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Research on an equilibrium development model between urban and rural areas of Henan including carbon sink assets under the dual carbon goal

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With the improvement of China's industrialization and urbanization level, the problem of urban–rural dual structure is becoming increasingly obvious. The balanced development of urban and rural areas is a problem that China is striving to solve. Against the background of dual carbon goal, urban enterprises are reducing carbon emissions, while the rural carbon sink potential is huge, and carbon optimization is becoming the basis for balanced urban–rural development co-occurrence. This paper discusses the construction of an urban–rural mutual aid model from the perspective of carbon sink value. Using the case study method and the system theory research method, this paper analyzes the development status of rural agriculture and farmers, reveals the potential economic value of rural carbon sink assets, constructs an urban–rural mutual aid mechanism for industry feedback into agriculture, and proposes an implementation path for urban–rural mutual aid and the coordinated development of carbon sink assets under the dual carbon goal. The results show that the urban–rural mutual assistance model of carbon sink assets is conducive to the balanced development of urban and rural areas in Henan Province and the common prosperity of the people.

KEYWORDS

equilibrium development, dual carbon goal, carbon sink trading, carbon sink assets, urban and rural areas, common prosperity

Introduction

The frequency of extreme weather in recent years is a warning of the climate crisis and even the “worst situation.” If left unaddressed, it will cause the ecosystem to collapse, with dire consequences for humans. The Earth is the only home shared by mankind. The only way to tackle climate change is to work together. On 22 September 2020, China proposed at the 75th Session of the UN General Assembly that it would increase its national independent contribution and adopt more effective measures and policies to reach peak

CO₂ emissions by 2030 and strive to achieve “carbon neutrality” by 2060. “Carbon neutrality” refers to human production activities emitting greenhouse gases, such as CO₂ and CH₄, and the amount of “carbon” recovered through greening and technology, in order to enable carbon accounting and achieve carbon balance or neutralization. Greenhouse gases are the cause of global warming, and controlling greenhouse gas emissions is an important basis for sustainable human development. “Carbon peak” and “carbon neutrality” have been incorporated into the national overall development plan and the overall plan for ecological progress, and an extensive and profound social systematic reform is being undertaken. The Henan Provincial Party Committee and provincial government attach great importance to the implementation of General Secretary Xi Jinping’s vision of “carbon peak” and “carbon neutrality” as an important political task, unswervingly implementing the new development concept and jointly promoting high-quality development and high-level protection.

In the past four decades, unbalanced urban and rural development has occurred due to the rapid development of urbanization. Rural residents are mainly engaged in the corresponding primary industry, while urban residents are engaged in the corresponding secondary and tertiary industries. Since the secondary and tertiary industries represent the most advanced productivity, urban residents receive relatively high benefits. Furthermore, agricultural productivity is low, so farmers obtain relatively low income. This clearly shows that urban and rural areas have two economic systems with different levels of productivity development. There are differences in the internal elements and operation modes of these two systems, which lead to two different development results for urban and rural areas and the widening gap between them. Moreover, the development of urban and rural productive forces in China is unbalanced; the development of urban productive forces is fast, while the development of rural productive forces is slow, which leads to an imbalance between urban and rural development and prominent differences between them. In China’s dual economic and social structure, the development of urban and rural productive forces is not synchronized, and the changes in urban and rural production relationships are not consistent. Therefore, in order to implement an urban-biased catch-up industrialization strategy, the government has formulated a complete set of urban–rural isolation systems, thus creating urban–rural differences under the dual economic and social structure. The 19th National Congress of the Communist Party of China clearly proposed establishing a new type of urban–rural relationship. Its goal is to enhance the vitality of rural development, gradually narrow the gap between urban and rural development, promote the common prosperity of urban and rural areas, and achieve balanced development through urban development and integrated urban and rural areas. Under this requirement, it is difficult for Chinese urban enterprises to develop continuously under the

condition of emission reduction, and the development potential of rural carbon sink assets is huge, so it is necessary to establish a carbon emission and storage coordination mechanism in urban and rural areas.

Since China’s reform and opening up, China has vigorously developed the economy and ignored the potential value of rural carbon sink assets. Research on rural carbon sink resources is extremely scarce, and there is no research on how rural carbon sink assets form a mutual development mode with urban industry. Since China’s agricultural economy entered the 21st century, due to the implementation of various national agricultural policies, the living standards of farmers have been greatly improved, but many contradictions in rural development still exist. Therefore, it is both innovative and of great significance to explore the advantages of carbon sink resources in rural areas and form a mutual assistance mode with urban industrial development.

Henan Province in China is the birthplace of Chinese civilization. It is necessary to explore carbon sink resources to realize the balanced development of urban and rural areas, which is of great significance to the realization of the common prosperity of the people in China. Agriculture is an important area to achieve the “dual carbon” goal. Promoting the dual carbon strategy in agricultural and rural areas is not only an important part of accelerating the construction of an agricultural ecological civilization but also an important measure in implementing the rural revitalization strategy. Against the background of the dual carbon goal, it is necessary to adhere to the principle of sustainable development and urban and rural integration, establish a mutual assistance model between urban and rural areas based on carbon optimization, and realize the balanced development between urban and rural areas, which is of great significance for the common prosperity of the people in China.

Literature review

This important issue has attracted the general attention of scholars at home and abroad, and the research closely related to this topic can be summarized as follows.

In the study of balanced development, the greenhouse effect is caused by CO₂ emissions (Alvarado et al., 2021). The main reasons for the increase in greenhouse gases are economic growth and burning of fossil fuels such as coal, gasoline, and natural gas (Isik et al., 2021). With the continuous progress of industrialization and urbanization, the economy is growing rapidly, social productivity is continuing to improve, and energy consumption is emitting a large amount of CO₂ (Feng, 2017). The resulting ecological problems have caused immeasurable economic losses (Qiao, 2022; Zhang, 2016; Yin, 2017). In recent years, an increasing number of scholars have undertaken research on low-carbon and sustainable development. Isik et al. (2021) investigated the validity of the environmental Kuznets curve (EKC) hypothesis in eight OECD

