Calculation of Carbon Sink of Bamboo Forest in Zhejiang Province and Its Value Realization Path

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Abstract. The biomass method was applied to measure the carbon sequestration status of bamboo forests in Zhejiang province, and the carbon emissions of Zhejiang province from 1989 to 2018 were estimated by using the energy activity CO2 emission measurement method, and the carbon sink contribution of bamboo forests was analyzed by comparison. The results show that the total carbon sequestration in bamboo forests increased from 18,206,400 t to 34,604,000 t during the ninth national forest inventory, with a net increase of 16,397,600 t and a growth rate of 90.07%, showing an overall increasing trend, among which moso bamboo forests are the main carbon sequestration species; the carbon emissions in Zhejiang province showed a stable growth trend, but the growth rate has decreased in recent periods; the amount of carbon sequestered by bamboo forests and carbon emissions show a convergent growth trend, but the amount of carbon sequestered by bamboo forests is relatively small for the overall carbon emissions, and the contribution of carbon sequestration is small. In order to effectively contribute to the process of carbon peaking and carbon neutrality in Zhejiang province, corresponding measures should be taken to effectively play the function of bamboo forest carbon sink and realize its value.

1.Introduction

At the 75th session of the United Nations General Assembly, China formally proposed the strategic goals of achieving carbon peaking by 2030 and carbon neutrality by 2060, which promoted the process of green transformation of China's economy and society [1]. The promotion of the strategic goals of "carbon peaking and carbon neutral" cannot be achieved without the role of natural resources [2]. As the largest carbon reservoir on land, forests play an important role in maintaining the global carbon balance [3]. Bamboo forest is an important part of forest resources, and can play a good carbon emission reduction effect [4]. Zhejiang province has the second largest bamboo forest area in China, and is an important growth area for bamboo forests in China. In the process of achieving the goal of "carbon peaking and carbon neutral" in Zhejiang province, bamboo forest carbon sink projects cannot be ignored.

The carbon storage and biomass of bamboo forests have been studied by scholars since the late 20th century [5]. After entering the 21st century, the research on bamboo forest carbon sink began to explore the influence of management methods on the amount of carbon sequestered in bamboo forest [6], etc. With the promotion of national policies, bamboo forest carbon sink has gradually become a research hotspot. Li Jia et al [7] analyzed the economic benefits of bamboo forest carbon sink projects in Anji county, Zhejiang province. Ao Guiyan et al [8] explored the productivity of carbon sink bamboo forest and its main influencing factors. Zhang Yiru et al [9] pointed out that the ecological and economic values of bamboo forests are high. Wang Bing et al [10] pointed out that bamboo forests have the strongest carbon sequestration capacity among forest resources, and the growth of bamboo forest area has a significant effect on the enhancement of forest carbon sink capacity in China. The existing research on bamboo forest carbon sinks is extensive, but it lacks synergistic analysis with the goal of "carbon peaking and carbon neutrality". Therefore, based on the development of bamboo forest carbon sink in Zhejiang province, this study puts forward some suggestions for the realization of bamboo forest carbon sink value, which will help Zhejiang achieve the goal of " carbon peaking and carbon neutral ".

2.Data and methods

2.1. Data collection

The measurement of carbon sequestration in bamboo forests in this study is based on the Ninth National Forest Inventory Report. Regarding the measurement of CO2 emissions in Zhejiang province, this study used the China Energy Statistical Yearbook as the benchmark. Due to the differences in the content of the statistical yearbook record compilation, in order to better analyse the relationship between CO2 emissions and the amount of carbon

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sequestered in bamboo forests, this study systematically organizes energy consumption data from 1989 to 2018 in Zhejiang province and uses a five-year cycle for statistical accounting.

2.2. Analytical methods

2.2.1 Average biomass method

The average biomass method was used to estimate the amount of carbon sequestered in bamboo forests [11]. The calculation formula is

$$W\,i = Bi \times Si. \quad (1)$$

Where, *Wi* is the biomass of bamboo forest (t), *Bi* is the biomass per unit area (t/hm²), *Si* is the area (hm²), and *i* is the bamboo forest species. Mainly divided into moso bamboo and miscellaneous bamboo, and the average biomass densities of moso bamboo and miscellaneous bamboo are taken as 81.90 t/hm^2 and 53.10 t/hm^2, respectively.

The calculation formula of carbon sequestration is:

$$Ci = Wi \times \sigma i. \quad (2)$$

Where, *Ci* is the amount of carbon sequestered in the bamboo forest (t), σi is the carbon content rate, *i* as above. The carbon content rate of moso bamboo was taken as 0.494 and that of miscellaneous bamboo was taken as 0.462 [12]. Since the first and third forest inventory did not classify the area of bamboo forests and moso bamboo forests were the main bamboo forest species in Zhejiang, the bamboo forest data from these two studies were treated as moso bamboo forest data in this study.

