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Measurement of Environmental Efficiency of Low-Carbon Agriculture and Dynamic Evolution of Time and Space

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Abstract

At the moment of fully realizing the goal of " double carbon ", the development of low-carbon agriculture is inseparable from the realization of sustainable agricultural development and the overall revitalization of rural areas. At present, my country's agriculture is in a critical period of green and low-carbon transformation, and agriculture has entered a new stage of low-carbon development. This paper takes Anhui Province, a large agricultural province, as the research object, uses the panel data from 2011 to 2020, and examines the dual attributes of agricultural carbon sinks and carbon emissions to accurately measure the environmental efficiency of low-carbon agriculture in Anhui Province. The research results show that: the environmental efficiency of low-carbon agriculture in Anhui Province is showing an increasing trend year by year, and will reach its peak in 2020; from the perspective of time series changes, the development of low-carbon agriculture in Anhui Province can be divided into three stages: budding, development, and maturity; In terms of spatial development differences, the three regions of northern Anhui, central Anhui, and southern Anhui show different development characteristics. Based on the research conclusions, this paper puts forward development and improvement suggestions from the government and farmers. This paper has important theoretical value and practical significance for accurately grasping the potential of agricultural carbon emission reduction, solving the problem of uneven development of low-carbon agriculture among regions, and promoting agricultural environmental protection.

Keywords

Low-Carbon Agriculture; Environmental Efficiency; Temporal And Spatial Evolution; Agricultural Carbon Emission Reduction.

1. Introduction

Agriculture is the basic industry that supports the construction and development of the national economy, and it is also the second largest source of carbon emissions after industry. Under the background of " dual carbon ", the development of low-carbon agriculture is an inevitable choice to achieve sustainable agricultural development. As a responsible big country, China has no time to delay the development of low-carbon agriculture.

Anhui Province is rich in resources, with many rivers and lakes in the province, warm climate and suitable humidity. It is an excellent place for the development of agricultural production and has a huge potential for carbon emission reduction. Since the 18th National Congress of the

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Communist Party of China, Anhui Province has actively adjusted the structure of agricultural production and vigorously developed green ecological agriculture. The " two reductions " of pesticides and fertilizers and the " two utilizations " of straw and manure have achieved remarkable results, and rural revitalization has been comprehensively promoted. Farming has entered a new era. Based on the empirical data of Anhui Province, this paper scientifically and reasonably measures the environmental efficiency of low-carbon agriculture from the dual perspectives of carbon sinks and carbon emissions, and explores the law of its dynamic spatio-temporal evolution, in order to provide useful information for the development of low-carbon agriculture and rural green revitalization in Anhui Province. learn from.

2. Literature review

Around the theme of this article, the relevant research closely related to this article can be sorted into three categories: one is research on agricultural carbon sinks; the other is research on agricultural carbon emissions; the third is research on agricultural environmental efficiency.

2.1. Research on agricultural carbon sinks

The term " carbon sink " comes from the "Kyoto Protocol" signed by the parties to the United Nations Framework Convention on Climate Change, which means removing carbon from the air.CO^2The general term for the processes, activities and mechanisms of The carbon absorption of China's agricultural system is greater than carbon emissions, and the agricultural sector is a huge carbon sink rather than a carbon source (Liu Yunfen, 1998)[1]. Agriculture has a huge carbon sink function. Agricultural carbon sinks mainly include soil carbon sinks and vegetation carbon sinks, among which soil carbon sinks are the main ones (Luo Jiwen, 2010)[2], which can be measured from the quality of agricultural products, crop planting area and The " carbon sink function " of agriculture is systematically sorted out from three angles of returning straw to the field (Xia Qingli, 2010)[3]. Due to the long-term high-input and high-consumption agricultural production methods and other reasons, China's agricultural net carbon sinks and agricultural economic development are in a strong negative coupling state (Yang Guo, 2016) [4], improving agricultural carbon sink capacity is An inevitable choice for the development of low-carbon agriculture. At present, scholars at home and abroad focus on the functional analysis of agricultural carbon sinks, the analysis of carbon sink driving and influencing factors, and the construction of agricultural carbon sink trading mechanisms (He Ke, 2022)[5].

