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Research Article

Progress of forest carbon sink research in China from 2000-2022 — a visual analysis based on CiteSpace

Abstract

As the mainstay of the terrestrial ecosystem, forests sequester carbon which is an important path to achieve the "double carbon" vision in China. Experience many years of ecological civilization construction in China, forest carbon stock has increased year by year and forest carbon sink function has been greatly enhanced, which has played a positive role in the overall increase of global forest carbon sink function. In this paper, there are 428 documents on forest carbon sink research topics in China National Knowledge Infrastructure (CNKI) database. We used CiteSpace software to analyze process the important domestic academic literature, figures and research hotspots in the field of forest carbon sink research were sorted out by means of knowledge mapping. The main results of the analysis show that: ①The research on forest carbon sinks has started relatively late in China, and the number of published articles has shown a rapid upward trend, indicating that the research field is increasingly mature. ②China has achieved many achievements in the research of forest carbon sinks, such as forest carbon sink measurement, and the carbon sequestration capacity of different tree species. ③Researching forest carbon sinks, adopting corresponding measures for forest carbon storage, can increase the carbon storage per unit area of forests, enhance the carbon sink effect, and provide important technical support for the sustainable development of forests under the goal of low carbon development.

Keywords: forest carbon sink, forest productivity, forest carbon sink ecological value, carbon sink measurement, citespace

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Introduction

The concept of carbon sink originates from the *United Nations Framework Convention on Climate Change* adopted by the United Nations General Assembly on May 9, 1992, which defines a sink as any process, activity or mechanism that removes greenhouse gases, aerosols or precursors of greenhouse gases from the atmosphere.[1] *The Kyoto Protocol* adopted in 1997 recognized the contribution of forest carbon sinks to mitigate climate warming and required the strengthening of sustainable forest management, vegetation restoration and conservation.[2] It allowed developed countries to undertake afforestation and reforestation carbon sinks projects in developing countries, and use the carbon credits generated by the projects to offset their domestic emission reduction targets. Carbon sinks have obvious cost advantages and great ecological value without compromising economic development, and have attracted widespread attention from governments and academia. China joined the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and is actively involved in global climate governance.[3] In 2020, China's carbon emission intensity decreased by 18.8% compared to 2015, and by 48.4% compared to 2005. China surpassed its commitment to the international community of reducing carbon emissions by 40-45% in 2020 and has cumulatively reduced carbon dioxide emissions by approximately 5.8 billion tons fundamentally reversing the trend of rapid carbon dioxide emissions growth.President Xi Jinping has proposed that China will achieve Peak Carbon by 2030 and Carbon Neutrality by 2060; the Central Economic Conference of the Communist Party of China (CPC) has included "doing a good job in achieving peak carbon and carbon neutrality" as an annual priority task, demonstrating global determination and confidence in achieving peak carbon and carbon neutrality. In 2020, the Central Economic Work Conference included the implementation of large-scale national greening actions and the enhancement of ecosystem carbon sink capacity as the key tasks of China's economic work in the opening year of the 14th Five-Year Plan.[4] As an important means to achieve carbon peaking and carbon neutrality, research and practice on forest carbon sink measurement and carbon sink capacity enhancement have been continuously promoted. Therefore, further research on forest carbon sinks has become a hot topic in academic circles.

In recent years, studies research on forest carbon sinks in academia mainly involves: the role of forests in carbon sequestration and the factors influencing carbon sequestration, the expansion and application of forest carbon sequestration function and influencing factors of forests, expansion and application of forest carbon sink estimation methods, assessment of the status and potential of forest carbon sinks, optimization of forest carbon sink estimation models, and revelation of the spatial and temporal distribution pattern of forest carbon sinks.[5] Some scholars in China and abroad have summarized the estimation methods of forest carbon sinks and the influencing factors of forest sequestration capacity. Zhu[6] conducted a study on the spatial demand for forest carbon sinks in industrial sectors of 29 provinces (regions and cities) across China. Yao.[7] empirically analyzed the static efficiency and dynamic evolution of forest carbon sinks in 29 provinces (cities and districts) in China using the forest stock expansion method and DEA-Malmquist method. Lin .[8] used the wet burning method to determine the carbon content of major silvicultural tree species in South China, taking into account their growth, exploring and comparing the carbon sink capacity among tree species, families and vegetation types. Xu[9] summarized the mechanism of biological factors, climatic and soil factors on forest carbon sequestration based on the hierarchical relationship among the influencing factors.

