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Policy Approaches to Increase Carbon Sequestration Capacity by Optimizing Layouts of Ecological Construction

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Abstract
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Keywords
carbon neutrality ecological construction ecological layouts carbon sequestration capacity policy approaches

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Policy Approaches to Increase Carbon Sequestration Capacity by Optimizing Layouts of Ecological Construction

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Abstract: Improving carbon sequestration capacity through ecological construction is one of the important ways to achieve the goal of “carbon neutrality” in China. Based on the analysis of the current situation and trend of ecological carbon sequestration in China, this study summarizes the main challenges in the increment of ecosystem carbon sink in China. This study also surveys the current situation and trend, the significant carbon sequestration capacity of forests, the recovery phase of carbon sequestration capacity of grassland, and the carbon sequestration benefits of major ecological projects. Then, the new challenges of China are analyzed, including the backlog of over-mature forests affecting the carbon sequestration capacity of forests, the limited land area suitable for planting forests and grasses, the less diversified investment mechanism of ecological engineering, the imperfect supporting policies and measures for ecological carbon sequestration, and the increasing demand for forest products. To make the “peak carbon emissions” and “carbon neutrality” goals reached as scheduled, the study points out that it is necessary to optimize the layout of ecological construction and to improve the capacity of ecological carbon sequestration through the optimization of the internal structure of ecosystem and the regional coordination of ecological construction.

In terms of the optimization of the internal structure of the ecosystem, several policy suggestions are put forward: restarting orderly renewal and forests logging, enhancing the ecological carbon sequestration capacity of the grassland, and fully implementing the water diversion project on the western line. For example, some related research suggestions are proposed on forest management, including redesigning the forest regeneration route, conducting pilot programs in some forest areas, constructing modern standard system of forest logging, and improving basic facilities of intermediate cuttings. In terms of the land layout optimization of ecological construction, this study suggests that the government should establish an overall plan with differentiated regional carbon neutrality paths, promote the coordination of regional ecological protection and clean energy, accelerate the improvement of ecological environment, and utilize national land space highly efficiently. DOI: 10.16418/j.issn.1000-3045.202210110006-en

Keywords: carbon neutrality; ecological construction; ecological layouts; carbon sequestration capacity; policy approaches

Carbon emissions reduction and carbon sequestration are the two decisive factors to achieve the goals of “peak carbon emissions” and “carbon neutrality”. Carbon sequestration mainly focuses on the ecological conservation, construction, and management. Considering the natural growth of vegetation and ecological construction, we believe that China’s terrestrial ecosystem plays an important role in carbon sink, which will be continued in the future (1). Since the 18th National Congress of the Communist Party of China, China has incorporated ecological civilization into the Five-sphere Integrated Plan, advocating to build a community with a shared future for mankind and a clean and beautiful world. So far, it has carried out a series of fundamental and groundbreaking work, thus making breakthroughs in protecting and remediating ecological environment and addressing climate change. In 2021, Xi Jinping, the general secretary of the Communist Party of China Central Committee, stressed at the ninth meeting of the Central Committee for Financial and Economic Affairs that “To peak carbon emissions and achieve carbon neutrality is an extensive and profound systemic reform for the economy and society and should be incorporated into the overall layout of building an ecological civilization.” He called for a spirit of perseverance in achieving the goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. From the perspective of the long-term goal of carbon neutrality, it is necessary to optimize the layout of ecological construction through the internal structure optimization of ecosystem and the regional coordination of ecological construction for the carbon sequestration capacity improvement of the ecosystem. The internal structure is optimized by giving play to the carbon sequestration capacities of important ecosystems. Relying on regional features and endowments, regional coordination can be realized by the selection of differentiated paths for the improvement of ecological carbon sequestration capacity.
1 Current situation and trend of ecological carbon sequestration

