prediction ARTMA, the predicted and real forest values of three different countries and climatic zones fit well, and the basic trend of the curve is consistent.
3. The series tests of time series prediction are all stable, and the prediction results are determined as white noise series through residual analysis, and the model has excellent performance.

2.3. Model evaluation

ARIMA (p, d, q) is one of the time series forecasting analysis methods, in which AR is "autoregressive", p is the number of autoregressive terms, MA is "sliding average", q is the number of sliding average terms, and d is the number of differences made to make it a smooth series. Although differencing does not appear in the name of ARIMA, it is a key step.

The ARIMA (p, d, q) model can be shown as follows:

$$\left(1-\sum_{i=1}^{p}\emptyset_i L^i\right)(1-L)^d X_t=\left(1+\sum_{i=1}^{q}\theta_i L^i\right)\epsilon_t \tag{1}$$

L is the lag operator (Lag operator). $d \in Z, d > 0$.

The analytic hierarchy process (AHP) is used to evaluate the value of forest resources. It combines quantitative analysis with qualitative analysis, and uses the experience of decision makers to judge the relative importance of Various forest value indicators for different types of forests through Delphi method. In this paper, by constructing the criterion layer of evaluation indicators, namely, the types of forests, quantitative evaluation is carried out on project hierarchy, namely, common different forest values.

3. Experimental analysis

3.1. ARIMA prediction of carbon sequestration

The ARIMA model is used to analyze and model the carbon sequestration of different forests in the three countries every five years in time series, and to predict the carbon sequestration after 100 years under natural development conditions[5]. The model is based on the following concept: since the carbon sequestration amount to be predicted in the time series is generated randomly by various factors under natural conditions and human factors, the random process of the series does not change with time, so the structure of the random process can be accurately described and described. Future values of carbon sequestration can be derived from past observations of carbon sequestration. In ARIMA model, the future value of carbon sequestration is expressed as a linear function of lag term and Random interference term in the current and lag period [6], that is, the general form of the model is shown as follows:

$$Y_t = c + \alpha_1 Y_{t-1} + \cdots + \alpha_p Y_{t-p} + \epsilon_t + \beta_1 \epsilon_{t-1} + \cdots + \beta_q \epsilon_{t-q} \tag{2}$$

(1) Stationarity Test

Firstly, carry out stationarity test for time series, including unit root test ADF and analysis of ACF and PACF graphs. If the series does not meet stationarity conditions, non-stationary time series can be transformed into stationary time series by difference transformation or logarithmic difference transformation, and the order of difference can be determined(Table. 1).

Table 1. ADF test list for the three country

ADF test list for France							
Variable	The differential order	t	p	AIC	The critical value		
					1%	5%	10%
France	0	-0.224	0.936	45.24	-6.045	-3.929	-2.987
	1	-1.826	0.367	46.248	-7.355	-4.474	-3.127
	2	-1.463	0.552	38.959	-10.417	-5.778	-3.392

ADF inspection list in Italy							
Variable	The differential order	t	p	AIC	The critical value		
					1%	5%	10%
Italy	0	1.767	0.998	34.417	-7.355	-4.474	-3.127
	1	-26.396	0.000***	38.081	-7.355	-4.474	-3.127
	2	-19.197	0.000***	29.494	-10.417	-5.778	-3.392

ADF inspection list for Iceland							
Variable	The differential order	t	p	AIC	The critical value		
					1%	5%	10%
Iceland	0	-6.623	0.000***	-13.221	-6.045	-3.929	-2.987
	1	-14.222	0.000***	-5.105	-7.355	-4.474	-3.127
	2	-11.129	0.000***	-3.127	-10.417	-5.778	-3.392

ADF test results show that Iceland is Stable time series when the difference is 0, and the p-value of unit root test is less than 0.05, which is significant and rejects the null hypothesis. In Italy, when the difference was order 1, the p-value of the unit root test was less than 0.05, presenting significance at the level and rejecting the null hypothesis. This series was Stable time series. France is Unstable time series, and France can become Stable time series after Differential transformation, and the order of Differential transformation is 0.

ACF and PACF diagrams (no longer shown here, please see the attachment for details) were made. Since BOTH ACF and PACF were trailing, they passed the stability test and were judged to be ARIMA models[7-10].

