Measurement of the Fair Value of Forest Carbon Sinks – Taking Yixing National Forest Park as an Example

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Management of forest carbon sinks can be viewed as a strategy to deal with climate change. To promote the establishment and improvement of the forest carbon market, it is important to measure the economic benefits of China's existing forest carbon sinks with special weighting to forests along with protection of nature. Objectively measuring the value of a carbon sink is an important prerequisite to play the role of forest carbon pool and improve the efficiency of carbon sinks. This paper considers the strategy and process of forest carbon sink value accounting from two aspects of forest carbon storage and value, puts forward a set of forest carbon sink fair value accounting ideas, and considers Yixing forest farm as the research area. The following methods were used to compare the forest carbon stock of the Yixing National Forest Park. First, the economic benefits of forest carbon sink were evaluated with a market approach and carbon fair value. Next, the biomass expansion factor method and income approach were used to compute the forest carbon stock of Yixing National Forest Park, indicating a high carbon fair value.

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INTRODUCTION

The concentration of greenhouse gases, primarily carbon dioxide (CO_2), continues to rise in the Earth's atmosphere. This has led to the increasingly serious problem of global warming in the world. Forests are the main body of the terrestrial ecosystem and the largest carbon stock on land (Pan *et al.* 2011). They are receiving increasing attention as carbon sinks (Richards and Stokes 2004; Malhi 2012; Wei and Shen 2022). The reasonable measurement and disclosure of the value of forests as carbon sinks has become the primary focus of many researchers. The value of forest carbon sinks is ascertained by two factors: the physical quantity of forest carbon sinks and the value of carbon sinks per unit.

Accurate measurement of the physical quantity of forest carbon sinks is the basic link of carbon cycle research and carbon sink afforestation. Thus, it is one of the important topics in current studies on carbon sinks (Brown 2002; Versace *et al.* 2021). The most commonly used method for measuring the physical quantity of forest carbon sinks is by calculating carbon storage through biomass (Yang *et al.* 2014; Torresan *et al.* 2020). Some commonly used biomass carbon measurement models are the biomass expansion factor method, the allometric equation, and the volume biomass method. As the basis for forest carbon sink measurement, thousands of biomass models have been established in China and elsewhere (Ter-Mikaelian and Korzukhin 1997; Zianis *et al.* 2005; Dong *et al.* 2014; Ozdemir *et al.* 2019). The industry standards for tree biomass models and carbon measurement parameters of 13 major tree species have been released by China. These models are basically allometric equations (relative growth equations). They are used to solve the relationship problems between tree biomass and other measured factors such as diameter and tree height at a specific time, without involving factors of time and the environment (Xu *et al.* 2007; Cao and Li 2019). Even though the accuracy of the model is high, the application range of the model is connected to the size of the modeling sample and the sampling range. When estimating the forest carbon storage (source), at least two surveys are required. From this, only the changes in the carbon sinks during the survey period can be obtained. The volume biomass method establishes a fitting equation between the storage and biomass based on the measured data just as in the case of the allometric equation. It then calculates the forest biomass through equation generalization. Xu *et al.* (2007) used the measured biomass and storage data of different tree species at different age groups to establish a model between the storage and biomass by using regression analysis. This will help in studying the winter variation of vegetation carbon storage in China's forest ecosystem (Brown and Lugo 1984; Qiu *et al.* 2023). Forest biomass can be estimated by the biomass expansion method, which is considered as a preferred method for estimation (Brown and Lugo 1984). The method uses the storage data of major global forest types that is provided by the Food and Agriculture Organization (FAO) of the United Nations in order to estimate the aboveground biomass of global forests (Veroustraete *et al.* 2002; Bai *et al* 2023). For estimation, the average value of the ratio of biomass to log volume as an expansion factor is taken. Then, the forest carbon storage is calculated based on the forest storage obtained from the forest inventory. There is a good correlation between the forest stand volume and biomass. This is because the forest stand volume comprises forest type, age, condition of the site, and stand density. The relationship between forest carbon storage and forest stand biomass is used to calculate biomass. This can help in removing the influence of these factors on stand biomass (Fang *et al.* 2001; Fang and Wang 2001). The demand for stand-scale carbon sink measurement has further expanded due to the development of carbon sink afforestation. With the development of carbon sink afforestation, the efficiency and accuracy of the measurement of carbon sinks need be increased.

To deal with global climatic changes, many countries around the world have taken to increasing forest carbon sinks as a way to slow down carbon emissions. This has been done because of the important role and cost advantage of forest carbon sinks in climate changes (Kooten *et al.* 1995). The process of measurement of forest carbon sink value is very complex. It involves ecology, economics, forestry, accounting, *etc*. (Liu *et al.* 2013). The forest carbon sink value is dependent on the physical quantity (carbon storage) and the carbon sink value per unit. The method used for determining the price carbon sink price depends on the purpose of measurement. This includes the shadow price, industrial emission reduction costs, carbon tax, and the transaction price of carbon sinks. The carbon sink price determined based on the industrial emission costs varies greatly and is unstable, since the cost of reduction of industrial emission, too, varies greatly. Although the carbon tax is relatively stable, it lacks real-time adjustment with the market. The shadow price is not suitable for measurement. However, in the generally free market, it is very close to the actual market price. Therefore, the transaction price of carbon sinks is best suited to reflect the market price of carbon sinks. It can also best reflect the fair value of carbon sinks.

In July 2014, the Ministry of Finance promulgated the Accounting Standards for Enterprises No. 39-Fair Value Measurement (CAS39). Under this, the fair value is defined as: “The price paid to receive or transfer a liability when selling an asset in an orderly transaction between market participants on the measurement date.” Fair value is also known as fair market value and fair price. The value of forest carbon sinks is mainly obtained by multiplying the fair price of forest carbon sinks based on physical measurement (carbon storage). The fair value is used for this purpose. The method to choose and determine the fair price of carbon sinks to constitute the fair value is the primary focus of the paper. As mentioned in the relevant provisions of CAS39, it can be concluded that in a mature market, the market price reflects the fair value of the transaction. The carbon trading price can best reflect the market price of carbon sinks. It can also best reflect the fair value of carbon sinks. It will be difficult to the price inquiry of carbon sinks if the forest carbon sink markets at home and abroad are not mature enough. Thus, according to CAS39, finding the primary market or the most favorable pricing for trading is the difficulty faced in obtaining the fair value of forest carbon sinks. It is also difficult to measure the value of forest carbon sinks objectively and fairly.

Under the huge pressure of emission reduction, the government has started using carbon emissions trading as the major means of emission reduction to control greenhouse gas emissions (Nay and Bormann 2014). According to the “Emissions Gap Report 2020” that was released by the United Nations, presently there are 31 trading markets of “carbon emission allowances” that can be referred to as “carbon markets” and 30 carbon tax mechanisms in the world. The carbon pricing mechanisms cover nearly 12 billion tons of carbon dioxide emissions in 46 countries and 32 regions. These account for approximately 22% of the total global greenhouse gas emissions (Neagu and Teodoru 2019). Through years of development, the carbon pricing mechanisms have gradually become well-developed. The geographic scope of participating countries has continuously expanded. The market structure, too, has been deepened at multiple levels. As early as 2011, local pilot carbon emissions trading markets were launched by China in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen. These markets have subsequently been opened to the public since June 2013. On July 16th, 2021, the national carbon emissions trading market was officially opened at Shanghai Environment Energy Exchange as one of the core policy tools to achieve emission peaking and carbon neutrality. The first national carbon trading price was 52.78 yuan per ton. Presently, the first to enter the national carbon emissions trading market is the key emitter of the power generation industry. It no longer participates in the local carbon emissions trading. The other industries whose emissions do not meet the standards for “key emitters” still participate in the local carbon emissions trading.