However, most of the existing summaries focus on the introduction of specific measurement methods, rarely sort out and evaluate the correlations and differences between the measurement methods, lacking a comprehensive review and evaluation of the correlation and differences between the methods, and a long-term development perspective, which cannot reflect the development of forest carbon sinks in China. Therefore, this paper focuses on forest carbon sink measurement methods, the practical effects of forest carbon sinks and the carbon sequestration capacity of tree species to provide a more comprehensive and accurate forest carbon sink measurement method for China, further outline the effects of forest carbon sinks and the carbon sequestration capacity of tree species. It also provides an effective reference for China on the road to "Carbon Peak and Carbon Neutral".

Data sources and research methods

Data sources

In this paper, we used the Chinese academic research papers in the general database of China Knowledge Network Infrastructure (CNKI), and the terms that may cover the research on forest carbon sink. The search analysis and classification were carried out based on the topics, keywords and titles of the Chinese academic research papers in the database, such as "forest carbon sink", "forestry carbon sink", "carbon sink measurement", "forest carbon sink trading", "carbon storage", etc. Considering the large amount of literature on carbon sinks in the database, the time zone of research papers selected in this paper was set from 2000 to 2022. After systematic searching, matching and eliminating duplicate papers, 428 relevant papers were finally selected and exported in Refworks format.

Research methods

In terms of research methods, firstly we used Citespace software for literature analysis, imported CNIK's literature into the software, conducted keywords co-occurrence, cluster analysis and research author analysis through Citespace software to obtain the corresponding type mapping. Secondly, we used Origin software for statistics and graphing of the number of articles posted, so as to express the research trends of forest carbon sinks in the past twenty-two years.

General characteristics of China's forest carbon sink in the past 22 years

Temporal distribution of the literature

It can be seen that, the research on forest carbon sinks in China has shown an obvious upward trend (Figure 1). Although the number of publications declined from 2010 to 2014, the number of publications on forest carbon sinks in China has surged in the past five years, which shows that forest carbon sinks are still a hot topic today. Since 2018, the total number of articles about forest carbon sinks in China has increased year by year, with a minimum annual increase of 20 and a maximum increase of 47. Based on the annual publication characteristics, research on forest carbon sinks in China can be divided into three stages.

The first phase was from 2000-2010, has demonstrating a slow and vibrating increase. As early as 1997, in order to mitigate the global warming trend, *The Kyoto Protocol*, an international act to limit carbon dioxide emissions from all countries in the world, was adopted by representatives of 149 countries and regions in Kyoto, Japan, which recognized the important role of forests in reducing carbon emissions. This led to the formation of the international "carbon emissions trading system" (referred to as "carbon sinks"). In December 2003, the nineth Conference of the Parties to the *United Nations Framework Convention on Climate Change* (UNFCCC) was held, the international community reached a consensus on the inclusion of afforestation and reforestation activities in carbon sink projects, new operational rules were established to officially launch the implementation of afforestation and reforestation projects. This has created favorable conditions for the official launch of afforestation and reforestation projects. In this environment, forestry carbon sink measurement has gradually become a research hotspot, which mainly involves the study of functions and pathways.

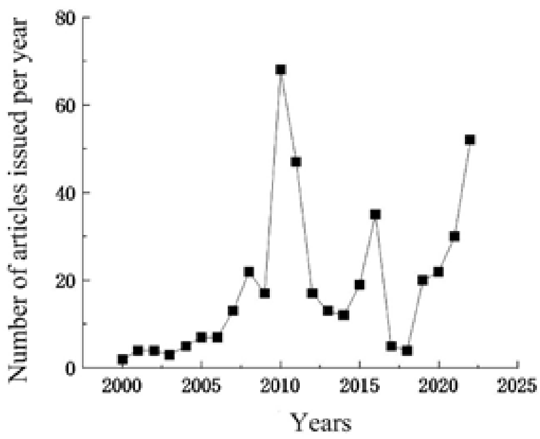

Figure 1 Annual issuance of forest carbon sink from 2000-2022.

