

Study on Economic Value Assessment of Forest Carbon Stocks in Guangdong Province

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Abstract

Forest carbon sinks are a critical pathway for China to achieve its “dual-carbon goals”. Scientifically evaluating the economic benefits of forest carbon stocks in Guangdong Province holds significant importance for advancing the establishment and enhancement of the region’s forest carbon sink trading market. This study assessed the forest carbon stock of Guangdong Province using the forest accumulation expansion method and calculated its economic value by incorporating carbon stock prices. The results revealed Guangdong Province’s substantial potential for forest carbon sinks, with forest carbon stock reaching 7.23×10^8 t in 2021. The economic value of forest carbon stock has shown a fluctuating increasing trend, rising from 5.25×10^{10} CNY to 7.07×10^{10} CNY, representing a total increase of 34.75%. Spatially, the distribution pattern exhibited “higher in northern and western Guangdong and lower in the Pearl River Delta and eastern Guangdong”, with an emerging trend toward balanced development. To maximize the carbon sinks potential, Guangdong Province should focus on establishing a comprehensive forest carbon sink measurement system, increasing awareness and education about forest carbon sinks, and fostering the growth of its forest carbon sink trading market.

Keywords

Forest; Carbon Stock; Economic Value; Carbon Sink.

1. Introduction

In recent years, global warming caused by carbon dioxide emissions has increasingly threatened human life, ecological stability, and sustainable social development. Addressing this challenge requires two primary strategies: reducing carbon emissions through energy conservation and emission reduction technologies, or enhancing carbon sequestration in forests through afforestation and reforestation efforts [1]. As the largest component of terrestrial ecosystems, forests play a vital role in the carbon cycle. By absorbing carbon dioxide through photosynthesis, forests store two-thirds of the organic carbon in terrestrial ecosystems, both in plant biomass and soil. Forest carbon sinks are widely regarded as one of the most cost-effective and efficient methods for mitigating carbon emissions and addressing climate change. In 2020, China set ambitious goals to achieve carbon neutrality and peak emissions, positioning forest carbon sinks as a key strategy for combating climate change. Valuing the economic benefits of forest carbon stocks quantifies the ecological service provided by forests in absorbing carbon dioxide, which supports the development of government-led ecological compensation mechanisms, and facilitates the establishment of a robust forest carbon sink trading market.

Numerous scholars have conducted extensive research on the economic valuation of forest carbon sinks, yielding significant results [2] [3], [4]. Currently, different provinces and cities in

China have calculated and studied the value of their forest carbon stocks. For instance, the economic value of forest carbon stocks in Beijing ranged from 54.14×10^8 to 232.15×10^8 CNY [5]. Similarly, the economic value of forest carbon stocks in Heilongjiang Province between 1999 and 2018 exhibited a decreasing trend influenced by exchange rate fluctuations [6]. Despite abundant research in northern China, where forest resources are more plentiful, studies on forest carbon sink valuation in southern China, particularly Guangdong Province, remain limited.

As one of China's leading forestry and economic provinces, evaluating the economic value of forest carbon stocks in Guangdong Province is crucial for advancing the development of its forest carbon sink trading market and supporting China's "dual carbon" goals. In this context, this paper takes Guangdong Province as the study area, measures the forest carbon stock of Guangdong Province through the forest stock expansion method, evaluates the economic value of its forest carbon stock, and puts forward corresponding countermeasures and suggestions.

2. Materials and Methods

2.1. Study Area

Guangdong Province (Figure 1) is situated in southern China, bordered by Guangxi to the west, Fujian to the east, and Hunan and Jiangxi to the north. Its geographic coordinates range from latitudes 20° to 25° north and longitudes 109° to 117° east. The province comprises four regions: the Pearl River Delta (Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing), Eastern Guangdong (Shantou, Shanwei, Chaozhou, and Jieyang), Western Guangdong (Yangjiang, Zhanjiang, and Maoming), and Northern Guangdong (Shaoguan, Heyuan, Meizhou, Qingyuan, and Yunfu), encompassing 21 prefectures. Guangdong lies within the East Asian monsoon zone, characterized by abundant heat and precipitation, providing favorable natural conditions [7]. The province's topography features elevated mountains and hills in the north, transitioning to plains and tablelands in the central and southern regions. Its rich natural resources include an extensive forest area, covering 107,925.33 square kilometers, or 60.05% of the province's total land area as of 2019 [8].