(2) Identification and parameter estimation of ARIMA models

Through the use of some statistics that can describe the characteristics of the sequence, such as the autocorrelation (AC) coefficient and partial autocorrelation (PAC) coefficient, the possible form of the model is preliminarily identified, and then according to the order criteria such as AIC, an optimal model is selected from the available models. ARIMA model was constructed for stationary time series and parameters were obtained by statistical software fitting model. The results are as follows:

Based on France, AIC information criterion is used to automatically find the optimal parameters. The model results are ARIMA model (2,0,0) test table and based on 0 different data. The model formula is as follows:

$$y(t)=1272.408+1.623*y(t-1)-0.853*y(t-2) \tag{3}$$

Based on Italy, AIC information criterion is used to automatically find the optimal parameters. The model results are ARIMA model (0,1,0) test table and based on 1 different data. The model formula is as follows:

$$y(t)=231.4 \tag{4}$$

Based on Iceland, AIC information criterion is used to find the optimal parameters automatically. The model results are ARIMA model (1,0,0) test table and based on 0 different data. The model formula is as follows:

$$y(t)=3.195+0.78*y(t-1) \tag{5}$$

3.2. AHP Assesses Forest Value

The delphi method was used to analyze the pairwise judgment matrix of Project hierarchy of each criterion to reduce the uncertainty and inaccuracy brought by subjective factors. For Project hierarchy of the same level, each element of the above level was compared pairs by pair for the criterion, and the judgment matrix was established.

(1) Normalize to get the weight vector

The root method is used to calculate the approximate value of the eigenvector of the judgment matrix. $W_i = \frac{(\prod_{j=1}^{n} a_{ij})^{\frac{1}{n}}}{\sum_{i=1}^{n}(\prod_{j=1}^{n} a_{ij})^{\frac{1}{n}}}, ij = 12kn$. (Table. 2, Table. 3, Table. 4)

Table 2. The weight vector obtained after normalization of France

Node item	Value of carbon sequestration	Value of soil conservation	The value of biodiversity	The value of wood products	The value of social services	CR value	Consistency test
Coniferous forest	0.3704	0.0854	0.1371	0.3607	0.0464	0.0047	Pass
Broad-leaved forest	0.2739	0.0935	0.1536	0.4281	0.0508	0.0086	Pass
Mixed forests	0.412	0.0739	0.19	0.284	0.0402	0.0118	Pass

Table 3. The weight vector obtained after normalization of Iceland

Node item	Value of carbon sequestration	Value of soil conservation	The value of biodiversity	The value of wood products	The value of social services	CR value	Consistency test
Coniferous forest	0.39	0.0628	0.2065	0.2725	0.0681	0.0613	Pass
Broad-leaved forest	0.2777	0.0919	0.151	0.4322	0.0472	0.0086	Pass
Mixed forests	0.4179	0.0749	0.174	0.2881	0.0451	0.0162	Pass

Table 4. The weight vector obtained after normalization of Italy

Node item	Value of carbon sequestration	Value of soil conservation	The value of biodiversity	The value of wood products	The value of social services	CR value	Consistency test
Coniferous forest	0.3104	0.0786	0.1246	0.4417	0.0447	0.0179	Pass
Broad-leaved forest	0.2739	0.0935	0.1536	0.4281	0.0508	0.0086	Pass
Mixed forests	0.4179	0.0749	0.174	0.2881	0.0451	0.0162	Pass

(2) Consistency check

$$C.R. = \frac{C.I.}{R.I.} \tag{6}$$

When the random consistency ratio C.R.< 0.1, the calculated hierarchical ranking weight is considered correct and reasonable; otherwise, the judgment matrix needs to be readjusted until the consistency test passes.

3.3. Result analysis

The weight vector is denoted as W= (W1, W2..., Wn), is the criterion layer weight. The weight vector P= (P1, P2..., Pn) T, then W×P is the total score of each corresponding scheme layer, that is, the index to evaluate the value of all kinds of forest. Calculate and arrange the elements of each scheme layer to get the total ranking of levels, and the result of the total ranking of levels is the relative weight of the index to evaluate the value of all kinds of forest (Table 5, Table 6, Table 7, Figure 2).