2.2.2 Calculation of CO2 emissions based on energy activities

CO2 emissions are taken as the annual average value of the same period as the carbon sequestered by the bamboo forest. The calculation formula is:

$$CO2 = \sum Ej \times Fj. \quad (3)$$

Where, *CO2* represents the total *CO2* emission (million t), *Ej* represents the energy consumption (million t of standard coal), *Fj* represents the carbon emission factor of energy, and *j* represents the energy type.

3 Results and analysis

3.1. Analysis of carbon sequestration of bamboo forest in Zhejiang province

The carbon sequestration in bamboo forests in Zhejiang province are shown in Table 1. During the nine statistical periods, the amount of carbon sequestered in moso bamboo forests in Zhejiang province accounted for a large proportion of the total amount of carbon sequestered, which was above 85%. Without considering the missing data of the first and third time, the contribution of moso bamboo forest carbon sequestration was the largest in the second statistical period, reaching 94.04%, and the lowest in the sixth inventory, 88.97%. The trend of carbon sequestration in moso bamboo forests in the province is obvious, and the net increase of 1.6952 million t was achieved during the ninth inventory compared with the second inventory, with a growth rate of 150.22%. However, from the point of view of time, the contribution of miscellaneous bamboo forest carbon sequestration in the ninth inventory was low, only 8.16%. The carbon sink contribution of moso bamboo forest and miscellaneous bamboo forest in Zhejiang province is different, among which the carbon sink contribution of moso bamboo forest is significantly larger than that of miscellaneous bamboo forest due to its high carbon density and wide growing area. With the continuous improvement of bamboo forest management program, the amount of carbon sequestered in miscellaneous bamboo forests also shows a steady growth.

Table 1. Calculation results of bamboo carbon sequestration in Zhejiang province from 1973 to 2018

Statistic-al period	Moso bamboo biomass	Moso bamboo carbon sequest-eration	Miscell-aneous bamboo biomass	Miscell-aneous bamboo carbon sequest-eration	Total carbon sequest-eration
1973-1976	3685.50	1820.64	-	-	1820.64
1977-1981	3605.23	1780.98	244.26	112.85	1893.83
1984-1988	3981.98	1967.10	-	-	1967.10
1989-1993	3701.06	1828.32	307.45	142.04	1970.36
1994-1998	4325.14	2136.62	511.88	236.49	2373.11
1999-2003	5082.71	2510.86	673.84	311.31	2822.17
2004-2008	5352.17	2643.97	687.11	317.44	2961.41
2009-2013	5864.04	2896.84	623.39	288.01	3184.85
2014-2018	6433.25	3178.03	611.18	282.37	3460.40

3.2. Analysis of CO2 emissions in Zhejiang province

The total CO2 emissions in Zhejiang province during the period from 1989-1993 to 2014-2018 have grown significantly, and the growth rate of CO2 emissions has fluctuated. The CO2 emissions in Zhejiang province have been increasing steadily, from 62,390,000 t in 1989-1993 to 61,400,600 t in 2014-2018, with an absolute increment of 551,160,600 t, an increase of nearly 9 times. The CO2 emissions growth rate peaked during 1994-1998, due to the cost of energy consumption during that period. With the gradual advancement of the green development concept, the growth rate of CO2 emissions declined sharply after this period and showed an overall decreasing

trend during the next three national forest inventory periods.

3.3. Comparative analysis

3.3.1 Analysis of carbon sequestration of bamboo forests and CO2 emissions in Zhejiang province

The ninth inventory had a net increase of 16,397,600 t in the amount of carbon sequestered in bamboo forests compared with the first inventory, with a growth rate of 90.07%. During the nine inventories, the amount of carbon sequestered in Zhejiang province continued to rise, and the growth rate of the fifth inventory peaked at 4,027,500 t, with a growth rate of 20.44% compared with the fourth inventory. In general, the growth of carbon sequestration in bamboo forests in Zhejiang province during the nine inventories is obvious, and the growth rate is fluctuating but always positive.

In order to better analyse the carbon sequestration contribution of bamboo forests in Zhejiang province, this study divided the carbon sequestration of bamboo forests by CO2 emissions to calculate the percentage of carbon sequestration of bamboo forests. The percentage of carbon sequestered by bamboo forests in Zhejiang province was the largest in 1989-1993, reaching 31.58%, and decreasing in the later measurement periods. According to the statistical yearbook, the area of bamboo forest in Zhejiang province continued to grow during this period, but the new bamboo forest was still in the state of young forest, and the carbon sequestration capacity was significantly lower than that of mature bamboo forest and over-mature bamboo forest. The carbon fixation capacity of mature bamboo stands reached the strongest, but the carbon fixation efficiency began to decline again. The growth characteristics of bamboo make the total carbon sequestration of bamboo forests in the whole province increase, but there is an upper limit to the increase. In addition, CO2 emissions from industry in Zhejiang province are increasing every year. The above two reasons lead to the increase of the total amount of carbon sequestered by bamboo forests in the province, but the proportion of carbon sequestered to the province's carbon emissions is in a state of decline.

