LOW-CARBON AGRICULTURAL DEVELOPMENT IN CHINA
A Promising Cure for Global Warming

by

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This article explores the impact of high-standard farmland construction policy on green and low-carbon agricultural development, such policy has been ignored in literature from the perspective of policy evaluation and it is a promising cure for global warming. The effectiveness and impact mechanism of policy implementation are analyzed, it concludes that the policy significantly reduces agricultural carbon emissions by 12.3%, which benefits from the improvement of agricultural production efficiency. This paper opens a new window for policy-making for modern agriculture and the momentous challenge of the global warming.

Key words: *land remediation, agricultural carbon emissions, policy effects, high standard farmland construction policy, DID model, PSM-DID*

Introduction

Agricultural production accounts for 80% to 86% of the total emissions of the food system, including indirect emissions related to land cover change, and has significant regional differences [1]. Land use change is the second largest source of human greenhouse gas emissions [2, 3]. Relevant evidence indicates that agricultural production generates a large amount of other greenhouse emissions, accounting for approximately 25% of global emissions. Increasing fertilizer application is the main driving factor of agricultural carbon emissions [4]. However, agricultural production has the function of carbon fixation and reduction [5]. For China, there was no significant improvement in agricultural greenhouse gas emissions reduction during the period 2008-2017. China agricultural sector can reduce greenhouse gas emissions by 20-40%, with an average of 31% [6]. Many agricultural practices have the potential to reduce greenhouse gas emissions, the most prominent is to improve farmland [7]. It is worth noting that intensive crop management systems do not necessarily increase greenhouse gas emissions per unit of crop or food production [8]. Active land management provides the possibility of increasing terrestrial storage of various forms of carbon in soil [9]. The increase in the productivity of food crops will directly affect the emissions of land use changes, which makes the technology of planting crops potentially important for limiting the concentration of carbon dioxide in the atmosphere, additionally the energy system greatly affects land-use change emissions [10], so the energy harvesting technology [11] should also be adopted to

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challenge the global warming [12, 13]. Energy harvesting for smart agriculture has become a hot topic in reducing the emission [14], especially the nanotechnology [15, 16] for water harvesting [17, 18] and the vibration technology [19, 20] for wind-energy harvesting [21, 22].

The level of agricultural modernization can effectively reduce the intensity of agricultural carbon emissions [23]. High-standard farmland construction refers to the artificial improvement of farmland facilities, which is beneficial to agricultural production and the farmland environment [24]. High standard farmland construction can effectively promote the improvement of agricultural total factor productivity, mainly by promoting agricultural technological transformation and technological efficiency [25]. It follows that high standard farmland construction pilot policies can effectively promote agricultural technology progress [26], providing the possibility of reducing agricultural carbon emissions.

The Chinese government regards the construction of high-standard farmland as an important means to reduce agricultural carbon emissions. Therefore, has the implementation of policies played a role in reducing carbon emissions? Is there heterogeneity? What is its impact mechanism? These questions require urgent scientific assessment and their answers can scientifically assess the environmental effects of high-standard farmland construction pilot policies and have important theoretical and practical implications for promoting green and low-carbon agricultural development.

Based on the previous analysis, this article intends to expand the current research from the following aspects. Firstly, the perspective of policy effectiveness evaluation based on the difference in difference (DID) model, propensity score matching-difference in difference (PSM-DID) model, mediation effect model to clarify whether high-standard farmland construction policies can promote low-carbon and green agricultural development. Secondly, starting from two aspects of efficiency improvement and service involvement, this paper reveals the internal mechanism of the impact of high-standard farmland construction policies on agricultural carbon emissions reduction and conducts empirical testing of the impact mechanism. Discussion of these issues not only helps open up a new path for land remediation to drive agricultural carbon emissions reduction but also provides reference for the formulation and implementation of follow-up high standard agricultural construction policies.

Theoretical analysis and research hypothesis

Scale management and technological progress are the fundamental paths to achieving green and low-carbon agricultural development. The carbon emission reduction logic of the high-standard basic farmland construction policy is as follows.

