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Research on carbon sequestration cost accounting and value evaluation method

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Abstract: The existing research results at home and abroad on the cost accounting methods and benefit evaluation of forest carbon sequestration were applied and analyzed. The cost of carbon sequestration is studied based on partial forestry data in Guangxi, China, using ecological economic methods, taking into account forest rotation period and discount rate. The benefit of carbon sequestration is studied in Fujian, China, with reference to domestic and foreign research results and the concept of "market approximation coefficient". The results show that it is very necessary to analyze the carbon sequestration cost net income in evaluating the feasibility of carbon sequestration afforestation project implementation.

1. Introduction

In the current international environment, the potential of forests to slow the rise of atmospheric CO_2 concentration has been widely recognized. The Kyoto Protocol allows Parties to offset their committed emission reduction targets by afforestation and reforestation of fixed carbon sinks from 1990.

In the research process of forest carbon sequestration value, afforestation cost method and carbon tax rate method are often used to estimate the fixed CO_2 value. The estimated forest carbon sequestration value is either between the two or the average value of the two. Some western countries use the carbon tax system to limit CO_2 and other greenhouse gas emissions. For example, Norway's tax rate is $227 per ton of carbon; The United States is only $15. In recent years, China mainly uses the afforestation cost method to evaluate the carbon fixation value of forests[1].

The above research on carbon sequestration cost value is mainly limited to the current situation of forests at that time, which is a static research, and does not involve the change of carbon sequestration cost of forests with the increase of carbon reserves in the whole growth process. If the change of carbon sequestration cost of main plantation types is estimated based on the perspective of afforestation cost input in a complete rotation period, different discount rate scenarios are set using the principles of ecological economics to compare the present value of carbon sequestration cost of different plantation types and the impact of different discount rates on carbon sequestration cost of

main plantation types; At the same time, the analysis of changes in carbon sequestration costs and net benefits of major plantation types under the consideration of timber benefits can reduce the uncertainty of carbon sequestration cost estimation of major plantation types in China, and provide a scientific basis for China to formulate CO_2 emission reduction and exchange increase measures in the forestry field in the future.

2. Research Method

The cost of carbon fixation is calculated by considering three factors of forest age, afforestation cost and timber income; Evaluate the carbon sequestration benefits by considering the market approximation coefficient[2].

2.1. Calculation of Carbon Storage of Different Age Stands

The classical biomass age curve has been widely used in the study of predicting the dynamic change of biomass. For the four types of artificial forests of Pinus massoniana, Cunninghamia lanceolata, eucalyptus and Schima superba+Liquidambar formosana at different ages, the volume growth curve provided in the project of carbon sequestration reforestation in the Pearl River Basin of Guangxi was used, and combined with the relevant parameters provided in the project, the biomass growth curve was transformed into the biomass growth curve. The relationship between biomass per unit area and forest age was established for the other three types of tree species by sorting out the biomass literature published since 1980. The IPCC carbon content default value of 0.47 (IPCC, 2007b) is used to calculate the carbon storage per unit area, that is

$$S_c = 0.47B$$

S_c is the carbon storage of the forest (t C*hm^{-2}), and B is the biomass of the forest(t*hm^{-2}).Considering that the change of soil carbon storage is not obvious during the growth of plantation, the proportion of carbon storage of undergrowth vegetation and litter is small, and there is great uncertainty, only the carbon storage of forest trees is considered. The biomass growth curves of several plantations are shown in Figure 1.

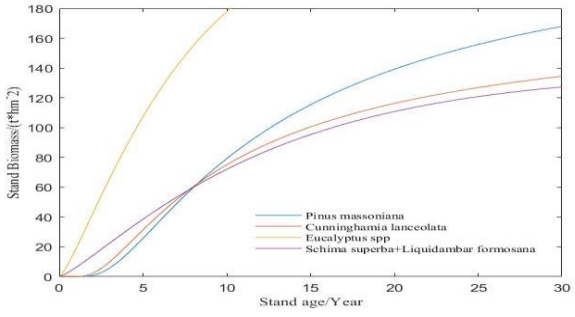

Figure 1: The biomass growth curves of several plantations.

2.2. Afforestation Cost

The data of various afforestation costs were investigated, including the costs of mountain refining, mountain clearing, land preparation, thinning and other processes, as well as land opportunity costs. Among them, the costs of mountain refining, mountain clearing, land preparation and planting are one-time inputs. Fertilization and tending are generally considered to be twice a year, with a total of six inputs for three consecutive years[3].[3]There is management and protection input in the whole process of forest growth. In combination with the thinning and rotation periods of various tree species

of artificial forest types, the afforestation cost is shown in the Table 1.

