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Research and Development Trend of Economic Value Assessment of Forest Carbon Sink—Take Fujian Province as an Example

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Abstract: In the process of human civilization and progress, ecological problems have become increasingly prominent. As the foundation of human survival and development, forest can not only provide a wide range of production and living resources, but also create a lot of economic benefits. Fujian Province is a big forestry province; the value of forest carbon sink is quite considerable. From the perspective of evaluation, the economic value of forest carbon sink in Fujian Province was estimated by determining the price of total forest carbon storage and carbon sink. Finally, from the three aspects of strengthening the government-oriented role to promote the scale economy of carbon sink, strengthening multi-party cooperation to promote the development of upstream and downstream multiple industrial chains, and increasing scientific and technological investment to promote the healthy development of carbon sink economy, this paper puts forward countermeasures and suggestions for the development of forest carbon sink in Fujian Province, so as to realize the sustainable development of forestry.

1. Introduction

Global warming has caused frequent extreme weather, which has seriously affected human life and economic development, and also destroyed forest ecosystem. In this context, the United Nations Environment Programme has put forward the important topic of "forest restoration and reconstruction", which aims to control the global average temperature rise above the pre-industrial level within 2 °C and achieve global carbon balance by the end of the 21st century through the conservation and management of forests. Forest carbon sink refers to the absorption of CO2 from the atmosphere by forest plants and the reduction of CO2 content through vegetation and soil. The 1997 Kyoto Protocol recognizes that forest carbon sink can promote the mitigation of climate change, and requires the strengthening of sustainable forest management, restoration and vegetation protection. At present, countries and international organizations are actively using forest carbon sink to address climate change. As one of the most convenient and effective methods to study the nature and change of carbon sink, carbon sink value assessment provides more accurate and reasonable data support for people. Compared with other emission reduction methods, forest carbon sinks,

which are more economical and efficient, have gradually become an important alternative for CO2 emission reduction [1].

Many scholars at home and abroad have begun to pay attention to and carry out theoretical and empirical research in related fields, and have achieved a certain degree of achievements and experience accumulation. Some representative scholars who first conducted forest ecosystem research, such as Kenneth R Richards et al. (2004), pointed out that carbon dioxide can be solidified through forests [2]. Lorena Soto-Pinto (2010) showed that agriculture and forestry system is one of the important ways of carbon sink, and carbon sink can effectively mitigate greenhouse effect [3]. Pugh Thomas A M (2019) pointed out the role of forest regrowth in the dynamics of global carbon sink through correlation analysis of forest carbon sink [4].

The relevant research in China started late, and the initial exploration was carried out with the carbon cycle as the carrier. Tu Huiping (2004) regarded forest as the main body of the ecosystem, proposed that forest be the dominant factor of its carbon cycle, and converted it into more carbon [5]. From the perspective of forest carbon sink and sustainable development, Huang Yan (2012) elaborated the concepts of low-carbon economy and forest carbon sink [6]. Chen Weihong et al. (2019) believe that forest carbon sequestration is an effective way to mitigate climate change, and its economic value has great potential [7]. Li Xiaoxiao and Pan Jiaping (2020) believe that forest carbon sink plays a key role in reducing CO2 concentration and mitigating global climate change, and the accounting of forest carbon sink has become a hot topic in current research [8]. Zhang Longsheng (2022) believes that the implementation of the "dual-carbon" strategy is an important action for China to cope with global climate change [9]. However, there is still a lack of systematic and comprehensive methodology for evaluating the economic value of forest carbon sink. The research results are only for reference, and have no direct and effective guiding significance for determining the amount of forest carbon sink and establishing carbon sink trading market.

Fujian is one of the key forest areas in south China, with mild climate, abundant rainfall, superior natural conditions, rich forest resources and tourism resources. In order to further promote the economic and social development of Fujian Province in the direction of green and low-carbon, promote the transformation and upgrading of the forestry industry in Fujian province, and enhance the function of forest carbon sink, the Fujian Provincial Forestry Bureau has put forward the initiative of "enhancing the capacity of forest carbon sink", and the reform of forest carbon sink system is imperative.

