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Sustainable Management of Land Resources: The Case of China's Forestry Carbon Sink Mechanism

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Abstract: Compared to more developed countries, the use of land resources is less efficient in China. China's vast forest land area gives it a rich and underutilized carbon sink. This is an important way for China to achieve the goals of "carbon peaking" and "carbon neutrality", which is of great significance to China's sustainable development. In the past 20 years, China has designed a series of policies to serve the development of forestry carbon sinks, namely the forestry carbon sink mechanism (FCSM). However, the questions of which policy is the most important, and what is the socio-economic value it generates, have not been fully investigated. Accordingly, this paper studied 30 provincial-level regions in China from 2005 to 2020 using the difference-in-differences (DID) model. The conclusions show that: (1) the FCSM does increase the socio-economic value of land resources, thus improving the sustainability of land resources; (2) the FCSM helps to increase forest coverage, forest stock volume and the forest coverage rate, which increases the social value of land resources from the greening path; (3) the FCSM helps to increase the gross forestry product, which increases the economic value of land resources through the path of increasing production value.

Keywords: difference-in-differences model; forestry carbon sink mechanism; governance and policy of land resources; socio-economic value of land resource management

Citation: Liu, H.; He, T. Sustainable Management of Land Resources: The Case of China's Forestry Carbon Sink Mechanism. *Land* **2023**, *12*, 1188. https://doi.org/10.3390/land12061188

Academic Editors: Matjaž Glavan and Jianjun Zhang

Received: 5 April 2023
Revised: 17 May 2023
Accepted: 3 June 2023
Published: 6 June 2023

1. Introduction

The *World Conservation Strategy* of 1980 called on humankind to recognize the need to consider the resource and ecological needs of future generations in the pursuit of economic development and the enjoyment of natural wealth. The *Rio Declaration* of 1992 emphasized that ecological protection is central to achieving sustainable development and called on countries around the world to take action according to their own circumstances. In 2015, 17 Sustainable Development Goals (SDGs) were presented in *Transforming our World: The 2030 Agenda for Sustainable Development*, which included the three dimensions of sustainable development: social, economic and environmental, as well as important aspects related to peace, justice and effective institutions [1]. The SDG15 emphasized the sustainable management of forests [1]. Today, sustainable development has become an important goal in the common quest for humanity. Researchers have been carrying out rich work on sustainable development from many perspectives, such as environmental protection [2–4], economic development [5–7] and human quality of life [8,9]. Greenhouse gas emissions are an issue that must be taken into account in the process of sustainable development. As shown in Figure 1, annual global CO2 emissions are increasing year by year and will be almost seven times higher in 2020 than in 1920. According to the IPCC, 1.5 °C of global warming above pre-industrial levels is due to greenhouse gases [10]. In addition, it has been shown that the increase in GHG emissions is associated with infectious and non-infectious diseases, negative effects on nutrition, water insecurity and other social disruptions [11]. Therefore, controlling greenhouse gases, especially carbon dioxide emissions, has become an important issue for humanity as it seeks to achieve sustainable development. China's total CO_2 emissions have been among the highest in the world for more than a decade [12]. Undoubtedly, China's practices and exploration of low-carbon development has important social value for the world's carbon reduction and environmental protection, as well as being an important inspiration for other developing countries to plan their own carbon reduction path.

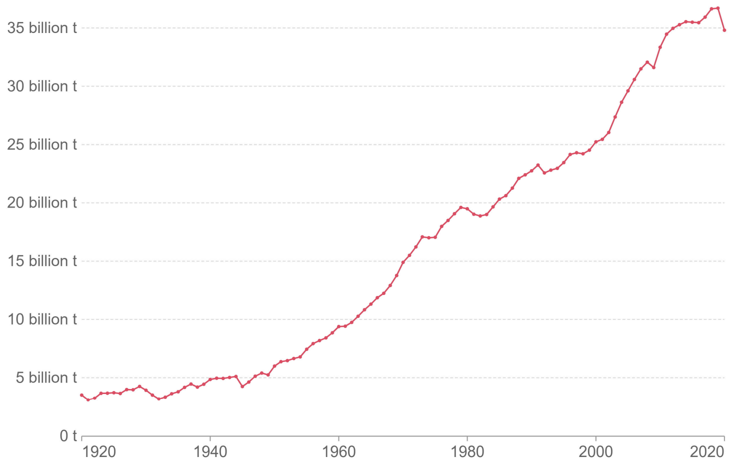

Figure 1. Annual global CO_2 emissions over the last 100 years. Source: Global Carbon Project [12].

On the other hand, after decades of rapid development, China's insufficient efficiency in the use of land resources has become increasingly evident [13]. Along with land degradation and increased urban pollution, the past extensive mode of growth can no longer meet China's demand for high-quality economic development. China urgently needs to improve the way it uses its land resources. A better way is to implement land control policies, such as what was described in the World Bank's "Land Reform Policy Paper" in 1975 [14], China's "Requisition-Compensation Balance of Arable Land" [15], etc. Although land management policies may also have negative effects, such as economic conflicts, social injustice and government corruption [16], overall, they have more or less increased the economic output of land resources.

In order to achieve low carbon development, the Chinese government has enacted a number of environmental regulatory policies in the last decade or so. One of the most promising and effective approaches is the emissions trading scheme (ETS) [17,18]. The ETS allows companies to purchase carbon sinks to partially offset emissions in excess of their allowances, creating the basis for the forestry carbon sink mechanism (FCSM). China has a potential market of nearly USD 31.35 billion in Chinese Certified Emission Reduction [19] as well as abundant forestry resources [20]. Therefore, against the background of record-high world carbon sink prices [21], the study of forestry carbon sinks in China is of practical value. The FCSM therefore not only contributes to environmental protection, but also generates economic value and thus improves the use of land resources.

Through reviewing the literature, this study found that the studies on forestry carbon sinks can be divided into the following categories.

The first category involves research on carbon sink forest construction technology. Technical barriers are one of the challenges in building carbon sink forests [22]. Examples include the depth of the oxic peat layer [23], landscape type [24,25], ground-level ozone concentration [26], atmospheric CO_2 concentration [27], tree age [28], blockchain technology [29], etc. This type of research is usually in the scientific and technical field and requires certain technical tools and analytical instruments to complete the research work. A few scholars have also conducted research from a management perspective, such as reasonable deforestation patterns [30] and the investment models applicable to forestry carbon sink projects [31].