1.1 Current situation of ecological carbon sequestration

(1) The role of forests in carbon sequestration is predominant. Since the reform and opening up, the forest coverage rate in China has increased from 12% in the early 1980s to 23% at present, with the forest stock volume reaching $1.75 \times 10^{10}$ m$^3$ and the national forest area $2.2 \times 10^6$ km$^2$ after unremitting afforestation for years. The area of artificial forests accounts for more than one third of the total forest area, and beating the target of annual afforestation goal for consecutive years makes the area of artificial forests rank first in the world (Figure 1). According to the research published in Nature in October 2020, the average annual carbon absorption volume of China’s terrestrial ecosystems is about 1.11 Pg C from 2010 to 2016, three times that (0.35 Pg C) reported by previous studies in China and other countries. Such a strong carbon sequestration capacity is equivalent to absorbing 45% of average annual anthropogenic carbon emissions in China during the same period [2]. The huge carbon sequestration capacity of terrestrial ecosystems in China is mainly contributed by its important forest areas, especially those in Southwest China. Also, forest areas in Northeast China are highly capable of carbon sequestration in summer. Against the background of decreased forest area around the globe, the huge investment in the restoration of natural forest vegetation and the strengthening of artificial forest cultivation in China helps the country rank the first regarding the average annual net increase in forest area in the world in recent 10 years and surge ahead compared with other countries [3]. In short, the efforts lead to a strong carbon sequestration capacity of terrestrial ecosystems in China.

(2) Grassland ecosystems have great growth potential as carbon sinks. As one of the widely distributed terrestrial ecosystems on the Earth, grasslands play a major role in the global carbon cycle. The area of natural grasslands in China is nearly $4 \times 10^6$ km$^2$, accounting for about 40% of the territorial area. They are mainly concentrated in the Northeast China Plain, Inner Mongolia Plateau, Loess Plateau, Qinghai-Tibet Plateau, and mountainous areas in Xinjiang, which are important parts of global grassland ecosystems. The total carbon storage of grasslands in China is 28.95 Pg C, including vegetation carbon storage of 1.82 Pg C and soil organic carbon storage of 27.13 Pg C [4]. The grassland biomass and soil carbon pool in China have not changed significantly in the past 20 years, namely that its grassland ecosystems constitute a neutral carbon sink [5]. Since 2000, many major ecological projects have been brought into effect in the grassland areas in China, such as controlling the sources of dust storms affecting Beijing and Tianjin, returning grazing lands to grasslands, protecting natural grasslands, comprehensively addressing stony desertification, and monitoring grasslands and making early warning, which has curbed grassland degradation to a certain extent. According to the assessment report issued by the Intergovernmental Panel on Climate Change (IPCC), each hectare of natural grassland is able to fix 1.3 t carbon per year, which is equivalent to reducing 6.9 t of CO$_2$ emissions. China’s grassland area occupies about $4 \times 10^6$ km$^2$, capturing around $5.2 \times 10^9$ t carbon (30%–50% of national carbon emissions [6]) per year, which is the same as an annual decrease of $2.76 \times 10^9$ t CO$_2$ equivalent (CO$_2$e). To sum up, grassland ecosystems have huge growth potential as carbon sinks. It is of crucial significance to improve the protection and restoration of grassland ecosystems for the achievement of carbon neutrality in China.

![Figure 1](image_url) Completion situation of China national afforestation from 2010 to 2020
(3) Major ecological projects exhibit a significant carbon sequestration effect. The carbon sequestration capacity of terrestrial ecosystems in China has been greatly improved by major ecological projects (such as the Natural Forest Protection Project, Project of Returning Cropland to Forests, Project of Returning Cropland to Grasslands, Yangtze River and Pearl River Shelter Forest Project) and the agricultural management practices of returning straw to the field. Research has been conducted on the spatial-temporal pattern changes of carbon density in ecosystems inside and outside the boundaries of six major ecological projects. The results showed that the major ecological projects play a key role in improving the ecosystem carbon storage and carbon sequestration capacity from 2000 to 2010. The carbon storage of ecosystems in areas under major ecological projects increased to 1.5 Pg C, and the average annual carbon sequestration capacity reached 132 Tg C, which can cancel out 9.4% of China’s CO$_2$ emissions from fossil fuel combustion in the same period. In the abovementioned areas under major ecological projects, 56% (74 Tg C) of the average annual carbon sink of ecosystems can be directly attributed to the major ecological projects.