2.2. Research on agricultural carbon emissions

Agricultural carbon emissions mainly come from the random disposal of agricultural waste, intestinal fermentation and manure management of livestock and poultry, agricultural energy use, rice growth, and biocombustion (Johnson et al, 2007)[6]. In addition, the transformation of land use is also an important factor for agricultural carbon emissions (Woomer et al, 2004)[7], and the farm management model also has a significant impact on agricultural carbon emissions (Lal, 2004)[8]. After combing the existing literature, it is found that many scholars have explored the temporal and spatial evolution characteristics of agricultural carbon emissions based on specific research perspectives. Scholars use the Dagum Gini coefficient decomposition (Liu Huajun, 2013)[9], the DEA-Malmquist index decomposition method and the Tobit model (Wu Xianrong, 2014) [10]and other methods to further decompose the influencing factors of carbon emissions. The study found that the level of agricultural economy has a strong role in promoting carbon emissions from agricultural land use, economic growth is the most important driving factor of agricultural carbon emissions (Li Guozhi et al., 2010) [11], trade terms effect is the leading factor for agricultural carbon emissions The primary reason for the change in quantity (Han Yuefeng, 2013) [12].

2.3. Research on the Environmental Efficiency of Agriculture

Agricultural environmental efficiency is an important indicator to measure the coordinated development of agricultural economy and resource environment, and the study of agricultural environmental efficiency is of great significance to the efficient use of agricultural resources (Xu Weixiang, 2021) [13]. Scholars at home and abroad have shown diversity in the research on the measurement of agricultural environmental efficiency, such as creating an environmental efficiency evaluation model based on input and output slack variables (Slack-Based Measure, referred to as SBM model) (Tone, 2001) [14], Based on the highly disposable production possibility set and directional distance function, construct an agricultural environmental efficiency measurement model (Zhang Ke, 2016) [15], and use the Global super-efficiency DEA model (Li Yan, 2019) [16], Using the super-efficient EBM model with unexpected output (Wang Mei, 2020) [17] to measure the agricultural environmental efficiency. Further studies have found that agricultural environmental efficiency is driven by many factors, and the level of human capital and the intensity of scientific and technological input affect agricultural environmental efficiency to a certain extent (Peng Jing, 2020) [18]; from a low-carbon perspective, China 's agricultural industry agglomeration The impact on environmental efficiency presents a significant "U- shaped " feature, and industrial agglomeration will improve the level of environmental efficiency through scale effects, technological effects, and social effects (Xu Bin, 2022) [19].

To sum up, the existing literature provides empirical inspiration and method reference for this paper to study the environmental efficiency and time evolution characteristics of low-carbon agriculture in Anhui Province, but there is still room for expansion. On the one hand, the existing literature on the quantitative research of agricultural environmental efficiency mostly focuses on the innovation of methods, while ignoring the comprehensiveness of the index system, usually only considering the carbon emission attributes of agriculture, and ignoring that the agricultural field is a huge carbon sink. Therefore, the calculation results may be inaccurate. On the other hand, earlier scholars usually studied low-carbon agriculture across the country based on the provincial scale. This paper takes Anhui Province, a large agricultural province, as the research object, and conducts research on low-carbon agriculture based on the city scale. In view of this, this paper incorporates both carbon sinks and carbon emissions into the index system to measure the environmental efficiency and spatial-temporal evolution characteristics of low-carbon agriculture in Anhui Province in the past ten years. This is of great significance for promoting the green transformation of agricultural development in Anhui Province and realizing the overall revitalization of rural areas.

3. Research methods and indicator construction

3.1. Method selection:

3.1.1. SBM-DEA model

DEA model (Data Envelopment Analysis) is a quantitative analysis method for relatively effective evaluation of comparable units of the same type based on multiple input indicators and multiple output indicators, using linear programming methods. The three-stage SBM-DEA model combines the advantages of non-radial SBM model and SFA to reduce the influence of environmental factors, and fully considers the influence of uncertain factors. In this paper, low-carbon agriculture in Anhui Province is taken as an example, and the development level of low-carbon agriculture in Anhui Province is evaluated [20] [21].

