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Economic Evaluation and Regional Coordination Analysis of Forestry Carbon Sink in Shandong Province, China

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Abstract:

Under the background of carbon neutrality and carbon emission peak, forest area shrinks sharply due to more frequent human social activities and natural or human factors, so the issue of global climate warming has attracted unprecedented attention of the mankind. The Chinese government has been trying to increase forest carbon sinks by issuing various policy documents and implementing measures such as land greening, forest resource protection and forest quality improvement on a large scale. Forest carbon sink has aroused wide concern due to its low cost, easy implementation and ability to effectively lower greenhouse gas concentrations. Study on the economic value of forest carbon sinks and its influencing factors will help us understand forest carbon sinks and provide a basis for the government and forestry organizations at all levels to conduct scientific and rational forest management. This paper studies the research results on forest carbon sinks at home and abroad. On this basis, the forest resources in Shandong Province are selected as the concrete research object. Based on the collected data and stock expansion method, the carbon sink of forest resources in Shandong province is measured. Secondly, the carbon tax method and the afforestation cost method are selected to evaluate the economic value in carbon sink of forest resources in Shandong Province.

***Keywords**: Carbon neutrality, Carbon emission peak, Forest carbon sink, Regional economy.*

I. INTRODUCTION

In recent years, fossil fuels have been excessively used to meet various needs of mankind, and a lot of gases such as carbon dioxide have been released to the earth. The forest area has been greatly reduced around the world due to human or natural factor. [1]For instance, the Brazilian Amazon rainforest forest fire in August 2019 and the Australian forest fire in November 2019 damage forest ecosystems to a certain extent and further reduce the air purification effect of the forest. A large amount of greenhouse gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) in the air have caused global warming. On the one hand, climate warming causes the redistribution of global precipitation and the rise of sea levels, which breaks the balance of the natural ecosystems. On the other hand, the emission of terrestrial greenhouse gases results in higher continental temperature and smaller temperature difference, making the air flow slower. [2]Thus, haze weather forms in many cities, which impairs human health. The rapid climate warming increases the likelihood of natural disasters such as floods and droughts, which impacts agricultural, forestry, animal husbandry, fishery and other production activities, then subsequently damages ecological stability and hinders economic and social development. At this stage, the issue of

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global warming has attracted great attention from the mankind.

With the acceleration of industrialization, there is more and more serious global warming caused by the massive emission of CO_2-based greenhouse gases. Many steps have been taken to reduce CO_2 emissions in order to protect the common good of mankind. There are two main ways to reduce and stabilize the concentration of carbon dioxide in the atmosphere: one is to reduce industrialized carbon dioxide emissions; the other is to increase carbon dioxide absorption. [3] Since the industrialization stage is almost an inevitable stage for developing countries to move towards developed countries, it is particularly difficult to reduce the carbon dioxide produced by industrialization on a large scale. On the other hand, forests have received widespread attention from the international community because they can effectively absorb carbon dioxide through photosynthesis and reduce the concentration of greenhouse gases in the air. In efforts to cope with climate change, a healthy forest system plays an important role. Specifically, it can increase the carbon sink capacity of forests and reduce carbon dioxide emissions, thereby mitigating climate change. [4]The carbon dioxide absorbed by the forest ecosystem will be converted through photosynthesis of plants and stored in plants or decomposed by microorganisms. Such storage capacity is referred to as forest carbon sink. Forests play an irreplaceable role in carbon sinks. The long-term unit cost of forest carbon sinks is far lower than the cost of industrial upgrading and industrial pollution control and emission reduction. Effective measures such as afforestation and strengthened sustainable forest management can enhance forest carbon uptake.

II. LITERATURE REVIEW

Seen from relevant researches at home and abroad, foreign research on forest carbon sinks and related carbon sink project activities have a relatively earlier start than China. At present, foreign literature review mainly involves three aspects: the cognition of forest carbon sink, the assessment research of forest carbon sink and the factors influencing forest carbon sink.