1.2 New challenges of ecological carbon sequestration

1.2.1 Affected carbon sequestration capacity of forests by backlog of mature/over-mature forests

Since the Forest Law of the People’s Republic of China came into effect in 1984, China has strictly restricted the cutting of natural forests. Many local governments have carried out the ban on cutting and implemented management measures focusing on forest conservation for a long time. In 1987, the former Ministry of Forestry of China issued the Measures for the Administration of Forest Cutting and Regeneration which implemented the forestry construction policy of protecting forests universally, planting forests with great efforts, and combining cutting and planting of the forests for sustainable development on the basis of forest management. Also, it put the forest management plan into action and restricted cutting to give full play to the ecological, economic, and social benefits of forests. During the 13th Five-Year Plan period, the national forest cutting quota was $2.5 \times 10^8$ m$^3$ each year, and the allowable cut within five years accounted for about 1.45% of the national forest stock volume, far lower than the stock volume of mature or over-mature forests in China. In addition, China completely abolished the commercial logging quota of natural forests during the period. In 2017, all state-owned natural forests in China were included in stop-cutting subsidies, and stopping the cutting of non-state-owned natural commercial forests was incorporated into the subsidies of forests management and protection step by step. The rule of cutting quotas for natural forests restrains the time, capital, and labor force that are invested by forest operators in afforestation management and protection to some extent. As a result, some people plant trees without maintenance or turn to other industries.

At present, mature and over-mature arboreal forests are more than $3.6 \times 10^8$ km$^2$ in China with their area proportion beyond 20% and stock volume proportion near 40%. With the increase in the proportion of mature and over-mature forests in China’s forest resources, a large number of standing dead trees and rotten trees are overstocked and decay, which evolve into carbon sources and are thus disadvantageous to carbon neutrality. In some forest areas, the number of mature/over-mature forests increased, as a result of which photosynthetic carbon sequestration and respiratory carbon release are canceled out, namely that the overall carbon sequestration capacity decreased. As indicated by the previous forest resource inventory data of the Natural Forest Protection Project, the carbon sinks of over-mature forests across the whole region showed a downward trend.

1.2.2 Limited area of lands suitable for planting forests and grass

The carbon sequestration capacity of China’s terrestrial ecosystems benefits from the expanding forest area. However, China’s arid and semi-arid areas account for over half of the national territorial area, which puts more pressure on cultivated land preservation and makes the construction land far from enough, leading to limited area of lands suitable for planting forests. According to previous forest resource inventory data, the annual growth rate of national forest coverage rate has declined rapidly from nearly 20% to 5% since 1990s (Figure 2).

As the growth of China’s forest coverage rate will gradually enter the bottleneck period, only relying on the increase in afforestation area is not sustainable for forest carbon sequestration in the future. The forest coverage rates in North China, East China, and South-Central China suitable for tree planting all exceed 40%. The lowest forest coverage rate (< 9%) was found in Northwest China where drought, water shortage, and desert surface make afforestation difficult.

The analysis results of ecological lands from 1980 to 2018 showed a decrease in ecological lands in important ecological space (Figure 3). On the one hand, increased agricultural development activities are responsible for the decrease. The increase in ecological lands is contributed by agricultural lands. This indicated that marked restoration achievements have been made by ecological protection projects through returning cropland to forests and grasslands. On the other hand, the decrease in ecological lands is caused by their continuous occupation and destruction by development, construction, and agricultural activities, which renders the ecological protection situation serious.

1.2.3 To-be-established diversified investment mechanisms of ecological projects

At present, China’s major ecological projects are still mainly supported by government investment. The investment
channel is single, and the related funds need to be increased overall. Featuring public welfare and externality, ecological protection projects have low economic benefits and high risks. China’s current mechanisms of market investment and ecological compensation are still imperfect without effective policies and measures to attract social capital for ecological protection and restoration. Thus, social capital shows less willingness in ecological protection projects. In addition, the key regions of ecological projects are mostly those with insufficient financial resources, such as old revolutionary base areas, areas inhabited by ethnic minorities, remote and border areas, and poverty-stricken areas, where people are accustomed to waiting for assistance, relying on relief, and asking for materials to some degree \(^1\). Therefore, there is a lack of internal impetus in these regions to encourage the coordination of multi-level and multi-field funds and attract social capital actively promoting major project construction.