In the second category, the main focus is on the measurement of the productivity of forestry carbon sinks and carbon storage. The common measures are the Slacks-Based Measure (SBM) method [32], the DEA model [33], and the Malmquist–Luenberger index [34]. In addition, many researchers have furthered the analysis and discussion based on the measurement results. Chen et al. pointed out the contribution of forestry carbon sinks in reducing greenhouse gases and achieving carbon neutrality [35]. Shi et al. pointed out that there are deficiencies in the carbon trading market and imperfect accounting of forestry carbon sinks in China [36]. Wei and Shen analyzed the factors (urbanization rate, forestry financial allocation, etc.) affecting forestry carbon sinks in China [37]. Montagnini and Porras pointed out the shortcomings of the FCSM in China from the perspective of economic, social and environmental considerations [38].

The third category, which focuses on the role and drivers of forestry carbon sinks, is also a literature that is of interest in this study. As an investment project, forestry carbon sinks are not a sure thing [39,40]. In the field of economics, researchers typically use econometric models to examine the role and drivers of the FCSM. In terms of its role, the FCSM helps to upgrade the industrial structure at the county level and has a pro-poor effect [41]; the FCSM improves the environment [42]. In terms of drivers, factors such as climate change have a huge impact on the forestry carbon sink [43,44]. Meanwhile, human intervention is also an important factor that cannot be ignored, such as government subsidies [45], investment of fixed assets and FCSM projects [46].

It can be found that economists' studies in the field of forestry carbon sinks are focused on two effects: economic and social effects. The social effects are mainly in the promotion of greening and the reduction of greenhouse gases. However, from an economic standpoint, these studies are relatively crude in the use of econometric models, failing to better overcome the endogeneity problem. Therefore, this paper aims to improve the existing literature by using the DID model. On the one hand, several FCSM policies have been published in China since 2011, but no study has yet answered the question of which policy is most important for the development of the forest carbon sink. On the other hand, DID models have been used to identify causal relationships between variables. This helps to avoid the problem of model endogeneity, and thus can better identify whether the FCSM is delivering social and economic value. Figure 2 shows the process of proving the above questions.

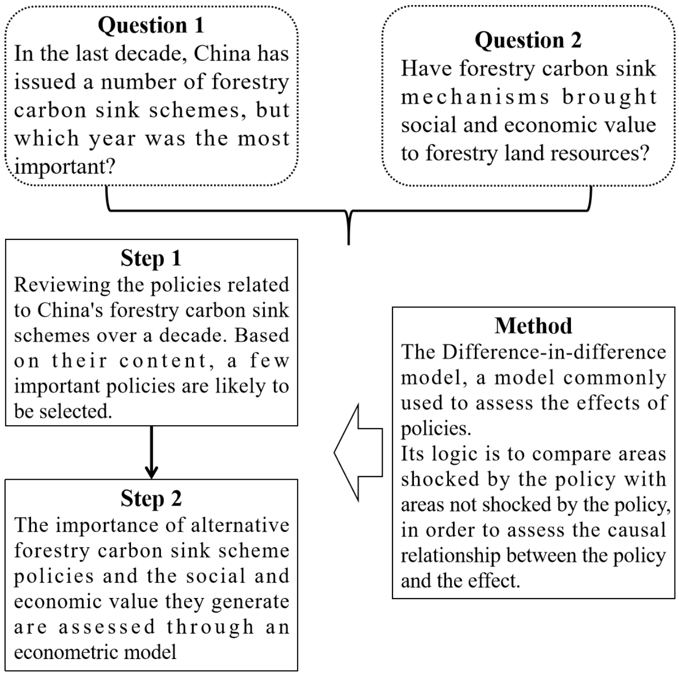

Figure 2. Guidance on research idea.

The remainder of this paper is structured as follows: Section 2 describes the materials needed for the study, including the details of the FCSM, the strategy for selecting the object of study (treatment group area), the basis for selecting variables, and the sources. Section 2 also shows the construction process of the research method (DID model). Section 3 reports the results of the study and the corresponding analysis, mainly including an analysis of the regression results of the DID model, an analysis of the social and economic value generated by the FCSM, and an extended discussion. Section 4 summarizes the previous findings and proposes policy recommendations.

2. Materials and Methods

2.1. Materials

2.1.1. Introduction to the Forestry Carbon Sink Mechanism

The forestry carbon sink is an important element in the process of "carbon peaking" and "carbon neutrality". The forestry carbon sink refers to the market-based means to participate in forestry resources trading, thus generating additional economic value (carbon sink). It can be divided into carbon sink afforestation, bamboo afforestation, forest management, bamboo forest management and grassland carbon sink, according to the type of subject matter. Carbon sink forests are forests created and managed according to certain methodologies and technical standards, and common methods include: the Climate-Community-Biodiversity Standard (CCB standard), the Verified Carbon Standard (VCS), the Kyoto Protocol Clean Development Mechanism (CDM), etc. Therefore, carbon sink forests are different from ordinary plantation forests in that they ensure that the project brings real, measurable and long-term carbon sequestration and environmental optimization effects for climate change mitigation [47].

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) is a basic framework for international cooperation to address global climate change and the cornerstone of forestry carbon sink implementation. The 1997 Kyoto Protocol further established three cooperative mechanisms for reducing greenhouse gas emissions: International Emissions Trading (IET), the Joint Implementation Mechanism (JI) and the Clean Development Mechanism (CDM). This was the prototype of the international carbon trading market, and also laid the foundation for the circulation of forestry carbon sinks. In China, the year 2011 is generally taken as the initial point for the rapid development of forestry carbon sinks. During the period from 2011 to 2021, many policies related to forestry carbon sinks were issued by relevant parts of China (see Table 1).

The above analysis shows that the FCSM is dependent on the ETS for its realization. In other words, the Chinese carbon emission trading market is the key to the implementation of the FCSM. Therefore, policies that contribute to the integration of the FCSM into the carbon emission trading markets are potentially important. From Table 1, there are two policies that have a turning point: the *Interim Measures for the Management of Voluntary Greenhouse Gas Emission Reduction Trading*[1] in 2012 (FCSM2012), and the *Guidance of the State Forestry Administration on Promoting Forestry Carbon Sink Trading*[2] in 2014 (FCSM2014).

FCSM2012 aims to promote ecological civilization, facilitate innovation in institutional mechanisms and give full play to the decisive role of the market in the allocation of resources for greenhouse gas emissions. FCSM2012 emphasizes that Chinese Certified Emission Reduction (CCER) projects can participate in carbon trading after application and certification. In terms of allowance management, free allocation will be the main focus initially, with paid allocation introduced in due course and the proportion of paid allocation gradually increased. For emission units that fail to fulfil their obligations to clear their allowances on time, the carbon trading authorities of the relevant regions will impose administrative penalties in accordance with the law. As a result, enterprises with excessive emission allowances will purchase forestry carbon sink transactions for offsetting.