Suppose there are n decision-making units (sample cities), and there are m input indicators to form an input matrix $X = (x_{ij}) \in R^{m \times n}$; K desired output and one non-expected output index form the output matrix: $Y = Y^g + Y^b = (y_{k(I)n}) \in R^{(k+l)\times n}$ The production possibility set under this sample is defined as:

$$P = \{(x, y^g, y^b) \big| x \geq X\lambda, y^g \leq Y^g\lambda, y^b \geq Y^b\lambda, y \geq 0\} \tag{1}$$

λ yes R^n A non-negative vector in, y^g is the expected output indicator, y^b is an indicator of undesired output. Introduce the slack variable s, and use s to calculate the efficiency score of each decision-making unit ρ :

$$\rho = \min \frac{1 - \frac{1}{m}\sum_{i=1}^{n}\frac{s_{\bar{i}}}{x_{io}}}{1 + \frac{1}{k+l}\left(\sum_{r=1}^{k}\frac{s_r^g}{y_{ro}^b} + \sum_{r=1}^{l}\frac{s_r^b}{y_{ro}^b}\right)} \tag{2}$$

st

$$\begin{cases} x_0 = X\lambda + s^- \\ y_0^g = Y^g\lambda - s^g \\ y_0^b = Y^b\lambda - s^b \\ s^-, s^g, s^b \geq 0 \end{cases} \tag{3}$$

in s^- and s^b represents the excess of input indicators and undesirable outputs, s^g Indicates a deficiency in the expected output indicators.

3.1.2. Malmquist exponential model

Malmquist productivity refers to the economic growth rate caused by the input of production factors other than labor and capital. The Malmquist index model can be used to measure the total factor productivity in different periods. On the one hand, it can judge the stability of the efficiency of each evaluated unit, on the other hand It is also possible to observe the changing trend of the efficiency value of each evaluated unit [22] [23]. It uses DEA as a tool to project the input and output results of the current period to the next period. The total factor productivity index from period t to period t+1 can be expressed as:

$$M(x^{t+!}, y^{t+1}, x^t, y^t) = \sqrt{\frac{D^t(x^{t+1}, y^{t+1})D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)D^{t+1}(x^t, y^t)}} \tag{4}$$

$$Effch = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \tag{5}$$

$$Tech = \sqrt{\frac{D^t(x^{t+1}, y^{t+1})D^t(x^t, y^t)}{D^{t+1}(x^{t+1}, y^{t+1})D^{t+1}(x^t, y^t)}} \tag{6}$$

in $(x^{t+1}, y^{t+1}), (x^{t+1}, y^{t+1})$ Represent the input-output vectors of period t and period t+1, respectively. For any decision unit, when M When greater than 1, it means that the total factor productivity of the evaluated object has increased from period t to period t+1; when M When it is less than

1, it means that the total factor productivity has declined; when M When equal to, it means that there is no change in total factor productivity during the period.

3.1.3. Kernel density method

Nowadays, the non-parametric method of sum and density is usually used to study the problem of such non-equilibrium distribution. The method to solve this kind of problem is mainly to use the density curve to further describe and analyze the distribution form of the random variable and make an effective estimate. Assuming that f (x) is the density function of random variable X, the following formula can be used:

$$f(x) = \frac{1}{Nh}\sum_{i=1}^{N} K\left(\frac{X_i - x}{h}\right) \tag{7}$$

3.2. Index data selection

This study mainly measures the agricultural environmental efficiency of 16 cities in Anhui Province from 2011 to 2020, and the scope of agriculture is relatively broad. We mainly take the planting industry as the research object, and take the labor force, land, chemical fertilizer, Machinery and irrigation are used as input elements. The specific research indicators are as follows:

Table 1: Input-output indicators of agricultural environmental efficiency

index		Variables and Descriptions
Input indicators	labor input	Employed persons in the primary industry (10,000 people)
	land input	Total sown area of crops (thousand hectares)
	Fertilizer input	Agricultural fertilizer application amount (10,000 tons)
	mechanical input	Total power of agricultural machinery (10,000 kilowatts)
	irrigation input	Cultivated land irrigated area (thousand hectares)
expected output indicators	Gross agricultural output value	Gross value of agricultural production (100 million yuan)
Undesired output indicators	Agricultural carbon emissions	Agricultural carbon emissions (10,000 tons)