The second phase is from 2011-2018. Although the overall trend of this period is decreasing, the number of publications has increased significantly compared with the previous period. Most of the articles published annually are above 15. In 2011, in accordance with the requirements of the "12th Five-Year (2011-2015) Plan" to "gradually establish a carbon emission trading market", China launched the pilot project of carbon emission trading in seven provinces and cities, in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen. period. The 2012 Qinghai Afforestation Project.[10] is the first carbon sink afforestation project supported by the China Green Carbon Sink Foundation with the main goal of accumulating carbon sinks and addressing climate change. The implementation of this project, in addition to generating the expected 205 800 tons of carbon sink in the next 30 years, will create a good living environment and natural landscape, and have a catalytic effect on spreading the concept of green and low-carbon. With the concepts of low carbon, carbon sink and carbon source, carbon footprint and carbon life cycle being proposed and emphasized, the importance of forests in reducing carbon emissions is becoming more and more prominent. In addition to the traditional methods of introducing forest carbon sink calculations, sophisticated calculations have been started for forest carbon sinks in a particular region. The focus is on estimating regional carbon sinks for certain vegetation and tree species types, for example, studies on biomass carbon sinks of China's forest vegetation and grasslands, estimation of net productivity of terrestrial ecosystems in China using ecological process models.

The third phase is after 2018, which is in a state of continuous increase with significantly higher annual publication volume than previous years. The 20th National Congress of the Communist Party of China proposed the goal of enhancing ecosystem carbon sink capacity and implementing major ecological protection and restoration projects.

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It proposed to implement major projects for ecological protection and restoration, and carry out integrated protection and restoration of mountains, water, forests, lakes, grasses and sands through deeply promote large-scale national greening action, consolidating the achievements of returning farmland to forest and grass, implement the project of precise improvement of forest quality, and continuously increase forest area and accumulation. After the General Office of the State proposed the carbon peak carbon neutral target, various local policies responded positively and accelerated the introduction of carbon emission reduction programs one after another to calculate the current carbon emissions and absorption. Domestic research on ocean carbon sinks has further intensified, and coupled with the linkage between various disciplines becoming closer, the scope of research on forest carbon sinks has expanded and the methods for calculating forest carbon stocks have become diverse.

Study authors

There are 306 nodes in the selected literature (Figure 2). The number of nodes is the number of authors, and the size of the nodes indicates how many articles the authors have published, the nodes are larger, the more articles the authors have published and the research is more active. There are 306 authors in the selected literature, and the number of articles by a single author is small, and most of the articles are the result of collaborative research by multiple scholars. The largest author of the nodes is Qiu Mengyuan, followed by more than 10 scholars including Wu Baohan, Zhang Zhenqi, Zhang Pingping, Li Tingting, Yang Gaimeng, Li Feng, Wang Zelin, Cai Huiwen, and Liu Jinshan (Table 1). The links between nodes indicate the depth of collaborative relationships, and the thicker the line the more collaborations. The chart has a total of 209 links, indicating a certain level of collaboration among Chinese scholars. Among them, such as Qiu Mengyuan and Wu Baohan in the same group, Zhang Pingping, Li Tingting, and others, as well as groups centered around Liu Jihua, have formed their respective circles of cooperation. The higher network density, the closer collaboration between authors and the healthier research network. The density of the keyword co-occurrence network is 0.0045, indicating that the cooperation among scholars is not very close and a tight collaborative network has not yet been formed. The color of the nodes represents different years, with redder nodes appearing earlier and yellower nodes appearing late.

Table 1 Ranking of authors' publications (top ten)

Authors	Number of articles/article
Qiu Mengyuan	23
Wu Baohan	22
Zhang Zhengqi	17
Zhang Pingping	17
Li Tingting	12
Yang Jiameng	11
Li Feng	10
Wang Zelin	8
Cai Huiwen	7
Liu Jinshan	4

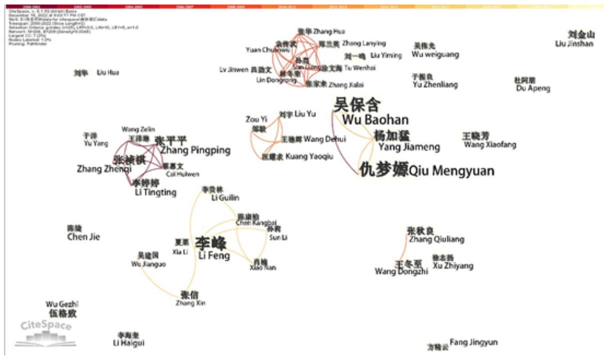

Figure 2 Author's map of forest carbon sink measurement studies, 2000-2022.