Table 1. Policies related to the forestry carbon sink scheme in China.

Date	Policy Name	Release Department	Key Content
2011-10	Notice on the Pilot Project of Carbon Emission Trading	National Development and Reform Commission	Agreed to launch carbon emissions trading pilot in 6 regions.
2012-06	Interim Measures for the Management of Voluntary Greenhouse Gas Emission Reduction Trading	National Development and Reform Commission	Recorded and certified CCER projects can participate in carbon trading.
2014-04	Guidance of the State Forestry Administration on Promoting Forestry Carbon Sink Trading	State Forestry Administration	Improved and promoted CCER forestry carbon sink projects.
2018-01	Opinions on the Implementation of Rural Revitalization Strategy	State Council	Promoted exploring market-based compensation systems such as forest carbon sinks.
2018-05	Opinions on further liberalization of collective management rights	State Forestry and Grassland Administration	Promoted actively developing forest carbon sinks and further exploring market-based compensation systems such as forest carbon sinks.
2018-12	Action Plan for Establishing Market-oriented and Diversified Ecological Protection Compensation Mechanism	National Development and Reform Commission and other nine departments	Sound carbon offset mechanism were based on CCER; encouraged the development of forestry carbon sinks through carbon-neutral, carbon-inclusive and other forms of support.
2020-12	Interim Measures for the Management of Carbon Emissions Trading (for Trial Implementation)	Ministry of Ecology and Environment	Provisions on the proportion of carbon emissions that could be offset by forestry carbon sinks.
2021-03	Interim Regulations on the Management of Carbon Emission Trading (Draft Revision) (Draft for Comments)	Ministry of Ecology and Environment	Encouraged enterprises and institutions to carry out forestry carbon sink projects.
2021-04	Opinions on Establishing a Sound Mechanism for Realizing the Value of Ecological Products	State Council	Sound carbon emission trading mechanism.

FCSM2014 aims to accelerate the construction of ecological forestry and forestry for people's livelihoods, strives to increase forestry carbon sinks, and actively promotes forestry carbon sink trading. In terms of basic principles, FCSM2014 emphasizes the need to adhere to and improve the trading of forestry carbon sink projects for CDM. In terms of a carbon trading market, China's National Development and Reform Commission has identified Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen as the national pilot regions for carbon emissions trading, requiring the pilot regions to study and consider relevant measures, including forestry, in light of the actual local situation. The FCSM2014 encourages research on forestry carbon sink laws and regulations, implementation schemes, trading models and regulatory systems. Overall, FCSM2014 brings forestry carbon sinks to the forefront on its own, and is a guiding policy to promote the development of forestry carbon sinks.

These two policies play a key role in the construction of the forestry carbon sink market. Therefore, this study adopts these two years (2012 and 2014) as the FCSM impact times of the DID model, respectively.

2.1.2. Treatment Group

Since the DID model was used to conduct this study, it was necessary to distinguish treatment and control areas. Here, treatment areas refer to areas where the FCSM has been effectively implemented; the remaining areas are control areas. Forestry carbon sink projects exist in most provinces in China. Taking CCER as an example, by 2021 there will be more than 23 provinces in China with CCER carbon sink projects. Further taking CCER as an example, the incomplete 2021 statistics show that 23 provinces in China had implemented CCER carbon sink projects. However, the scale of forestry carbon sinks in most provinces is small and cannot be considered as an effective impact due to their own forestry location factors (growing environment, plantable forest area, etc.). It is therefore necessary to select representative areas from these regions as treatment group areas.

In this study, the larger the number of treatment group areas, the more difficult it is to accurately capture the social and economic value generated by the FCSM; however, the smaller the number of treatment group areas, the more it affects the accuracy of the DID model from a statistical perspective. In this case, it is common practice to select areas that are more affected by the FCSM as treatment group areas, according to the actual situation. Because forest carbon sink projects can be implemented in any area in China, the project sponsor will prioritize the benefits as well as the feasibility of the project. Therefore, factors such as a more suitable environment for carbon sink forestry and a larger area of forested land were the primary considerations for project sponsors. Given the actual conditions in China, this study decided to select eight typical areas as treatment group areas, including Heilongjiang, Jilin, Hubei, Zhejiang, Jiangxi, Fujian, Guangdong and Guangxi. The remaining 22 provincial areas (excluding Hong Kong, Macau, Taiwan and Tibet) were taken as the control group. Figure 3 shows the distribution of the treatment group areas. Table 2 shows the basic information on the treatment group areas, i.e., the reasons for their selection.

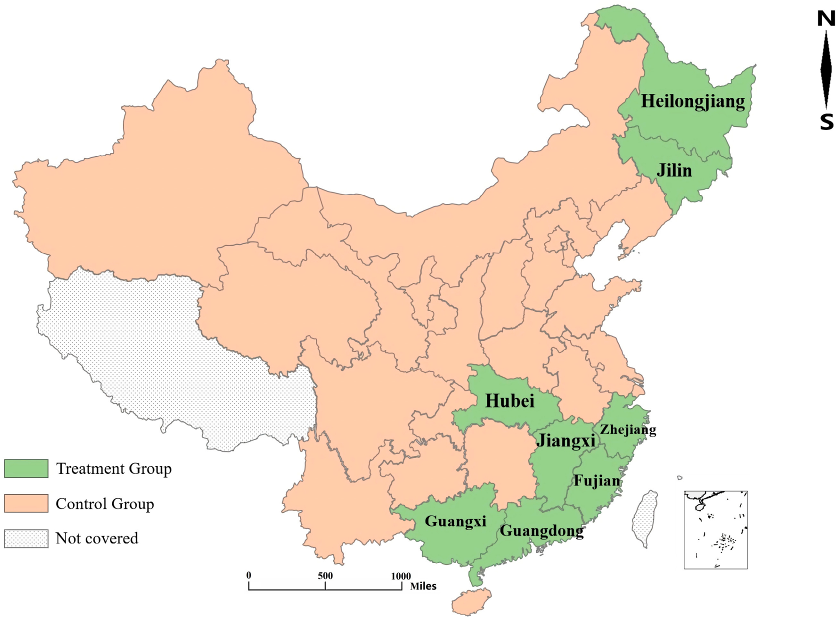

Figure 3. The distribution of treatment areas.

Table 2. Basic information on treatment group areas.