Regarding agricultural carbon emissions, we refer to the calculation methods of relevant references. The carbon emissions of agricultural production are mainly obtained by summing the carbon emissions caused by pollution sources such as chemical fertilizers, pesticides, and plowing:

$$E = \sum E_j = \sum T_j \times \delta_j \tag{7}$$

Where E represents the total amount of carbon emissions from agricultural production, T represents the total amount of input factors, δ Indicates the carbon emission coefficient of agricultural input elements. The carbon emission coefficients of various agricultural production inputs are as follows:

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Table 2: Carbon emission coefficient of agricultural production factors

carbon source	Carbon emission factor
fertilizer	0.8956 $kg \cdot kg^{-1}$
pesticide	4.9341 $kg \cdot kg^{-1}$
Agricultural film	5.18 $kg \cdot kg^{-1}$
plowing	312.6 $kg \cdot km^{-2}$
irrigation	20.476 $kg \cdot km^{-2}$

3.3. Data sources

The original data of the indicators selected in this paper come from the 2011-2020 "China Statistical Yearbook" and "China Rural Statistical Yearbook", and the SPSS software is used to perform descriptive statistics on the original data. Calculate the low-carbon agricultural environmental efficiency of 16 cities in Anhui Province from 2011 to 2020. On this basis, calculate the carbon sink amount and carbon sink intensity and analyze its structure through formulas.

4. Demonstration results and analysis

4.1. Measurement of the environmental efficiency of low-carbon agriculture in Anhui Province

Combined with the relevant data of the agricultural chemical fertilizer application amount, pesticide application amount, agricultural film application amount, effective irrigation area, and total power of agricultural machinery in each region from 2011 to 2020 in the "Anhui Statistical Yearbook", the agricultural carbon emissions of each city in Anhui Province are calculated. Agro-environmental efficiency results under conditions.

Table 3: Measurement results of agricultural environmental efficiency of cities in Anhui Province from 2011 to 2020

City	years									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Hefei	0.202	0.303	0.324	0.402	0.430	0.492	0.450	0.510	0.629	0.672
Huaibei	0.292	0.382	0.398	0.392	0.382	0.422	0.482	0.622	0.623	0.622
Bozhou	0.274	0.290	0.360	0.374	0.378	0.474	0.478	0.674	0.637	0.671
Suzhou	0.211	0.234	0.248	0.311	0.356	0.411	0.454	0.511	0.457	0.711
Bengbu	0.208	0.289	0.294	0.308	0.356	0.408	0.456	0.508	0.537	0.508
Fuyang	0.219	0.363	0.393	0.419	0.374	0.411	0.454	0.611	0.630	0.811
Huainan	0.212	0.291	0.320	0.412	0.386	0.412	0.586	0.412	0.584	0.712
Chuzhou	0.224	0.324	0.379	0.424	0.457	0.424	0.457	0.634	0.681	0.624
Lu'an	0.232	0.298	0.311	0.432	0.346	0.432	0.346	0.612	0.636	0.732
Ma'anshan	0.210	0.260	0.291	0.310	0.385	0.410	0.385	0.512	0.627	0.710
Wuhu	0.201	0.248	0.311	0.301	0.374	0.401	0.374	0.527	0.646	0.701
Xuancheng	0.229	0.294	0.329	0.392	0.385	0.428	0.485	0.582	0.594	0.728
Tongling	0.221	0.320	0.391	0.421	0.428	0.422	0.328	0.429	0.693	0.622
Chizhou	0.205	0.309	0.395	0.405	0.468	0.405	0.568	0.583	0.628	0.705
Anqing	0.216	0.311	0.366	0.416	0.427	0.410	0.327	0.476	0.594	0.710
Huangshan	0.211	0.291	0.311	0.349	0.447	0.411	0.427	0.492	0.602	0.711

From the measurement results of the agricultural environmental efficiency of 16 cities in Anhui Province, it can be seen that the average value of the agricultural environmental efficiency of the 16 cities is between 0.323-0.592, and the efficiency value is relatively low. Excessive input of agricultural production factors leads to an increase in the undesired output of agricultural production. It has a certain impact on the agricultural production environment, and there is still a lot of room for improvement [24] [25].