The construction of high-standard basic farmland has created powerful conditions for realizing agricultural scale management by *combining small fields with large fields*, and realizing centralized and continuous management of agricultural production. This measure has directly changed the size of the land parcel and helped achieve efficient operation of agricultural machinery and other equipment. Moreover, it has improved the utilization efficiency of agricultural materials through precise fertilization, pesticide application, and water-saving irrigation of agricultural machinery, thereby achieving carbon emission reduction.

In high-standard farmland construction pilot areas, agricultural production areas are becoming large-scale, and planting structures tend to be specialized, making it easier to achieve a professional division of labor in agricultural production. The division of labor will produce economies of scale effects, achieving optimal allocation of agricultural production factors and progress in agricultural technology [25]. The involvement of agricultural outsourcing services has led to the introduction of advanced technology, capital, labor, *etc.*, into the agricultural production process of small farmers, achieving an effective link between small farmers and modern agriculture and helping achieve carbon emission reduction. On the other hand, agricultural service organizations often have a higher green production capacity than small farmers. During the production process, embedded environmental protection technologies such as fertilizer reduction technology, precision fertilization technology, and biological agriculture technology can be beneficial to carbon emission reduction through large-scale agricultural machinery [27, 28].

Based on this, this article proposes the two hypotheses.

Hypothesis 1: High-standard farmland construction policies will help achieve green and low-carbon agricultural development.

Hypothesis 2: Policies mainly promote agricultural efficiency improvement and agricultural service involvement to further achieve agricultural carbon emission reduction.

Models, variables, and data

Model settings

To promote the reform of high standard farmland construction, the Hunan Provincial Government issued the *Pilot Work Plan for Comprehensive Reform of High Standard Farmland Construction* in 2015. The plan states that by 2020, Hunan Province will build 22.12 hectares of high standard farmland. High standard farmland construction includes improving the utilization efficiency, quality, and yield rate of farmland, improving the water conservancy facilities and irrigation guarantee rate of farmland, and establishing unified standards for electricity, water, soil, roads, forests, field fertilization management, and field agricultural science and technology services. Subsequently, the construction of high-standard farmland entered the standardized implementation stage. The Plan specifies carrying out comprehensive reform pilot projects for high standard farmland construction in 13 counties, including Liuyang City, Xiangxiang City, and Shimen County. The pilot project of the high standard farmland construction policy has the characteristics of gradually advancing by county, constituting a quasi-natural experiment. To identify the impact of high-standard farmland construction policies on green and low-carbon agricultural development, this paper constructs a DID model [29]:

$$y_{it} = \alpha + \beta \text{treat}_i \times \text{time}_t + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{1}$$

where y_{it} is the agricultural carbon emissions or agricultural carbon intensity of county i during period t, α – a constant, β and δ – parameters to be evaluated, treat_i – the virtual variable of the pilot county, $\text{treat}_i = 1$ for the disposal group, that is the counties selected as the high standard farmland pilot are controlled, and $\text{treat}_i = 0$ for the counties that have not conducted the pilot, time_t – a dummy variable of the policy implementation time point, X_{it} – a control variable that changes over time, μ_i – a fixed effect at the county level, γ_t – the fixed effect of the corresponding year, and ε_{it} – a random error term.

This article uses mediation effect model to verify the impact mechanism of the implementation of high standard farmland construction policies on the green and low-carbon development of agriculture. The first stage verifies the impact of the policies on agricultural productivity and the agricultural vertical division of labor. If the impact coefficient of the policy is positive, it indicates that the policy has significantly promoted the expansion of agricultural productivity and the vertical division of agricultural labor. The second stage verifies the impact of agricultural productivity and the vertical division of labor on agricultural green and low-carbon development.