2.1 Cognition of Forest Carbon Sink

The world's research on forest carbon sink began in the late 1960s, when the International Council for Science (ICUS) planned to collaborate with the United Nations Educational, Scientific and Cultural Organization (abbreviated as UNESCO) and proposed the International Biological Programme (IBP). The implementation of this plan marked the beginning of large-scale exploration of ecosystems in the international community and the beginning of research activities on forest carbon sink. At first, some countries studied the carbon balance of forest ecosystems in the region and the carbon cycle relationship between regional ecosystems and global ecosystems. Where, many representative scholars such as Prentice et al. [5] (1998) believed that carbon sink may exist in many regions in the world. Ben Jong (2000) pointed out that forest carbon sink is the main approach to alleviate the greenhouse effect [6]. In the article "Research Review on the Cost of Forest Carbon Sequestration", Kenneth R Richards et al. (2004) pointed out that forests help to absorb carbon dioxide in the atmosphere, and recommended carbon dioxide sequestration through forests [7]. In the article "Russia's Forests Cope with Climate Change", Lapenis A (2005) also believed that forests can play an important role in climate change [8]. By comparing four methods for filling missing measurement periods, Soloway A D et al. (2017) evaluated the uncertainty of annual net ecosystem yield estimates. Yan et al. (2018) argued that forests in the Amazon Basin experienced frequent and severe droughts, which severely affected its carbon cycle. At the same time,

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foreign scholars' research on forest carbon sinks is directly related to anti-poverty, with some constructive results achieved. Based on the Payment System for Ecosystem Services (PES), Milder et al. (2010) estimated that by 2030, forest carbon market could benefit 25 to 50 million low-income households. Based on community perception, L. chiaeugene et al. (2013) conducted research in two community forest carbon conservation projects in Nomedjoh and Nkolenyeng in southern Cameroon, and concluded that if the goals and activities of carbon projects are well implemented, it will likely improve the adaptability of forest communities.

2.2 Assessment of Forest Carbon Sinks Overseas Studies on Forest Carbon Sink Assessment Started Earlier

Ben et al. (2007) used the CO_2FIXV3.1 software to calculate the carbon sink potential of a 11,000-hm2 forest in Michoacan, central Mexico. Gregory et al. (2009) combined satellite and airborne mechanism strategy systems to monitor and measure forest carbon sinks in tropical rainforests. Willy Makundi et al. (2010) used the Integrated Science Assessment Model (ISAM) to study the impact of 20th century nitrogen dynamics on secondary forest regeneration. The results revealed enhanced carbon uptake by tropical secondary forests in the Indian region. The findings also indicate the importance of secondary forests for terrestrial carbon sinks. Pan et al. (2011) conducted a systematic assessment of carbon sinks in the world's forests from 1990 to 2007. Lun et al. (2012) conducted an accounting of forest carbon sink in China's forestry carbon pool and HWP carbon pool from 1999 to 2008. Using the stock difference method, Yang et al. (2014) conducted a systematic assessment of the development trend of China's HWP carbon pool from 1961 to 2012. Alivernini et al. (2016) used the CO_2FIX model to conduct a multi-period carbon sink analysis, finding that the compound annual growth rate of forest expansion was 0.26% during 1990-2012.

2.3 In the Research on the Factors Influencing Forest Carbon Sinks, Many Scholars Have Investigated the Reasons for the Cost of Carbon Sinks.

Englin and Callaway (1993) simulated the impact of carbon payments in Douglas fir's best rotation periods at carbon prices of $10-200/tm3, finding that carbon-related rotation periods were longer than traditional Faustmann optimal rotation period, which suggests that it is directly proportional to the price of the carbon market. Liu et al. (2012) believed that there was a strong correlation between carbon sink intensity and stand age. [9] Ercanli (2018) conducted a correlation analysis of forest carbon storage values and found that there is a positive proportional relationship between forest carbon storage and diversified development of forest structure. In general, overseas research on forest carbon sinks not only includes the theoretical knowledge of CMD carbon sink project, but also includes related practical projects. By slowly shifting from the regional forest ecosystem carbon cycle to the global forest carbon cycle, foreign studies have achieved certain results in the overall research process of forest carbon sinks, beginning to form a complete system.