4.2. Time-series evolution trend of low-carbon agriculture development in Anhui Province

4.2.1. Dynamic evolution of low-carbon agricultural development efficiency

In order to study the dynamic evolution characteristics of low-carbon agricultural development efficiency more clearly, in the next study, the Kernel density function is used to further discuss the dynamic distribution and trend evolution of low-carbon agricultural productivity and low-carbon agricultural technical efficiency in Anhui Province, with To clarify the regional differences and evolution characteristics of low-carbon agricultural development in Anhui Province.

We calculated the low-carbon productivity LTFP, technical progress and technical efficiency design data of 16 cities in Anhui Province in 2002, 2008, 2014 and 2020. The specific values are shown in the table below. Observing the data in the table, we can know that from 2002 to 2020, the low-carbon agricultural productivity of cities in Anhui Province showed a fluctuating upward trend.

Table 4: Low-carbon agricultural productivity and its decomposition in 16 cities (districts) of Anhui Province in some years

	2002			2008			2014			2020		
	EFF	TECH	LTFP	EFF	TECH	LTFP	EFF	TECH	LTFP	EFF	TECH	LTFP
Hefei	1.000	0.890	0.890	1.000	0.990	0.990	1.000	1.053	1.053	1.000	1.212	1.212
Huaibei	1.000	0.932	0.932	1.000	1.071	1.071	1.000	1.137	1.137	1.000	1.001	1.001
Bozhou	0.954	0.957	0.913	1.125	0.867	0.997	1.028	1.046	1.075	0.998	1.025	1.022
Suzhou	1.000	0.945	0.945	1.000	0.876	0.876	1.000	1.024	1.024	1.000	1.321	1.321
Bengbu	1.000	1.011	1.011	1.000	0.987	0.987	1.000	1.076	1.076	1.000	1.249	1.249
Fuyang	1.000	1.033	1.033	1.000	1.022	1.022	1.000	1.098	1.098	1.000	1.034	1.034
Huainan	1.000	1.129	1.129	1.000	1.208	1.208	1.000	1.177	1.177	1.000	1.305	1.305
Chuzhou	0.897	0.932	0.959	0.867	0.868	0.825	0.978	0.996	0.843	0.928	0.929	0.917
Lu'an	0.964	0.678	0.965	0.789	0.901	0.929	0.690	0.876	0.828	0.917	0.994	0.819
Ma'anshan	1.000	0.560	0.560	1.000	0.987	0.987	1.000	0.910	0.910	1.000	1.234	1.234
Wuhu	1.000	1.301	1.301	1.000	1.206	1.206	1.000	1.034	1.034	1.000	1.079	1.079
Xuancheng	1.000	1.037	1.037	1.000	1.207	1.207	1.000	1.309	1.309	1.000	1.291	1.291
Tongling	1.000	1.043	1.043	1.000	1.276	1.276	1.000	1.128	1.128	1.000	1.045	1.045
Chizhou	0.987	0.686	0.825	0.834	0.790	0.912	0.911	0.987	0.939	0.765	0.907	0.978
Anqing	1.000	1.023	1.023	1.000	1.211	1.211	1.000	1.039	1.039	1.000	1.289	1.289
Huangshan	1.000	1.398	1.398	1.000	1.079	1.079	1.000	1.215	1.215	1.000	1.304	1.304

4.2.2. The embryonic stage: 2002-2008

The period from 2002 to 2008 was the embryonic stage of the development of low-carbon agriculture in Anhui Province. At this time, the overall low-carbon agricultural development efficiency in Anhui Province is low, and both technological progress and technical efficiency are low. During this period, the country first proposed that the development of low-carbon agriculture is an important part of rural revitalization. The Anhui Provincial Government quickly responded to the call of the Party Central Committee to encourage the development of low-carbon agriculture in various parts of Anhui Province. Cities in Anhui Province responded one after another and started the initial exploration of developing low-carbon agriculture. However, due to the long-term agricultural development model that emphasizes economic benefits over environmental benefits, farmers' agricultural production concepts are difficult to change, and supporting facilities are weak, it is extremely difficult to promote low-carbon agriculture at the beginning.