The so-called “carbon emissions trading” refers to the Carbon Emissions Allowance (Neagu and Teodoru 2019) trading. CEA is mainly a market mechanism for trading carbon emission allowance as commodities. The so-called “carbon emissions allowance” refers to the allowances given to enterprises to emit greenhouse gases into the atmosphere. After approval from the local competent departments of the environment, enterprises will have a certain amount of allowance for “legal” greenhouse gas emissions within a stipulated time. When the actual emissions exceed the allowance, the enterprise will have to purchase the excess. On the other hand, when the actual emissions of the enterprise are less than the allowance, the balance can be sold externally. The Chinese Certified Emission Reduction (CCER) refers to greenhouse gas emissions registered in the Voluntary Greenhouse Gas Emission Reduction Transactions System in compliance with the relevant management regulations. This is done to reduce voluntary greenhouse gas emissions, as issued by the Ministry of Ecology and Environment. A total of 5 forest carbon sink transactions have been completed in the primary state-owned forest areas of Greater Khingan and Inner Mongolia, with a total transaction value of 1.91 million yuan since the year 2014. In 2020, the first forest carbon sink was delivered by the Forestry and Grassland Administration of Qinghai Province to Shell Energy (China) Limited based on certified carbon standards. The certified emission reductions amounted to 254,600 tons.

The carbon sinks owned by national forest parks such as Yixing National Forest Park Farm cannot be widely traded in the carbon market. However, their contribution to carbon neutrality cannot be ignored. The reasonable measurement of forest carbon sinks can help realize its value. This will eventually promote forest carbon sink trading. A direct, positive influence of this will be seen on the construction of ecological forestry, the improvement of climate and environment. It will also help in increasing the income of forest farmers. Simultaneously, it will urge China’s carbon market entities to shift from emission-controlled enterprises to diversified market entities. These include emission-controlled enterprises, non-emission-controlled enterprises, financial institutions, intermediaries, and individuals. This will accelerate the realization of emission peaking and carbon neutrality.

In this paper, the three common biomass carbon measurement models are compared at the forest stand scale. An effective method for small-scale forest carbon sink measurement is explored in order to form a scientific basis for the accurate measurement of carbon sinks. According to the CAS39, measuring the value of forest carbon sinks helps to reasonably measure the fair value of forest carbon sinks.

EXPERIMENTAL

Overview of the Research Area

The paper takes the forest of Yixing National Forest Park Farm (Yixing National Forest Park) as the research area (Fig. 1). Yixing National Forest Park is located southwest of Yixing, at the junction of Jiangsu, Zhejiang, and Anhui provinces. It has a total area of 3,400 hectares and includes Mount Song in the southern region and Mount Tongguan in the northern region. It belongs to the extension of the Tianmu Mountains. The main peak in the area, Mount Tongguan, is 521 meters above sea level. The mountains include ups and downs with ravines and gurgling streams. The region has a subtropical monsoon climate. It remains warm and humid throughout the year. There are four distinct seasons. The forest is dense, and the vegetation is rich. This is the zonal vegetation on the northern edge of the mid-subtropical zone. There are more than 200 kinds of wild animals. The main tree species of the region are *Pinus massoniana* Lamb., *Cunninghamia lanceolata* (Lamb.), *Quercus acutissima, etc*.

Data Sources

Field data from the Forest Planning and Design Survey (Second Class Investigation Data) of 2008 was used in this work. It is provided by Yixing National Forest Park, and it was used to calculate the forest carbon sinks. This mainly includes the dominant tree species (group), average diameter at breast height (DBH), average tree height, age class, and age group in each small class of the research area.

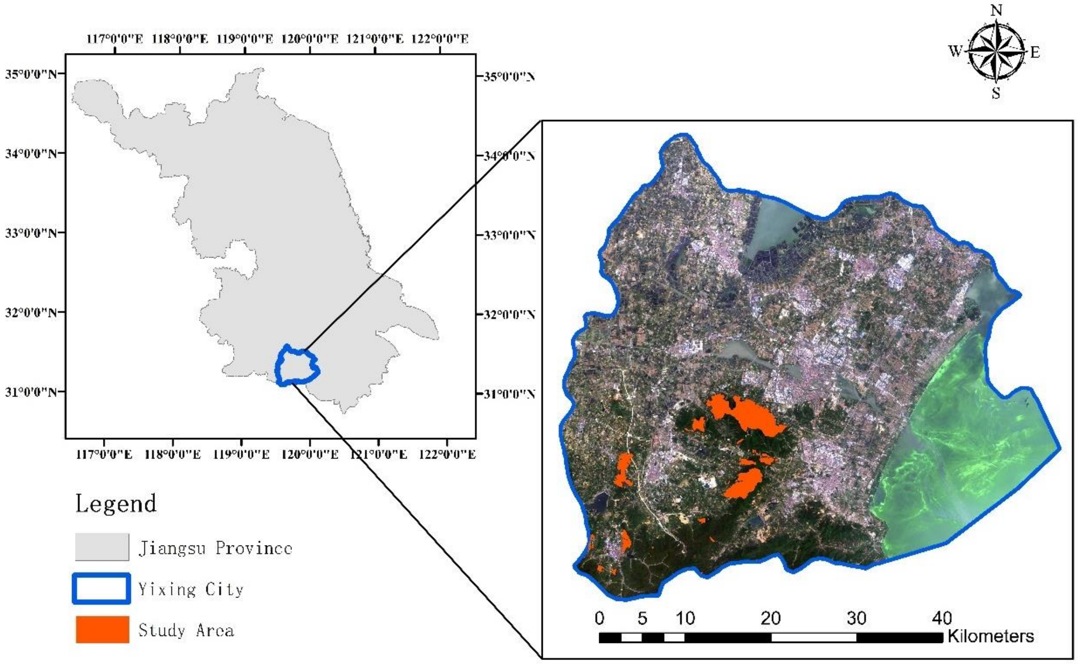

Fig. 1. Map of site location

Biomass Measurement

Allometric equation

The allometric equation is based on the field measurement of standard stand biomass. It fits the growth curve to establish a fit equation of DBH, tree height, and biomass. The allometric equation is a commonly used method for estimating tree biomass (Jenkins *et al*. 2003; Nay and Bormann 2014; Poudel and Temesgen 2016). In this paper, the allometric equations of dominant national tree species (group) which have been compiled according to the Main Technical Regulations of National Forest Inventory are used. The allometric equation of Jiangsu Province is also used here. If the data from Jiangsu Province is unavailable for some dominant tree species, data from the adjacent province is used. The allometric equation of each part of the standing tree is shown in Table 1. Here, D is the diameter at breast height (cm), H is tree height (m), WS stands for trunk biomass, WB is branch biomass, WL is leaf biomass, WT is total biomass aboveground, WR represents underground biomass, and W is total tree biomass quantity. Summarizing the biomass of each part gives the total biomass quantity W in the research area.

Volume-biomass method

Changes in factors such as age, site, individual density, and stand status are comprehensively reflected by the stand volume. The volume-biomass method establishes the functional relationship between the volume and the biomass. It also calculates the biomass based on the volume. In this work, the one-way log volume table of Jiangsu Province has been used to calculate the volume of standing trees as provided by the Jiangsu Forest Resources Monitoring Center (see Table 2).