2. Economic Value Assessment Method of Forest Carbon Sink

2.1 Forest Carbon Sink Measurement Method

Biomass method, storage method, biomass inventory method, vortex correlation method and so on are widely used to measure forest carbon sink. Among these methods, which method is the most appropriate is still controversial, but each has its own advantages and disadvantages, so in the application process, it should be combined with the actual use, so as to obtain more accurate measurement results.

Estimates of forest carbon sinks include trees above ground and elements below ground. This paper adopts the research method of Gao Hongjie (2020) on the economic value of forest carbon sink in Guangdong Province [10], also applies the accumulation expansion method to measure the forest carbon storage in Fujian province, and estimates the total carbon sink in Fujian Province with the accumulation of living wood as the research object, so as to improve the calculation accuracy. Forest stock expansion is a method based on biomass conversion factor first proposed by Xi Tingting and Li Shunlong (2006) [11]. The advantage of this method is that it has a large number of samples, so it is more convincing. It is calculated according to the stock volume of all trees in the

forest, almost including the stock volume of all trees on the entire earth surface, and does not require field measurement, and the accuracy is also greatly improved compared with the previous method. The specific methods are as follows:

(1)The total forest stock is composed of forest biomass carbon sink, understory plant carbon sink and forest land carbon sink. The specific formula is:

$$C=C_1+C_2+C_3 \quad (1)$$

Among: C represents the total stock of the forest; C_1 represents the carbon sink of forest trees; C_2 represents the carbon sink of understory plants; C_3 represents the carbon sink of forest land.

(2) According to relevant research methods, the indicators in formula (1) are further analyzed C_1, after the forest stock volume is obtained, the biomass is calculated by the stock expansion coefficient and volume density, and then the carbon content is multiplied on this basis.C_2 can passC_1 and the product of carbon conversion coefficient of understory plants.C_3 underwood C_1 and the product of carbon conversion coefficient of forest land. The specific formula is:

$$C_1=V\times\delta\times\rho\times y \quad (2)$$

$$C_2=\alpha\times V\times\delta\times\rho\times\gamma \quad (3)$$

$$C_3=\beta\times V\times\delta\times\rho\times\gamma \quad (4)$$

Among them: V stands for forest stock; δ represents the accumulation expansion coefficient; ρ represents volume density; γ represents the carbon content; α represents the carbon conversion coefficient of understory plants; β represents the carbon conversion coefficient of forest land.

(3) After sorting out the steps shown above, the comprehensive formula is as follows:

$$C=C_1+C_2+C_3= V\times\delta\times\rho\times\gamma+\alpha(V\times\delta\times\rho\times\gamma)+\beta(V\times\delta\times\rho\times\gamma) \quad (5)$$

After simplification:

$$C=(1+\alpha+\beta)\times V\times\delta\times\rho\times\gamma \quad (6)$$

Each conversion factor(δ, ρ, γ, α, β) taking the corresponding default values, the coefficients in formula 3.5 are calculated in accordance with the rules of the UN's governmental body, the Panel on Climate Change. Coefficient of accumulation expansion δ the default is1.90, bulk density ρ is 0.5, carbon content γ is 0.5, carbon conversion coefficient of understory plants α is 0.195, carbon conversion coefficient of forest land β is 1.244.

2.2 Assessment Method of Economic Value of Forest Carbon Sink

The economic value of forest carbon sink is determined by two factors, one is the aggregate storage amount of forest carbon, and the other is the unit price of carbon, so the specific formula is as follows:

$$Q=CxP \quad (7)$$

Among them: Q represents the aggregate economic value of forest carbon; C represents the carbon sink; P represents the carbon sink price.