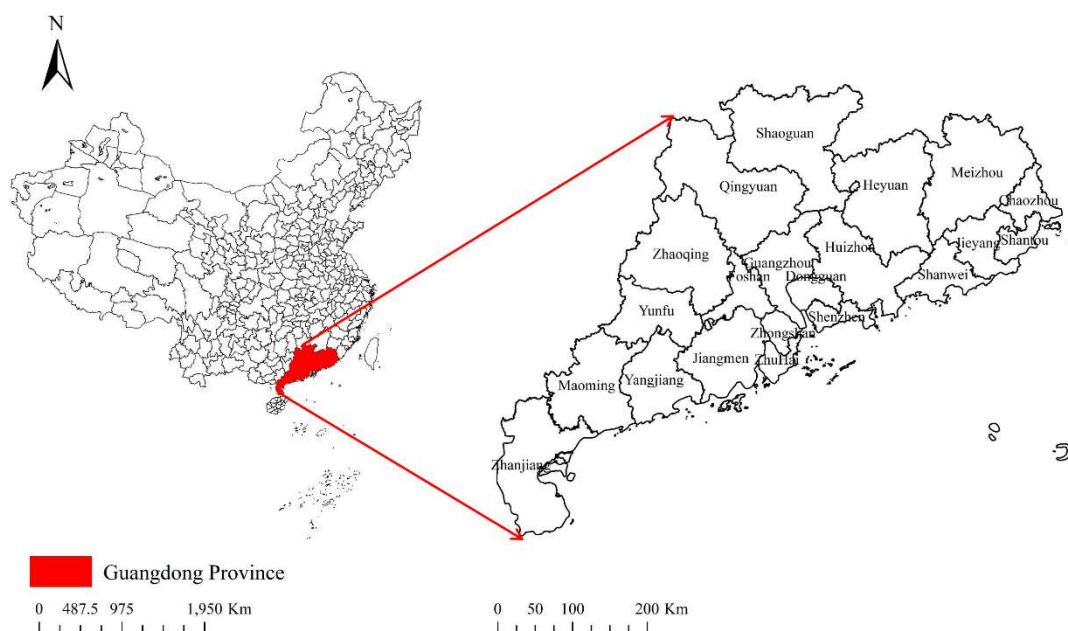


Figure 1. study area

2.2. Methods

2.2.1. Forest Accumulation Expansion Method

Most current measurements of forest carbon stocks tend to underestimate the total because they primarily focus on the carbon sequestration of above-ground tree biomass [9]. Limited research has been conducted on carbon storage in understory vegetation, subterranean humus, and forest soils. This study employed the forest accumulation expansion method to calculate forest carbon stocks, which provides a more comprehensive assessment. The calculation is expressed as:

$$C=V_1\delta\rho\gamma+\alpha V_1\delta\rho\gamma+\beta V_1\delta\rho\gamma \quad (1)$$

Where C is the forest carbon stock (t); V_1 is the forest stock (m^3); δ is the conversion coefficient of forest stock and biomass stock, with a value of 1.9; ρ is the conversion coefficient of forest biomass stock and biological dry weight, with a value of 0.5; γ is the conversion coefficient of biological dry weight and carbon sequestration, with a value of 0.5; α is the conversion coefficient of carbon sequestration by understory plants, with a value of 0.195; β is the conversion coefficient of carbon sequestration by woodland, with a value of 1.244.

2.2.2. Economic Valuation of Forest Carbon Stocks

Estimating the economic value of forest carbon stocks involves converting the fixed carbon absorbed by forests into monetary terms, thereby making the ecological benefits of forests more tangible. The economic value of forest carbon stocks is calculated based on the quantity of forest carbon sequestered and the unit price of carbon stocks, using the formula:

$$V=C\times P \quad (2)$$

Where V denotes the economic value of forest carbon stocks and P denotes the unit price of forest carbon stock. Based on the findings of previous scholar [10], the optimal price of forest carbon stocks in China is estimated to range between 10.11 and 15.17 USD/t. If the upper limit of the optimal price of forest carbon sinks is set at 15.17 USD/t and the corresponding annual average exchange rates of USD to CNY (RMB) from 2012 to 2021 are applied as 6.29, 6.10, 6.14, 6.23, 6.64, 6.75, 6.62, 6.90, 6.90, 6.90, and 6.45, then the price of forest carbon sinks in CNY per tonne is 95.42 CNY/t, 92.55 CNY/t, 93.14 CNY/t, 94.50 CNY/t, 100.73 CNY/t, 102.40 CNY/t, 100.43 CNY/t, 104.67 CNY/t, 104.67 CNY/t, and 97.85 CNY/t.

2.3. Data Sources

The forest stock volume data used in this study were sourced from the main statistics of forest resources and inventory data specific to Guangdong Province. The shapefiles were obtained from the Resource and Environmental Science Data Platform [10]. Missing data were addressed through linear interpolation.