countries. [Munir et al. \(2021\)](#) used comprehensive data from 31 provinces in China to study the impact of urban and rural migration and industrial agglomeration on environmental degradation at the regional development level, as well as the mitigation effect of urban and rural migration on the environment. [Ahmed et al. \(2022\)](#) proposed that industrialization and economic growth have had a significant negative impact on CO₂ emissions. In terms of the balanced development of urban and rural environment in China, [Liu \(2017\)](#) proposed that the current problems of agriculture, rural areas, and farmers in China are mainly reflected in the single-crop rural agricultural industry, the backward agricultural production mode, the backward agricultural industrial chain, the gradual transfer of the rural labor force to urbanized areas, the large urban–rural income gap, and the continuous deterioration of the rural ecological environment. This author also proposed effective solutions, such as optimizing the structure of agricultural industry, improving the ecological environment, addressing and optimizing the quality and ability of the rural labor force, and improving rural income. However, in Henan Province, these serious problems still exist, so it is increasingly necessary to improve them through the aforementioned ways. [Wang \(2022b\)](#) found that there are some problems in rural Henan, such as the transfer of the rural labor force to urbanized areas, the increasingly serious destruction of land and water resources, and the single-grain crop with a low sales price. Therefore, it is necessary to develop a low-carbon economy, adopt a new path for industrialization, optimize and adjust the energy structure and industrial structure, change the development mode of a high-carbon economy, and gradually change the original industrial structure dominated by high-energy and high-consumption industries in Henan Province, adopting the development mode of low energy consumption and low consumption. [Yuan \(2022\)](#) proposed vigorously developing low-carbon technology, setting differentiated emission reduction targets, promoting an ecological civilization, and flexibly expanding carbon sink trading. We should fully implement the concept of “clear waters and lush mountains are gold and silver mountains;” coordinate the role of governments, enterprises, and individuals in the carbon sink market; flexibly expand carbon sink trading; and achieve common prosperity and the dual-carbon goal.

Regarding the dual structure of urban and rural areas, based on the investigation of the data related to dual carbon goal, it is known that carbon sink assets have huge economic value potential. As the hinterland of the Central Plains and a large province in China, Henan has rich carbon sink resources, but these have not been fully exploited and utilized. Through carbon sink trading, the coordinated development of urban and rural areas can solve ecological environmental problems on one hand and promote the common prosperity of urban and rural areas on the other hand. [Zheng and Zhang \(2022\)](#) proposed that carbon emission trading is more flexible, more sustainable, and therefore

more effective in promoting the realization of the dual carbon goal. However, the carbon trading market system should be improved in several aspects, such as the determination mechanism of a total carbon emission standard, the initial allocation and auction system of carbon quota, the disclosure of carbon emission trading information, and the reward and punishment mechanism of carbon emission trading. [Xie et al. \(2021\)](#) asserted that domestic carbon sink projects have played an important role for forestry in tackling climate change, enriching carbon market trading products, reducing emission reduction costs, mobilizing social forces to increase awareness and action to combat climate change, increasing employment income and reducing poverty, expanding the ways and forms of forestry ecological compensation, and realizing the value conversion of carbon sink ecological products. [Wang \(2022a\)](#) argued that there are several problems in urban and rural development, such as imperfect policy systems, imperfect voluntary emission reduction management mechanisms, unclear project property rights, complex transaction processes for project development, relatively limited (single) carbon sink trading varieties and compensation mechanisms, an unclear understanding of forestry carbon sink trading, and high transaction costs and risks.

Regarding research on dual carbon constraints, in the decision-making process for developing a low-carbon economy and implementing carbon sink trading, many Chinese scholars have found through research that not only are there a large number of carbon sink resources in China but that there are also problems regarding their development and utilization. [Tang and Luo \(2022\)](#) proposed that actions must be taken to achieve peak CO₂ emissions and to accelerate industrial transformation and upgrading, with strenuous efforts needed to build a low-carbon energy system. [Fatima et al. \(2022\)](#) argued that the adoption of environmental protection technology can reduce the use of energy. [Tang and Jinglin \(2022\)](#) proposed that digitization can reduce carbon emissions by optimizing the industrial structure, adjusting the energy structure, improving the efficiency of government governance, and changing people’s means of production and way of life. [Munir et al. \(2019\)](#) asserted that there is a long-term balance between energy consumption, gross regional product (GRP), urbanization, construction, and CO₂ emissions, and that energy consumption growth, GRP growth, urbanization, and construction growth have a significant positive impact on CO₂ emissions. According to [Liu et al. \(2021\)](#), given that China is one of the world’s largest economies, foreign direct investment (FDI), technological innovation (TI), and trade are crucial to becoming carbon neutral. To achieve carbon neutrality, China needs to increase the proportion of its renewable energy in its total energy mix. To meet China’s energy needs, the share of renewable energy must be increased in relation to the consumption of non-renewable energy. [Ahmad et al. \(2021\)](#) studied the long-term and short-term heterogeneous links among urban concentration, non-renewable energy utilization intensity, economic development,

and the environmental emission index at the regional development level in China. Işik et al. (2020) discussed the relationship between tourism revenue, renewable energy consumption, and CO₂ emissions. Isik et al. (2021) studied the EKC and found that policymakers in U.S. states can determine and adjust their gold expenditure levels to prevent environmental degradation and GDP decline. According to Bai (2022), Henan Province is characterized by emerging industry and a heavy industry structure; energy consumption intensity is higher than the national average, especially in eastern developed areas, with the energy structure not being optimal in the fields of agriculture, chemical fertilizers, pesticides, agricultural films, diesel use, and agricultural irrigation, while ploughing has a significant impact on carbon emissions. Wang et al. (2022) proposed that the farmland ecosystem is a huge carbon pool and that Henan Province has developed agriculture, rich varieties of food crops, and extensive farmland, so it has the advantage of such exploitable resources. A low-carbon and high-quality agricultural development model can be realized by improving the agricultural low-carbon technology level, optimizing the energy structure, protecting the existing cultivated land, improving the agricultural production efficiency, optimizing the farming mode, adjusting the crop planting structure, and developing a circular agriculture model. Zhou and Hou (2021), based on the estimation of soil carbon sequestration potential and soil carbon sequestration economic analysis, concluded that the soil carbon library is the largest terrestrial ecosystem for carbon storage and that soil carbon sequestration has huge potential and multiple benefits, with most of the potential economic benefits being feasible in theory. However, the development of the soil carbon sequestration market is slow. Therefore, it is necessary to improve the soil carbon sequestration capacity in China, promote basic research and technical breakthroughs regarding soil carbon sequestration, strengthen the regulation and management of land use, and build a policy system with effective incentives. Wang (2017), in their evaluation of the carbon sequestration effect and the potential of the Farmland to Forest Project in Henan Province, also pointed out that this project has greater carbon sequestration potential under the harvesting scenario, so the carbon sequestration capacity of the Farmland to Forest Project can be improved by moderate logging after reaching the harvesting age. Feng (2017) concluded that land use is an important point for a low-carbon economy and carbon emissions, and also is one of the most important tools for carbon emissions control; however, while Henan has rich land resources, more research is required regarding land use in relation to carbon emissions, more help is required regarding land use planning, and there is a need for industrial structure regulation and development and improvement in several areas, such as a comprehensive guide on low-carbon economic and social development.