There are many calculation methods for carbon sink value, such as cost-benefit analysis, afforestation cost method, carbon tax law and average value method of carbon tax law and afforestation cost method, etc. The difference of calculation methods will directly affect the difference of results. In this paper, carbon tax law and average method of afforestation cost method are adopted. Firstly, afforestation cost method is used to select three different unit prices in Table 1 as the unit price of forest carbon sink, which are 260.9 yuan/ton c, 273.3 yuan/ton c and 305

yuan/ton c respectively. The results are estimated in turn, and then the carbon tax law is used to calculate the carbon sequestration price according to Table 2. That is, 1200 yuan/ton c was measured and the estimated result was obtained. Finally, the average value of the two methods was taken as the economic value of forest carbon sink in Fujian Province.

Table 1: Several common carbon sink unit prices

Author	Unit price	Unit	Research source
Jinsheng Shen, Ruifang Liang	253	CNY/ Ton C	Journal
National situation of biodiversity in China Research report	260.9	CNY / Ton C	Report
Songwei Jia	272.7	CNY / Ton C	Journal
Yuanzhao Hou	273.3	CNY / Ton C	Monograph
Tang Gao	15.17	Dollar/ Ton C	Journal
Gang Chen	10	Dollar/ Ton C	Journal
Sejun Shi, Min Huang	305	CNY / Ton C	Journal

Data source: Collation of relevant literature

Table 2: Standard Prices of Forestry Industry of the People's Republic of China (part)

No.	Nmae	Unit	Numerical value	Source and basis
1	Potassium chloride potassium content	%	50.0	Fertilizer product description
2	Diammonium sulfate fertilizer price	CNY t^{-1}	2400	Adopted Ministry of Agriculture China
3	Potassium chloride fertilizer price	CNY t^{-1}	2200	Agricultural information network
4	Organic matter price	CNY t^{-1}	320	(http://www.agri.gov.cn) Average price in spring 2007
5	Carbon sequestration price	CNY t^{-1}	1200	Adopt Sweden's carbon tax rate of $150 t^{-1}(Equivalent to RMB 1200 CNY t^{-1})
6	Produced oxygen price	CNY t^{-1}	1000	The website of the Ministry of Health of the People's Republic of China is adopted (http://www.moh.gov.cn) Average oxygen price in spring 2007

Data source: Forest Ecosystem Service Assessment Specification (LY/T1721-2008)

3. Assessment of Economic Value of Forest Carbon Sink in Fujian Province

3.1 Overview of the Study Area

Fujian Province is located in the southeast coast of China, and the mountain, tectonic valley and even the coastline are mainly trending northeast-south-southwest and northeast-south-southwest. The area of mountains and hills accounts for more than 90% of the total area of the province, known as "eight mountains, one water and one field". Fujian is close to the Tropic of Cancer and affected by monsoon circulation and topography, forming a warm and humid subtropical monsoon climate with abundant heat. 70% of the province's regions have accumulated temperature of ≥10℃ between 5000-7600℃, abundant rainfall and sufficient sunlight, so Fujian has extremely rich forest

resources. According to the 9th Forest resources inventory data, the forest coverage rate of Fujian Province is 66.8 percent, ranking first in China. The forest area of the province is 8.1158 million hm2, and the forest stock is 729 million m3. Fujian is an important forestry province in China, the first "National ecological civilization pilot zone" in the country, and the province with the highest forest coverage rate in the country. As one of the key forest areas in southern China, the forest area is 183.7474 million hectares, accounting for 19.55% of the total forest area in China. The total storage volume of living trees is 360 million cubic meters, accounting for 17.7% of the country. Moreover, the forestry development of Fujian started early, with abundant forestry resources and good basic conditions: first, the total amount of forest resources is large and the types are diverse; Second, the sound development of forestry industry system; Third, the economic characteristics of the forest are distinctive; Fourth, forestry reform has achieved remarkable results.

3.2 Assessment of Forest Carbon Sink in Fujian Province

According to the statistical results of the 1st to 9th forest resources inventory data in Fujian Province, the overview of forest resources in Fujian Province is shown in Table 3.