1.2.4 To-be-improved policies and measures supporting ecological carbon sequestration

With ecological forestry projects as an example, many problems can be found, including lagging legal concepts and ecological forestry development. Since the construction of ecological forestry projects is systematic, it is necessary to draw support from relevant laws and regulations. However, part of current laws and regulations fails to meet the demand of forestry development and even impedes project construction. With major water conservancy projects as an example, there are some problems during the implementation of relevant policies for land expropriation compensation, allocation of fund compensation, and resettlement, such as insufficiently transparent and unreasonable allocation of funds. These problems can easily lead to discontent among related people and even hinder project progress.

2 Approaches to improve the carbon sequestration capacity of key ecosystems

2.1 Restarting the orderly regeneration cutting of mature and over-mature forests

Some problems become prominent at present, such as the rise in the proportion of mature and over-mature forests, the limited lands for afforestation, and the increasing domestic demand for wood products. To achieve the goals of peak carbon emissions and carbon neutrality as scheduled, we should conduct the regeneration cutting of forests in a well-planned and step-by-step way in different regions

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through systematic planning, continuous monitoring, and security system improvement. In this way, forestry development can be boosted, and the carbon sequestration capacity of forests can be improved.

(1) Changing gradually policy ideas and designing the roadmap of forest regeneration for the goals of peak carbon emissions and carbon neutrality. The policy orientation dominated by the ban on cutting should be shifted overall, and a restart of forest cutting needs to be deployed systematically. On the one hand, efforts should be made to enhance the orientation of legal systems. The Forest Law of the People’s Republic of China and Regulations for the Implementation of the Forest Law of the People’s Republic of China should be revised to incorporate the sustainable carbon sequestration capacity of forests into the basic philosophy and principle and improve the relevant provisions of forest cutting. There is also a need to revise the Measures for the Administration of Forest Cutting and Regeneration so as to expand the scope of forest cutting and update the methods of forest cutting. On the other hand, China should improve the supporting policies on the methods and intensity of forest cutting, strengthen policy publicity, policy implementation, and science popularization, and popularize as soon as possible the forest cutting policy requirements and measures. Under the long-term framework of the goals of peak carbon emissions and carbon neutrality, a roadmap covering from ban on cutting to regeneration cutting should be designed. Forest carbon sequestration plays an important role in achieving the goals. Current attention is mainly paid to afforestation, while future forest carbon sequestration potential should be re-estimated after the regeneration cutting is taken into account. According to the stage goals of peak carbon emissions and carbon neutrality, a long-term regeneration cutting roadmap can be formed, namely afforestation first with cutting as a supporting approach → equal emphasis on afforestation and cutting → cutting first with afforestation as a supporting approach.

(2) Strengthening top-level plan and carrying out pilot cutting of mature and over-mature forests. The layout should be coordinated to form a top-level design of forest cutting, and a forest cutting system should be created from national to provincial level. Under the guidance of the overall principle of giving priority to the ecological function of forests and fully considering the needs of regional forest economic development, a phased, regionalized, and differentiated cutting strategy is required to be formulated to construct a three-level (nation–province–forest area) planning system for forest cutting according to the distribution of mature forests in China. State-owned forest farms with sophisticated infrastructure should take the lead in carrying out the pilot cutting of mature and over-mature forests. Stand age should be considered first for pilot cutting, and the infrastructure, management system, and human resources of forest areas should also be taken into comprehensive consideration. It is suggested to choose the mature forests in state-owned forest farms in Greater Khingan Mountains, Lesser Khingan Mountains, and Changbai Mountains in Northeast China for the first batch of pilot cutting.