Province	Total Area	Landscape Features	Climate Environment	Forestry Resources
Heilongjiang	473,000 km^2	Characterized by "five mountains, one water, one grass and three fields".	(1) Continental monsoon climate; (2) Precipitation: 400–650 mm, concentrated in summer.	(1) One of the largest forestry provinces in China; (2) Forested land: 232,451 km^2.
Jilin	187,400 km^2	The eastern mountains and the central and western plains.	(1) Temperate continental monsoon climate; (2) Precipitation: 400–600 mm, with 80% concentrated in summer.	(1) Asia's largest planted forest: Jingyuetan National Forest Park; (2) Forested land: 87,690 km^2.
Hubei	185,900 km^2	56% mountains, 24% hills, 20% plains and lakes.	(1) Subtropical monsoonal humid climate; (2) Precipitation: 860–2100 mm.	(1) Forestry land: 92,801 km^2.
Zhejiang	105,500 km^2	High in the southwest and low in the northeast, dominated by mountains.	(1) Monsoonal humid climate; (2) Precipitation: 1600 mm.	(1) Known as the "southeast plant treasure house"; (2) Forest land: 66,797 km^2.
Jiangxi	166,900 km^2	Mainly hilly and mountainous.	(1) Subtropical warm and humid monsoon climate; (2) Precipitation: 1341–1943 mm.	(1) With 139.66 million acres of red soil, suitable for plant growth. (2) Forest land: 106,667 km^2.
Fujian	124,000 km^2	90% mountainous and hilly areas.	(1) Subtropical maritime monsoon climate; (2) Precipitation: 1400–2000 mm.	(1) Highest forest cover in China; (2) Forest land: 76,667 km^2.
Guangdong	179,725 km^2	Mountains (33.7%), hills (24.9%), tablelands (14.2%), plains (21.7%).	(1) Central subtropical, southern subtropical and tropical climate; (2) Precipitation: 1300–2500 mm.	(1) Forestry land: 100,342 km^2; (2) Fertile soil.
Guangxi	237,600 km^2	Mainly mountainous, hilly, terrace and plain types of landforms.	(1) Subtropical monsoon climate zone and tropical monsoon climate; (2) Precipitation: 1653 mm.	(1) Forest land: 148,667 km^2, and the mountains account for 69.7%; (2) High-quality plant growing environment.

Source: information from provincial government websites, summarized by the authors.

2.1.3. Variables Design

The explained variables aim to reflect the social and economic value of the output from the use of forestry resources. Therefore, this study designed the explained variables based on two dimensions, social value and economic value, respectively.

As mentioned above, the social value of the FCSM is mainly in the form of greening, which, if implemented effectively, will contribute to the construction of carbon sink forests, thereby increasing the area of green vegetation in a sustainable and long-term manner. The increase in green vegetation will help to reduce carbon dioxide in the atmosphere and release oxygen. At the same time, the increase in green vegetation helps to restore ecosystems, stop desertification and mitigate soil erosion. This study uses forest coverage (100 km^2), forest cover (%), forest stock volume (10,000 m^3) and area of nature reserve (100 km^2), respectively, to reflect the increase in green vegetation, indirectly showing its social value.

1. Forest coverage (FC) includes the area of coniferous forests of natural origin and artificial origin, the area of broad-leaved forests, the area of mixed coniferous forests

and the area of bamboo forests, excluding the area of shrub woodlands and the area of open woodlands. In addition, this indicator also does not include the area of green land for residents and the area of road and bank protection woodland of railroads, roads, rivers and ditches in the statistics. Since this indicator covers the subject of most forestry carbon sink projects, it can better reflect growth in the area of green vegetation.

2. The forest coverage rate (FCR) is the ratio of forest area to total land area, and is an important indicator of the actual level of forest resources and forest land occupation in a country (or region). Since its denominator is the total land area, the indicator will show significant changes only when the forest resources increase significantly.
3. Forest stock volume (FSV), also known as wood storage, is the total volume of standing timber in a forest. It is a measure of the abundance of forest resources in a country or region. General forestry production can be harvested from mature forests. Although most carbon sink forests cannot be harvested, China still classifies carbon sink forests as forest stock for statistical purposes.
4. Area of nature reserve (NR) is the area of a typical territory designated for the purpose of protecting various important ecosystems and their environments, saving endangered species, and preserving natural historical heritage. Nature reserves have a high-quality ecological environment and are very suitable for carbon sink projects. Although natural forests in nature reserves do not include forestry carbon sinks, their superior geographical locations and ecological environments are suitable for forestry carbon sink projects. However, at present, China does not allow forestry carbon sink projects in nature reserves. It is worth mentioning that the construction of nature reserves and the establishment of forestry carbon sink projects may develop synergistically. Therefore, the aim of this study is to investigate whether the FCSM promotes the construction of nature reserves.

According to the previous section, land management policies such as the FCSM can increase the economic output of forest land resources. The FCSM converts the amount of CO_2 absorbed by forests into a share of the carbon sink, which is traded and profitable via the carbon sink market. Although the economic output of forest land is reflected in the primary, secondary and tertiary industries, the base of these three is too large to reflect the increase in output due to the FCSM. Therefore, this paper only uses the gross forestry product indicator (RMB million) to reflect the development of forestry from an economic perspective.

In the literature that uses the DID model, the explanatory variable is an interaction term between a time dummy variable and an individual dummy variable. This explanatory variable captures whether a region is shocked by an event (policy) in a specific period. In this study, it is expressed as whether region i has implemented an FCSM policy in year t'. This study sets this dummy variable to $D_{it'}$. Details of the construction of $D_{it'}$ are shown in Section 2.2. In addition, as the study needs to compare the regression results of different explained variables, they are required to have common control variables. However, this requirement is clearly difficult to meet. At the same time, the spatial fixed effects variable (μ_i) used in this paper also functions as a control variable, controlling for the effects from provincial characteristics. Therefore, the inclusion of other control variables is not considered in this study.

2.1.4. Data Sources

The raw data of this paper are mainly from the *China Statistical Yearbook* (https://data.cnki.net/, accessed on 15 October 2022.) and the *China Research Database Service Platform* (https://www.ceads.net/, accessed on 15 October 2022.). Table 3 shows the results of descriptive statistics for these raw data. Due to significant order-of-magnitude differences between the data, their logarithmic form was used for the regression analysis.

Table 3. Descriptive statistics of raw data.