Table 3: Total stock of living trees in Fujian Province from 1974 to 2018

No.	Inventory time	Storage of living wood (10,000 cubic meters)
1	1974	24330.00
2	1978	43055.91
3	1988	37888.24
4	1993	39465.20
5	1998	41763.62
6	2003	49671.38
7	2008	53226.01
8	2013	66674.62
9	2018	79711.29

Data source: Forest resources inventory in Fujian Province over the years

Based on the forest stock expansion method, the carbon sink content involved in various aspects in Fujian Province during 1974-2018 was obtained successively by combining formula (2), formula (3) and formula (4). The results are shown in Table 4:

Table 4: Forest biomass carbon sink, understory plant carbon sink and forest land carbon sink in Fujian Province from 1974 to 2018

Year	Carbon sequestration of forest biomass (10,000 tons)	Understory carbon sink (10,000 tons)	Carbon sink of forest land (10,000 tons)
1974	11556.75	2253.57	14376.60
1979	20451.56	3988.05	25441.74
1988	17996.91	3509.40	22388.16
1993	18745.97	3655.46	23319.99
1998	19837.72	3868.36	24678.12
2003	23593.91	4600.81	29350.82
2008	25282.35	4930.06	31451.25
2013	31670.44	6175.74	39398.03
2018	37862.86	7383.26	47101.40

Data source: calculated in this study

According to formula (1) or formula (5), the total forest carbon sink of Fujian Province from 1974 to 2018 can be obtained, as shown in Table 5:

Table 5: Total forest carbon sink in Fujian Province from 1974 to 2018

No.	Year	Total forest carbon sink (10,000 tons)
1	1974	28186.91
2	1979	49881.35
3	1988	43894.47
4	1993	45721.42
5	1998	48384.20
6	2003	57545.54
7	2008	61663.66
8	2013	77244.21
9	2018	92347.52

Data source: calculated in this study

The results in Table 5 show the total forest carbon sink of Fujian Province from 1974 to 2018. According to the measurement results, the forest resource coverage rate of Fujian Province increased year by year from 1988, and the total forest carbon sink fluctuated up and down slightly from 1979 to 1998, but the overall increase was relatively slow. The total forest carbon sink increased significantly from 2003 to 2018, and in general, the total forest carbon sink increased from 1974 to 2018 in Fujian Province. The development of forestry in Fujian Province, on the one hand, is due to the implementation of the national natural forest, public welfare forest protection policy since 1998, so that the original forestry management mode has changed; On the other hand, due to the adjustment of forestry policy, the reduction and reduction of forestry tax since 2001 and the reform of forest right system since 2002, the vast number of farmers in Fujian Province actively participate in forest construction and increase the stock of living trees in forest land.

The results showed that the carbon sink capacity of mixed broad-leaved forest and fir was higher than that of other tree species. According to the data of the ninth forest resources inventory, the total area of mixed broad-leaved forest and Chinese fir in Fujian Province is more than 50%, and the dominant tree species in Fujian Province also determines its carbon sink capacity. Coupled with the unique terrain and climate conditions, Fujian Province has a good forest resource base and a good carbon sink prospect. Fujian Province should make full use of its ecological advantages and develop forest carbon sink to achieve sustainable development.

3.3. Economic Value of Forest Carbon Sink in Fujian Province

The evaluation of the economic value of forest carbon sink is mainly determined by the total amount of forest carbon sink and the price of carbon sink. The total forest carbon sink of Fujian Province from 1974 to 2018 has been calculated by using the forest stock expansion method combined with the formula. Therefore, the selection of carbon sink prices needs to be more careful. This paper uses the carbon tax rate method and the mean value method of afforestation cost method, in which different unit prices of 260.9 yuan/ton c, 273.3 yuan/ton c and 305 yuan/ton c are selected for afforestation cost method. Meanwhile, the carbon tax law adopts 1200 yuan/ton c as the calculated price, and takes the average value of the final calculation of the two methods. The actual economic value of forest carbon sink in Fujian province was obtained. The calculation results of the economic value assessment of forest carbon sink in Fujian Province from 1974 to 2018 are shown in Table 6:

Table 6: Economic value of forest carbon sink in Fujian Province from 1974 to 2018

Year	Economic value of forest carbon sink in Fujian Province under different calculation methods (100 million CNY)					Average economic value (100 million CNY)
	Carbon tax law	Cost method of afforestation				
	1200yuan/ton	206.9 CNY /ton C	273.3 CNY /ton C	305 CNY/ton C	Mean value	
1974	3382.43	583.19	770.35	859.70	737.75	2060.09
1979	5985.76	1032.05	1363.26	1521.38	1305.56	3645.66
1988	5267.34	908.18	1199.64	1338.78	1148.86	3208.10
1993	5486.57	945.98	1249.57	1394.50	1196.68	3341.63
1998	5806.10	1001.07	1322.34	1475.72	1266.38	3536.24
2003	6905.46	1190.62	1572.72	1755.14	1506.06	4205.81
2008	7399.64	1275.82	1685.27	1880.74	1613.94	4506.79
2013	9269.31	1598.18	2111.08	2355.95	2021.74	5645.52
2018	11081.70	1910.67	2523.86	2816.60	2417.04	6749.37

Data source: calculated in this study

Table 6 shows the economic value assessment results of forest carbon sink in Fujian Province from 1974 to 2018. According to the calculation result, the calculation result obtained by using afforestation cost method is much smaller than that obtained by carbon tax law, so it is more reasonable to take the average value of the two as the final calculation result. The economic value of forest carbon sink in Fujian Province from 2008 to 2018 was 45.679 billion yuan, 564.552 billion yuan and 674.937 billion yuan, respectively. During 1979-1998, the forest carbon sink in this region was at the economic value level of about 330 billion yuan, showing a relatively stable state. However, during the period from 2008 to 2018, under the promotion of major forestry projects such as national policy support, forest city construction and national greening action, the forest living wood stock in Fujian Province has increased rapidly in recent years, so the carbon sink economy of forest resources has increased year by year, and the economic value of carbon sink in 2018 has reached about 674.937 billion yuan.

4. Countermeasures and Suggestions for Developing Forest Carbon Sink in Fujian Province

4.1. Strengthen the Guiding Role of the Government and Promote the Scale Economy of Carbon Sinks

In the current situation of the contradiction between forestry development and environmental resources, a series of specific laws, regulations and policies must be formulated in order to seize the opportunity and vigorously develop the low cost and multi-income forestry carbon sink economy. Fujian Province is recognized as an important ecological area in the world. China's forestry development is early, the forest resources are rich, the basic conditions are superior, and the scientific guidance of the government needs to be strengthened. First, the government should properly formulate financial support policies, expand the sources of ecological compensation funds for the forestry carbon sink economy, and carry out financing through a variety of ways. For example, set up carbon tax, forest resource royalties and other taxes, encourage financial institutions to carry out corresponding credit or carbon reserves, and provide adequate financial support for investors in forest carbon sink projects; Secondly, with reference to countries and regions with developed carbon sink markets and economies, and according to the specific conditions of Fujian Province, relevant policies should be formulated to support and support the carbon sink trading in

Fujian province, and a scientific carbon sink trading market should be established and improved through government-led and enterprise participation, and technical support should be provided. Third, strengthen the publicity and publicity of the carbon sink economy, let the public understand the connotation and development prospects of the carbon sink economy, promote the important role of the carbon sink economy in reducing global warming, enhance the public's awareness of environmental protection, and encourage more people to participate in the development of the carbon sink economy. The government shall take measures such as supervision, increasing support, establishing a sound system and mechanism, and improving the carbon sink trading market. It will promote the decision-making of forest farmers, form a virtuous circle, and form economies of scale.