Research hotspot analysis

Software CiteSpace was used to analyze the keyword mapping of 428 documents, the keyword co-occurrence mapping in Figure 3 and the keyword clustering mapping in Figure 5 were obtained. Figure 3 can reveal the high frequency hotspots in the research field and reflect the mainstream direction of the research field. Figure 4 reflects 321 hotspots, the links of the nodes indicate whether there is a connection between the keywords, and the thickness indicates the relevance of the keywords. There are 806 links in the plot, indicating that several major keywords (such as carbon stock, forest density, carbon density) have some connections with other keywords. The higher network density means the stronger correlation between keywords, which is 0.0157 in the plot, indicating that the links between keywords are not strong and the correlation is low. The size of the circles of the nodes represents the frequency of the keywords. From the results, carbon stock is the keyword with the highest frequency in all the analyzed literature, followed by carbon sink, forest carbon sink and carbon density, the frequency of the top 10 ranked keywords is shown in Table 2. The color of the nodes represents the year of appearance, with the more yellow nodes appearing earlier and the more red nodes appearing later.

Table 2 Ranking of the number of keyword occurrences (top ten)

Key words	Frequency of occurrence	Frequency of occurrence
carbon stock	128	0.63
carbon sink	94	0.48
carbon density	72	0.22
biomass	58	0.15
forest carbon sink	50	0.39
forest	29	0.1
planted forest	23	0.08
climate change	18	0.12
carbon accounting	13	0.05
papers accounting	11	0.03

In order to explore the deep connection among the research hotspots, Figure 5 used the clustering function of CiteSpace to perform keyword clustering analysis. Since the selected journals were all Chinese journals, K clustering under LLR algorithm was adopted, and seven labels were selected. The Q value of this graph is 0.5468 (higher than 0.3), indicating a significant clustering structure, and the S value is 0.8672 (higher than 0.5), indicating a reasonable clustering

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structure in which keywords have both connections and independence the largest cluster among the seven labels is carbon density, indicating that this topic is the hottest research point and cross-combined with other research hotspots and diversified development, which is consistent with the conclusion obtained in Figure 4.

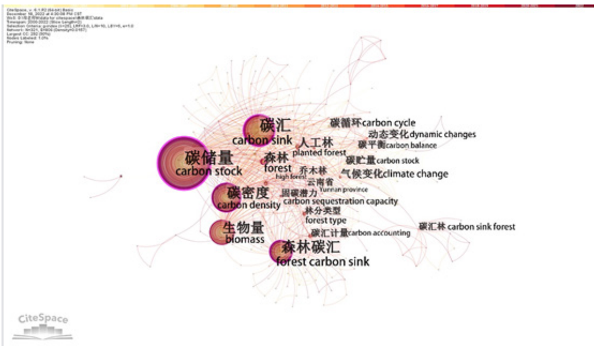

Figure 3 Keyword co-occurrence mapping.

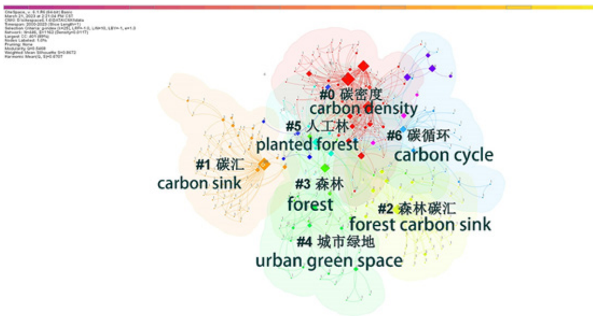

Figure 4 Keyword clustering mapping.