Although low-carbon agriculture in Anhui Province faced many obstacles at the beginning of its development, due to various incentive policies and financial support issued by the government, low-carbon agriculture in Anhui Province has achieved certain development. The concept of green development of agriculture has gradually penetrated into the hearts of farmers, supporting facilities have been gradually improved, and more organic fertilizers and mechanized farming have appeared in field farming.

4.2.3. Development stage: 2008-2020

From 2008 to 2020, low-carbon agriculture in Anhui Province has entered the development stage. At this stage, the overall low-carbon agricultural development efficiency in Anhui Province has been greatly improved, and both technological progress and technical efficiency have been significantly improved.

The government's ability to provide a good policy environment and financial support provides a good development environment and material basis for low-carbon agriculture in Anhui Province at this stage. Through more in-depth publicity and promotion, the development concept of low-carbon agriculture has been well known and accepted by a wider range of farmers. People are willing to adopt a more green and environmentally friendly way to develop agriculture in agricultural production. Environmentally friendly organic fertilizers; In terms of farming methods, it is more important to choose efficient machinery; In terms of agricultural development models, innovate green and environmentally friendly development models, such as the rice and shrimp co-cropping model, and the resource utilization of livestock and poultry waste. At the same time, more green enterprises are emerging. For example, Zhongxing Mushroom Technology Co., Ltd. in Dingyuan County, Chuzhou City, Anhui Province has created a new wheat straw - agaricus bisporus - organic fertilizer - wheat planting green agricultural circular industrial chain, which not only allows agriculture The reuse of waste and stalks can also increase the income of the village collective economy by about 1 million yuan per year, and drive 800 people to find jobs at their doorsteps.

4.2.4. Mature stage: after 2020

After 2020, low-carbon agriculture in Anhui Province will enter a mature stage. The overall low-carbon agricultural development efficiency in Anhui Province has reached a relatively high level, and the technical level is relatively mature. After years of development and accumulation, governments at all levels in Anhui Province have adopted low-carbon development of agriculture as the agricultural development policy. With the construction of new countryside, agricultural supporting materials are relatively complete. More low-carbon agricultural technologies have been developed and promoted, and more new farmers have devoted themselves to rural and agricultural construction.

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In the future, low-carbon agriculture in Anhui Province will continue to advance in breadth and depth, using low-carbon agriculture to fully empower the development of rural revitalization, and build the vast countryside into a greener, more environmentally friendly, and more fertile area.

4.3. Comparison of spatial differences in the development of low-carbon agriculture in Anhui Province

4.3.1. City-region comparison of agricultural carbon emissions and carbon sinks

Judging from the ranking of agricultural carbon emissions in 16 cities in Anhui Province in 2020, the top 6 regions are Fuyang City (10.49 million tons), Haozhou City (8.62 million tons), and Suzhou City (7.59 million tons)., Bengbu City (6.15 million tons), Chuzhou City (5.91 million tons), and Hefei City (5.62 million tons), the total carbon emissions of the 6 cities (districts) accounted for 64.28% of the country's total agricultural emissions; the last 6 regions Followed by Huangshan City (650,000 tons), Tongling City (970,000 tons), Chizhou City (1 million tons), Xuancheng City (1.93 million tons), Ma'anshan City (1.98 million tons), Huaibei City (2.05 million tons), the total carbon emissions of these six places only accounted for 12.43% of the province. Among them, Fuyang City, which ranks first, will have a total agricultural carbon emissions of 10.49 million tons in 2021, which is equivalent to 16 times that of Huangshan City, which ranks the last. It can be seen that the total agricultural carbon emissions vary greatly between different regions. From the perspective of regional distribution, the areas with more developed traditional agriculture are the main sources of agricultural carbon emissions in Anhui Province. As far as the current situation is concerned, the main agriculture in Anhui Province is still dominated by the traditional development model, which adheres to the principle of high input and high output, and the industrial model is relatively simple. As a result, the total amount of agricultural carbon emissions remains high.