Analysis of unbalanced development between urban and rural areas in Henan Province

Single development path of the agricultural industry

As an important birthplace of Chinese civilization, Henan has thousands of years of civilization and was once considered a world leader. This raises the question of why Henan is so down and out now. With the emergence of scientific and technological civilization, Henan, which relies on agricultural civilization, has failed over time to keep up with developments, and the proportion of its agricultural economy has gradually declined in relation to national economic development. As a major agricultural province, Henan still has many problems in its agricultural development, although its agricultural production is growing steadily. This is mainly reflected in uncertainty in the industry, the mainly single variety of agricultural products, the unreasonable layout, and the lack of timely promotion of high-quality products.

As can be seen from Table 1; Figure 1, Henan, as the hinterland of the Central Plains, has the fertile alluvial plain of the Yellow River and unique natural conditions, which are extremely suitable for crop growth, but this has also created a strange phenomenon in Henan: the variety of agricultural products is relatively limited (single); and the layout is not reasonable. Henan, in terms of the agricultural production of plants, mainly produces food crops such as wheat and corn, and the crops here are all the base products. Furthermore, economic efficiency is not high, most farmers do not dare to be bold in terms of innovation, and it is difficult to achieve breakthroughs in the industrial structure; in contrast, in Jiangsu and Zhejiang, Fujian, this phenomenon can lead to the high value of agricultural products. Moreover, high-quality varieties have not been promoted in a timely manner. At present, the corn and wheat seeds used by farmers in most rural areas of Henan Province have no fixed brand, and there is a great imbalance. The popularization and use of seed research and development technology is limited, and the new technology is not fully promoted, resulting in great uncertainty and variations in grain yield.

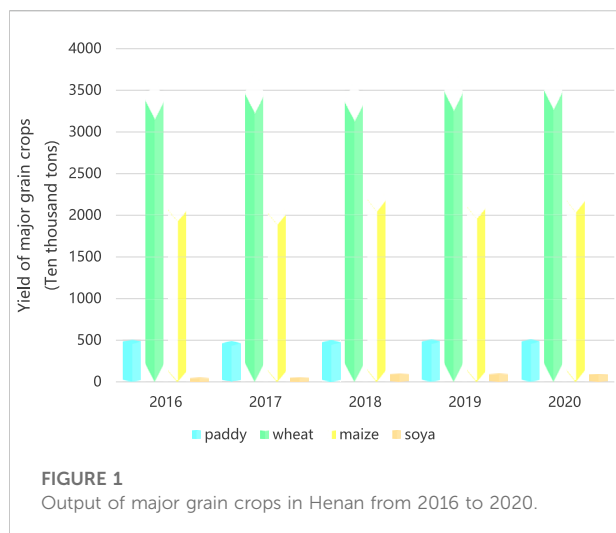
The structure of the agricultural industrial chain is backward

From Figure 2, it can be seen that the short agricultural industrial chain in Henan Province is mainly reflected in the low level of agricultural mechanization, the insufficient growth of leading agricultural enterprises, and the lack of long-term unified planning for the agricultural industry, resulting in low agricultural benefits. Most agricultural products in Henan

TABLE 1 Sown area of crops in Henan Province from 2016 to 2020.

| Species | 2016 | 2017 | 2018 | 2019 | 2020 |
|-----------------------------|-----------|-----------|-----------|-----------|----------|
| Food | 11,219.55 | 10,915.13 | 10,906.08 | 10,734.54 | 10,738.8 |
| Oil | 1,302.35 | 1,397.49 | 1,461.40 | 1,533.93 | 1,597.53 |
| Cotton | 50.03 | 40.00 | 36.68 | 33.80 | 16.20 |
| Best fire plants | 4.11 | 3.29 | 3.00 | 2.82 | 1.59 |
| Sugar | 2.42 | 2.31 | 2.03 | 1.62 | 1.51 |
| Tobacco | 109.21 | 103.95 | 94.88 | 86.50 | 80.52 |
| Chinese herbal medicine | 99.81 | 112.19 | 132.44 | 153.59 | 159.52 |
| Vegetables and edible fungi | 1,682.12 | 1,736.14 | 1,721.09 | 1,732.94 | 1,753.78 |
| Melon and fruit | 312.36 | 318.24 | 307.69 | 308.60 | 301.06 |
| Flowers | 86.35 | 147.56 | 92.18 | 123.56 | 119.75 |
| Other | 120.77 | 103.80 | 103.77 | 88.09 | 91.08 |

Unit: thousand hectares.



Province are still rough-processed, and there are few deep processing and fine processing agricultural products. There is little direct connection between agricultural production and agricultural enterprises, and the development of order agriculture, digital agriculture, and other models is insufficient.

The processing mode of agricultural products in Henan is backward, and the price is low. For farmers, most agricultural products are sold in the state of harvest, almost without processing, so farmers earn the lowest price. The agricultural sales link also has problems; even though the agricultural harvest and agricultural products increase every year, farmers still do not make money. The root of the problem is that agricultural products cannot be sold or only sell for low prices, so farmers cannot make money, let alone get rich. In addition, Henan Province's agricultural production lacks long-term unified planning, full play is not given to the scale effect, and local

agricultural products lack a brand effect; the problem lies in not establishing a comprehensive agricultural sales system, relying instead on the ability of farmers to sell agricultural products. At the same time, in most rural areas of Henan Province, the main agricultural economic subjects are farmers, so it is difficult to form economies of scale and difficult to adapt to the needs of modern market economy. Farmers can only have a single agricultural product sales model; they go to the countryside to collect food, and selling food crops cheaply accounts for the majority of Henan rural sales channels for farmers. As the agricultural product price is low, farmers' income is low, which leads to the enthusiasm of rural farmers gradually decreasing and their traditional power weakening, which in turn leads to more and more farmers giving up farming and leaving their villages. More and more farmers are choosing to work in cities, meaning that the rural labor force is gradually flowing to the cities.