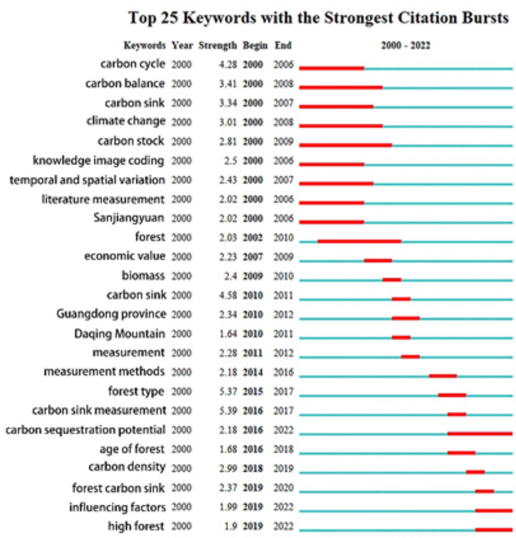

Figure 5 Keyword mutation analysis.

Through CiteSpace's burst detection technique, which detects nodes with increased citation frequency or co-occurrence frequency within a certain time period, it is possible to predict the research direction in the field. In this study, the CNIK data were analyzed for keyword emergence, and the 25 keywords with the highest emergence intensity were selected (Figure 5). The results of the keyword emergence analysis show that the literature in the field of forest carbon sink measurement frontiers covers a wide range of keywords, and keywords from different subject categories emerge at different times. As can be seen in the figure, the research area is divided into 2 phases as follows:

(1) The key words from 2000 to 2010 have been increasing, including "carbon cycle", "carbon balance", "climate change" " carbon source", "carbon sink" and so on. In terms of the duration and intensity of the keywords, carbon sink-related research has gradually gained attention in China since 2000; from the content reflected by the keywords, the research on carbon cycle and carbon storage has received more attention in carbon sink research; The research results of CAS also show that the carbon sink of forest ecosystem in China accounts for about 81.3% of the total carbon sink of terrestrial ecosystem in China between 2001 and 2010. This shows that forests are the most important carbon sink in terrestrial ecosystems, and especially in China, forest carbon sinks have a clear advantage over other ecosystems. In addition, knowledge mapping to understand forest carbon sinks has been used at that time.

(2) From 2011 to 2022, the largest number of keywords began to appear, including "carbon sink measurement", "measurement method" and "carbon density". The duration and intensity of the keywords indicate that forest carbon sinks received more attention from scholars in 2010, the content of the keywords indicates that calculating carbon density and carbon sequestration potential is a popular method for scholars to conduct research. For example, Dong[11] estimated the carbon sink of forests in Liaoning Province by using the conversion factor continuous function method; Zhang[12] established a regression model for forest carbon sink accounting by collecting data on forest stock, growth, dieback and harvest from 1990 to 2007 using the stock conversion method.

Progress in the main areas of forest carbon sink research in China

Forest carbon sink measurement methods

The calculation method of forest carbon sink is the basis for evaluating the ability and ecological benefits of forest carbon sink and is an indispensable part of carrying out forest carbon sink projects or activities. At present, there are various methods for estimating forest carbon sink in China, mainly about biomass method, accumulation volume method, eddy correlation method, relaxed eddy accumulation method and forest soil carbon determination method. Various carbon sink estimation methods are very different in terms of applicability and research accuracy,[13] the comparative analysis of advantages and disadvantages is shown in Table 3.

Biomass method: The biomass method, the stand biomass carbon counting model, that calculates carbon content in biomass by directly or indirectly measuring forest plant biomass and multiplying it by carbon percentage contained in the biomass (carbon fraction, CF) Stand biomass was estimated using the biomass factor method, the anisotropic growth equation method, and the woody volume source biomass method. In the calculations, local parameters and the latest international reference values were used in preference to the IPCC reference values when they were not available.[14]

Zhang .[15] used the calculation method of forest carbon stocks, greenland information and combined with field survey data, to estimate the carbon stocks of typical greenland recreation and health parks in Shanghai. Li.[16] and other scholars used the carbon stock estimation methods commonly, by international organizations such as IPCC and other countries around the world to summarize the current status of carbon stocks in China as a whole in each province and estimated the carbon stocks of different forest species, forest stand origins and age groups in China. Chen[17] used the main data of Hubei forest resources type II survey results (1999) to project the biomass and carbon stocks of Hubei forests using the conversion factor continuum function method and estimated the economic value of forest carbon sinks in the whole Hubei province.