Table 1. The Allometric Equation of Each Part of the Standing Tree

Species (Group)	**Aboveground Biomass**	**Underground Biomass**	**Whole Tree Biomass**
Pinus thunbergii Parlatore	$\mathrm{WT} = 0.0462(\mathrm{D}^2 \times \mathrm{H})^{0.9446}$	$\mathrm{WR} = 0.0064(\mathrm{D}^2 \times \mathrm{H})^{1.0427}$	-
Pinus massoniana Lamb.	-	-	$\mathrm{W} = 0.00951(\mathrm{D}^2 \times \mathrm{H})^{1.138668}$
Cunninghamia lanceolata (Lamb.) Hook.	-	-	$\mathrm{W} = 0.0657(\mathrm{D}^2 \times \mathrm{H})^{0.8896}$
Cryptomeria fortunei Hooibrenk ex Otto et Dietr.	$\mathrm{WS} = 0.2716(\mathrm{D}^2 \times \mathrm{H})^{0.7379}$; $\mathrm{WB} = 0.0326(\mathrm{D}^2 \times \mathrm{H})^{0.8472}$; $\mathrm{WL} = 0.0250(\mathrm{D}^2 \times \mathrm{H})^{1.1778}$; $\mathrm{WP} = 0.0379(\mathrm{D}^2 \times \mathrm{H})^{0.7328}$; $\mathrm{WT} = \mathrm{WS} + \mathrm{WB} + \mathrm{WL} + \mathrm{WP}$	$\mathrm{WR} = 10.329 + 0.09(\mathrm{D}^2 \times \mathrm{H})$	-
Metasequoia glyptostroboides Hu et W. C. Cheng	-	-	$\mathrm{W} = -5.826 + 0.047(\mathrm{D}^2 \times \mathrm{H})$
Cupressus funebris Endl.	$\mathrm{WT} = 0.02479 \times \mathrm{D}^{2.0333}$	$\mathrm{WR} = 0.0261 \times \mathrm{D}^{2.1377}$	-
Other conifers	$\mathrm{WS} = 0.02357(\mathrm{D}^2 \times \mathrm{H})^{0.9660}$; $\mathrm{WB} = 0.0138(\mathrm{D}^2 \times \mathrm{H})^{0.730}$; $\mathrm{WL} = 0.0663(\mathrm{D}^2 \times \mathrm{H})^{0.5011}$; $\mathrm{WT} = \mathrm{WS} + \mathrm{WB} + \mathrm{WL}$	$\mathrm{WR} = 0.02588(\mathrm{D}^2 \times \mathrm{H})^{0.84}$	-
Quercus L.	$\mathrm{WS} = 0.00888(\mathrm{D}^2 \times \mathrm{H})^{1.08}$; $\mathrm{WB} = 0.01(\mathrm{D}^2 \times \mathrm{H})^{0.90}$; $\mathrm{WL} = 0.00378(\mathrm{D}^2 \times \mathrm{H})^{0.94}$; $\mathrm{WT} = \mathrm{WS} + \mathrm{WB} + \mathrm{WL}$	$\mathrm{WR} = 0.00641(\mathrm{D}^2 \times \mathrm{H})^{0.99}$	-
Cinnamomum camphora (L.) Presl	-	-	$\mathrm{W} = 0.05560(\mathrm{D}^2 \times \mathrm{H})^{0.850193}$
Other hardwood Species	-	-	$\mathrm{W} = 0.08280(\mathrm{D}^2 \times \mathrm{H})^{0.928894}$
Paulownia fortunei (Seem.) Hemsl.	-	-	$\mathrm{W} = 0.0574(\mathrm{D}^2 \times \mathrm{H})^{0.8925}$
Other softwood Species	$\mathrm{WS} = 0.012541(\mathrm{D}^2 \times \mathrm{H})^{1.144}$; $\mathrm{WB} = 0.004786(\mathrm{D}^2 \times \mathrm{H})^{1.006}$; $\mathrm{WL} = 0.047180(\mathrm{D}^2 \times \mathrm{H})^{0.769}$; $\mathrm{WT} = \mathrm{WS} + \mathrm{WB} + \mathrm{WL}$	$\mathrm{WR} = 0.004808(\mathrm{D}^2 \times \mathrm{H})^{1.119}$	-

Table 2. One-way Log Volume Table of Chief species in Jiangsu Province

Diameter Class	State Masson pines (*Pinus massoniana* Lamb.) & slash pines (*Pinus elliottii* Engelmann.)	Collective Masson pines (*Pinus massoniana* Lamb.)	Japanese red pine (*Pinus densiflora* Sieb. et Zucc.) & Japanese black pine (*Pinus thunbergii* Parlatore)	Cupressaceae	*Cunninghamia lanceolata* (Lamb.) Hook.	*Metasequoia glyptostroboides* Hu et W. C. Cheng	*Quercus*	Other broad-leaved trees
6	0.0098	0.0074	0.0092	0.0092	0.0072	0.0122	0.0099	0.0087
8	0.0201	0.0152	0.0187	0.0187	0.0161	0.0248	0.0208	0.0173
10	0.0345	0.0262	0.0324	0.0324	0.0293	0.0436	0.0373	0.0298
12	0.0532	0.0407	0.0505	0.0505	0.0473	0.0693	0.0604	0.0467
14	0.0762	0.0589	0.0731	0.0731	0.0706	0.1026	0.0906	0.0687
16	0.1037	0.0811	0.0999	0.0999	0.0997	0.1441	0.1281	0.0961
18	0.1359	0.1073	0.1309	0.1309	0.1351	0.1939	0.1729	0.1294
20	0.1727	0.1379	0.1657	0.1657	0.1770	0.2523	0.2250	0.1690
22	0.2144	0.1730	0.2041	0.2041	0.2259	0.3192	0.2840	0.2151
24	0.2609	0.2128	0.2459	0.2459	0.2822	0.3945	0.3499	0.2679
26	0.3125	0.2575	0.2910	0.2910	0.3463	0.4782	0.4221	0.3278
28	0.3690	0.3072	0.3391	0.3391	0.4185	0.5699	0.5004	0.3949
30	0.4307	0.3622	0.3901	0.3901	0.4992	0.6696	0.5845	0.4692
32	0.4976	0.4225	0.4440	0.4440	0.5888	0.7769	0.6742	0.5509
34	0.5697	0.4884	0.5006	0.5006	0.6876	0.8917	0.7692	0.6401
36	0.6471	0.5600	0.5600	0.5600	0.7959	1.0138	0.8694	0.7368
38	0.7300	0.6375	0.6221	0.6221	0.9142	1.1429	0.9745	0.8410
40	0.8182	0.7210	0.6869	0.6869	1.0427	1.2790	1.0844	0.9527
42	0.9120	0.8107	0.7543	0.7543	1.1817	1.4219	1.1992	1.0719
44	1.0113	0.9067	0.8243	0.8243	1.3317	1.5714	1.3185	1.1986
46	1.1163	1.0093	0.8970	0.8970	1.4929	1.7275	1.4426	1.3327
48	1.2269	1.1185	0.9723	0.9723	1.6656	1.8900	1.5711	1.4742
50	1.3433	1.2345	1.0502	1.0502	1.8503	2.0589	1.7043	1.6229
52	1.4654	1.3574	1.1308	0.1308	2.0471	2.2342	1.8419	1.7790
54	1.5934	1.4875	1.2139	1.2139	2.2565	2.4158	1.9841	1.9421
56	1.7273	1.6248	1.2997	1.2997	2.4787	2.6036	2.1308	2.1124
58	1.8671	1.7694	1.3881	1.3881	2.7140	2.7977	2.2820	2.2896
60	2.0130	1.9216	1.4790	1.4790	2.9628	2.9980	2.4377	2.4738

Table 3. Parameter Table of Volume-biomass Method

Tree Species	Age Group	Parameters in Formula (1)			
		a	b	n	R
Evergreen broad-leaved trees	Young growth forest (≤40a)	17.5941	0.9501	212	0.89793
	Half-mature forest (41~60a)	39.3752	0.8593	79	0.87157
	Mature forest (≥61a)	43.4173	0.8389	63	0.85043
Pinus koraiensis Siebold et. Zuccarini	Young growth forest (≤40a)	33.2049	0.4834	24	0.87828
	Half-mature forest and Mature forest (≥41a)	54.7293	0.4108	19	0.81886
Pinus armandii Franch., *Pinus taiwanensis* Hayata , *Pinus densata* Mast.	Young growth forest (≤30a)	15.6557	0.6333	29	0.8874
	Half-mature forest (31-50a)	45.5374	0.4139	13	0.88483
	Mature forest (≥5la)	47.6751	0.4292	17	0.87098
Betula, Populus	Young growth forest (≤30a)	21.5600	0.5750	120	0.88449
	Half-mature forest (31~50a)	39.9348	0.5917	67	0.87491
	Mature forest (≥51a)	29.6156	0.6257	45	0.89799
Abies, Picea, Tsuga	Young growth forest (≤60a)	49.0802	0.3420	28	0.92086
	Half-mature forest(61~100a)	29.3993	0.4920	33	0.92218
	Mature forest (≥101a)	53.6120	0.3917	118	0.86682
Cryptomeria, Cupressus, Pinus elliottii Engelmann	Young growth forest(≤10a)	35.2538	0.4741	24	0.82247