III. MODELING METHODS AND DATA SOURCES

3.1 Evaluation Methods for the Economic Value of Forest Carbon Sinks

There are many methods for evaluating this value. Two indexes are mainly involved in the evaluation. One is the aggregate carbon content and the other is the unit price of carbon. The former is the primary measurement index. In this study, the total carbon dioxide absorbed by the forest during its growth was

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used to determine this index.

3.2 Measurement Method of Forest Carbon Sinks

According to the contents of the literature consulted, many scholars have carried out research on it, whether at home or abroad, and abundant related measurement methods are used, three of which are widely used. The first is biomass method, the second is stock method, and the third is the chamber method. In addition, vorticity correlation method and biomass inventory method are also widely used in practice. These methods have respective advantages, also with some disadvantages. Take biomass method and stock method for example. Their advantages are that the calculation is simple and easy to understand. The disadvantage is that the sampling only involves the part above the surface and lacks data for the part below the surface, so the measurement results are biased to a certain extent. [10] Take vorticity correlation method as another example. It allows continuous measurement, but the disadvantage is that the instrument is expensive, and measurement requires relatively complex method, and the results can only be obtained after a long observation cycle, which greatly increases the experimental cost. Therefore, in the actual application, it is necessary to select the most appropriate method in light of the actual needs in the specific situation, thereby guaranteeing the accuracy of the measurement results to the greatest extent. The estimation of forest carbon sinks should involve two aspects. One is the tree part above the surface, and the other is the element part below the surface, including understory plants, humus, and fixed carbon content in soil. At present, the research mainly focuses on the relevant measurement of the forest part above the surface, while the part below the surface is difficult to measure and has many uncertainties, which is thus scarcely studied. Hence, the result calculated according to the current estimation method is generally lower than the actual content. In order to reduce the measurement error, Xi Tingting and Li Shunlong (2006) proposed a different estimation method based on the basic method of biomass conversion factor, namely the forest stock expansion method. [11]The advantage of this method is that abundant samples are taken, so it is more convincing. The sample used in its measurement is the total stock of all standing trees in the forest, specifically the sum of four different types of tree stocks: four-sided trees, scattered trees, open forests and forests, which involve almost all the tree stocks on the surface. [12] Moreover, it does not require on-the-spot measurement, which is highly feasible. The most important thing is that the estimated results have greatly higher accuracy compared with the previous method. Based on comprehensive consideration, this study will adopt this measurement method as follows:

(1) Calculate the total carbon sink of the forest. First, it is necessary to understand which parts it consists of. Specifically, it includes three parts in total. The first part is the fixed carbon content of forest biomass, which is expressed by C_1; the second part is the fixed carbon content of understory plants, which is expressed by C_2. The third part is the fixed carbon content of forest land, which is represented by C_3. The sum of the three is the calculated index, which is represented by C:

$$C = C_1 + C_2 + C_3 \quad (3.1)$$

In the equation: C—the total forest carbon sink; C_1—fixed carbon content of forest biomass; C_2—fixed carbon content of understory plants; C_3—fixed carbon content of forest land.

(2) According to the relevant research methods, we will further analyze the indexes in the formula (3.1), the first is C_1. To solve this index, the tree biomass should be first calculated, and then the dry weight of the tree biomass is calculated on this basis, which is finally multiplied by the bulk density to calculate the fixed carbon content of forest biomass. The specific formula is shown in (3.2). The second is C_2, which

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can be calculated through the carbon conversion coefficient of understory plants on the basis of the previous formula. The specific formula is shown in (3.3). The last is C_3, which can also be calculated through the forest land carbon conversion coefficient on the basis of formula (3.2). The specific formula is shown in (3.4):

$$C_1 = V \times \delta \times \rho \times \gamma (3.2)$$
$$C_2 = \alpha \times V \times \delta \times \rho \times \gamma (3.3)$$
$$C_3 = \beta \times V \times \delta \times \rho \times \gamma (3.4)$$

In the equation: V—the stock of standing trees in the forest; δ—the stock expansion coefficient; ρ—the bulk density; γ—the carbon content rate; α—the understory plant carbon conversion coefficient; β -- forest land carbon conversion coefficient.