Table 3 Comparison of common forest carbon sink calculation methods

Method name		Advantages	Disadvantages
Biomass methods	Average biomass method, Average conversion factor method, Conversion factor continuous function method	Straightforward, easy to calculate, wide range of applications	The requirements of the model are relatively high and require in-depth study of biomass models for different tree species in different regions. Neglect of below-ground carbon content and large calculation errors.
Accumulation volume method		More convenient calculation, wide range of applications, high accuracy.	The conversion factor is too absolute to calculate the influence of other factors (such as climate, etc.) on it, and the calculation error is large.
Remote sensing estimation method		Save time and effort with accurate data.	Influenced to varying degrees by terrestrial organisms.
Eddy correlation method		Forest CO_2 fluxes can be calculated.	The equipment is expensive, the operation and calculation process is complicated, and the error is affected by the season.
Relaxed eddy accumulation method		Direct tracking of atmospheric CO_2 exchange with forests.	The equipment is expensive, the operation and calculation process is complicated, the detection is difficult, and the error is affected by the season.

Accumulation expansion method: The method of carbon estimation is the forest stock data to obtain the biomass and convert it into the carbon sequestration of the forest. The specific principle is to sample and measure the main tree species in the forest to obtain the average capacity of the main tree species (t/m^3), using the forest stock data to obtain the biomass, and then use the conversion factor between carbon mass and biomass to finally obtain the amount of carbon sequestered in the forest.[18]

Zhang[19] studied the forest carbon stock in Fujian Province from 1978 to 2018 based on the accumulation method and found that the forest carbon stock showed an increasing trend; Shi .[20] used the accumulation method to measure the forest carbon sink in Beijing from 2009 to 2013 showing that the growth rate of carbon stock in planted forests was higher than that in natural forests; Zhang.[21] used the forest stock expansion method to measure forest carbon sinks in Yunnan Province from 2007 to 2017, and used the market value method to assess the economic value of forest carbon sinks. The results showed that the forest carbon sink in Yunnan Province has been increasing steadily and the economic value has been growing, and it has great potential to develop a forest carbon sink. Using this method, Huang.[22] accounted for the total carbon sink as well as the carbon stock of tree forests in Inner Mongolia forests from 1999-2018, the results showed that the forest area, cover, forest stock and live tree stock in Inner Mongolia showed an increasing trend.

Remote sensing estimation method: Remote sensing estimation method is based on remote sensing technology (GIS) to obtain various vegetation status parameters and combine with a ground survey to calculate the biomass distribution of forest ecosystem by analyzing the spatial classification and time series of vegetation. The main statistical methods used are regression analysis, mainly using forest aboveground biomass as the dependent variable, and remote sensing spectral information, vegetation indices, and texture features as the independent variables to estimate the forest aboveground biomass in the study area through regression analysis and convert it to carbon storage according to the carbon coefficient.

Yin[23] used statistical measurement methods to obtain the basic information about Wuhan Garden Expo Park site through ENVI and GIS software, combined with construction drawings and on-site sampling research. It evaluated the vegetation, soil and water bodies of the park separately. Yin[24] took urban green areas within the fifth ring in Haidian District, Beijing as an example, and used the remote sensing data of HMS-2 as the information source to extract 139 sample sites in four categories of green areas, namely, park green areas, protective green areas, accessory green areas, and regional green areas, for carbon storage estimation studies. It was found that there were significant differences in the carbon stock values and normalized vegetation index (NDVI) of each type of sample site, the fitting model between NDVI and carbon stock was constructed by regression analysis.

Forest carbon sink practice effect

Different carbon sequestration mechanisms have different carbon sequestration effectiveness, thus resulting in different forest carbon sequestration effects. Generally, technical planning is differentiated based on effects. Forest carbon sequestration effects can be explored from the ecological, economic, and spatial aspects. The ecological, economic, spatial effects of forest carbon sequestration and other ecological systems such as ocean carbon sequestration have similarities and differences due to differences in the main contributors to carbon sequestration and the ways in which carbon sequestration is calculated. However, the ultimate goal is to improve the environment and achieve sustainable development of human society.