Based on this, some model settings for mechanism validation are:

– Phase I model:

$$M_{it} = \alpha + \beta \text{treat}_i \times \text{time}_t + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{2}$$

where M_{it} are the mechanism variables set in this article, which are agricultural productivity and agricultural vertical division of labor. The setting of other variables is the same as that in eq. (1).

– Phase II model:

$$y_{it} = \alpha + \beta \text{treat}_i \times \text{time}_t + \delta M_{it} + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{3}$$

The setting of each variable in eq. (3) is the same as in eqs. (1) and (2).

Variable selection

Explained variable. The explained variable in this article is agricultural green and low-carbon development, measured by agricultural carbon emissions (Carbon) or agricultural carbon intensity (TQD). In view of relevant research, this paper selects six indicators to estimate the carbon emissions in the unexpected output of agriculture, including fertilizer, pesticide, plastic sheeting for agricultural use, agricultural diesel, agricultural irrigation, and agricultural cultivation. The emission coefficients of the mentioned six types of emission sources are 0.896 kg/kg, 4.934 kg/kg, 5.180 kg/kg, 0.593 kg/kg, 20.476 kg/ha, and 312.6 kg/ha, respectively. For the measurement of agricultural carbon intensity, the ratio of total agricultural carbon emissions to total agricultural output value is used to measure carbon intensity.

Core explanatory variables. The core explanatory variable of this article is the high standard farmland construction policy. To reflect the impact of the policies on low carbon and green development of agriculture, the interactive term representation of $\text{treat}_i \times \text{time}_t$ is used.

Control variables. To further control the impact of other factors on the low-carbon and green development of agriculture, referring to the relevant literature, the following control variables are selected in this article:

– (1) Urbanization rate (Urban), which is the percentage of the urban population to the total population, is used to reflect the development stage of the county.
– (2) Income of rural residents (Income), which is measured by the per capita disposable income of rural residents, is used to characterize the level of economic development in the county. To eliminate the impact of price factors, this article uses 2007 as the basis for the consumer price index to conduct an adjustment.
– (3) The proportion of grain crops (Str) is measured by the proportion of grain crop sown area to total crop sown area to control the impact of crop planting structure on low carbon and green development of agriculture.
– (4) Labor transfer (Labor) is measured by the proportion of non-agricultural workers in rural employment.
– (5) The level of mechanization (machine) is measured by the ratio of the total power of agricultural machinery to the total sown area of crops.
– (6) Cultivated land scale (Scale) is expressed by dividing the total sown area of crops by the total rural population.

Mechanism variables. The mechanism variables in this article are the agricultural production efficiency (APE) and the involvement of agricultural services (APS). To measure and calculate the agricultural production efficiency, based on the research of relevant scholars, seven types of input indicators and 1 type of expected output are selected to construct the evaluation index system, in which the input indicators are land input, labor input, fertilizer input, pesticide input, plastic sheeting for agricultural use input, agricultural machinery power input, and irrigation input. The expected output is represented by the total agricultural output value. The super-efficiency SBM model is used to measure the APE, while the level of involvement of agricultural services is measured by the ratio of the output value of agricultural, forestry, animal husbandry, and fishing services to the sown area of crops.

Data sources and descriptive statistics

This article uses panel data from 88 counties in Hunan Province from 2008 to 2020. The data are from the *China County-level Statistical Yearbook (County and City Volume)*, *Hunan Statistical Yearbook*, *Hunan Rural Statistical Yearbook*, and various county-level statistical yearbooks and statistical bulletins, and interpolation is used to supplement the individual missing data. The descriptive statistical characteristics of each county can be obtained from the authors.

Empirical test

Benchmark regression results

Table 1 reports the estimated results of the basic regression model (the parallel trend test can be obtained from the authors).