(3) After sorting out the steps shown above, the comprehensive formula is established as follows:

$$C = (1 + \alpha + \beta) \times V \times \delta \times \rho \times \gamma (3.5)$$

Each conversion factor (δ, ρ, γ, α, β) has a corresponding default value, which is stipulated by the United Nations Government's Subsidiary Committee on Climate Change, and each coefficient in formula 3.5 is calculated according to relevant regulations. The first is the stock expansion coefficient δ, whose default value is 1.90; the second is the bulk density or dry weight coefficient ρ, whose default value is 0.5; the third is the carbon content rate γ, whose default value is 0.5; the fourth is the understory plant carbon conversion factor α, whose default value is 0.195; and the final is the forest land carbon conversion factor β, whose default value is 1.244.

IV. GENERAL SITUATION AND EVALUATION CONTENT OF FORESTRY CARBON SINK DEVELOPMENT IN SHANDONG PROVINCE

4.1 Overview of the Development of Forestry Carbon Sink Economy in Shandong Province

Carbon sink economy mainly aims to achieve a low-carbon economy, and the national carbon reserve helps improve the ecological environment. The survey research shows that the economic value of forestry carbon sinks plays a very important role in the total output value of forestry economy in Shandong Province. Seen from forestry carbon sinks in various regions, the economic distribution of carbon sinks is unbalanced in Shandong Province due to local geographical and climatic conditions.

4.2 Contents of Economic Benefit Evaluation of Forestry Carbon Sink

4.2.1 About overall efficiency

Through the investigation, it can be found that Shandong Province has relatively low comprehensive efficiency in carbon sink economy in 2021, and it is difficult to use resources to create more benefits in most cases. Some areas in Shandong Province have relatively high carbon sink benefits, with good technology implementation and good scale efficiency in practical application. In the coastal areas of Shandong Province, there are abundant forestry resources. Coupled with good climate and environment and abundant rainfall, there are increased types of forest trees, with development of forestry resources strengthened in this context. In the central and western regions of Shandong Province, due to the general ecological environment, no significant advantage is exhibited in the development of forestry resources, and ecological advantages are difficult to show. In particular, in the process of forestry development, invested funds and equipment fail to reach an optimal state.

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4.2.2 About technical efficiency

Seen from technical efficiency, a significant improvement is achieved compared with the technology of previous years. In the actual operation process, low technical efficiency will directly affect the economic input and output. This situation is a result of factors such as economic underdevelopment and backward technology, and some input machinery and equipment cannot well support the development of forestry systems.

4.2.3 About scale efficiency

It is critical to grasp the scale efficiency of carbon sinks. In recent years, the scale efficiency of carbon sinks has reached a certain level in Shandong Province, demonstrating relatively good scale efficiency of carbon sinks in Shandong Province. However, in the comparison of actual data, it can be found that scale efficiency is relatively good in some areas of Shandong Province, but poor in some areas, mainly due to factors such as climatic conditions and economic development. In the actual operation process, due to the constraints of economic development and other factors, there are scarce forest resources in some areas, which directly reduces the benefits of carbon sinks.

4.3 Content Analysis on Regional Coordination of Forestry Carbon Sinks in Shandong Province

Through comparative analysis and investigation, it can be seen that the evaluation of the economic benefits of forestry carbon sinks in Shandong Province will create a certain impact on the coordination and stability of the region. It is necessary to coordinate between the two, and control carbon sinks from multiple perspectives, so that the forestry development and management in Shandong Province moves towards a scientific and rational direction.