Variable	Units	Mean	Std. Dev.	Min	Max	Obs.
Forest coverage (FC)	100 km^2	685.4464	597.9148	1.89	2614.85	480
Forest coverage rate (FCR)	%	32.30269	18.3175	2.94	66.8	480
Forest stock volume (FSV)	10,000 m^3	40,185.84	49,560.69	33.24	197,265.8	480
Area of nature reserve (NR)	100 km^2	355.4916	558.4313	9	2183.49	453
Gross forestry product (GFP)	RMB million	14,600,000	18,100,000	16,987.5	96,800,000	419
$D_{i,2012}$	-	0.1500	0.3574	0	1	480
$D_{i,2014}$	-	0.4375	0.4966	0	1	480

2.2. Method: Difference-in-Difference Model

The difference-in-differences (DID) model is one of the more popular econometric models, and is often used in economics to assess whether there is a causal link between a shock generated by an event and an outcome. Furthermore, DID naturally alleviates the endogeneity problem of econometric models. The purpose of this paper is to examine the social and economic value of China's FCSM. Since FCSM implementations are event shocks, they meet the basic requirements of the DID model. The basic construction of the DID model used in this study is shown in Equation (1).

$$Y_{i,t} = \alpha + \beta * D_{it\prime} + \mu_i + \varepsilon_{i,t} \quad (1)$$

where, i denotes the serial number of a province ($1 \leq i \leq 30$), and t denotes the serial number of a year ($2005 \leq i \leq 2020$), t' is the time point of the event impact (2012 or 2014, Section 2.1.1 for detail). $Y_{i,t}$ are the set of explained variables. $D_{it'}$ is the key explanatory variable, whose coefficient β is our interest value. μ_i is a spatial fixed effects variable, also known as provincial fixed effects in this study. Because the 30 provincial areas each have their unique characteristics, it is necessary to use the variable μ_i to control for possible interference from these characteristics. $\varepsilon_{i,t}$ is the error term.

Assume that $D_{it'} = Treat_i \times Post_{t'}$. The $Treat_i$ term is the treatment group dummy variable. If i region belongs to the treatment group, then i = 1; otherwise, i = 0. The $Post_{t'}$ term is the time dummy variable. If t' is in and after the policy shock year, then $Post_{t'} = 1$; otherwise, $Post_{t'} = 0$. For $Post_{t'} = 1$ in this study, there are two situations, i.e., $t' \geq 2012$ and $t' \geq 2014$.

3. Results and Discussion

3.1. Results and Analysis of Baseline Regression

Introduction to the Forestry Carbon Sink Mechanism

Table 4 shows the regression results based on Equation (1). Among them, the $D_{i,2012}$ term is the result of using 2012 as the initial year of FCSM shock, whereas the $D_{i,2014}$ term is the result of using 2014 as the initial year of FCSM shock.

Table 4. Results of FCSM identifying forestry land use variables.

Explained Variables	ln (FC)	FCR	ln (FSV)	ln (NR)	ln (GFP)
$D_{i,2012}$	0.1142 *** (3.67)	4.2681 *** (6.60)	0.3202 *** (6.08)	−0.0361 (−1.00)	1.3507 *** (13.44)
$D_{i,2014}$	0.2096 *** (7.19)	4.7496 *** (8.44)	0.3961 *** (8.10)	−0.0360 (−0.55)	1.2529 *** (17.56)
Provincial fixed effect	YES	YES	YES	YES	YES
R^2 ($D_{i,2012}$)	0.2382	0.3995	0.2527	0.1055	0.3245
R^2 ($D_{i,2014}$)	0.3367	0.3803	0.4425	0.1055	0.5848

Note: t-value in parentheses; *** $p < 0.01$.

It can be found that the regression results with FC, FCR, FSV and GFP as the explained variables all passed the 99% confidence test, and the corresponding coefficients are positive. The regression results for the explained variable of area of nature reserve did not pass the 90% confidence level test. The above results indicate that the implementation of the FCSM significantly increased the forest area in treatment group areas, increased their forest cover and forest resource, and increased their forestry income. Meanwhile, comparing different FCSM shock years, it shows that the regression results with 2014 as the FCSM shock year were better than those of 2012, overall. The possible explanations are as follows: (I) there is a time lag due to the development of forestry carbon sink projects and the construction of carbon sink forests, which may be 1–3 years, according to the basic regulations of CCER projects; (II) the FCSM policies of 2012 and 2014 complement each other and their policy effects are superimposed. The proof towards these possibilities will need to be developed in further research in the future.

When the explained variable is FC, the coefficient of the $D_{i,2012}$ term is 0.1142 and the *t*-value is 3.67; the coefficient of the $D_{i,2014}$ term is 0.2096 and the *t*-value is 7.19. Obviously, the effect of FCSM2014 on the corresponding regional forest coverage is much more improved than that of FCSM2012. In other words, the eight treatment group areas had an overall enhancement of about 20.96% in forest coverage after the implementation of FCSM2014 compared to the control group areas.

When the explained variable is FCR, the coefficient of the $D_{i,2012}$ term is 4.2681 with a *t*-value of 6.60, and the coefficient of the $D_{i,2014}$ term is 4.7496 with a *t*-value of 8.44. Similarly to above, the stronger policy effect was generated by FCSM2014. This indicator is similar to the indicator for FC, but it is a relative indicator, as it takes into account the effect of the area of the region's own land area on the growth of the forest area. The results show that the forest coverage rate in treatment group areas increased by 4.7496 percentage points overall compared to control group areas after the implementation of FCSM2014, which also indicates that the FCSM has a greater impact on forest areas and has been able to significantly increase the level of forest coverage rate.

When the explained variable is FSV, the coefficient of the $D_{i,2012}$ term is 0.3202 and the t-value is 6.08; the coefficient of the $D_{i,2014}$ term is 0.3961 and the *t*-value is 8.10. It can be found that when 2014 was the impact year of the FCSM, the forest stock volume is elevated more than that of 2012, but the difference was limited. Of course, compared with the increase of the FCSM on forest coverage, its contribution to forest stock volume was greater, i.e., the treatment group areas had a greater increase of 39.61% in forest stock volume than the other areas, as a whole.

When the explained variable is GFP, the coefficient of the $D_{i,2012}$ term is 1.3507 with a *t*-value of 13.44, and the coefficient of the $D_{i,2014}$ term is 1.2529 with a *t*-value of 17.56. Unlike the previous variables, the enhancement of the gross forestry product by FCSM2014 was smaller than that of that of 2012, but the difference is not significant. It shows an overall increase of 135.07% in gross forestry output values in the treatment group areas compared to other areas after the implementation of FCSM2012. One possible reason is that the capital inflow of forestry carbon sink investment after the FCSM2012 led to an increase in gross forestry product, but the growth of carbon sink forests and further output gains take a certain amount of time, thus leading to a relatively smaller corresponding coefficient in 2014.

3.2. Analysis of the Social and Economic Value Generated by the FCSM

The results of Section 3.1 argue for the social and economic value of the FCSM, i.e., increasing the area of green vegetation and improving the economic output of forestry land resources. This subsection will combine the mapped data to show the impact effect of the FCSM more visually. The specific strategies are as follows.