	Half-mature forest(11-20a)	47.6005	0.4741	23	0.96934
	Mature forest (≥21a)	69.3512	0.393	29	0.88959
Other deciduous broadleaf trees	Young growth forest(≤40a)	21.8281	0.7084	93	0.88907
	Half-mature forest(41~60a)	22.2598	0.8398	76	0.91967
	Mature forest (≥61a)	55.4361	0.4265	41	0.87656
Larix gmelinii (Ruprecht) Kuzeneva	Young growth forest(≤40a)	30.4438	0.6194	93	0.95598
	Half-mature forest(41~80a)	14.3096	0.6425	22	0.97264
	Mature forest (≥8la)	33.7734	0.5558	29	0.92675
Pinus massoniana Lamb.	Young growth forest(≤20a)	12.1063	0.5093	158	0.84717
	Half-mature forest(21-30a)	38.6436	0.4934	98	0.80683
	Mature forest (≥31a)	21.2812	0.5497	35	0.91996
Cunninghamia lanceolata (Lamb.) Hook.	Young growth forest(≤10oa)	14.6212	0.6765	83	0.8740
	Half-mature forest(11~20a)	32.8777	0.3858	111	0.8887
	Mature forest (≥21a)	0.5264	0.5115	100	0.93833
Pinus tabulaeformis Carr.	Young growth forest (≤30a)	14.4807	0.7106	125	0.91632
	Half-mature forest(31~50a)	4.9498	0.8115	79	0.91841
	Mature forest (≥51a)	8.4727	0.6983	77	0.96866
Pinus yunnanensis Franch. *Pinus kesiya*	Young growth forest(≤30a)	31.7207	0.507	22	0.95799

Royle ex Gordon var. *langbianensis* (A.Chev) Gaussen	Half-mature forest(31-50a)	4.2304	0.7185	15	0.98616
	Mature forest (≥51a)	-10.0118	0.7892	20	0.99687
Pinus sylvestris Linn. var. *mongolica* Litv.	Young growth forest(≤40a)	1.1302	1.1034	72	0.99975
	Half-mature forest and Mature forest (≥41a)	55.7950	0.2545	12	0.96227

Table 4. Carbon Storage and Density of Different Tree Species, Diameter Classes and Age Classes

Tree Classes	**Area (hm^2)**	**Allometric Equation Method**		**Biomass Expansion Factor Method**		**Volume-Biomass Method**	
		Carbon Storage (t)	**Carbon Density (t/hm^2)**	**Carbon Storage (t)**	**Carbon Density (t/hm^2)**	**Carbon Storage (t)**	**Carbon Density (t/hm^2)**
Coniferous forests	137.06	8401.06	61.29	5543.90	40.45	11137.27	81.26
Broad-leaved forests	18.17	1699.42	93.53	4205.96	231.47	4162.68	229.09
Small caliber class (1-10 cm)	19.18	604.76	31.53	1085.83	56.61	2093.36	109.15
Medium caliber class (11-20 cm)	130.75	7691.83	58.83	6506.02	49.76	10825.68	82.79
Large caliber class (21- cm)	5.30	1803.89	340.50	2158.01	407.34	2380.91	449.41
Young age class (1-20a)	26.43	1759.92	66.59	3459.71	130.91	4302.70	162.81
Middle age class (21-40a)	52.88	4989.01	94.35	3640.48	68.85	6498.22	122.89
Old age class (41-60a)	75.93	3351.55	44.14	2649.67	34.90	4499.03	59.25
Total	155.23	10100.48	65.07	9749.86	62.81	15299.95	98.56

The stand biomass takes the community as the unit based on the stand storage, to calculate the biomass-storage fit equation as established by Xinliang Xu (Xu 2007). The specific parameters are shown in Table 3. In the formula, Y is the stand biomass (Mg) and V is the storage (m 3).

$$B_{ij} = \mathrm{a} + \mathrm{b}V_{ij} \tag{1}$$

In the formula, B_{ij} stands for the biomass of a certain age group and a certain type of forests (Mg). V_{ij} is the storage of a certain age group and a certain type of forest (m^3). The parameters a, b are constants, is a certain type of forests, and j is a certain age group.

Biomass expansion factor method

Basic wood density, biomass expansion factor, and root/shoot ratio are included in the biomass expansion factor method. Basic wood density, which is also called trunk bulk density, is the mass of dry matter in wood per cubic meter. The formula for calculation of stand biomass (B) (Cao and Li 2019) is as follows:

$$B = V \cdot D \cdot F \cdot (1 + R) \tag{2}$$

In Eq. 2, V represents the stand storage (m^3), D is the basic wood density ($Mg \cdot m^{-3}$Mg), F is the ratio of aboveground biomass to trunk biomass (dimensionless), and R is the root/shoot ratio. The wood density of the dominant species in the community is distinguished by tree species. The rest of the tree species take different values according to the type of standing trees (see Table 1). F is distinguished by the type of standing trees. For sclerophyllous and broad-leaved forests, the value is 1.79. On the other hand, the value for coniferous and broad-leaved forests is 1.54 (Xu *et al.* 2007). R is uniformly 0.24 (Cao and Li 2019).

Carbon Storage Measurement

Different plants have different carbon content. However, there is no significant correlation between carbon content and ecological characteristics such as wood density and tree height or between statistical characteristics like relative growth rate and mortality (Fang *et al.* 2001). The carbon storage is calculated by multiplying the biomass with the carbon content. In the paper, the carbon content is uniformly 0.47 (Cao and Li 2019).

Carbon Sink Value Measurement

Measurement Methods

The physical quantity (carbon storage) and the carbon sink value per unit determine the value of the forest carbon sinks. The forest carbon sink has a positive externality. It is an accessory to the cultivation of forest resources. The production cost of afforestation is already included in the tangible wood assets. It is impossible to allocate these between the forest assets and the forest carbon sinks. Therefore, it is impossible to obtain the production costs of forest carbon sinks. Thus, the historical cost or actual cost cannot be used for measurement. It is more reliable to choose the fair value to measure forest carbon sinks, which truly reflects its value.

(4) Fair value measurement of forest carbon sinks

According to Accounting Standard CAS39, fair value is a market-based measurement. When an asset is being measured *via* fair value, differences in market sophistication may affect fair value. According to Articles 9, 10, 11, and 12 of CAS39, when an enterprise measures its assets or liabilities *via* fair value, it shall be assumed that the orderly transaction of selling the assets or transferring the liabilities is conducted in the primary market. In the absence of a primary market, the enterprise should assume that the transaction is conducted in the market most favorable for the assets or liabilities. The primary market refers to the market with the largest volume of transactions and the highest activity level of transaction in assets or liabilities. In addition, the most favorable market means the market where assets can be sold at the highest price or liabilities transferred at the lowest price, with transaction and transportation costs included. The primary market or the most favorable market should be the trading market that an enterprise can enter on the measurement date without being required to sell assets or transfer liabilities. And the fair value of relevant assets or liabilities should be measured at the price of the primary market. In the case of no primary market, the enterprise shall measure the fair value of assets or liabilities at the price of the most favorable market.

At present, in China, to put forest carbon sinks in the carbon trading market for carbon trading activities, the enterprise must get approval from the carbon-sink project of Clean Development Mechanism (CDM) or China Certified Emission Reduction (CCER). Otherwise, the enterprise will temporarily be blocked from the market. Therefore, the primary market or the most favorable market for forest carbon sinks cannot be identified for the time being. According to CAS39, the fair value of forest carbon sinks should be measured by valuation. To be more specific, Article 18, Chapter VI of CAS39 stipulates that (Poudel and Temesgen 2016) enterprises shall measure relevant assets or liabilities *via* fair value, and the valuation techniques mainly include the market approach, the income approach, and the cost approach. The cost approach, in particular, reflects the amount of money currently required to replace the service capacity of the asset (usually called current replacement cost). As mentioned before, the forest carbon sink is an accessory to the cultivation of forest resources, and the production costs of forest carbon sinks cannot be collected and allocated in afforestation. Therefore, the cost approach is not suitable. The paper, instead, applies the market approach and the income approach to estimate the fair value of forest carbon sinks.