Table 1. Estimation results of basic regression model

	Agricultural carbon emissions			Agricultural carbon intensity		
	(1)	(2)	(3)	(4)	(5)	(6)
$treat_i \times time_t$	–0.091** (0. 575)	–0.123** (0.428)	–0.123** (0.670)	0.002 (0.009)	0.002 (0.007)	0.006 (0.009)
Urban		–5.078** (3.231)	–5.078** (3.652)		0.096** (0.054)	0. 096* (0.054)
Income		1.904*** (0. 771)	1.904*** (0.573)		–0.003 (0.013)	–0.003 (0.018)
Str		–2.766* (2.407)	–2.766* (2.577)		0.051** (0.041)	0.051 (0.076)
Labor		0.991 (1.996)	0.991 (2.216)		0.014 (0.034)	0.014 (0.042)
Machine		0.088* (0.059)	0.088* (0.083)		–0.001 (0.001)	–0.001 (0.001)
Scale		–0.232** (0.264)	–0.232** (0.351)		–0.011* (0.004)	–0.011* (0.146)
Constant	3.276*** (0.140)	–9.09** (6.627)	–9.098* (4.747)	0.264*** (0.012)	0.2657** (0.112)	0.265** (0.147)
n	1144	1144	1144	1144	1144	1144

Note: ***, **, * Represents a significance level of 1, 5, and 10%, respectively, the county fixed effect and year fixed effect have been controlled, and the estimated results are omitted, (1) and (4) without adding control variables, (2) and (5) represent estimated results of ordinary standard error, (3) and (6) represent estimated results of robust standard error.

As seen from the lists (1)-(3) in tab. 1, under the condition of simultaneously controlling the county and year fixed effects, regardless of the standard error, the negative impact of the implementation of the policies on agricultural carbon emissions has been tested at a significance level of 5%, with an estimated coefficient of –0.123, which indicates that the implementation of policies has suppressed an average of 12.3% units of agricultural carbon emissions, with significant economic significance, while other conditions remain unchanged. Therefore, *Hypothesis 1* has been verified. From the estimated results in columns (4)-(6) of tab. 1, the estimated coefficient is positive, but it has not passed the significance test. A possible reason for this is that the pilot policy promotes the efficiency of farmland utilization, while it promotes the planting of food crops in the pilot counties. However, because grain prices have remained at a relatively low level for many years, the income from planting grain is not very high, and an increase in the proportion of cash crops planted in non-pilot counties will bring higher economic benefits, which will cause agricultural carbon intensity in non-pilot counties to decrease, making the impact of the pilot policies on agricultural carbon intensity insignificant. Based on this, the following article will mainly analyze agricultural carbon emissions.

Robustness analysis

Placebo test. To further exclude the impact of unobservable variables on policy effects, the year of policy implementation was changed to 2011 for a placebo test, and samples before policy implementation were retained. The inspection results are shown in tab. 2 (1). From the results in tab. 2 (1), it can be found that the impact of coefficient $\text{treat}_i \times \text{time}_t$ is negative but not significant. This can indicate that there was no policy effect before the policy, so the previous estimation results are robust.

Table 2. Robustness test results

	Taking 2011 as the policy implementation time point	PSM-DID	Consider interference from other relevant policies
	(1)	(2)	(3)
$\text{treat}_i \times \text{time}_t$	–0.092 (0.542)	–0.141** (0.613)	–0.081* (0.540)
Agricultural socialized service policy			–0.431** (0.167)
Control variable	control	control	control
Constant	–3.926*** (2.929)	–19.632* (11.545)	–9.973** (4.739)
n	616	1144	1144

Note: ***, **, * Represents a significance level of 1, 5, and 10%, respectively, the county fixed effect and year fixed effect have been controlled, and the estimated results are omitted, the control variables are the same as tab. 1, and the estimated results are omitted, the data in the column (1) are estimated results of sample data from 2008 to 2014

Evidence based on PSM-DID. To further eliminate the impact of sample selection bias on the estimation results, this article selects the dual difference propensity score matching (PSM-DID) method for analysis. The specific approach is to use the kernel matching method to match the per capita grain output, per capita GDP and farmers' income as the selection criteria. Based on the matched samples, the DID model was reused for analysis. The results are shown in (2) of tab. 2. It can be seen that the estimated results using the PSM-DID model still support the negative impact coefficient of the policies on agricultural carbon emissions, so the benchmark model results in this article are considered robust.