3.3.2 Comparative analysis of carbon sequestration increment of bamboo forests and CO2 emission in Zhejiang province over the same period of time

With the continuous social and economic development, the CO2 emissions in Zhejiang province are increasing and tend to rise continuously. However, the increase of carbon sequestration in bamboo forest is insignificant in front of the carbon emission of the whole province, and the amount of CO2 conversion is obviously insufficient. This indicates that under the existing bamboo forest project status, the carbon sink operation capacity of bamboo forest resources still needs to be improved, and it is not only necessary to give full play to the natural emission reduction function of bamboo forest resources, but also to use resources to strengthen the conversion function of bamboo forest resources, so as to gradually increase the amount of carbon sequestered in bamboo forests.

3.3.3 Analysis of the growth rate of bamboo carbon sequestration and CO2 emission in Zhejiang province

Combining the growth rates of carbon sequestration and CO2 emissions from bamboo forests in Zhejiang province. The growth rate of carbon sequestration in bamboo forest and the growth rate of CO2 emissions are both positive during these five statistical periods, and the growth rate of CO2 emissions is much larger than the growth rate of carbon sequestration in bamboo forest, but the growth rate of CO2 is in a decreasing state. This is because Zhejiang province has continuously promoted emission reduction and controlled carbon emissions. However, the amount of carbon sequestered by bamboo forests in the existing situation does not have a good sequestration effect on the CO2 emissions of the whole province. The potential of bamboo forest carbon sink needs to be tapped.

4 Conclusions and suggestions

4.1. Conclusions

The amount of carbon sequestered in bamboo forests in Zhejiang province has been increasing significantly, achieving an absolute increase of 16,397,600 tons during the nine forest inventory periods, with a growth rate of 90.07%. Although the amount of carbon sequestered in bamboo forests has increased in each statistical period, the amount of carbon sequestered is very small compared to the CO2 emissions of the whole province. CO2 emissions are increasing day by day, and the growth of carbon sinks in bamboo forests is much lower than the growth of carbon emissions in the same statistical period. Due to the growth characteristics of bamboo forests and the continuous carbon emissions, the carbon sequestration capacity of bamboo forests is limited, and the carbon sequestration contribution of bamboo forests in Zhejiang province shows a decreasing trend, and the carbon sink potential of bamboo forests needs to be explored.

4.2 Suggestions

Focus on stabilizing the increment of bamboo forest carbon sink and effectively consolidate the development of bamboo forest carbon sink. The bamboo forests participating in the bamboo carbon sink project should be reviewed to confirm the growth environment and health status of the existing bamboo forests. We should continue to explore scattered bamboo forests that have not joined the bamboo carbon sink project, introduce talents and technologies in these fields, provide effective guidance and scientific and systematic teaching to local bamboo farmers, and create professional support organizations. This will not only help to increase the number of carbon fixation subjects in bamboo forests, but also effectively

promote the re-employment of local farmers, which is an efficient way to coordinate the development of ecology, economy and society.

Standardize and guide the carbon sink management program, and reasonably improve the bamboo forest carbon sink potential. In view of the current development situation of bamboo forest carbon sinks, the government should formulate clear policies and regulations, continuously improve the rules of bamboo forest carbon sinks trading, strengthen the research and application of bamboo forest science and technology, and realize key technological innovation. At the same time, bamboo forest carbon sinks can be used to promote the integrated development of primary, secondary and tertiary industries, innovate industry-driven mechanisms, explore and effectively utilize the multiple functions and values of bamboo forests, and then promote the organic combination of bamboo forest carbon sequestration and carbon reduction by enterprises, so as to maximize the realization of the economic value of bamboo forest carbon sinks.

Effectively combine the main enterprise carbon sinks and scientifically control the quantity of enterprise emissions. For the excessive carbon emissions of heavy polluting enterprises, we should first establish exclusive and clear emission indexes for different types of enterprises, so as to restrain the emission indexes and emission methods of heavy polluting enterprises. At the same time, the government can provide the necessary guidance to these management departments of enterprises, so that they can, on the basis of data support and according to their own development needs, organically integrate with the CCER carbon emission offset mechanism. This kind of carbon emission rights trading makes heavy emission polluting enterprises reduce emissions by means of bamboo forest carbon sinks, which is conducive to realizing the economic value of bamboo forest carbon sinks.

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