Urbanization of the permanent resident population in Henan Province is continuing to increase

With the continuous development of urban industrialization and urbanization, the urbanization rate of the permanent resident population in Henan Province is also increasing through the data survey (as shown in Figure 3). At the end of 2021, the permanent resident population of Henan Province was 98.83 million, including 55.79 million urban residents and 43.04 million rural residents. The urbanization rate of permanent residents was 56.45%, 1.02 percentage points higher than that at the end of the previous year. There were 793,000 births, and the birth rate was 8.00 per thousand; 73,000 people died, with a mortality rate of 7.36‰. The natural population increase was 63,000, with a natural growth rate of 0.64‰.

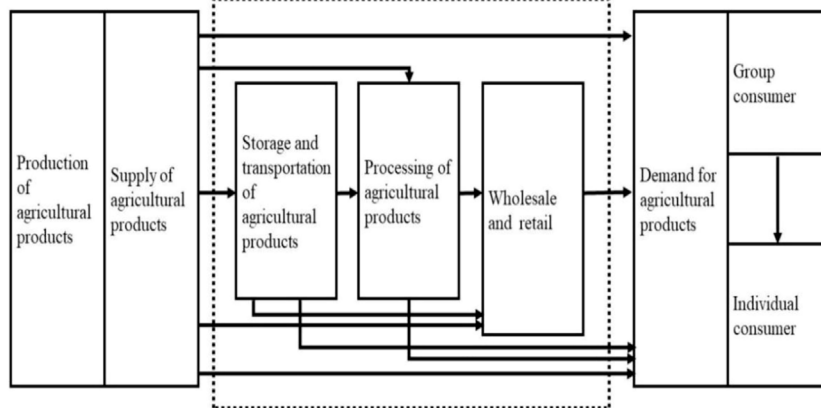


FIGURE 2
Structure of the agricultural industrial chain in Henan Province.

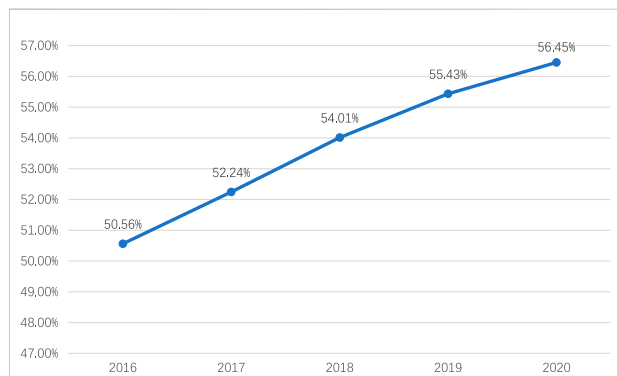


FIGURE 3
Urbanization rate of the permanent resident population in Henan Province from 2016 to 2020.

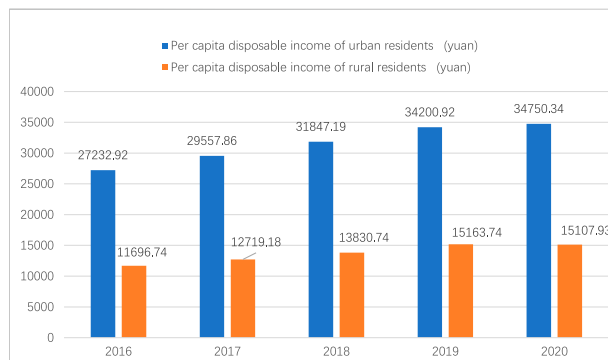


FIGURE 4
Comparison of urban and rural residents' income in Henan Province.

At the same time, in 2021, Henan added 1.2539 million urban jobs, 404,600 urban unemployed people were reemployed, and 138,400 urban people with employment difficulties were employed. The registered urban unemployment rate at the end of 2021 was 3.40%. An additional 476,300 rural workers were transferred to new jobs, and 202,300 returned to their hometowns to start businesses. A total of 31,343,300 rural laborers were transferred, of which 18.7836 million were transferred within the province and 12.5597 million were exported from outside the province.

There is a large income gap between urban and rural residents in Henan

With the continuous development of society, the total income of urban residents per capita and the total income of

rural farmers in Henan Province is showing a rapid growth trend.

Figure 4 clearly shows that the per capita disposable income of urban residents in Henan increased from 27,200 yuan to 37,500 yuan from 2016 to 2020. The per capita disposable income of rural residents increased from 11,700 yuan to about 16,100 yuan. The total income of urban and rural residents maintained a steady upward trend, but the income gap was still large. At the same time, the growth trend of urban residents' per capita disposable income was stronger than that of rural residents, and the gap was gradually widening.

The income of farmers is composed of five major sectors, namely, productive income, operational income, property income, labor income, and policy income. After many years, these five major income streams have entered a bottleneck period, and there is basically no growth. Even though the central government's transfer payment is generous, and tens of trillions of

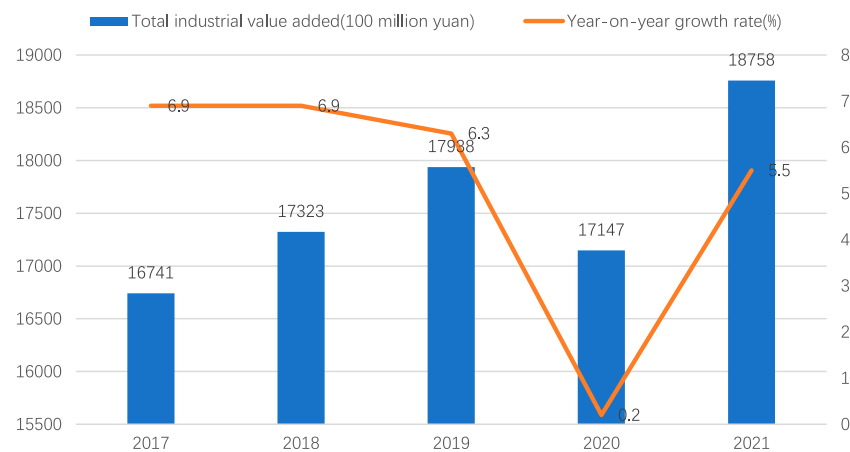


FIGURE 5
Total industrial added value of Henan Province from 2017 to 2021 and its growth rate.

dollars are invested in agriculture, rural areas, and farmers every year, this has not increased farmers' income. Henan Province has a large population, with about 122 million people (in the seventh census in 2021). According to the statistics of the National Bureau of Statistics, Henan has the largest number of migrant workers, with about 1,845 people working every year. At the same time, higher education resources are in short supply, with only one Project 211 university. People in Henan cannot only grow food; however, there is a lack of good universities to provide a good future and to develop science and technology, and without good scientific research institutions, it is difficult to develop the economy. For Henan farmers seeking work, due to low technical skills, work to sell labor, and low wage income, coupled with the cost of leaving home, their natural income is far lower than that of urban residents. Although rural areas under the socialist system have witnessed some improvements in medical facilities and various social security aspects, some remote villages are still in a relatively backward state, suffering from inconvenient transportation, limited medical facilities, relatively poor education, and gaps in social security.