(3) Strengthening the orientation of the goals of peak carbon emissions and carbon neutrality and building a modern standard system for forest cutting. A forest carbon exchange monitoring database should be established to provide a scientific basis for restarting forest cutting. China’s forests are characterized by wide distribution, large coverage, rapid growth, and rich species. To achieve the goal of maximizing the benefits of forest carbon sequestration capacity, China should construct carbon exchange monitoring and evaluation systems of forest ecosystems of different species at different stand ages in various climate zones for comprehensively measuring and evaluating the carbon sequestration potential of forest regeneration and its contribution to the goals of peak carbon emissions and carbon neutrality. The results can provide a basis for the scientificity and accuracy of forest cutting. The reasonable cutting intensity should be determined according to the types and maturity of forests, and the thinning standards for different forest types should be established. Technical standards of cutting and negative lists need to be established for the purpose of improving carbon sequestration by forest soil. There remains a need to comprehensively consider the carbon sequestration benefits, ecological benefits, and economic benefits of forests to determine the optimal rotation of different types of forests. The carbon sequestration potential of forests can be exploited through the rotation of mature forests. In addition, technical standards of forest cutting and negative lists should be established to avoid the influences of large-scale soil disturbance and prescribed burning on carbon sequestration by forest soil during cutting.

(4) Strengthening support & guarantee and improving basic facilities for thinning or selective cutting. The situation of manual cutting needs to be changed, and the research, development, and production capacities of forestry equipment need to be improved. In China, the development of forestry equipment starts late and is slow due to its weak research and development capacity, which results in the low mechanization and automation levels of timber cutting and makes manual cutting dominant in many regions. Therefore, more efforts should be made to improve the research, development, and production capacities of forestry equipment to promote its shift from traditional manual operation to mechanization, automation, and standardization. Investment should be increased in infrastructure construction in forest areas, accompanied by strengthened policy support, to build a modern infrastructure network adaptive to thinning and selective cutting. For a long time, the policies of forest conservation give rise to backward forest infrastructure,
insufficient total road resources, and difficulty in ensuring water and electricity supply in forest areas. For this reason, starting from the adaptation to the goal of regeneration cutting, the government should scientifically and reasonably design the densities and levels of networks for water, electricity, and roads to construct modern infrastructure networks in forest areas.

2.2 Improving carbon sequestration capacity of grassland ecosystems

According to the “two-step” strategic assumption to achieve the goals of peak carbon emissions and carbon neutrality, Chinese government should establish a goal-oriented forcing mechanism. In addition, it needs to study and plan the short- and long-term goals of grassland development, set the targets and indicators of grassland carbon sequestration in each stage, and provide approaches and policy suggestions.

(1) Clarifying new requirements for grasslands under the goals of peak carbon emissions and carbon neutrality and strengthening the top-level design of grassland carbon sequestration. It is necessary to accelerate the formulation of Action Plan of Grassland to Address Climate Change in which the government makes clear the medium and long-term goals of grasslands to address climate change under the framework aiming at peak carbon emissions and carbon neutrality and formulates supporting policies and management measures accordingly. Adaptive policies for grassland management under climate changes should be formulated on the premise of ensuring grassland ecological balance, the sustainable utilization of resources, and the sustainable development of regional economy and society. In addition, ecological engineering and technical measures will be selected and adopted according to local conditions to improve the carbon sequestration capacity of grasslands in China.

(2) Improving technologies supporting grassland carbon sequestration and establishing differentiated functional zones of grassland carbon sequestration. On the basis of optimizing the allocation of science and technology resources and grasping the direction of grassland technological innovation, the government should establish functional zones of grassland carbon sequestration which are suitable for grassland types in different regions. Regarding mature grasslands with high quality, it is suggested to implement moderate grazing and keep the grassland-livestock balance, and the sustainable development zones of grasslands need to be delimited. As for degraded, sandy, and salinized grasslands, grazing prohibition, seedling, and reseeding should be carried out, and the grassland restoration zones need to be delimited. In regard to the unique grassland ecosystems in the Qinghai-Tibet Plateau, the core protection zones of grassland carbon sequestration should be designated.

(3) Monitoring grassland carbon sequestration capacity and scientifically analyzing the change of grassland carbon sequestration. Grassland monitoring indicators should be further enriched, such as grassland vegetation and soil organic carbon in ground monitoring, so as to provide a firm foundation of data and information for grasping the status and dynamic changes of grassland carbon sequestration in China scientifically and accurately.