3. Results

3.1. Characteristics of Time Evolution

As shown in Table 1, the forest carbon stock in Guangdong Province indicated a fluctuating upward trend from 2012 to 2021. It increased from 5.50×10^8 t in 2012 to 7.23×10^8 t in 2021, marking a 31.4% improvement over ten years. This growth can be attributed to national policies and the effective leadership of the Guangdong Provincial Government, which launched a new round of greening efforts in 2012. The implementation of key ecological projects, such as the forest carbon sink, ecological landscape forest belt, urban forest integration, and rural

greening initiatives, contributed to the substantial increase in the province's forest carbon stock during this period.

The economic value of forest carbon stock also reflected a fluctuating upward trend, with more pronounced variations. From 2012 to 2016, the value rose from 5.25×10^{10} RMB to 6.94×10^{10} RMB. However, it declined in 2017 and 2018, dropping to 6.75×10^{10} RMB and 6.32×10^{10} RMB, respectively. The value then recovered from 2019 to 2020, reaching 7.27×10^{10} RMB in 2020, before slightly declining to 7.07×10^{10} RMB in 2021. These trends highlight Guangdong's rich forest resources and its strong potential for developing forest carbon sinks, supported by its ecological and geographical advantages.

Table 1. Monetary accounting table of forest carbon stock in Guangdong Province.

Year	Forest carbon stock (1×10^8 t)	Forest carbon stock value (1×10^{10} RMB)
2012	5.50	5.25
2013	5.85	5.42
2014	6.23	5.80
2015	6.59	6.23
2016	6.89	6.94
2017	6.59	6.75
2018	6.29	6.32
2019	6.70	7.02
2020	6.95	7.27
2021	7.23	7.07

3.2. Characteristics of Spatial Evolution

To better understand the spatial variations in forest carbon stock economic value in Guangdong Province, we used ArcGIS 10.8 to generate a spatial distribution map of forest carbon stock economic value. The data were classified into four levels based on the Natural Breaks classification method. As shown in Figure 2, the spatial distribution of the economic value of forest carbon stocks revealed a pattern of “higher values in northern and western Guangdong, and lower values in the Pearl River Delta and eastern Guangdong”. The highest values concentrated in northern cities such as Shaoguan, Qingyuan, Heyuan, and Meizhou, where forest carbon stocks were abundant. Between 2012 and 2021, these four cities accounted for more than 50% of the total forest carbon stock value. This was largely due to the extensive forest coverage and favorable ecological conditions in northern Guangdong. Conversely, cities like Maoming and Yangjiang, located on the southwest coast, exhibited lower levels of development, which also corresponded to lower forest carbon stock values. In contrast, the Pearl River Delta and eastern Guangdong, with fewer forest resources and a more developed economy, have seen reductions in carbon stock due to activities such as timber production and land development, resulting in the lowest forest carbon stock values in these regions.

By comparing the spatial distribution of forest carbon stock economic values in Guangdong Province between 2012 and 2021, it is evident that the overall trend has been an increase in forest carbon stock economic value, consistent with the previous analysis. The number of cities with low carbon stock economic values has significantly decreased, while the range of cities with intermediate economic values has expanded. This suggests an overall upward trend in forest carbon stock economic value, along with a reduction in disparities between regions, reflecting more balanced development. Notably, cities such as Maoming, Yangjiang, Yunfu, and Zhaoqing have shown more pronounced improvements, with their rankings rising by one level, indicating a significant increase in forest carbon stocks in these areas.