Calculate the agricultural carbon sinks of 16 cities in Anhui Province in 2021, and on this basis, calculate the carbon sink intensity and analyze its structure through formulas. The following table lists the agricultural carbon sinks, composition structure and carbon sink intensity of each city in Anhui Province. Looking at the table below, we can know that both food crops and economic crops account for a large proportion of the carbon sinks of the cities in Anhui Province. In terms of carbon sink intensity, there are differences between regions. The regions with the highest carbon sink intensity are Wuhu, Bengbu, and Fuyang. On the one hand, it is related to their relatively developed agriculture, and on the other hand, they are closely related to the carbon sink function of crops in recent years. relevant.

Table 5: Agricultural carbon sinks in Anhui Province

area	food crops		Crops		total	strength	ranking
	Total amount / ton	proportion	Total amount / ton	proportion	Total amount / ton	ton / ha	
Hefei	2889469	51.34%	2738909	48.66%	5628378	8.195338232	6
Huaibei	1493605	72.68%	561317	27.32%	2054922	7.045269719	9
Bozhou	5051884	58.60%	3568638	41.40%	8620522	9.288484808	4
Suzhou	4496158	59.23%	3095006	40.77%	7591164	7.321837528	7
Bengbu	2805504	45.61%	3345332	54.39%	6150836	9.739146682	2
Fuyang	5216412	49.68%	5283352	50.32%	10499764	9.289878141	3
Huainan	3074460	74.00%	1080146	26.00%	4154606	7.266968801	8
Chuzhou	4656914	78.76%	1255660	21.24%	5912574	6.53366411	15
Lu'an	3456750	69.91%	1487638	30.09%	4944388	6.741513776	14
Ma'anshan	1047960	52.77%	937998	47.23%	1985958	8.59167896	5
Wuhu	1351357	42.04%	1863394	57.96%	3214751	9.762941075	1
Xuancheng	1266761	65.41%	669762	34.59%	1936523	6.890339407	13
Tongling	562786	57.92%	408919	42.08%	971705	6.94243602	10
Chizhou	632533	62.93%	372649	37.07%	1005182	6.179726789	16
Anqing	1903019	51.16%	1817064	48.84%	3720083	6.919655662	12
Huangshan	286598	43.78%	368104	56.22%	654702	6.936872219	11

We can observe that the development efficiency of Chuzhou City, Wuhu City, and Lu'an City is relatively high, while that of Tongling City is low, and there are differences in the development of low-carbon agriculture among regions. The reason is that Chuzhou, Wuhu, and Lu'an started to develop low-carbon agriculture earlier, and the government has adopted a number of measures to support the development of low-carbon agriculture. Comparing the data obtained from the questionnaire, we can also know that the farmers in these three places have low-carbon agriculture. High level of understanding and participation [26].

4.3.2. Northern Anhui: High carbon emissions and low carbon sinks, in the embryonic stage

Agriculture in northern Anhui occupies an important position in the central region and even in the whole country. For a long time, the agricultural economic construction in this area has not been paid attention to, and the agricultural development mode is relatively traditional and extensive. With the implementation of the strategy of the rise of the central part of the country and the needs of the overall economic development of Anhui, the agricultural and economic development of northern Anhui has been widely concerned.

According to the calculated data, the agricultural carbon emissions in northern Anhui are at the highest level of total carbon emissions in Anhui Province. During the period from 2015 to 2018, the agricultural carbon emissions in northern Anhui accounted for more than 46% of the overall proportion of Anhui Province; at the same time, northern Anhui The regional carbon sink intensity is low, ranking the lowest among the three major regions. It shows that the current level of low-carbon agriculture development in northern Anhui is relatively low, and it is still in its infancy, and breakthrough development is still needed. Central Anhui: The development efficiency is steadily improving, and it is in a mature stage.