The industrial structure of Henan is not reasonable

The total industrial added value of Henan in 2021 was 1,878.530 billion yuan, an increase of 5.4% over the previous year.

As shown in Figure 5, the added value of industrial enterprises above designated size in Henan province increased by 6.3% over the previous year. By category, the added value of mining fell by 7.6%, manufacturing by 7.7%, and electricity, heat, gas, and water production and supply by 3.6%. By key industries, the added value of the energy and raw material industries increased by 2.0%, accounting for 44.1% of all industries above the designated size. Manufacturing of consumer goods grew by 8.4%, accounting for

26.1% of industries above the designated size. The five leading industries grew by 9.6%, accounting for 46.1% of industries above the designated size. Traditional pillar industries grew by 2.1%, accounting for 48.4% of industries above the designated size. Industrial strategic emerging industries grew by 14.2%, accounting for 24.0% of industries above the designated size. High-tech manufacturing grew by 20.0%, accounting for 12.0% of industries above the designated size. Industries with high energy consumption grew by 2.1%, accounting for 38.3% of industries above the designated size.

It can be seen from the data that, while the industry is developing rapidly, the problems and challenges facing the industrial development of Henan Province are as follows: the industrial structure is unreasonable; the level is low; small enterprises still account for the vast majority; the degree of concentration is not high; and the level of product structure is low. The overall level of Henan's products is low, with more primary products of resources and rough processing, and fewer middle and high-end products with high added value and deep processing. There are many high-energy consumption and high-pollution products. There are more general agricultural products, but few high-quality and efficient agricultural products. Industrial development is still dominated by material resource consumption, and the contribution of science and technology is low.

The rural ecological environment in Henan is deteriorating

There are many environmental problems in the process of rural urbanization in Henan. Urban expansion, encompassing industrial land, residential land, construction land, and transportation facilities land, has led to the rural arable land area decreasing sharply, the increasing desertification of the land, most township

farmers losing their land, and the marginalization of rural farmers because of the loss of farming land, giving up farming, and going out to work, resulting in barren farmland. At the same time, the backward production mode of Henan agriculture has caused a prominent clash between the environment and resources. Farmers' short-term behavior, in order to increase production and increase value, such as the long-term extensive use of chemical fertilizers and pesticides, is causing soil and water pollution. Owing to land consolidation and soil acidification, fertile land resources are declining sharply, and the traditional agricultural flood irrigation method is causing a great waste of water resources, resulting in more water scarcity. Furthermore, due to the deforestation of a large number of rural areas, soil erosion is becoming increasingly serious, and the problem of agricultural land conversion is also serious, leading to the arable land area gradually shrinking, and land desertification is also a serious problem. At the same time, the unregulated discharge from urban industries is causing groundwater pollution and the shortage of drinking water resources for farmers. In the context of the development of industrialization, the waste treatment facilities are not perfect, villagers' environmental protection consciousness is weak, and regulations are not in place, among other problems, leading to industrial gas emission, industrial waste not being handled properly, industrial pollution negatively affecting the environment, more litter, sewage being drained off, and problems of water and soil pollution. This situation has caused the destruction of China's agricultural ecosystem and the deterioration of the rural ecological environment.

Value of rural carbon sink assets and urban low-carbon cost in Henan Province

Status of rural carbon sink assets in Henan Province

At present, the carbon sink projects that have been carried out in China include grassland carbon sink, forest carbon sink, and marine carbon sink, while there are few carbon sink projects involving agriculture. Agriculture is the second largest source of carbon emissions in China. Promoting carbon emission reduction and sequestration in agriculture and rural areas is an important part of achieving carbon peak and carbon neutrality. As an important agricultural province and a major grain-producing area, Henan Province's carbon emission intensity is much higher than the national average level, and it also has relatively rich carbon sink resources.

The agricultural ecosystem has a huge potential capacity to sequester carbon. If the rate of straw return in China increases from the current 15% to 80%, the balance of soil carbon in China's farmland will change from the current annual net discharge of $9.5 \times$

107tC to the absorption of $8.0 \times 107\text{tC}$ from the atmosphere. Assuming that comprehensive measures can increase soil organic matter by 30%–40% within 30 years, China's cultivated land alone can increase carbon sequestration by nearly $1.0 \times 109\text{tC}$. Adopting reasonable agricultural measures to increase the carbon sequestration capacity of agricultural soil will play an important role in mitigating climate change. The irrigated area of farmland in Henan Province is 5,403.67 thousand hectares, and the farmland soil in Henan Province has obvious potential for carbon sequestration and emission reduction. Under the influence of farmland soil management activities, such as cultivation, irrigation, and fertilization, the quality of the agricultural soil carbon pool will change rapidly, thus affecting the total amount of greenhouse gases in the entire atmosphere. In recent years, the carbon sequestration and the carbon sequestration intensity per unit of sown area in Henan Province have shown an increasing trend. The carbon sequestration capacity of the farmland ecosystem in Henan Province has been continuously enhanced, and the carbon sequestration is greater than the carbon emissions. In the decomposition of carbon source factors, the improvement of the agricultural energy utilization level, the agricultural low-carbon technology level, and the control of the labor force scale can effectively reduce carbon emissions. In the decomposition of carbon sink influencing factors, the carbon sink coefficient and the carbon sink technology level have positive effects on carbon absorption, and wheat has the strongest carbon sink capacity.

Soil carbon sink in farmland is transformed from a carbon source to a carbon sink by adopting conservation tillage measures, expanding the paddy field planting area, increasing the application of organic fertilizers, increasing straw return to the field, land use mode, and crop rotation system, making a significant difference to the soil organic carbon pool. The farmland soil carbon sink project is based on the function of soil carbon sequestration and emission reduction. The carbon sequestration service is paid for by the carbon sequestration party to offset the carbon emission in the environment.