1. The market approach is a valuation technique that uses the same or similar assets, liabilities, or the combination of assets and liabilities with other relevant transaction information. The same or similar assets of forest carbon sinks are listed with the Carbon Emission Allowance (Neagu and Teodoru) and the CCER projects. Articles 10, 14, and 23 (Poudel and Temesgen 2016) of CAS39 stipulate that when an enterprise identifies the primary market or the most favorable market, it should consider all reasonably obtainable information, but it is unnecessary to examine all the markets. Generally, the market where an enterprise normally sells assets or transfers liabilities can be considered as the primary market or the most favorable market. When an enterprise measures relevant assets or liabilities *via* fair value, it shall consider the assumptions of how market participants try to maximize economic benefits while pricing the assets or liabilities. If there is a bid and an asking price, the fair value of the asset or liability is determined at a price that is in between the bid and the asking price, and that best represents the current fair value. Enterprises are not restricted from using the middle rate between the bid and asking price or any other practical pricing conventions used by market participants to measure the underlying asset or liability. In addition, the volume and frequency of trade in China's carbon markets are different from one another, and not every market has daily trading volumes. To conclude, we find the average actual transaction price of each carbon market in the year prior to the

measurement date. We take the proportion of the trading volume of each market in that year to the national trading volume as the weight. Then, we calculate the average actual transaction price of each market *via* weighted means to get the simulated price—fair price. The simulation model is as follows,

$$V = \sum_{= 1}^{\mathrm{n}} p_{\mathrm{i}} \cdot V_i \tag{3}$$

where V is the simulated price, p_i is the possibility of entering market i—annual carbon trading volume of the market divides total trading volume of all markets, V_{i} is the average transaction price of market i in that year:

$$\sum_{i=1}^{n} p_i = 1 \tag{4}$$

2. The income approach is a valuation technique that converts future earnings into a single present value. Carbon trading is not a tangible process. From the perspective of buyers or market participants, carbon emissions trading is like investing in financial derivatives—focusing more on expected revenues. The above-mentioned market approach is based on the historical actual transaction price of each market yet ignores the future profitability of carbon sinks.

According to CAS39, in case of no observable market data on the measurement date, enterprises can refer to the recent price of carbon sinks in the domestic trading market, to predict the future price based on historical transaction data, select an appropriate discount rate, and use weighted mean to calculate the fair value of the carbon sinks.

On the measurement date, in the 8 domestic carbon markets, the trading volume is small and trading activities are not active enough. So, the average number of transactions in each trading market can be taken to calculate the average growth rate of trading prices in the past five years—assumed as the expected steady growth rate, with the forecast period of 5 years. At the same time, bank lending rate is selected as the discount rate, to calculate the current value of carbon sinks *via* the income approach.

RESULTS AND DISCUSSION

Measurement of Carbon Storage

Three different methods of calculating carbon storage give different values (Table 4). From highest to lowest, the value obtained under the volume-biomass method is 15,300 t, the allometric equation gives 10,100 t, and the biomass expansion factor method gives 9750 t. The average carbon density is also different. Ranking from highest to lowest, the value under the volume-biomass method is 98.6 t·hm^{-2}, under the allometric equation, it is 65.1 t·hm^{-2}, and under the biomass expansion factor method it is 62.8 t·hm^{-2}. In each community, the results of carbon storage and density obtained using the biomass expansion factor method and the allometric equation were similar. The carbon storage and density obtained by the volume-biomass method were significantly larger than the other two, probably due to the parameters (table) used by the volume-biomass method dividing different age classes, while the young age class is mostly set to be 40 years. There are few stands older than 40 years in the research area. This leads to the overestimation of carbon storage and density calculated using the volume-biomass method.

The area of coniferous forests taken for research is 137 hm^{2}. This is larger than 18.2 hm^{2} which is the area of the broad-leaved forests. The carbon storage of coniferous forests calculated by the three methods is also higher than that of the broad-leaf forests. This is consistent with the actual situation. Here, it is worth noting that the biomass expansion factor method takes into account the wood density and the ratio of aboveground wood biomass to the trunk biomass. Hence, the calculated carbon storage ratio and the carbon density of the broad-leaved forests are both higher than those calculated using the other two methods. This shows that coniferous forests have a relatively lower carbon storage. Moreover, the carbon storage of broad-leaved forests is low when calculated using an allometric equation. This may be related to the poor match between the allometric equation used in this paper, and the data in the research area, since allometric equations mostly depend on the data used in the modeling process.

To explore the results from the three methods of calculation of carbon storage and density for different diameter classes easily, the paper divides the diameters of the research area into three classes: the small diameter class (1 to 10 cm), the medium diameter class (11 to 20 cm) and the large diameter class (>21 cm). Their areas are 19.2 hm^2, 131 hm^2, and 5.3 hm^2, respectively. There is a certain positive correlation between carbon storage and area. Thus, the carbon storage calculated by the three methods is also the largest in the medium-diameter class. Meanwhile, the carbon storage in the large-diameter class is greater than that in the small-diameter class because the large-diameter class has larger wood storage.

Likewise, in this work the stand age of the research area was divided into three classes: the young age class from 1 to 20 years, the middle age class from 21 to 40 years, and the old age class 41 to 60 years. The results of the calculation using the three methods show that the carbon storage of the middle-age class is the largest. It can also be seen that the carbon storage of the young-age class calculated by the allometric equation was significantly smaller than the calculated using the biomass expansion factor method and the volume-biomass method. Meanwhile, the carbon storage of the old-age class was larger than the results calculated using the biomass expansion factor method. From the perspective of carbon density at different age classes, the results obtained using the three methods show that with the increase in age, the carbon density becomes increasingly smaller. This may be related to the stand renewal and succession. The crown density and the stand density are high for the young-age class. Meanwhile, the crown density and the stand density are low for the old-age class.

To compare the calculation results from the three methods, a table was drawn. The table shows the maximum value, the minimum value, the mean value, the standard error of the mean value, and the standard deviation as a whole for coniferous and broad-leaved species, different diameter classes, and different age classes. The mean value of the volume-biomass method is generally greater than the one obtained in the allometric equation and the biomass expansion factor method (except for broad-leaved, small-diameter, and large-diameter classes). In terms of the standard error of the mean value, generally, the standard error of the mean value of the biomass expansion factor method is greater than the one in the volume-biomass method, which is in turn greater than the one in the allometric equation. However, there is no such rule for the classification of coniferous and broad-leaved species, diameter class, and age class. In terms of the extreme values, generally, the minimum value in the volume-biomass method is greater than the one in the biomass expansion factor method, which in turn is greater than the one in the allometric equation. The maximum value does not show obvious regularity. However, the acquisition of the maximum value may be related to individual stands with large carbon storage. In terms of the standard deviation, the standard deviation of the biomass expansion factor method is greater than the one in the volume-biomass method, which is in turn greater than the one in the allometric equation. However, there is no evident regularity in different classifications.

In addition, in order to express the relationship more naturally among the three methods, the three methods are made into a scatter chart one by one based on different classifications for fitting, and the following figure shows the results:

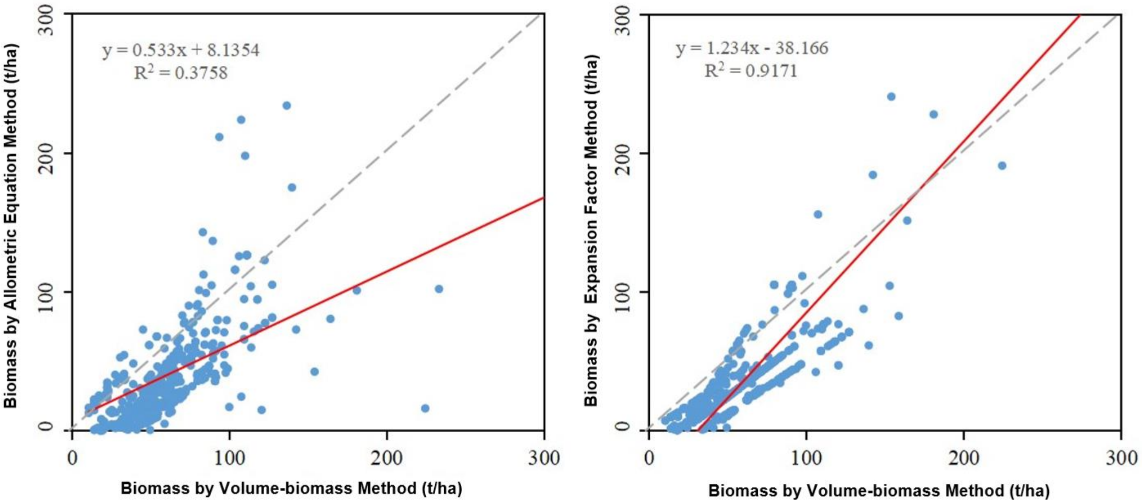

Fig. 2. Scatter chart of overall biomass

Concerning the differences between the three methods of calculating total biomass, since both the biomass expansion factor method and the volume-biomass method use the stand volume as a factor for calculating biomass, they had a higher R^2 value, which was 0.9171. However, the allometric equation is calculated directly from the relationship among biomass, DBH, and tree height. Therefore, the R^2 is lower than that of the volume-biomass method, which is 0.3758. In terms of the slope of the fit equation, the fit slope of the allometric equation is estimated at 0.533, which is much smaller than 1.234 calculated by the biomass expansion factor method. To show the differences among the three methods for carbon storage calculation more clearly, the paper divides the coniferous and broad-leaved species, diameter class, and age class, and makes a comparative study of the three methods simultaneously.