After the implementation of the FCSM, it generated social and economic value. Therefore, with the policy shock as the node, there should be significant differences in forestry land use in the two sample intervals before and after. This study used maps to show these changes and agglomeration characteristics.

3.2.1. Social Value Generated by the FCSM

The social value generated by the FCSM is reflected in the construction of the greening, i.e., the increase in forestry coverage (FC), forestry coverage rate (FCR) and forest stock volume (FSV). Figure 4 shows the changes in FC and FCR between 2014 and 2020, respectively. The "Top ten", "Middle ten" and "Last ten" represent the range of positive change from high to low.

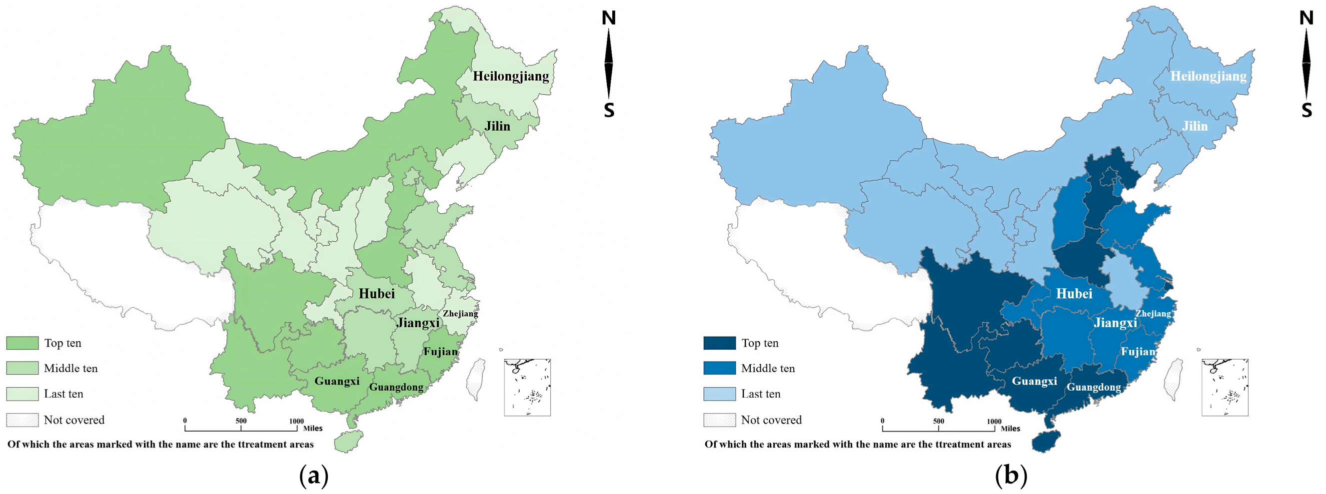

Figure 4. Distribution of forestry land use indicators. (**a**) Change of forestry coverage (FC); (**b**) Change of forestry coverage rate (FCR).

From Figure 4a, the "Top ten" regions are mainly located in southern and northwestern China, indicating that the FC in these regions has increased more after 2014. One important reason for the high growth of FC in southern China is the suitable climate and environment for plant growth; the large variation of FC in northwest China is related to its vast land area and abundant land resources, in addition to the climatic and environmental factors. However, among the eight treatment areas set in this paper, only Guangxi, Guangdong and Fujian are in the "Top ten". This indicates that the impact of FCSM policy on FC goes beyond the treatment group areas set in this paper, which is consistent with the previous section. Of course, this does not affect the conclusions of the econometric model, because the growth of FC in the remaining five areas is also above the average.

From Figure 4b, the "Top ten" regions are mainly located in southern China, indicating that the FCR in these regions has been increased to a higher extent after 2014. At the same time, Figure 4a,b show that the "Top ten" areas overlap to a greater extent, mainly in southern China. Combined with the analysis in the previous paragraph, it can be found that the increase of FC and FCR in southern China was higher after 2014, which indirectly reflects that the FCSM had a higher promotion effect on forest area in southern China than in northwestern China. An important reason for this is that northwestern China has a large volume of land and forest land, which provides the basis for a substantial increase in its forest area. This explanation also applies to Fujian, which has a larger increase in forest area, but has the highest forest cover in the country. Therefore, the increase in FCR in Fujian is limited and it is not a "Top ten" region in FCR.

Overall, the FC and FCR of 8 treatment areas improved more under the impact of the FCSM, while some of the 22 control areas also gained significant positive improvement. This is mainly concentrated in the southwestern part of China. This indicates that, on the one hand, these areas are rich in forestry resources and suitable ecological environments; on the other hand, there may be a spillover effect of the FCSM, which triggers the learning imitation behavior of neighboring regions. Finally, both Figure 4a and b show spatial clustering characteristics, which indicates that the impact of the FCSM is closely related to the locational characteristics of regions.

From Figure 5, the "Top ten" areas are mainly located in southern and northeastern China, indicating that the improvement of forest stock volume (FSV) in these areas is high after 2014. The reasons for the concentration in southern China are similar to the previous section. However, an important reason for the concentration in northeastern China is that the FCSM does not yet involve nature reserves, while northeastern China has many nature reserves with extremely rich forest stock volume. Among the "Top ten" areas, six of them are treatment group areas, namely, Guangxi, Guangdong, Fujian, Jiangxi, Jilin and Heilongjiang, which indicate that the FCSM is more prominent in improving FSV. Combined with the findings in Figure 5, it can be concluded that the FCSM has a significant policy impact on the southern region of China. Of course, due to data limitations, this study only analyzes and discusses the effect of the FCSM on forestry land use in the greening dimension based on four aspects: forest coverage, forest coverage rate, forest stock volume and area of nature reserve. It is believed that when more abundant data are available, more detailed and richer studies can be conducted using the methods of this study.