Example of carbon sink trading in Henan Province

Li Xiao-long from Zhengzhou, Henan Province made 30 million yuan from carbon trading in 2019 and 2020. Many people think he is an air or coal seller, which is an incorrect perception. Even Li Xiao-long's father did not understand this and thought his son was being defrauded by a pyramid scheme. In fact, it is a kind of carbon sink trading, and "carbon emission manager" has been listed as a professional role by the state. The state sets the total amount of carbon emissions each year and caps the amount of emissions granted to relevant enterprises. Surplus credits can be traded on the national carbon market and sold to companies with excess carbon emissions. In this way, more refunds and less subsidies will ensure that the total national carbon emission does not exceed the target each year. In order

to reduce emissions and save money, enterprises will also strive to achieve environment-friendly development. Regarding Bruce Lee, in 2019 and 2020, the company's carbon emission surplus was more than 800,000 tons, resulting in a carbon sink trading profit of more than 30 million yuan. The actual number of carbon sink employees in Henan is about 100. The demand for carbon sink employees is high, the employment prospects are very good, and the income is considerable.

The development prospects for carbon sink trading in Henan are good

A unified national carbon emission trading market was established at the end of 2017, and the first carbon sink trading was officially launched on 1 January 2021. According to the National Development and Reform Commission, the trading volume of China's carbon trading market is expected to reach 250 million tons in 2021, and the annual turnover will reach 6 billion yuan. Compared with the 13th Five-Year Plan period, the trading volume of carbon sinks during the 14th Five-Year Plan period is expected to increase by three to four times, and the accumulative trading volume is expected to exceed 100 billion yuan by 2030.

Regarding the 2022 decision to comprehensively advance the rural revitalization of the key work, the State Council of the Central Committee of the Communist Party of China emphasized the reduction of development and the application of carbon-sink-type agricultural technology, promoting agricultural carbon sink value realization, promoting the development of green agriculture and rural areas, rural ecological revitalization guidance work, exploring establishing carbon sink products' value realization mechanisms, and developing agricultural carbon sequestration potential for reducing emissions. China's rural areas have great potential in low-carbon agriculture and carbon sink. On one hand, they can contribute to the national carbon emission reduction work. On the other hand, they can provide financial support for farmers through carbon sink trading, improve agricultural production modes, and increase farmers' income.

Henan is located in the Central Plains and the middle and lower reaches of the Yellow River, encompassing a total area of 167,000 square kilometers, and is a province with a large population in China. There are many mountain ranges between Henan and other provinces, and the existence of these mountains undoubtedly constitutes a large amount of forest carbon sink resources for Henan. In addition to mountainous areas, there is also a large plain area in the central and eastern parts of Henan Province. As a strong agricultural province, the cultivated land in the plain area also represents a large amount of natural soil carbon sink resources for Henan Province. In the analysis of the current situation of Henan Province, we can also see that, in recent years, the annual

urban industrial development of Henan Province has been consuming a large amount of energy, resulting in high pollution, and the agricultural ecological environment has also been deteriorating. Therefore, Henan Province set up its own carbon trading platform, looking for buyers for low carbon emission reduction projects through the market mechanism. The aim is for carbon sink projects to attract more social funds, with technology and personnel participating in the construction and development of the agricultural carbon sinks projects, as well as attracting more resources for carbon sequestration management, which will not only improve the land's ecological environment quality but also address the agricultural increase remit. Furthermore, the rich variety of carbon trading products, reducing the discharge costs of industrial enterprises, and making more carbon sink project emission reductions are all key elements in the carbon trading market, helping improve the carbon market trading activity and further promoting the coordinated development of urban industry and rural agriculture, going far beyond simple reduction activity and having practical outcomes and far-reaching significance. Therefore, Henan's "carbon sink trading" market has good prospects.

Necessity of low carbon cost for urban industrial development in Henan Province

The inertia of Henan's traditional extensive economic growth model is continuing to escalate, exacerbating the constraints of resources, energy, and the environment on economic growth, coupled with the situation that Henan has the largest population; thus, compared with the whole country and other provinces, Henan's resource and energy supply shortage is particularly obvious.

The country's per capita resource base reserves of oil, natural gas, coal, and primary electricity and other energy are several times larger than those of Henan. As can be seen from Table 2, the per capita resource base reserves of Henan Province are relatively low, but the energy consumption is relatively high, and far higher than the total energy production. The annual comprehensive energy consumption of industrial sectors above the designated size in Henan Province reaches nearly 150 million tons of standard coal, and the power consumption index of Henan Province's unit GDP reaches more than 1300 kWh/ten thousand yuan, which is much higher than that of developed provinces such as Jiangsu and Zhejiang, as well as Shandong and Anhui. At the same time, there are more than 700 industrial enterprises consuming more than 10,000 tons of standard coal per year. Henan's energy supply is increasingly tight, and its energy consumption is increasing day by day.

Therefore, Henan must change the mode of industrial economic development in order to achieve sustainable economic development. The low-carbon economy in

TABLE 2 Comparison of total primary energy production and consumption in Henan Province from 2016 to 2020.

| Ten thousand tons | Category | 2016 | 2017 | 2018 | 2019 | 2020 |
|-------------------|--|--------|--------|--------|--------|--------|
| Total production | Raw coal | 8,629 | 8,914 | 8,252 | 8,510 | 8,322 |
| | Oil | 456 | 400 | 370 | 361 | 343 |
| | Natural gas | 48 | 41 | 39 | 41 | 42 |
| | Primary electricity and other energy sources | 572 | 872 | 1,070 | 1,422 | 1,706 |
| Consumption | Raw coal | 16,831 | 15,868 | 15,839 | 15,075 | 15,080 |
| | Oil | 3,192 | 3,236 | 3,467 | 3,501 | 3,481 |
| | Natural gas | 1,161 | 1,285 | 1,314 | 1,360 | 1,342 |
| | Primary electricity and other energy sources | 1,116 | 1,773 | 2,039 | 2,386 | 2,548 |

Henan's development needs to focus on the input and output efficiency and economic returns, which requires us to optimize the allocation of resources, improve the quality and efficiency of economic development, change the economic growth mode, optimize the industrial structure, reduce the energy consumption of industrial production, update consumption patterns, and reduce the cost of urban industrial low-carbon industries. We must develop a low-carbon economy and take a new path for industrialization. To optimize the adjustment of the energy structure and the industrial structure, as well as the transformation of the high-carbon economy development mode, the concept of a low-carbon economy must permeate almost every aspect of society, via the development of "low-carbon economy" urban industries created through the effective promotion of sustainable development of policy mechanisms and security systems in order to better promote the industrial upgrading and enterprises' technological innovation in Henan Province. In Henan Province, the original industrial structure dominated by industries with high energy consumption and high consumption should be gradually changed, and the development mode with low energy consumption and low consumption should be gradually adopted.

Construction of a coordinated development model for urban and rural areas in Henan Province

Improve the carbon sink trading system and policy system

- 1) The government should improve the incentive policy mechanism and reward and punishment policies.
- 2) We should pay attention to social publicity and raise farmers' awareness.