In terms of coniferous and broad-leaved species: (1) The allometric equation and the volume-biomass method achieved a low R^2 of 0.3007 for conifers. This is much lower than the R^2 of broad-leaved species, which was 0.9034. The scatter distribution of the fit equation indicates that the allometric equation and the volume-biomass method are distributed on both sides of the bisector. Meanwhile, the fit result of the allometric equation of broad-leaved species was much smaller than the one obtained in the volume-biomass method. (2) The R^2 value of the biomass expansion factor method shows similar results as well. The biomass expansion factor method and the volume-biomass method had a low R^2 value at 0.6602 for conifers. This is much lower than the one for broad-leaved trees at 0.9775. The scatter chart of the biomass expansion factor method and the volume-biomass method indicates that the R^2 of the biomass expansion factor method for conifers was smaller than the one in the volume-biomass method.

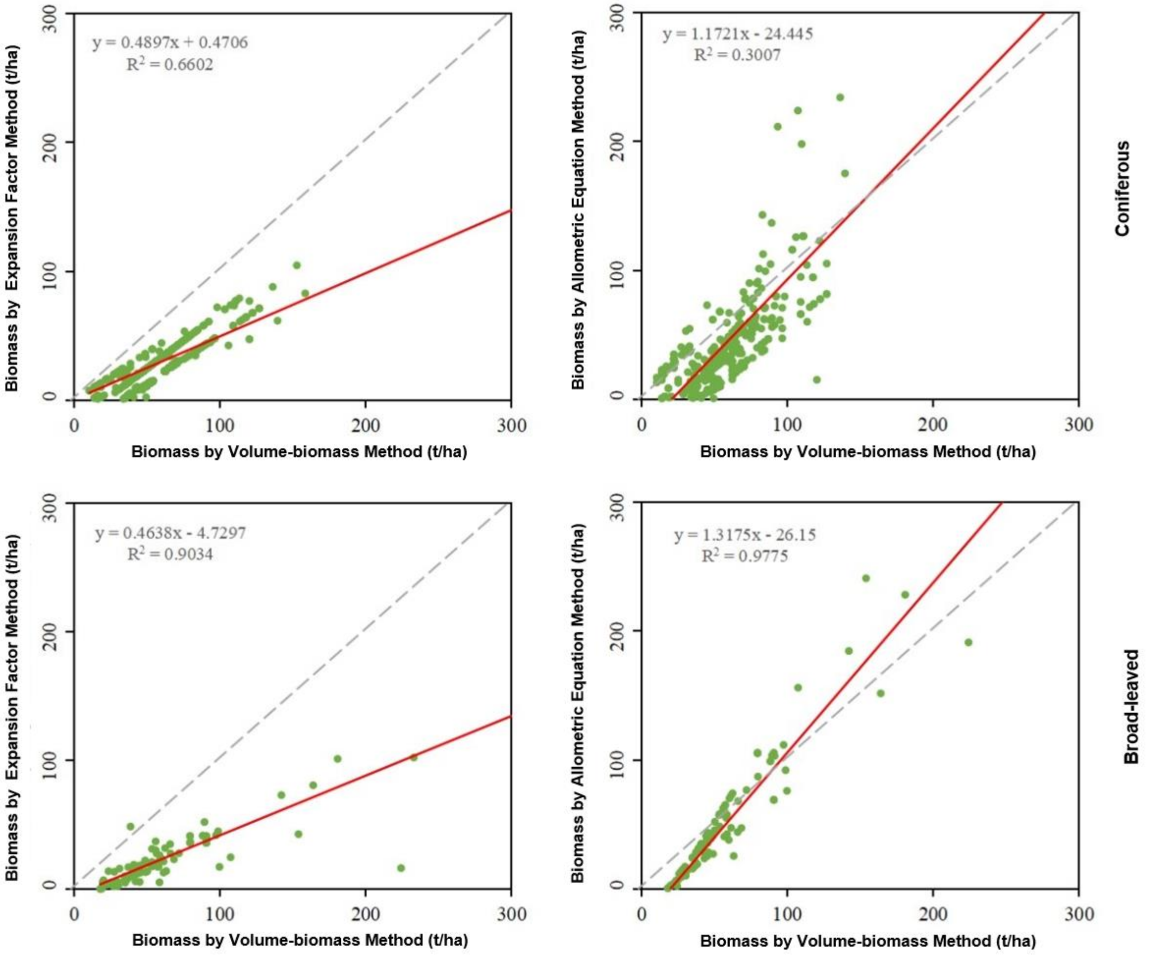

Fig. 3. Scatter chart of coniferous and broad-leaved tree species

In terms of diameter: (1) Small diameter class: The R^2 of the allometric equation and the volume-biomass method for the small diameter class was only 0.1345. This is much lower than that of broad-leaved species at 0.7402. The scatter distributions were similar to the R^2 of the small-diameter class at 0.1345. The scatter distribution of the combined equations indicates that the R^2 of the allometric equation and the biomass expansion factor method was smaller than that obtained for the volume-biomass method. (2) Medium diameter class: The R^2 of the medium-diameter class using allometric equation and the volume-biomass method was 0.2126. This is much lower than the R^2 of the broad-leaved species, which was 0.5136. The results calculated using the allometric equation and the biomass expansion factor method show that the data points were distributed on both sides of the bisector. Yet, most of them were smaller than the ones in the volume-biomass method. (2) Large diameter class: The R^2 using the allometric equation, the biomass expansion factor method, and the volume-biomass method were all relatively high at 0.6729 and 0.9831, respectively. The results calculated using the allometric equation show that the spots were distributed on both sides of the bisector. However, the R^2 of the biomass expansion factor method was smaller than that of the volume-biomass method.