Economic effects: In recent years, the Chinese government has accelerated the construction of local pilot projects of carbon emission trading and the national carbon emission trading market. As a carbon trading item in the carbon emission trading market, forest carbon sinks can not only improve the financing environment of forestry industry, but also provide a mechanism to realize the value of forest carbon sinks.[25]. By incorporating carbon sequestration in forest carbon sequestration trading, financial guidance and catalytic role have been fully played, further improving the understanding of carbon finance by banking and other financial institutions, and promoting the active development of diversified and personalized carbon finance products. On the basis of traditional carbon finance products such as green credit, green bonds, innovative carbon finance products are continuously introduced to support businesses and individuals to participate in the forest carbon sequestration trading market.

Ecological effects: Forests are not only an important carrier of the global carbon cycle but also the largest carbon storage system in the world. The total global carbon reserves are about 248 million tons, of which the carbon content of forest ecosystems is about 1.15 trillion tons. It not only has the effect of carbon reduction, but also has the effect of purifying the atmosphere and reducing harmful substances, known as "the most efficient carbon dioxide absorption device. "Research shows that in an area of 1 ha, if the vegetation cover reaches 40% or more, it can absorb 1000kg of harmful gases and CO_2. Nowadays, in order to actively respond to global climate problems, countries all over the world are taking strong measures, such as restoring damaged ecosystems, planting trees to increase the amount of carbon absorption and reduce the level of CO_2 in the atmosphere. Forest carbon sinks improve air quality and provide a suitable living environment for human beings. Therefore, forest carbon sinks have a certain ecological value.[26]

Social effects: Forest carbon sink has a strong public benefit, its role in improving air quality and slowing down global warming are beneficial to all mankind. Afforestation and effective development of forestry resources can help strengthen the function of forest carbon sinks, which can not only create social wealth but also increase employment opportunities. To some extent solving social employment problems, and thus maintaining social stability.Forest carbon sink can provide a large number of jobs for rural people, increase farmers' income, provide farmers with a way to get rich in all aspects in multiple ways, and actively respond to the national "three rural-agriculture, rural areas and farmers□" policy. In addition, the carbon sink function can improve the physical and chemical properties of soil, increase the fertility of soil, and positively promote afforestation and reforestation work. After achieving certain results in afforestation, the accessory value of the forest can be developed such as the development of ecotourism projects and the establishment of natural eco-reserves to provide opportunities for human contact with nature, enhance environmental awareness, and increase awareness of forest carbon sequestration.

Forest carbon sink and carbon sequestration capacity of tree species

The carbon sequestration capacity of different species and forest stands can vary significantly because they are located in different forest ecosystems and are affected by factors such as *Schima superba, Eucalyptus spp*, *Acacia confusa* and *Falcataria falcata*have high carbon sequestration capacity, while slow-growing species, economic forests and coniferous forests have low carbon sequestration performance locally in Dongguan.[27]

The results of a study by Lin.[28] based on 11-year-old tree species in Dongjiang forest in Guangdong Province showed that the carbon content of different species, families and types differed to a highly significant level; the carbon content of the same species was in the order of main stem > side branches > bark > leaves, and the carbon content of different species was in the order of evergreen conifer > evergreen broad-leaved forest> deciduous broad trees, and 12 species such as *Podocarpus formosensis*, *Pinus massoniana-Nageia fleuryi* and *Magnolia sumatrana* are high carbon content species, which can be widely used in the carbon sink afforestation in the southern subtropical region of South China. The more suitable carbon sink species in Hubei province are *Ginkgo biloba, Quercus variabilis, Liquidambar formosana, Pistacia chinensis* and *Cinnamomum camphora*; the more suitable carbon sink species on limestone mountains or alkaline soils are cypress and cypress; and the more suitable carbon sink species in high-altitude areas in western Hubei are *Keteleeria davidiana* and *Keteleeria fortunei* .[29]. In addition, in order to make the selection of carbon sink species more precise in each region, the province was divided into five regions: Northeast Hubei, Southeast Hubei, Southwest Hubei, Northwest Hubei, and Jianghan Plain.And the more suitable carbon sink species were determined for each region. Therefore, the selection of tree species for carbon sink afforestation should be tailored to local conditions and suitable trees to give full play to the maximum value of tree species.