Table 1: The afforestation cost.

item	Pinus massoniana	Cunninghamia lanceolata	Eucalyptus spp	Schima superba+Liquidambar formosana
Controlled Burning	750.0	750.0	750.0	750.0
Site Clearing	180.0	180.0	180.0	180.0
Site preparation	900.0	900.0	900.0	900.0
Planting	697.6	960.3	725.0	508.6
Tining	768.0	931.2	0.0	444.0

2.3. Calculation of carbon sequestration cost with or without consideration of wood revenue

Plantinga et al. (2001) and Richards et al. (2004) studied or summarized the carbon sequestration cost of forests on a regional or national scale using the same accounting method. In order to calculate the change of carbon sequestration cost of each tree species in a rotation period, the carbon sequestration cost calculation formula in the above literature is quoted:

$$C_{PVn} = \sum_{i=1}^{n} \frac{C_i}{(1+r)^i}$$

C_{PVn} represents the present value of total cost per hectare in n years (yuan*hm^{-2}); C_i represents all investment expenditure per hectare of forest in the i^{th} year; r is the social discount rate. The calculation formula of present value C_n (yuan*t^{-1}) of carbon fixation cost when the forest age is n years is:

$$C_n = C_{PVn}/S_n$$

S_n is the carbon storage of the stand at the age of n years(t C*hm^{-2}). At the end of the rotation period, the gross profit of timber sales minus direct costs such as timber harvesting costs, transportation and taxes is the main component of timber income. In order to analyze the dynamic change of carbon fixation cost when considering the timber income in the process of forest growth, it is understood that the timber income means that there is benefit in the process of timber accumulation from afforestation to the end of rotation, and the net accumulation of the whole stand's annual stock is calculated. The timber income is calculated according to the annual change of the stock, which can be obtained as follows:

$$M_n = \sum_{i=1}^{n} \frac{P_i}{(1+r)^i}$$

M_n represents the present value (yuan*hm^{-2}) of the accumulated timber income per hectare of stands in n years, and P_i represents the total timber income of net increase in the i^{th} year. Then, considering the timber income, the present value of carbon fixation cost C_n^S (yuan*t^{-1}) formula is:

$$C_n^S = (C_{PVn} - M_n)/S_n$$

After the total fixed CO_2 amount of the forest each year is calculated, which is converted into pure carbon, and then multiplied by the carbon tax rate [US dollars/t (CO_2)] or the replacement standard

of afforestation cost (yuan/m^3) to obtain the total value of fixed CO_2 of the forest, and finally multiplied by the "market approximation coefficient" to obtain the market value of fixed CO_2 of the forest. The market approximation coefficient can be calculated by the formula as followed:

$$\begin{cases} l = 1/(1+e^{-t}) \\ t = T-3 \\ T = 1/E_n \end{cases}$$

l is the coefficient of development stage; t is the time; e is the base of the natural logarithm; E_n is Engel coefficient.

2.3.1. Equations

$$S_c = 0.47B \quad (1)$$

$$C_{PVn} = \sum_{i=1}^{n} \frac{C_i}{(1+r)^i} \quad (2)$$

$$M_n = \sum_{i=1}^{n} \frac{P_i}{(1+r)^i} \quad (3)$$

$$\begin{cases} l = 1/(1+e^{-t}) \\ t = T-3 \\ T = 1/E_n \end{cases} \quad (4)$$

3. Conclusions

Based on the above analysis and actual data, we can draw the following conclusions.

3.1. Change of Carbon Sequestration Cost of Main Plantation Types

According to the cost tables in table 1 afforestation costs, the afforestation costs incurred by the four types of plantations are calculated on an annual basis, and the annual afforestation costs are brought into the carbon sequestration cost calculation formula that does not take into account timber income, and the carbon sequestration costs incurred annually for four types of planted forests are obtained[4] in the Table 2.

Table 2: The carbon sequestration cost.

item	Pinus massoniana	Cunninghamia lanceolata	Eucalyptus spp	Schima superba+Liquidambar formosana
first year	3138.67	3544.29	2433.33	2650.10
second year	2989.21	3375.51	2317.46	2523.90
third year	2846.86	3214.77	2207.11	2403.71
fourth year	2711.30	3061.69	2102	2289.25

3.2. Afforestation Cost

The above accounting is relatively rough. It does not include the whole process of carbon emissions from harvested biomass and carbon storage and release in forest soil, and has received limited restrictions on forest resources in Fujian Province. The above data are based on the average accumulation of mature forests, and there is no hierarchical calculation of the growth period.

Although there are some limitations, this accounting result is still valuable. First of all, in line with the socialist market economy, the "market approximation coefficient" has been introduced to construct four economic structural models of fixed CO_2 benefits of forest forests, and promote the marketization of forest ecological benefits. Second, on the basis of relatively scientific calculation, the fixed CO_2 value of forests in Fujian Province is roughly estimated, which also has great reference value for the carbon fixation value applied to other regions; third, the accounting of the fixed CO_2 value of forest environmental resources alone has confirmed the major ecological and environmental benefits of forests; fourth, the whole accounting provides reference and reference for the scientific management and asset evaluation of forest resources in Fujian Province and other regions.

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