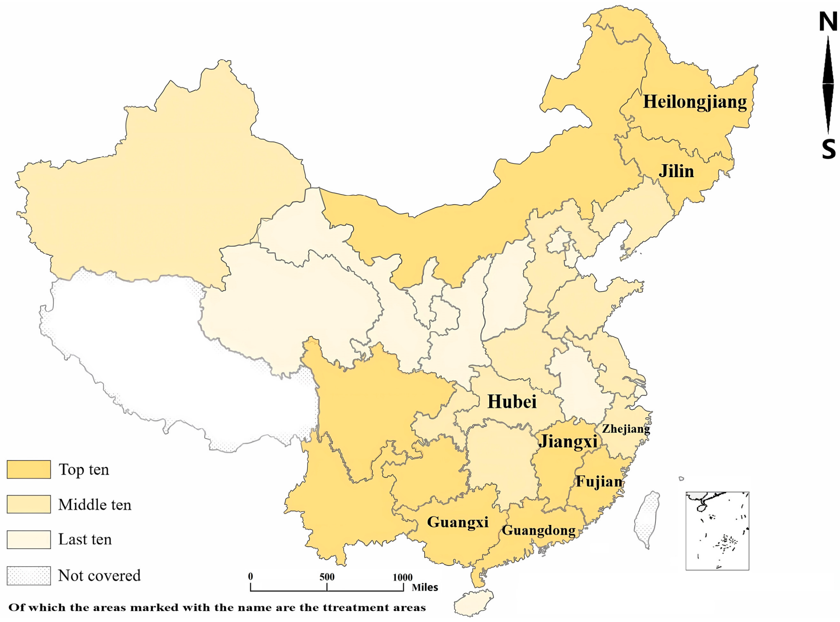

Figure 5. Change of forest stock volume (FSV).

3.2.2. Economic Value Generated by the FCSM

The economic value generated by the FCSM is reflected in the gross forestry production (GFP). Figure 6 shows the overall change in GFP between 2014 and 2020. The "Top ten", "Middle ten" and "Last ten" represent the range of positive change from high to low.

As shown in Figure 6, the "Top ten" regions are clearly clustered in southern China, indicating that the GFP growth in these regions was significant after 2014.

The possible reasons for the high change in GFP in the southern provinces are as follows: (1) since the currently opened carbon emission trading markets (Guangdong, Shenzhen, Fujian, Shanghai, Hube, and Chongqing) are mainly located in the south of China, it is easier for the neighboring provinces to learn about carbon emission trading and start related project activities; (2) many southern provinces have favorable ecological environments and richer land resources, and the plant growth cycle is significantly shorter than that in the north, which facilitates the successful implementation of forestry carbon sink projects; (3) the FCSM policy may have spillover effects. When treatment areas carry out forestry carbon sink activities and obtain objective benefits from them, their neighboring areas can be informed of the relevant information faster than other areas, so that they can imitate and learn from them.

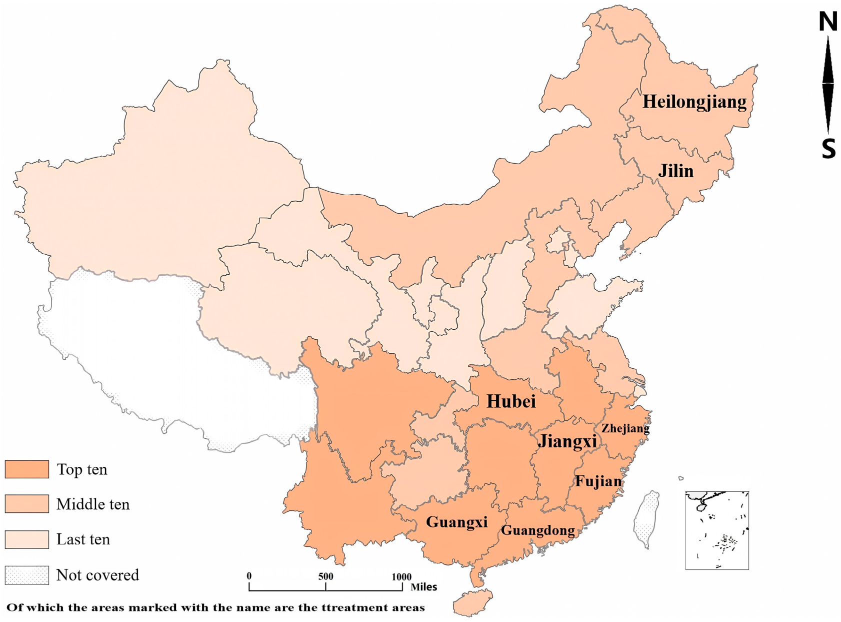

Figure 6. Change of gross forestry production (GFP).

Among the eight treatment areas in this paper, only Heilongjiang and Jilin in northeastern China are not among the "Top ten" areas, suggesting that FCSM policy has a significant policy impact on the southern region of China from the economic development dimension. Combined with the findings in Figure 4, it can be concluded that the FCSM has had a significant policy impact on the southern region of China. Of course, due to data limitations, this paper only uses a comprehensive variable, GFP, as a measure. It is believed that more interesting conclusions will be obtained in future studies using more microscopic data and richer indicators.

3.3. Discussion

The social and economic value of the FCSM as a land resource management tool has been discussed in this study. This subsection discusses the argumentation ideas and methods for the effectiveness of the FCSM, respectively. This section also analyses the shortcomings of the study and looks forward to future work.

3.3.1. Discussion on the Argumentation Ideas for the Effectiveness of the FCSM

The argument for the effectiveness of the FCSM is made by examining and comparing the social and economic value it generates. Kooten and Sohngen start from a cost–benefit perspective and show that not all forestry carbon sink projects are worthwhile. They find that the costs of sequestering carbon are some USD 3–280 per tCO_2, with variations from country to country. For example, in Canada and the USA, carbon sequestration costs range from a low of about USD 2 to nearly 80 per tCO_2 [39]. Bjørnstad and Skonhoft compare the carbon reduction effects of forests as a substitute for fossil fuels and as a carbon sequestration tool, based on the substitutability of commodities. The former reduces fossil fuel consumption and indirectly reduces carbon emissions, whereas the latter directly absorbs CO_2 from the atmosphere and thereby reduces carbon emissions. In comparison, the emission reduction effect of forests as a carbon sequestration tool is superior [40]. This view is supported by Ma et al., who found that replacing fossil energy with forest bioenergy was effective in reducing emissions in mature commercial forests where it already existed [42]. The above studies demonstrate the effectiveness of the FCSM in terms of cost–benefit ratio and commodity substitution. This paper argues for the effectiveness of FCSM policies from the perspective of factual evidence. This study used provincial panel data from 2005 to 2020 to verify the social and economic value of the FCSM using a DID model. As initiating a forestry carbon sink project is a commercial activity, if the project did not bring positive benefits to the project initiator, then such a project is not said to have had a large-scale impact, i.e., the social and economic benefits mentioned in this paper. Therefore, if the FCSM had a significant impact, then forestry carbon sink projects under the influence of the FCSM policy are worthwhile overall. In addition, Song and Peng point out that government subsidies, especially indirect subsidies to insurance companies, are beneficial to the development of forestry carbon sink projects [45]. With the support of the FCSM policy, China's forestry carbon sink projects have received support from local governments, which has also led to a reduction in their costs. Similarly, government support has also helped to strengthen investment in forestry fixed assets, which is important for developing forestry carbon sinks and increasing forestry GDP [46,48].