Discussion and Conclusion

Discussion

Forest ecosystems have high biomass, carbon sequestration and net productivity. Research on forest carbon sinks with cultivation of carbon sink forests can advance the need for market-oriented forest ecological services in China.[30] With the development of forest carbon sink assessment and technology, more and more studies are used to address the problems faced by human beings. The overuse of fossil fuels and deforestation have led to increasing concentrations of greenhouse gases in the atmosphere, the global temperature is rising. The agreement on greenhouse gas emission reduction adopted at the Paris Climate Conference has made an important contribution to achieving a global temperature increase below 2°C from pre-industrial levels within the 21st century.[31] Applying the theory of forest carbon sink research to practice can achieve the monitoring of global carbon sink scale, guarantee national ecological security, sustainable human economic and social development. Therefore, the main line of research on forests as an important carbon sink ranges from measuring forest carbon balance to estimation of stable regions to applying the theory to the practice of monitoring the scale of global carbon sinks. The research hotspots, on the other hand, range from whether forests are carbon sinks to the formation mechanism of forest carbon sinks to the realization of sustainable forest carbon sinks under monitoring and management. In terms of establishing the evaluation method system of forest ecosystem carbonstorage, while retaining the advantages of the existing evaluation system, China continuously optimizes its carbon stock measurement methods by fully absorbing and assimilating advanced foreign experience. With the completion of the multi-scale and all-round monitoring network of ecosystems as well as the accumulation of rich ecological parameters and observation data, forest carbon sink evaluation will develop in the direction of multi-method integration and multi-scale compatibility, and the integration of multi-source information to build a forest carbon sink evaluation method system. From 2020 to 2050, it is an important window period for China to achieve the goal of "double carbon", and the improvement of forest carbon sink forecasting capability is an important foundation for implementing and adjusting related policies. Therefore, it is urgent to further improve the capacity of forest ecosystem carbon sink and ecosystem service function assessment and prediction.[32]

Conclusion

Forests, as an important component of the Earth's ecosystem, are not only a natural ecological resource, but also an important carbon sink, playing an important role in mitigating greenhouse gas effects, protecting the environment, and promoting biodiversity. Therefore, the study of forest carbon sinks has important theoretical and practical significance. First, the measurement and assessment of forest carbon sinks can provide us with basic data for a more accurate understanding of the role forests play in CO_2 absorption. Studies on forest carbon sink assessment need to take into account the changes in CO_2 uptake by different forest types, regions, and growth stages while measuring. They also need to focus on factors such as the CO_2 released by abandoned forests and the impact of human activities on forests. The results of these assessments can enable ecological protection departments and related sectors to formulate more scientific policies, also provide more convincing theoretical basis and practical experience for countries in mitigating climate change.

Second, the study of forest carbon sinks also has important practical significance. In the context of global warming, forest carbon sinks are widely regarded as an important means to mitigate CO_2 emissions and prevent climate change. Considering the potential of carbon sinks and the importance of forests themselves, governments have begun to invest more in soil and water conservation, ecological construction, ecological protection and ecotourism. In this process, joint research exchanges between different countries have become more frequent, and global carbon sink management is gradually taking shape. Finally, the study of forest carbon sink also calls us to establish the concept of ecological civilization and promote the harmonious development of human and nature. The current environmental changes brought about by human activities have had a great impact on global ecological security and sustainable development, and the ecology in some areas has been damaged to an irreversible extent. Therefore, in the protection and management of forest carbon sinks, we should adhere to the path of ecological civilization, continuously promote ecological engineering construction and ecological protection measures, fully realize the ecological, social and economic benefits of forest carbon sinks, create an ecologically and environmentally friendly society, and promote the harmonious development of man and nature. In summary, the study of forest carbon sinks is of great significance for concrete practices and future strategies, provides governments with multiple perspectives on development strategies. Therefore, whether it is through the comparison of carbon sequestration capacities in different tree species and selecting excellent carbon sequestration species, or carbon sink calculations and timely evaluation of the carbon sequestration capacities in different regions, all have important significance for in-depth evaluation of carbon sequestration effects. The implementation of carbon sink afforestation can improve the carbon stock per unit area of forest, enhance the carbon sink effect, and provide important technical support for the sustainable development of forest under the goal of "low carbon" development.

Acknowledgments

None

Conflicts of interest

There is conflicts of interest relevant to this article, declared by the authors.

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