4.2. Strengthen Multi-Party Cooperation to Drive the Development of Upstream and Downstream Industrial Chains

The first is to vigorously develop the province's forest carbon sink tourism. Today, with the increasing material living standards, more and more people begin to pay attention to the cultivation and relaxation of the spiritual level, and the number of people who are keen on traveling is increasing. Through reasonable protection and development of the unique natural conditions of our province, the forest carbon sink area will be built into a place with ecological and ornamental value, which can not only promote the development of tourism, but also promote the development of local economy, but also provide a lot of funds for the development of forest carbon sink economy, and set up a good image for the development of forestry carbon sink economy of the province. Second, vigorously develop circular forestry. Fujian Province has a high forest coverage rate since ancient times and has rich experience in afforestation. According to the local conditions, some forest farmers in Fujian Province have adopted the compound management mode with various benefits. For example, vigorously develop forestry cultivation, use the forest to raise poultry, and raise waterfowl in the nearby sea area. In this way, some forest products are real, animals in the forest can be used as food for poultry and aquatic products, livestock feces and other secretions can be used as fertilizer, so that the forest soil becomes fertile, trees grow better, forming a multi-level recycling chain, so that multiple industrial chains coordinated development. If this method is extended to carbon sink forest, it can make use of the income of carbon sink forest to make up for the low income of carbon sink forest in the early stage, and achieve a win-win situation of ecological and economic benefits.

4.3. Increase Investment in Science and Technology to Promote the Healthy Development of Carbon Sink Economy

Science and technology is the primary productive force. In the context of new technological revolution, science and technology plays an important role in the formation and development of productive forces. First, the introduction of foreign advanced and suitable afforestation technology and equipment, vigorously implement forestry management projects and forestry demonstrations. Only in this way can we realize the sustainable development of forestry carbon sink economy and the protection of ecological environment. The second is to strengthen forest protection measures and infrastructure construction, strengthen the construction of forest management system and forest benefit distribution reform, enhance the comprehensive utilization efficiency of forest resources, and promote the sustainable development of forestry economy in Fujian Province. Third, it is necessary to strengthen the scientific research and development of green fertilizers and other fertilizers in Fujian Province, promote the development and utilization of forestry resources from multiple aspects, enhance the protection of forest ecological environment, so as to improve the value of forest carbon sink. The fourth is to reasonably increase the salaries of forest rangers and

other practitioners to stimulate their enthusiasm for work. Through improving the forestry ecological compensation system, establish relevant policies and measures to reduce the damage of afforestation to forest resources.

5. Conclusions

By combining forest carbon storage and sink with ecological compensation benefit mechanism, this study broke the single-dimension calculation of forest carbon storage and sink in Fujian Province or only studied forest ecological compensation, innovated the original research on ecological compensation based on forest ecosystem service value, and built a forest ecological compensation mechanism different from the traditional one. In this study, the forest carbon sink and its economic value in Fujian in the past 30 years were calculated, and the dynamic changes of forest carbon storage and carbon sink were investigated by using different spatial and temporal scales. Relying on databases such as China Forestry Statistical Yearbook (2001-2018) and Guangdong Rural Statistical Yearbook (2001-2018), based on the data from the official websites of the Ministry of Agriculture of China, the National Forestry and Grassland Administration of China, the National Bureau of Statistics of China, the Ministry of Water Resources, the China Meteorological Administration, the China Customs and other relevant departments, the economic value of carbon sink of forest resources in Fujian Province from 2000 to 2017 was evaluated, which can help forestry managers and relevant departments timely grasp the development status of regional forest carbon sink economy. Improve the formulation of relevant policies.

Due to the constraints of data and scientific research conditions, it is not possible to classify and make statistics for each type of forest in Fujian Province. Therefore, the measurement of forest carbon sink is limited to a large range of macro data, and only quantitative statistical methods are adopted for statistical analysis without field investigation. In addition, due to the omission or ambiguity of some data in the actual calculation, even if the data of other yearbooks and relevant departments are combined, there may be unstable data, resulting in errors in the calculation results.

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