4.3.3. Central Anhui: Environmental efficiency is making steady progress and is in a mature stage

Central Anhui has superior natural conditions, more land, sufficient fertility, higher grain output, higher contribution rate of agricultural science and technology, and higher per capita net income of farmers. The data show that agricultural carbon emissions in central Anhui have been in a stable development stage, and carbon emissions have declined since 2014; due to the increasing improvement of technology and infrastructure, the quality of farmers is relatively high, and the development efficiency of low-carbon agriculture is at the leading level in Anhui Province.

In order to achieve long-term development of low-carbon agriculture, central Anhui still needs to make full use of land resources, increase technology investment, innovate development models, and promote existing environmental protection development models, such as the rice-shrimp co-cropping model. Play a leading and radiating role to drive the overall development of low-carbon agriculture in Anhui Province.

4.3.4. Southern Anhui: The three regions with the lowest carbon emissions are in the development stage

The terrain in southern Anhui is dominated by hills, which limits the agricultural development in southern Anhui to a certain extent, and the development lags behind. However, due to the implementation of low-carbon agricultural policies in this region, the total carbon emissions have decreased year by year in recent years, which is the lowest level in the three regions, accounting for between 12% and 16% of the total agricultural carbon emissions in Anhui Province. Therefore, low- carbon agriculture The development prospect is broad.

Combined with the local natural conditions and industrial development foundation, we should develop characteristic low-carbon agriculture according to local conditions. Only by adapting measures to local conditions can the southern Anhui region play a greater role in reducing carbon emissions. The government organizes and leads superior leading enterprises, strengthens technological breakthroughs, and builds a modern low-carbon agricultural demonstration that integrates the agricultural leading industry system, industrial management organization and service system, agricultural technology support and management guarantee system, and has the natural characteristics and historical and cultural heritage of the southern Anhui mountainous area. It is an important practical exploration for the construction and development of modern low-carbon agriculture in mountainous areas.

5. Conclusions and Suggestions

This study found that: first, considering the dual attributes of agricultural carbon sinks and carbon emissions, the average value of low-carbon agricultural environmental efficiency in Anhui Province between 2011 and 2020 was between 0.323 and 0.592, but it showed an overall upward trend and reached its peak in 2020. Second, according to the development trend of low-carbon agricultural environmental efficiency in Anhui Province, it can be roughly divided into three stages: the embryonic stage from 2002 to 2008, the development stage from 2008 to 2020, and the mature stage after 2020. Third, there are regional differences in the development level of low-carbon agriculture in Anhui Province, showing three major regional characteristics, namely: northern Anhui - high carbon emissions and low carbon sinks, in the embryonic stage; central Anhui - moderate environmental efficiency There is progress and it is in the mature stage; the southern Anhui region-the three regions with the lowest carbon emissions are in the development stage.

In order to improve the development level of low-carbon agriculture in Anhui Province, provide useful experience for other provinces, and effectively stimulate and release the potential of agricultural carbon emission reduction, based on the above research conclusions, this paper puts forward the following suggestions. (1) Government: coordinate regional development and promote technology development and promotion. The carbon emissions of the 16 prefecture-level cities in Anhui Province have obvious regional differences. According to the natural conditions of different regions and the specific actual situation of carbon emissions, emission reduction targets are established and corresponding low-carbon emission reduction work is carried out. Strengthen the driving role of high-level areas, drive the industrial upgrading and development of low-level areas, and promote coordinated regional development by "using high to lead low". On the other hand, the government should increase investment in and support for low-carbon technology research, and further promote the efficient progress of technology research and development and innovation. Improve the relevant guarantee work for the continuous promotion of low-carbon agriculture, and provide financial and policy preferences and support to enterprises and farmers. (2) Farmers: Strengthen green and low-carbon awareness, and enhance awareness of emission reduction actions. As the main body of low-carbon agricultural production, farmers should actively respond to the call of the party and the government, cultivate awareness of energy conservation, emission reduction, low-carbon environmental protection, and establish the subject awareness of protecting the ecology and building a beautiful homeland in daily life and agricultural production practice. At the same time, we should use various channels to actively invest in learning related advanced technologies and skills related to low-carbon agriculture, improve the overall quality of our own agricultural production, and better implement and practice low-carbon emission reduction technologies in actual production activities.

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