4.3.1 About the double-high area

Through the analysis of the double-high area, we can know that the coverage rate of forest vegetation is relatively high in the coastal area with rich species resources and good forestry development trend. In order to give full play to the role of carbon sink economy, local government departments should strengthen the protection of forest resources and better improve the economic level and economic benefits of forestry carbon sink. The Heilongjiang area of Shandong Province has relatively abundant forestry resources, which is a key development area in the province. Strengthening the forestry management can promote the industrialization development of forestry. In this process, it is possible to give play to the advantages of forestry resources and promote the sustainable development of regional economy. The Inner Mongolia area of Shandong Province plays an important role as an ecological barrier. In the process of forestry construction, it is necessary to strengthen the research on forestry technology to continuously increase the economic benefits of carbon sinks and the development level of the regional economy. In the double-high area of Shandong Province, there is relatively high comprehensive benefit from carbon sink economy. Through the key research and promotion of the project, it is possible to promote the coordinated development of the region, which is of great significance for promoting the development of the regional economy.

4.3.2 High-efficiency area

The high-efficiency areas in Shandong Province mainly include Weihai City, Qingdao City, where the

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share of forestry resources is relatively low, but the economic benefits are relatively high. In the process of actual operation, the area intensifies efforts on greening and afforestation, and strengthens the integration of resources. The Qingdao Municipal Government provides important support in the operation process to promote the effective development of greening and afforestation projects, and strengthens the integration of forestry resources to increase the carbon sink benefits. Based on the actual situation of regional economic development, Weihai City strengthens the management of forest logging, attaches importance to the standardization in forestry land use, which consolidates the benefits of carbon sink economy, and greatly enhances the sustainable development of the regional economy.

4.3.3 Low-efficiency area

Seen from regional division, the low-efficiency areas mainly include Linyi City, Heze City. The area has relatively rich forest resources, but the investment in carbon sink elements is insufficient, and the resource allocation is relatively poor. The forestry area of Linyi City is in the forefront of the province in terms of felling volume and stock, but the development speed is relatively slow, the technical level is poor, and the relationship between economic development and ecological benefits is not well coordinated. In the long run, it will be detrimental to the improvement of carbon sink benefits.

4.4 Methods for the Coordinated Development of Forestry Carbon Sink Economy

4.4.1 Increase the coordinated construction of forest capacity

Considering diversity of forests, forestry workers should pay attention to the use and scientific planning of forest resources to ensure that the management of the regional carbon sink industry meets project operation objectives. Forestry workers can establish appropriate compensation measures based on the low-carbon market development status, and evaluate ecological benefits and ecological functions to promote the development of the forestry industry. It is necessary to pay attention to the construction of laws and regulations, and effectively implement laws and regulations. In addition, forestry workers should also strengthen the analysis of forest diversity and species, and establish a corresponding consumption compensation mechanism to promote the economic growth of regional forestry and change the unfavorable factors in the process of forestry development. It is necessary to pay attention to the investigation of the carbon sink economy, choose appropriate improvement measures to boost the development of the carbon sink economy.

4.4.2 Emphasize industrial management coordination

There is need to strengthen the forestry management, determine the objectives of forestry resource management, increase the management value and implement management objectives, attach importance to the construction of natural forests, and fully create ecological and economic benefits of forestry resources. It is necessary to determine the goal of ecological protection, effectively implement the goal, regulate industrial economic benefits, and give full play to the value of carbon sink economy. There is need to pay attention to the management of forest layout and species diversity, increase the technical level in the management process, so that various factors of the forest can develop in harmony.

V. CONCLUSION

From the above elaboration, it can be known that strengthened analysis of the carbon sink economic

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model and continuous technology optimization can improve the production efficiency of the industry. Relevant workers should pay attention to the construction of forestry coordination function, establish the goal of low-carbon development, and give full play to the advantages of carbon sink economy. Generally speaking, some areas in Shandong Province have relatively rich carbon sink aggregates. By increasing effective management of resources, it is possible to give full play to their economic advantages. Also, there is need to increase investment in technology, attach importance to the use of advanced equipment, and continuously optimize carbon sink production factors, thus promoting the development of carbon sink economy.

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