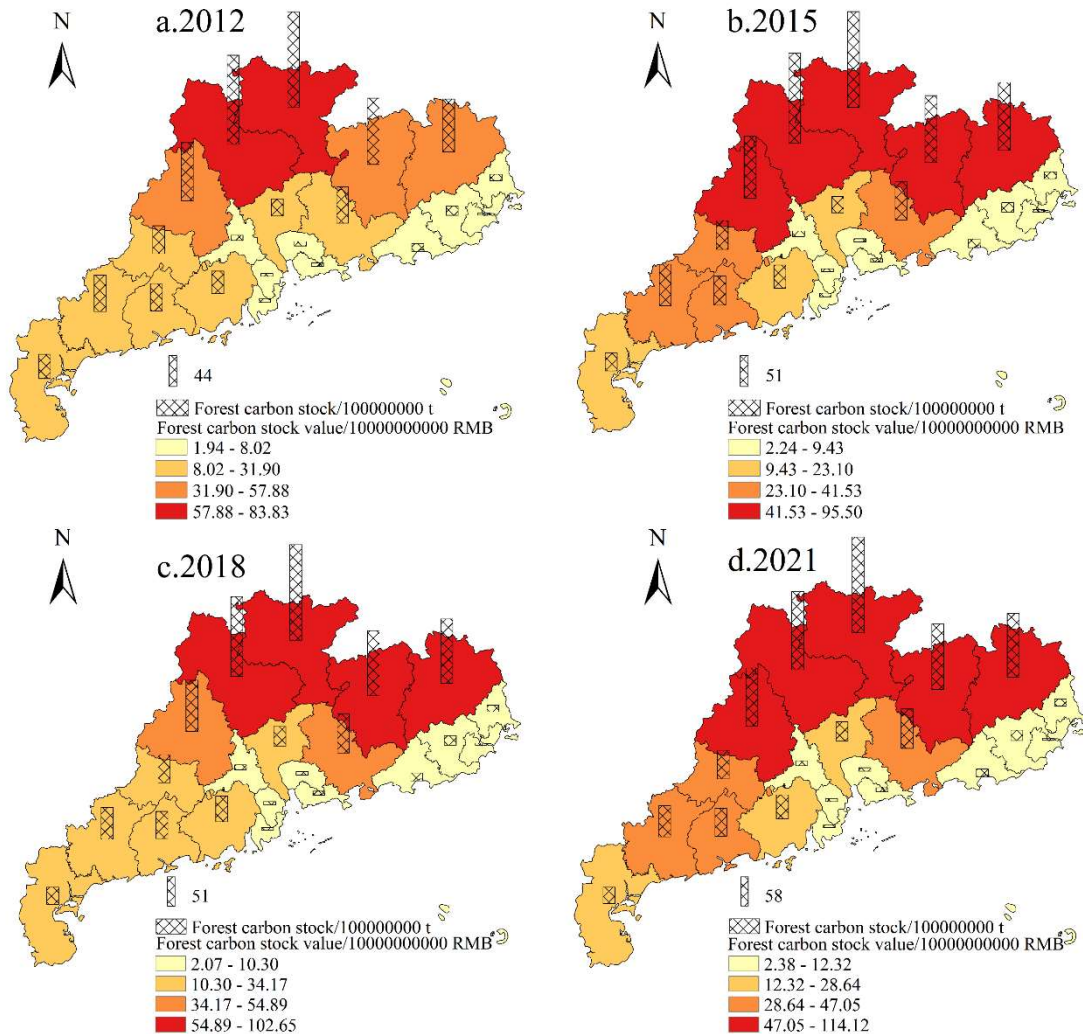


Figure 2. Spatial distribution of forest carbon stock values.

4. Conclusion and Recommendation

This study estimates the forest carbon stock in Guangdong Province using the forest stock expansion method and calculates the economic value of carbon sinks. The key findings are as follows: Forest carbon stock and carbon stock economic value in Guangdong Province showed a continuous upward trend, with forest carbon stock and forest carbon stock value increasing from 5.50×10^8 t and 5.25×10^{10} RMB in 2012 to 7.23×10^8 t and 7.07×10^{10} RMB in 2021, respectively. The spatial distribution pattern of forest carbon stock economic value was characterized by “higher values in northern and western Guangdong, and lower values in the Pearl River Delta (PRD) and eastern Guangdong”. Cities with higher forest carbon stock economic values were primarily located in the mountainous regions of northern Guangdong, with Maoming, Yangjiang, Yunfu, and Zhaoqing showing significant improvements.

To promote the development of forest carbon sinks in Guangdong Province, enhance the conversion of ecological benefits into economic value, and leverage ecological advantages for the province’s sustainable development, the paper proposes the following recommendations:

Establish a forest carbon stock measurement system. This system is crucial for enabling forest carbon sinks to be traded and for promoting the continuous development of the carbon sink trading market. While various methods for measuring forest carbon stocks exist, there is no universally recognized system for forest carbon sinks. Due to the variability in results from different methods, it is vital to develop a locally applicable measurement system.

Increase public awareness of forest carbon sinks. Despite Guangdong's abundant forest resources, the development of forest carbon sinks has been slow. Therefore, relevant authorities should enhance public education and awareness campaigns on forest carbon sinks to increase understanding and support.

Explore the carbon sink market and expand trading opportunities. Based on the forest resource survey data, the total value of forest carbon stocks in Guangdong is estimated at 7.07×10^{10} RMB, indicating significant potential for further development. Expanding the forestry carbon sink trading market and exploring new trading channels will be crucial for maximizing the ecological, social, and economic benefits of forest carbon sinks.

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