2.3 Giving full play to carbon sequestration gain of water diversion project on the western line

Carbon sequestration functions of major ecological construction projects include water diversion, desertification control, protection, and restoration. In addition to increasing the carbon sequestration capacities of natural ecosystems such as forests, grasslands, wetlands, and farmlands, it is also recommended to give birth to new carbon sinks by improving the basic conditions of regional ecological vegetation. While systematically promoting ecological protection and restoration projects, the government is suggested to start the water diversion project on the western line, which thus gives full play to carbon sequestration gain of the water diversion project and supports the carbon neutrality process in Northwest China. The water diversion project on the western line mainly provides water resources for the development of Northwest China and accelerates the ecological protection and high-quality development of the upper and middle reaches of the Yellow River. Although its implementation is faced with problems such as large engineering difficulty, impact on ecological environment, and huge engineering investment, this project can solve some cost-benefit issues in the process of project implementation through carbon sequestration and carbon emissions reduction under the framework of the goals of peak carbon emissions and carbon neutrality.

The effects of the water diversion project on the western line in pushing forward peak carbon emissions and carbon neutrality are as follows. Promoting the increase in grassland and wetland areas and natural vegetation restoration. Ecological water conveyance projects help promote natural vegetation restoration in arid and semi-arid areas under the projects and increase grassland and wetland areas, thus forming new natural carbon sinks. Solving the problems of water utilization for agricultural development and increasing cultivated land area. In the arid and semi-arid regions of western China with serious water shortage and limited agricultural development, the project can address the shortage of water for agricultural development and improve farmland carbon sequestration. Here, Heishanxia ecological irrigation zone is taken as an example. Its annual water supply in the planned water allocation scheme for the first phase of the project is $1.8 \times 10^8$ m$^3$, and the area of newly developed irrigation zones is about 280 km$^2$, including 116.7 km$^2$ of
grasslands, 77.3 km² of farmlands, and 86 km² of woodlands \[12\]. Promoting the development of clean energy such as photovoltaic energy and optimizing energy structure. On the one hand, the development of photovoltaic energy and other new energy requires water to clean photovoltaic panels. The water diversion project on the western line can provide water for clean energy development and reduce carbon sources by optimizing the energy structure. On the other hand, photovoltaic arrays are arranged on the surface of the channel and the ground of the protective belt, so as to form a large-scale banded photovoltaic power station, which reduces the emissions of nearly \(6.03 \times 10^6\) t CO₂ each year and also helps reduce the overall carbon emissions of the project \[13\].

New carbon sequestration gain of the water diversion project on the western line can be converted to be the cost input for the project implementation through the carbon emissions trading market. Therefore, importance should be attached to the comprehensive benefit evaluation of the project in carbon sequestration and carbon emissions reduction during the project implementation, and the benefit should be integrated into the overall consideration of ecological benefits. It is necessary to explore and establish an ecological compensation mechanism based on the carbon emissions trading market and to introduce non-governmental capital so that diversified investment channels can be constructed.

3 Key points in ecological construction and optimization of territorial spatial layout

3.1 Coordinating and establishing differentiated paths to achieve the goals of peak carbon emissions and carbon neutrality

Under the influences of natural conditions, economic development, and industrial and energy structures, there are significant differences in the carbon budget in different areas, which will still exist for some time in the future \[14\]. Therefore, at the national level, the government should take the way of thinking in system theory and form a top-level design and strategic layout of the carbon neutrality after taking into account the basic characteristics, the status quo, and the future trends of the carbon budget in different areas. The government should also clarify the functional orientation and policy priorities of different regions so as to promote regional coordinated development while pursuing peak carbon emissions and carbon neutrality \[15\].

Three suggestions are provided for planning the paths to achieve the goals of peak carbon emissions and carbon neutrality. 1) Focusing on carbon sequestration in key ecological areas such as northeastern and western China. It is crucial to further strengthen the construction of ecological barriers, take solid steps to advance key ecological projects and large-scale afforestation, and tap the regional carbon sequestration potential as far as possible to strongly support pursuing the goals of peak carbon emissions and carbon neutrality. The regional advantages in biology, landscape, climate, and energy should be exploited to build a green industrial system based on biomedicine, clean energy, tourism culture, and high-class agriculture and animal husbandry. 2) Centering on the transformation and upgrading of industries and energy in traditional industrial areas such as central and northern China. On the one hand, the upgrading of traditional industries such as steel and machinery should be intensified, and the active green transformation of industrial processes is required to further develop green manufacturing. On the other hand, the energy structure should be optimized by gradually reducing the proportion of traditional energy. Moreover, the local governments should also establish long-term cooperation mechanism with western regions rich in clean energy resources to increase the proportion of clean energy. 3) Concentrating on low-carbon development in developed regions such as eastern and southern China. With research and innovation of low-carbon technologies as a main leverage, it is essential to take the lead in controlling total emissions and carry out comprehensive and whole-process green transformation of production and life in terms of energy structure transformation, industrial energy consumption transformation, low-carbon urban construction, and green lifestyle.