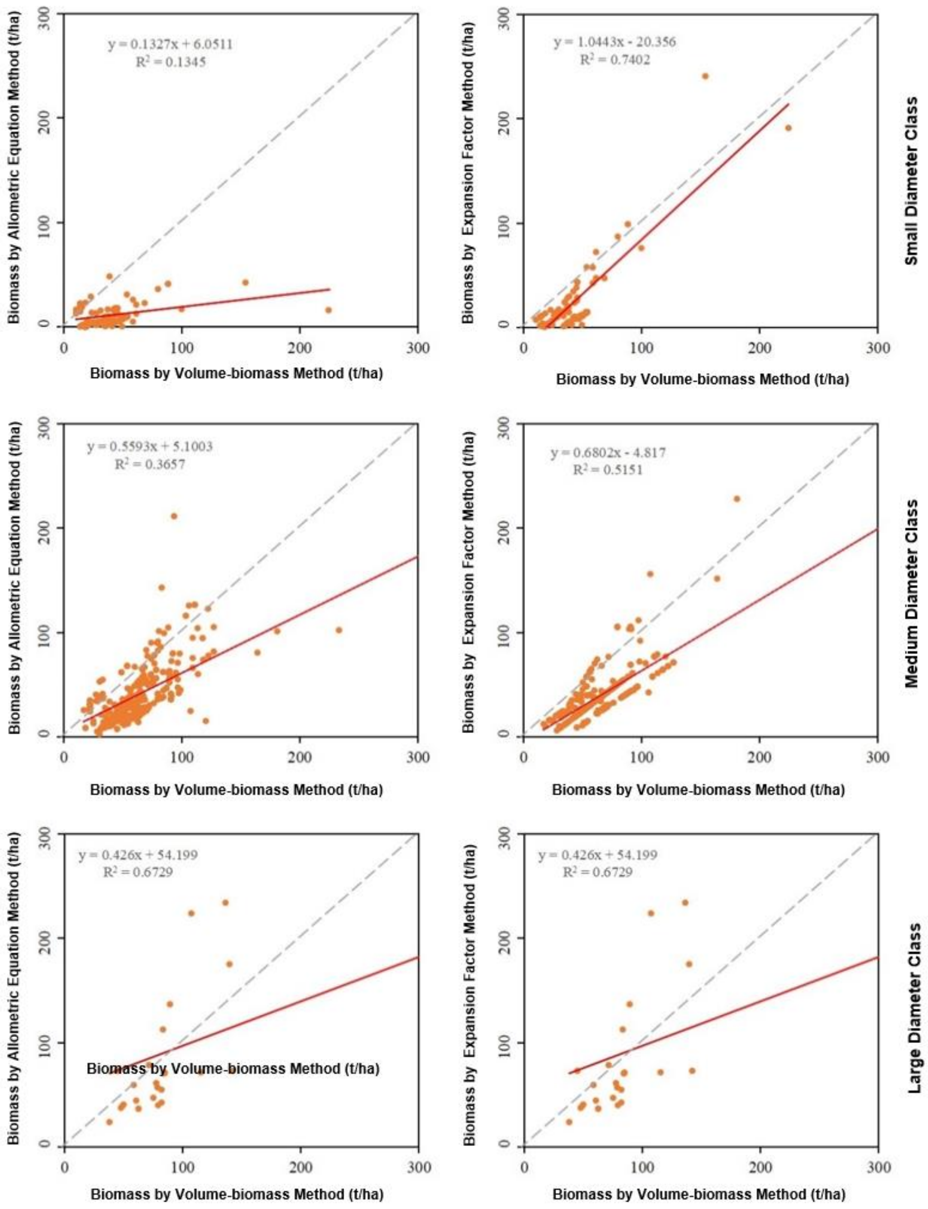

Fig. 4. Scatter chart of tree diameter class

In terms of age class: (1) Small age class: The R^2 of the allometric equation, the biomass expansion factor method, and the volume-biomass method were all high at 0.8898 and 0.9729, respectively. The scatter distribution of the scatter fit equation indicates that the R^2 of the allometric equation and the biomass expansion factor method was smaller than in the volume-biomass method in most cases. (2) Middle age: The R^2 using allometric equation, biomass expansion factor method and volume-biomass method were not high at 0.3248 and 0.5905, respectively. The allometric equation and the biomass expansion factor method were distributed on both sides of the bisector. Yet, most of the results were smaller than that of the volume-biomass method. (2) Old age: R^2 of the allometric equation, the biomass expansion factor method, and the volume-biomass method were relatively low at 0.242 and 0.4081, respectively. The results of the allometric equation show that there were distributions on both sides of the bisector. The R^2 of the biomass expansion factor method was smaller than that of the volume-biomass method.

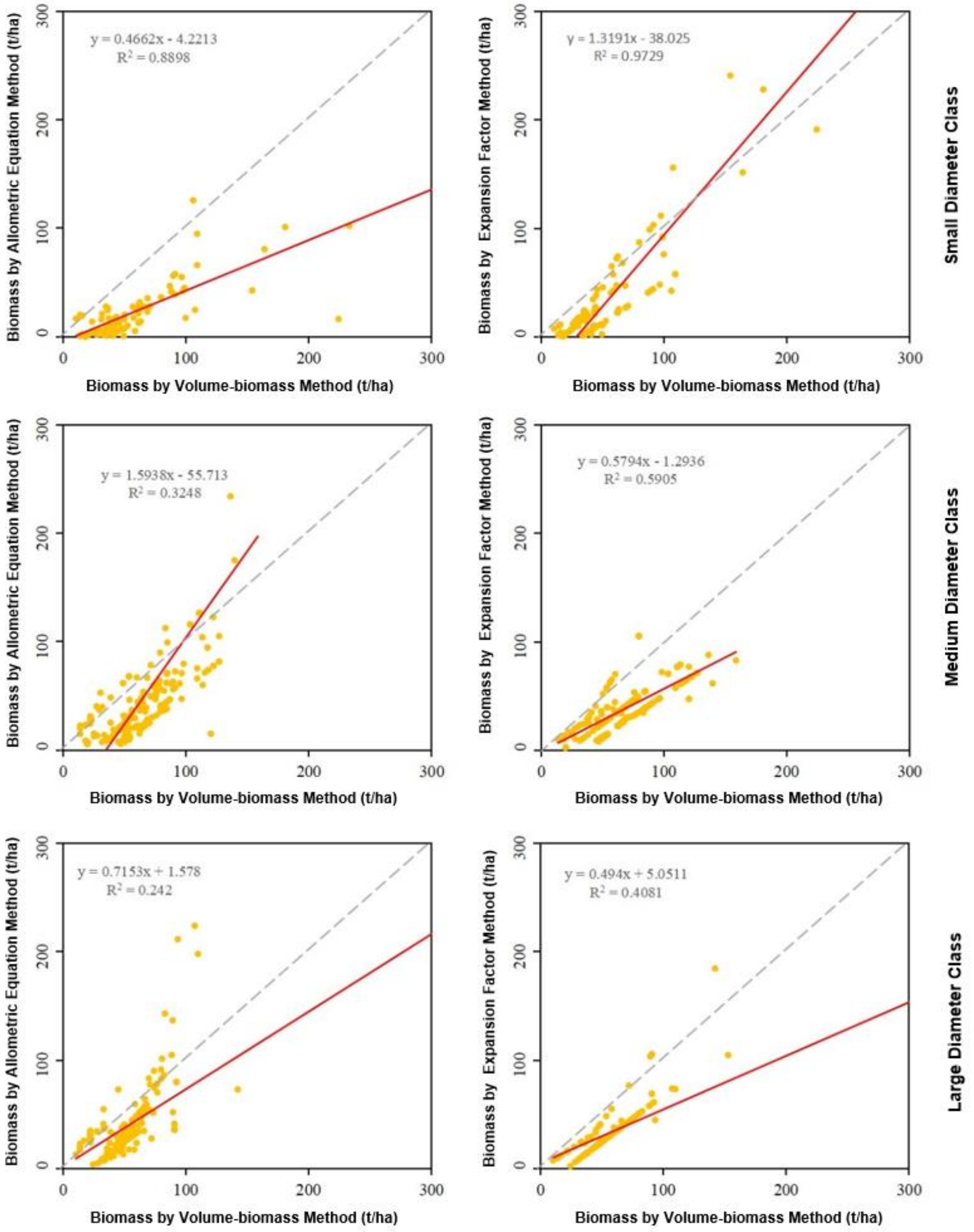

Fig. 5. Scatter chart of tree age class

The Fair Value of Forest Carbon Sinks in Yixing National Forest Park Farm

Results estimated by the market approach

Table 5 presents the transaction prices of carbon markets in China in 2021. The simulated price V can be obtained as 28.96 yuan/ton.

Table 5. Yearly Transaction Prices of Carbon Markets Before the Measurement Date in 2021 (yuan)

Carbon Markets	**Transaction Amount**	**Trading Volume**	**P_i (%)** (Transaction Amount Ratio of Carbon Markets)	**V_i** (Average Actual Transaction Price)	**V**
Beijing	852.65	17.96	4.35	47.47	2.06
Shanghai	703.33	17.21	4.17	40.87	1.70
Guangdong	7248.86	242.38	58.70	29.91	17.56
Tianjin	2352.92	94.86	22.97	24.80	5.70
Shenzhen	99.95	15.13	3.66	6.61	0.24
Hubei	662.68	23.94	5.80	27.68	1.60
Chongqing	35.70	1.43	0.35	24.97	0.09
Total	11956.09	412.91	100	-	28.96

Results estimated by the income approach

Table 6. Annual Average Transaction Prices

Year	**Average Trading Price**	**Rise (%)**
2015	26.38	0
2016	18.24	-30.86%
2017	15.66	-14.13%
2018	27.30	74.30%
2019	30.80	12.81%
2020	29.19	-5.23%
Average rise	-	7.38%

The value of carbon sinks is,

$$P = \frac{\sum \frac{A_0(1+g)^i}{(1+r)^i}}{n} \quad i = 1,2,\dots,n \tag{5}$$

where P represents the estimated fair value of forest carbon sinks, A_0 represents the recent market price of forest carbon sinks on the measurement date (this paper uses the average market transaction price in 2020), A_i is the predicted carbon sink price (earning) in year i, r is the bank lending rate, g is the expected growth rate of earnings, and n represents the number of years of earnings. Therefore, the estimated fair value P can be obtained as 31.33 yuan/ton.