The government plays an extremely important role in promoting the development of rural carbon sink trading. It is necessary to strengthen the support for rural grassroots participation in carbon sink assets and the mutual assistance mode of urban-rural trading. At the same time, we need to increase support for agriculture, encourage farmers to develop agricultural production, raise the prices of agricultural products, and stimulate farmers' enthusiasm for agricultural production. We need to encourage migrant workers and college students to return to their hometowns to start businesses, improve the overall quality of the rural labor force, vigorously develop modern planting techniques, and thoroughly develop the rural economy and agricultural production. Governments at all levels need to attach great importance to the development of agriculture, actively participate in carbon sink trading, increase farmers' income, and improve the national economy.

At the same time, the government should promote the trading of ecological resource rights and interests in an orderly manner. In accordance with the principle of "compensation for occupiers, restoration for damages, payment for beneficiaries, and profit for protectors," we need to make comprehensive use of natural resource policies and gradually create a system for realizing the value of ecological products. The use of incentive policies and punishment rules can achieve the effect of the two-way regulation and control of enterprise performance risk. The institutional arrangement with clear rewards and penalties can not only crack down on illegal behaviors that hinder the carbon emission trading market but also stimulate the participation and activity of urban enterprises and rural individuals, in order to cultivate their awareness of carbon emission reduction, with the law playing a guiding and educational role.

Farmers are energy producers and consumers. As a major agricultural province, Henan Province accounts for large number of farmers in the country. However, the overall quality of farmers in Henan Province is still not high, and most of them still retain traditional concepts and do not understand the importance of low-carbon agriculture. The low-carbon development of rural areas requires extensive participation of farmers, and there is a need to guides farmers to actively participate in low-carbon actions. Government units should strengthen social publicity and theoretical and practical training; in particular, relevant departments and local leaders should correctly understand and publicize the value of carbon sink trading, thus stimulating farmers' enthusiasm for innovation and creation. The ecological awareness of farmers should be strengthened, and the publicity regarding farmers and various platforms should be combined to introduce the basic concept of low-carbon projects and the necessity of development to them, thus consciously establishing the awareness of low-carbon development. Incentive mechanisms, such as advanced selection, should be established to enhance farmers' enthusiasm to participate in carbon sink trading.

Improve the land use mechanism

Changes in land use patterns affect the carbon cycle of terrestrial ecosystems. Land utilization can be reduced, land yield can be increased, crop planting area can be expanded, and carbon sequestration capacity can be enhanced. We need to coordinate projects, such as comprehensive land improvement, high-standard farmland construction, the comprehensive utilization of agricultural waste, the improvement of the living environment, and the development of ecological and circular agriculture, to improve the biodiversity of farmland ecosystems and to reduce agricultural non-point source pollution. We need to attach importance to the protection of cultivated land and increase soil carbon storage. As an important element of agricultural production, cultivated land is not only an important subject for carbon emissions but also an important element of carbon sequestration.

As a major agricultural province in China and the core area of national grain production, Henan has a vast land area, so it should play a greater role in balancing national food security and dual carbon goal, reduce carbon input in production, and increase the carbon sink capacity of the cultivated land ecosystem. We should continue to pay attention to the ecological security of cultivated land, encourage the return of straw to the field, and reduce environmental pollution. We should actively develop an ecological cycle and carbon sequestration agriculture with low input, high yield, and low emissions and expand the coverage of ecological planting, farming, and arable land. We need to vigorously develop field

crops, such as rice and wheat, with high carbon sequestration benefits and low carbon sequestration costs and increase the carbon sink of crops while ensuring national food security. At the same time, we should return farmland to forests, afforest barren mountains, and strengthen the management of plantation forests. We should focus on solving common problems, such as soil erosion, acidification, and salinization; advocate soil testing and formula fertilization; promote the application of organic fertilizers; increase soil organic matter; minimize the use of chemical fertilizers and pesticides; and reduce carbon input. We need to conduct ecological accounting for the annual carbon sequestration of ecological resources, such as forests, orchards, wetlands, and farmland, and establish an ecological carbon sink trading mechanism between governments at all levels and between governments and enterprises.

Explore the carbon sequestration potential of major rural resources in Henan Province

Henan is located in the Central Plains and has a huge potential for soil carbon sequestration and forestry carbon sequestration due to its innate geographical conditions. Against the background of increasingly urgent global climate governance requirements, soil carbon sequestration may become an important solution to mitigate climate change. In order to better explore the huge emission reduction and sink increase benefits of soil carbon sink in Henan Province, we should focus on the following work. First, we need to promote basic research and technical breakthroughs for soil carbon sink. Second, we need to strengthen the regulation and management of land use, as well as carrying out ecological restoration of degraded land, improving soil carbon sink capacity, and promoting the realization of carbon neutrality. Third, we need to build a policy system with incentive effects. The realization of soil carbon sequestration potential depends not only on technological development but also on sound supporting policies.

The forestry carbon sink project plays an important role for forestry in addressing climate change. Through the market mechanism, the forestry carbon sequestration project can attract more social funds, technology, and personnel to participate in forestry carbon sequestration project construction and development, and attract more resources into forest carbon sequestration management, which will not only improve the afforestation area for carbon sinks but will also improve the quality of the forest and promote forest sinks, thus effectively developing the important role of forestry in tackling climate change. At the same time, the existence of forestry carbon sink trading will also promote employment and increased income for forest farmers and alleviate poverty. Forest farmers participating in forestry carbon sink projects, such as

afforestation, forest protection, and forest operation, can obtain employment opportunities and labor income. Compensation income through forestry carbon sink projects can provide an effective way to achieve poverty alleviation in poor areas. Forestry carbon sink not only expands the ways and forms of ecological compensation for forestry ecological construction and ecological protection and restoration but also realizes the value transformation of carbon sink ecological products, practicing the concept of “clear waters and green mountains are gold and silver mountains.”

Therefore, only by strengthening the carbon sequestration potential of rural resources can one achieve the implementation of carbon sink trading, promote the coordinated development of industry and agriculture, build a mechanism for industry feeding back to agriculture, promote rural development, and promote the increase of farmers' income.