3.3.2. Discussion on the Argumentation Methods for the Effectiveness of the FCSM

The methods of examining the effectiveness of the FCSM are diverse. Lin and Ge used the SBM-DEA model to assess the role of carbon sink forests in mitigating the greenhouse effect and increasing regional production [34]; Sun et al. used the differential game model to derive the ecological utility (abatement mechanism) of forestry carbon sink projects [29]; Tian et al. used structural dynamic methods to predict the role of carbon sink forests in mitigating the greenhouse effect in the USA over the next century [49]; similarly, Kaipainen et al. studied the issue using the CO_2FIX model [50]. In contrast to these studies, this study is characterized by the use of an econometric model (DID model). This approach alleviates the problem of pseudo-causality. For example, when assessing the impact of the FCSM using methods such as the DEA model, the biggest struggle is the inability to identify a range of impacts as originating from FCSM policies. Similarly, Shi et al. used the difference-in-differences with variation in treatment timing (VTT-DID) model for their study. They examined the pro-poor role and ecological value of the FCSM from an industrial structure provincial perspective, using county-level data from Sichuan Province as an example [41]. However, their study took the implementation of forestry carbon sink projects as the node of DID, and there are significant differences between different forestry carbon sink projects. Therefore, its method has some degree of shortcomings. This study was better able to avoid this problem by taking the implementation of policy as the nodal point. It also avoided the problem that the findings of this study may only be applicable to one region by using 30 provincial regions in China as the target population.

3.3.3. Research Shortcomings and Future Work

The shortcomings of this study are as follows: (1) This paper lists nine major FCSM policies in China for the period 2011–2021. However, due to data length constraints (model requirements), the other seven FCSM policies are not examined in this paper. This, of course, does not affect the conclusions drawn in this paper. (2) In Section 2.1.2, the screening strategy for treatment group areas is not data dependent.

Accordingly, future work could be extended in two ways: (1) To use the methodology of this paper to compare the impact of FCSM policies across countries. (2) To investigate various other FCSM policies in China, especially those that are not yet supported by sufficient data.

4. Conclusions and Recommendations

In attempting to explore the economic and social value generated by sustainable management for land resources, this paper uses the example of the FCSM in China. Using panel data for 30 provincial regions in China from 2005 to 2020, and with the help of a DID model, the paper addresses two questions: (1) in which year the most effective FCSM policies were implemented; (2) whether the FCSM generates economic and social value. The main marginal contributions of this paper are that (1) it enriches the study of FCSM policies by drawing on the methodology of economics; (2) it designs a strategy that can effectively identify the social and economic value generated by the FCSM, compared to existing studies, by drawing on the DID model.

The conclusions show that:

1. The FCSM policies for 2012 and 2014 are all in effect. However, overall, FCSM2014 has had a stronger effect than FCSM2012.
2. In terms of social value, the implementation of the FCSM has significantly increased forest coverage (FC), the forest coverage rate (FCR) and the forest stock volume (FSV) in the eight treatment group provinces. Among them, the largest increase in forest stock volume was observed. However, the implementation of the FCSM has not contributed to the construction of nature reserves (NR). On the one hand, this is due to the fact that natural forests in nature reserves are not the target of FCSM; on the other hand, it may be due to the fact that there are no relevant incentive policies and regulations, so that investors do not include nature reserves in their investment visits. These promotion effects are characterized by spatial agglomeration. The spatial agglomeration characteristics of FC, FCR and FSV differed when the FCSM generated policy shocks, but all of them had the characteristics of "southern agglomeration".
3. In terms of economic value, the implementation of the FCSM has significantly increased the gross forestry product of the eight treatment group provinces. This promotion effect has spatial agglomeration characteristics. When the FCSM produced a policy shock, the increase in gross forestry production (GFP) was higher in southern China than in other regions.

Based on the above, it can be concluded that the FCSM contributes to social and economic value. Therefore, this paper makes the following recommendations on how to optimize the effectiveness of the FCSM.

1. The FCSM makes forestry land resources sustainable in terms of social and economic value. However, the development of the forestry carbon sink business in China is lagging behind. This paper finds that the 2014 FCSM policy is the most efficient forestry carbon sink policy, which verifies this point. Therefore, the current scale of forestry carbon sinks in China is relatively small and the system is still not perfect. In this regard, this paper puts forward recommendations to expand the scale of forestry carbon sinks and improve the related systems in order to give full play to the effectiveness of the FCSM policy. (1) Increase the proportion of forestry carbon sinks to offset corporate carbon emissions. According to Section 2.1.1, the value of China's forestry carbon sinks is that they can offset the carbon emission amount of polluting industries, but this percentage is 5% or 10%, which cannot meet the demand of many enterprises to offset carbon emissions. Therefore, the initial number as well as the allocation ratio of allowances issued in national and local carbon markets can be improved to increase the proportion of forestry carbon sinks offsetting carbon allowances. This pathway can directly increase market demand for carbon sinks, thereby stimulating the establishment of forestry carbon sink projects. (2) Simplify the management process of forestry carbon sink projects. Forestry carbon sink projects are characterized by large areas, multiple elements, and complex measurement and monitoring methods, which constrain the efficiency of their development and implementation. In order for enter-

prises to actively participate in promoting forestry carbon sink projects, it is necessary to simplify the relevant processes and clear the project obstacles for participating entities, for example, through the use of innovative accounting methods, such as using remote sensing, big data and other means. This pathway is an important element in improving the forestry carbon sink system, which can speed up and smooth out forestry carbon sink projects and lower the entry threshold. (3) Developing regionally differentiated FCSM policies. The FCSM has the most obvious positive impact on the southern regions of China, but there is variability in the impact on northern China (northeast and northwest). This is related to the locational factors in the northern region. Therefore, policymakers can better leverage and incentivize the impact of the FCSM on different regions by developing policies with regional differentiation.

2. The FCSM is unable to act on the expansion of nature reserves. At present, FCSM policies are not allowed to be carried out in nature reserves, public welfare forests and other forest stands. However, it cannot be denied that the areas around nature reserves have rich carbon sink potential. In the future, we can study new development strategies, state-sponsored development and other means to release the carbon sink potential of related areas.

Author Contributions: Conceptualization, H.L. and T.H.; methodology, H.L.; software, T.H.; formal analysis, H.L.; writing—original draft preparation, H.L. and T.H.; writing—review and editing, T.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Notes

[1] Original information from: http://www.gov.cn/gongbao/content/2015/content_2818456.htm, accessed on 5 May 2022.

[2] Original information from: http://www.forestry.gov.cn/sites/main/main/gov/content.jsp?TID=2088, accessed on 5 May 2022.

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