Results show that the fair value of forest carbon sinks estimated by the income approach was slightly higher than that estimated by the market approach, which is in line with the buyer's or the investor's prediction and investment demand for the expected appreciation of purchased assets. According to the international market, the average market price of carbon sinks will stabilize around USD 8. At present, the average price of carbon trading in China is lower than that in the international market, but it will, as usual, eventually get closer to the international market price. Hence, the income approach can produce more accurate and practical results.

Fair value of forest carbon sinks in Yixing National Forest Park Farm

The biomass expansion factor method is considered effective in estimating forest biomass, and it has been widely applied and accepted in the past few decades. Therefore, the paper decided on the biomass expansion factor method to measure the carbon sink in Yixing National Forest Park Farm but selected the income approach for general measurement of carbon sink. The results of the fair value of carbon sinks in Yixing National Forest Park Farm are presented in Table 7. The total fair value of carbon sinks calculated by the income approach is 305,000 yuan, and the average fair value is 1,970 yuan/hm^2. In terms of leaf types, the total fair value of coniferous forest carbon sinks is 174,000 yuan, higher than that of broad-leaved forest—132,000 yuan. However, the average fair value is quite the opposite—that of coniferous forest is 1,270 yuan/hm^2, which is lower than that of broad-leaved forest—7,250 yuan/hm^2. Next, in terms of diameter class, the fair values of carbon sinks are ranked: 204,000 yuan of medium diameter class > 67,600 yuan of large diameter class > 34,000 yuan of small diameter class. Meanwhile, the average fair values are ranked: 12,800 yuan/hm^2 of large diameter class > 1,770 yuan/hm^2 of small diameter class > 1,560 yuan/hm^2 of medium diameter class. As for age class, the fair values are ranked: 114,000 yuan of middle age class > 108,400 yuan of young age class > 83,000 yuan of old age class. Meanwhile, the average fair values are: 4,100 yuan/hm^2 of young age class > 2,160 yuan/hm^2 of middle age class > 1,090 yuan/hm^2 of old age class.

Table 7. Fair Value of Carbon and the Average Fair Values of Carbon yuan/hm^2 of Different Tree Species, Diameter Classes, and Age Classes

Tree Class	Fair Value of Carbon (yuan)	Average Fair Value of Carbon (yuan/hm^2)
Coniferous forests	173690.39	1267.30
Broad-leaved forests	131772.73	7251.96
Small caliber class (1-10cm)	34019.05	1773.59
Medium caliber class (11-20cm)	203833.61	1558.98
Large caliber class (21-cm)	67610.45	12761.96
Young age class (1-20a)	108392.71	4101.41
Middle age class (21-40a)	114056.24	2157.07
Old age class (41-60a)	83014.16	1093.42
Total	305463.11	1967.84

Discussion

The data required for an allometric equation is simpler and more convenient in practice. However, the results of the allometric equation are highly dependent on the adaptability of the data established by the equation and the application site. Thus, it easily leads to large deviations. In the paper, the one-way log volume table of Jiangsu Province was used to calculate the storage. Only the diameter at breast height was used as the factor for calculating the storage. Thus, it leads to a few deviations between the values of the volume-biomass method and the biomass expansion factor method. The biomass expansion factor method is considered better for the estimation of forest biomass by storage. It was originally proposed by Brown and Lugo in 1984. The method uses the storage data of global major forest types provided by the Food and Agriculture Organization (FAO) of the United Nations. It is also used in subsequent studies. For example, Fang *et al.* (2001) used the biomass expansion factor method for calculating the biomass carbon density in China and compared it with the northern hemisphere (Hu and Wang 2008). When compared to the volume-biomass method, the biomass expansion factor method takes into account the log density. This makes the calculation of carbon storage more precise and accurate. Furthermore, the coniferous forests of Yixing National Forest Park Farm are mostly cedarwood, pines, *etc.* Thus, log density is relatively small. This is consistent with the results obtained using the volume-biomass method and the biomass expansion factor method. The volume-biomass equation forms the basis for the volume-biomass method, which was established based on local sample conditions in China. However, the results calculated using the volume-biomass method have the possibility of overestimating the carbon storage of coniferous, middle-diameter, and middle-aged stands. The volume-biomass method was proposed based on 6 forest inventories from the year 1973 to 2003. The biomass data were mostly sampled in areas with dense forests such as the northeast and the southwest of China. However, it remains to be considered whether it is suitable to be applied in the Jiangsu Province.

The market approach and the income approach are major choices to measure the fair value of forest carbon sinks. In detail, the market approach selects historical data—the trading volume of each market in the past five years—as weight. Then it calculates the weighted mean of the transaction price of each market to get the fair price of the carbon sink, to further obtain the fair value of forest carbon sinks. The income approach, on the other hand, assumes the average increase in the transaction price of carbon sinks in the past five years as the expected steady growth rate, so as to predict the value in the next five years. Then, it chooses bank lending rate as the discount rate, to discount the future value and get the fair price of the carbon sink *via* the weighted mean, to further get the fair value of the forest carbon sinks. The valuation techniques of both approaches use the actual market transaction price as the input value of valuation, in line with the requirements of fair value measurement. However, forest carbon sinks cannot be traded in the market at present, due to limitations of market access, so the simulated price may be different from the actual transaction price. The market approach, on the other hand, is too conservative because it estimates the fair price of forest carbon sinks based on previous transaction prices. Buyers or investors, as major participants in the forest carbon sink trading market, always assume their current purchase is rational, because the future value exceeds the current price by a large margin. So, the fair value estimated by the income approach is higher than that by the market approach. Obviously, it is more reasonable to estimate the current fair price through the predicted future value of forest carbon sinks, which is in line with the expectation of investors. Additionally, the current transaction price of carbon sinks in China is much lower than the international price, but it will, as usual, eventually get closer to the latter. Therefore, the price is generally expected to rise.

China’s national forest parks, with Yixing National Forest Park Farm as an example, are protected by the policy from entering the market for trading. As a result, the economic value of their carbon sinks may be ignored or underestimated. In recent years, the implementation of the ecological compensation mechanism and the policy of realizing the value of ecological products has drawn attention to the value of non-tradable carbon sinks. Nonetheless, with the development of the market economy and the intensifying global warming, it is more important to study the forest carbon storage and carbon sink value of protected forest stand. To be specific, it can help calculate the carbon sequestration efficiency of forest stands, promote the accounting of green GDP, and estimate the value of carbon storage of forest stands based on the international market price of carbon sinks, in order to further facilitate international carbon trading. In addition, exploring the carbon storage of different sites offers significant guidance on afforestation based on carbon storage. And studies on carbon storage in Yixing National Forest Park Farm also lays a foundation for screening out suitable models for stand improvement.

CONCLUSIONS

1. The carbon storage and density were calculated for the Yixing National Forest Park Farm by the allometric equation, the volume-biomass method, and the biomass expansion factor method. The carbon storage calculated by the volume-biomass method was 15,300 t, which was greater than that obtained by the allometric equation at 10,100 t. This is greater than that obtained by the biomass expansion factor method, which was 9,750 t. The results obtained for carbon density were similar to this. The carbon density calculated by the volume-biomass method was 98.6 $t \cdot hm^{-2}$, which was greater than that calculated by the allometric equation (65.0 $t \cdot hm^{-2}$), and that calculated by the biomass expansion factor method (62.8 $t \cdot hm^{-2}$).
2. In this work, the fair value of forest carbon sinks was estimated and measured *via* the market approach and the income approach. To be specific, the fair value was 22.0 yuan/t when calculated by the market approach, and 31.3 yuan/t when calculated by the income approach.
3. Based on this work it is recommended to employ the biomass expansion factor method and the income approach to calculate the fair value of carbon storage and carbon sinks in Yixing National Forest Park Farm. Results show that the fair value of forest carbon sinks in Yixing National Forest Park Farm is 305,000 yuan, and the average fair value of carbon sinks is 1,970 yuan/hm^2, indicating that the existing forest stand of Yixing National Forest Park Farm has a relatively high fair value of carbon sinks.

Author Contributions

Yuanyuan Chen designed the study and conducted parts of experiments and data analysis; Yuanyuan Chen wrote the initial manuscript; Jie Qiu and Chong Jia revised the manuscript. All authors read and approved the manuscript. There are no conflicts of interest involving the authors.

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