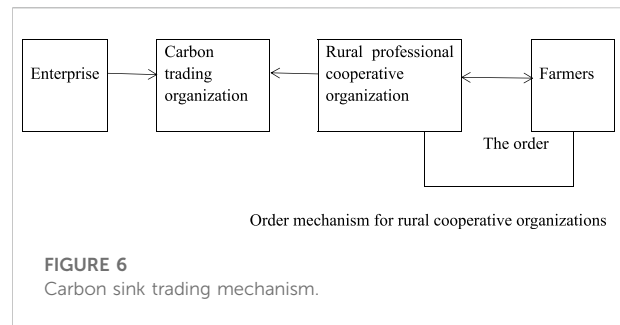
Build a mutual assistance mechanism for industry to feed back to agriculture

- 1) Establish the operational mechanism for the ecological carbon sink trading market in Henan Province.

To continuously develop and improve the carbon trading market in Henan Province, it is necessary to construct a platform for the carbon trading market, facilitate urban industrial carbon emission reductions for carbon trading programs, make carbon emissions quotas that can be sold in the trading platform, and set up the mechanism for carbon trading, thus improving urban industrial development and reducing the consumption of carbon, which will also benefit rural people at the same time.

As shown in Figure 6, this agricultural carbon sink trading mechanism comprises three main agricultural carbon trading entities (rural enterprises, professional organizations, and farmers), a carbon trading mechanism, and related mechanisms (a farmers' benefit sharing mechanism and the mechanism for farmers' cooperative organization). Enterprises that join the carbon trading institution voluntarily and legally commit to achieving their quantitative greenhouse gas emission targets by reducing emissions or purchasing carbon emission reduction targets from compensation projects. The function of rural professional organizations is to organize farmers, help farmers who are willing to implement low-carbon agricultural technologies sign contracts or orders, sell their greenhouse gas emission reduction indicators to carbon trading institutions, and then return the profits to farmers according to the signed contracts, in order to improve farmers' income.

- 2) Improve the group cultivation mechanism for carbon sink trading in Henan.



We need to expand and cultivate medium-sized enterprises in Henan to become the main players in purchasing carbon sinks and strengthen cooperation with Internet enterprises to expand the group of carbon sink buyers. We need to strengthen territorial space management and control; enhance ecosystem service capacity; explore low-carbon land use patterns; promote development, utilization, protection, and restoration; adopt natural and artificial comprehensive governance measures; improve the quality and stability of ecosystems and enhance their ability to regulate the climate; sequester carbon and release oxygen; reduce emissions; and increase sink capacity. There is a need to cultivate all these areas in the carbon trading market; only if all these areas are addressed can there be buyers and sellers. Urban industrial units must actively participate in carbon sink trading so that urban industry can effectively reduce carbon emissions and effectively feed back into the development of agriculture. The buyers of carbon sinks can be enterprises, various green carbon funds, and civil organizations. Individual farmers, rural collective economic organizations, and rural professional cooperative organizations can provide or sell agricultural carbon sinks. In addition, intermediaries are also necessary participants in the agricultural carbon sink trading market. The participants of carbon sink trading need education and training on low-carbon knowledge before they can enter the trading structure and participate in market trading.

Conclusion

Agriculture is an important area in achieving the dual carbon goal. Promoting the dual carbon strategy in agricultural and rural areas is not only an important part of accelerating the construction of an agricultural ecological civilization but also an important measure in implementing the rural revitalization strategy. Against the background of the dual carbon goal, adhering to the principle of sustainable development and urban-rural integration, and according to the representative analysis of agriculture, rural areas, and farmers in Henan,

Henan still has some problems, such as the unreasonable rural industrial structure, the single industrial structure, the backward production mode, increasing rural environmental pollution, low land-use efficiency, the low overall quality of the farmer labor force, and slow income growth. It is necessary to establish a mutual assistance model between urban and rural areas based on carbon optimization to realize the balanced development of urban and rural areas. Accordingly, we propose the following four suggestions:

- 1) Improve the carbon sink trading system in Henan. We need to strengthen overall planning at all levels of government to strengthen social publicity, to improve farmers' awareness of participation, to constantly improve various encouraging policies, and to encourage urban industrial units and rural farmers to actively participate in carbon sink trading projects. Furthermore, government departments should implement plans more reasonably according to regional differentiation and local conditions.
- 2) Improve the land-use mechanism. Changing the land-use mode will affect the carbon cycle of the terrestrial ecosystem, reduce land utilization, improve the land yield rate, and expand the planting area of crops, thus improving the carbon sink capacity and enhancing the carbon sequestration capacity of the ecosystem.
- 3) Consolidate the main carbon-fixing potential in rural Henan. It is necessary to continuously strengthen the huge potential of soil carbon sink and forestry carbon sink in order for this to be more helpful in implementing rural carbon sink trading, to promote the coordinated development of urban industry and rural agriculture, to build a cooperative development mechanism of industry feeding back into agriculture, to promote rural development, and to promote the increase of farmers' income.
- 4) Build an urban–rural mutual assistance mechanism in which industry feeds back into agriculture. By building industrial feedback into the agriculture mechanism of urban and rural mutual assistance, it will be possible to promote the principle of the carbon sink trading mode (for enterprises and individual trading), to help farmers participate in carbon sink trading through an income guarantee mechanism, to encourage enterprises to reduce carbon emissions, to drive the diversified development of rural agriculture, to promote the rural environment, rural labor, and young people in order to provide good employment opportunities, to improve farmers' income level, to quickly promote the development of rural areas, to further reduce the gap between urban and rural areas, and to promote common prosperity.

In previous studies, many opinions and suggestions have been put forward, based mainly on the current situation of the urban–rural dual structure, the potential value of ecological carbon sink resources, and improving the carbon sink trading system, but there are relatively few views on how to promote the coordinated development of urban and rural areas by building a carbon sink trading market. The current study addresses this gap in two key ways. First, it focuses on the current situation of urban and rural development in Henan, combined with the current situation for the coordinated development of an urban and rural carbon sink market trading system, aiming to solve the problem of urban low carbon emission reduction, and also encouraging rural farmers to actively participate in the development of the carbon sink market, thus providing benefits both for farmers and enterprises through realizing the coordinated development of urban and rural areas. Second, against the background of the dual carbon goal, this study will be of great significance in the context of exploring carbon sink resources nationwide in adhering to the principle of sustainable development and urban and rural integration, and in establishing a mutual assistance model between urban and rural areas based on carbon optimization, which will be key in realizing the balanced development of urban and rural areas and the common prosperity of the people in China. A limitation should be noted, however, in that this study has only examined the low-carbon field. Future studies should conduct in-depth research on the zero-carbon field and the negative-carbon field in order to further solve the problem of urban–rural balance and ultimately achieve common prosperity for the people.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

WY was employed by State Grid Jiangxi Electric Power Co., Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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