Table 5. Indicator total ranking weight of France

Guidelines		Coniferous forest	Broad-leaved forest	Mixed forests	Total sort weight
Criteria layer weights		0.2222	0.6667	0.1111	
Scheme layer single sort weight	Value of carbon sequestration	0.3704	0.2739	0.4120	0.394
	The value of soil conservation	0.0854	0.0935	0.0739	0.382
	The value of biodiversity	0.1371	0.1536	0.1900	0.079
	The value of wood products	0.3607	0.4281	0.0508	0.021
	The value of social services	0.0464	0.0508	0.0402	0.006

Table 6. Indicator total ranking weight of Iceland

Guidelines		Coniferous forest	Broad-leaved forest	Mixed forests	Total sort weight
Criteria layer weights		0.4161	0.4579	0.1260	
Scheme layer single sort weight	Value of carbon sequestration	0.39	0.2777	0.4179	0.404
	The value of soil conservation	0.0628	0.0919	0.0749	0.344
	The value of biodiversity	0,2065	0.1510	0.4322	0.096
	The value of wood products	0.2725	0.4322	0.0472	0.018
	The value of social services	0.0681	0.0472	0.0451	0.009

Table 7. Indicator total ranking weight of Italy

Guidelines		Coniferous forest	Broad-leaved forest	Mixed forests	Total sort weight
Criteria layer weights		0.2222	0.6667	0.1111	
Scheme layer single sort weight	Value of carbon sequestration	0.3104	0.2739	0.4179	0.461
	The value of soil conservation	0.0786	0.0935	0.0749	0.346
	The value of biodiversity	0.1246	0.1536	0.1740	0.069
	The value of wood products	0.4417	0.4281	0.2881	0.021
	The value of social services	0.0447	0.0508	0.0451	0.007

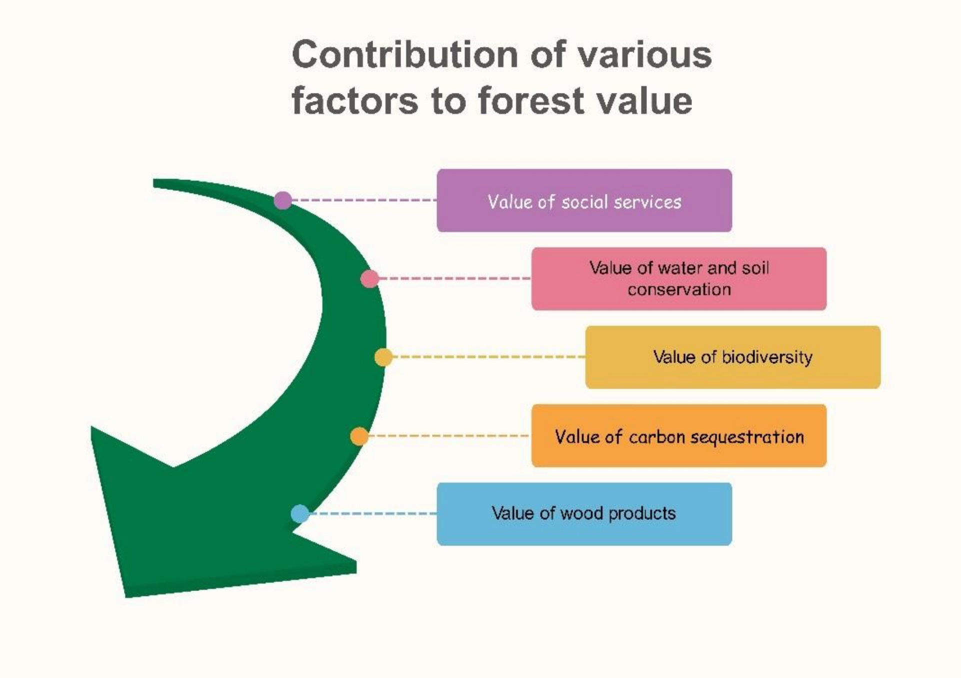

Figure 1. Contribution of various factors to forest value

4. Conclusions

In this paper, the modals used have some advantages. Firstly, in the time series prediction, the predicted and real forest values of three different countries and climatic zones fit well, and the basic trend of the curve is consistent. Secondly, when using AHP to construct judgment matrix, the consistency test has been passed and the matrix construction has referred to many literatures and experts' suggestions.

In the end, in order to maximize carbon sequestration, people should ensure that they are on the ridge, that is, that the proportion of trees that are cut down in the year is equal to the proportion of trees that are dying in the forest at that time.

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