3.2 Advancing green and low-carbon development in underdeveloped areas in all respects

Underdeveloped areas are core forces in advancing peak carbon emissions and carbon neutrality owing to their advantages in carbon sequestration, clean energy, and ecological resources \[16\]. However, influenced by different regional policies and self-development needs, these areas cannot but accept industries from East China that have high energy consumption and emissions. With the emissions of greenhouse gas rising, the areas are faced with increasing pressure of emissions reduction \[17\]. Thus, the development ideas of underdeveloped areas should be adjusted as soon as possible to give full play to their advantages in green development and expand and deepen the value transformation paths of natural resources, by which win-win outcomes can be achieved for regional economy, society, and ecology \[18\].

The goals of peak carbon emissions and carbon neutrality in underdeveloped areas need to be coordinated with other regional strategic measures. 1) When carrying out major regional development strategies such as the ecological conservation and high-quality development of the Yellow River Basin and the large-scale development of the western region, the government should highlight the guiding role of the goals of peak carbon emissions and carbon neutrality and improve the policies related to clean energy security and carbon...
sequestration. In addition, it needs to promote the transformation of regional economic development while making full use of the green resources in underdeveloped areas to better serve national strategies. © Under the guidance of the green development philosophy, a sound policy system for rural ecological revitalization is to be established. Additionally, the government should consolidate and advance the achievements of rural revitalization in underdeveloped areas by integrating rural revitalization with ecological compensation mechanisms, national major ecological projects, ecological industry development, and clean energy industry. © The government should encourage underdeveloped areas to participate in the trading of clean energy and permits for carbon emissions and water use. Further, it should establish and improve cross-regional and inter-provincial trading mechanisms and quota systems to fully ensure the interests of underdeveloped areas, boost their development, and thus achieve common prosperity and coordinated development of regions.

3.3 Coordinating ecological conservation and clean energy development

The steady growth of clean energy consumption is a powerful measure to optimize the energy structure and achieve low-carbon development in China. However, the severe overlapping of the distribution areas of clean energy resources with ecological space in China leads to a prominent contradiction between clean energy construction and ecological conservation. Some areas with abundant energy resources cannot even be exploited due to restrictions at different levels and various control measures, which has an impact on the development of related industries and regions. [19]. Therefore, it is urgent to make clear the relationship between ecological conservation and clean energy development and address the main contradiction between the two in space, management, and other aspects. In this way, we can promote the improvement of regional ecological environment and the efficient utilization of territorial space while scientifically boosting the development of clean energy.

Three suggestions are provided to coordinate ecological conservation and clean energy development. © Ecological vulnerability and sensitivity should be evaluated scientifically. Depending on the richness of solar energy and wind energy resources and their suitability for development and utilization, the special land type for new energy should be separately set to reserve space for photovoltaic and wind energy projects. © The government should enact the strictest regulations for evaluating ecological and comprehensive impacts. With the regulations, it needs to clarify the impacts of project construction on local ecosystems, whole ecosystems, and the realization of the goals of peak carbon emissions, carbon neutrality, and local modernization. The coordination of clean energy layout based on scientific evaluations and reasonable planning should be a special part of territorial spatial plans for regions rich in clean energy resources. © The clean energy projects and the restoration projects of ecological systems of mountains, rivers, forests, farmlands, lakes, grasslands, and deserts must be coordinated to improve regional ecological environment and promote the efficient use of territorial space. The green circular industry system based on clean energy resources needs to be further developed to help regional green development in an all-round way.

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