Consider the impact of other policies. During the policy implementation period, Hunan Province began implementing the agricultural socialized service policy in 2013, which will inevitably have an impact on agricultural carbon emissions. Therefore, taking into account the agricultural socialized service policy in this article, the estimated results are shown in (3) of tab. 2. After excluding the interference of the agricultural socialized service policy, the high standard farmland construction policy still has a significant negative impact on agricultural carbon emissions.

Further analysis: Mechanism analysis

According to the previous analysis, the agricultural carbon emissions inhibition effect of the policies may not only have a direct effect but also further reduce agricultural carbon emissions by promoting agricultural efficiency improvement and agricultural service involvement. Based on this, we empirically test the impact mechanism of the policies based on the mediation effect model set forth above, and the results are shown in tab. 3.

Table 3. Analysis of impact mechanism

	Agricultural productivity	Service involvement	Agricultural carbon emissions		
	(1)	(2)	(3)	(4)	(5)
$treat_i \times time_t$	0.031** (0.031)	0.022** (0.178)	–0.169** (0. 485)	–0.132** (0.549)	–0.141** (0.544)
agricultural productivity			–0.806*** (0.746)		–0.937* (0. 753)
Service involvement				–0.175** (0.229)	–0.168* (0.225)
Control variable	Control	Control	Control	Control	Control
Constant	1.161*** (0.331)	–9.413*** (2.201)	–2.510*** (3.388)	–8.955* (4.778)	–9.103** (4.884)
n	1144	1144	1144	1144	1144

Note: ***, **, * Represents a significance level of 1, 5, and 10%, respectively, the county fixed effect and year fixed effect have been controlled, and the estimated results are omitted, the control variables are the same as tab. 1, and the estimated results are omitted

As seen from tab. 3, the policies can significantly promote the improvement of agricultural production efficiency, with an estimated coefficient of 0.031 and a significance level of 5%. Furthermore, from the results in (3) of tab. 3, it is observed that agricultural production efficiency can effectively reduce agricultural carbon emissions, indicating that policy implementation can further reduce agricultural carbon emissions through the path of agricultural production efficiency. From the perspective of agricultural service involvement, the results in (2) and (4) of tab. 3 show that policies can deepen the level of agricultural service involvement, while agricultural service involvement can further promote agricultural carbon emissions reduction, both of which have passed the significance test. Therefore, the two impact mechanism routes proposed above have been verified. The policies can effectively curb agricultural carbon emissions by promoting efficiency improvement and involving small farmers in the division of the labor economy.

Conclusions

Based on panel data of counties in Hunan Province from 2008 to 2020, this paper uses the high standard farmland construction pilot policy set in 2015 as a quasi-natural empirical study to identify the impact and mechanism of policies on agricultural carbon emission reduction using the dual difference method. The main research conclusions of this article are as follows.

- The benchmark regression results show that, on average, the pilot policy significantly reduced agricultural carbon emissions by 12.3%, but the impact on agricultural carbon intensity is not significant.
- The impact mechanism indicates that the carbon emission reduction effect of the policy mainly benefits from the improvement of agricultural production efficiency, and the policy can achieve the carbon emission reduction effect by increasing the involvement of farmers in the division of labor economy. This paper offers a new angle for policy-making for modern agriculture and the momentous challenge of the global warming.

From the research conclusions of this article, the following two inspirations are proposed. First, we need to further improve high-standard agricultural construction policies, develop various forms of moderate-scale operations, promote intensive and specialized agricultural production to achieve economies of scale, and play the role of high-standard agricultural construction policies in increasing production and reducing carbon emissions. Second, in the realistic context of labor transfer and the weakening of agricultural labor, it is necessary to develop agricultural socialized services in accordance with local conditions, bring small farmers into the development track of agricultural modernization, alleviate labor constraints in agricultural production processes through service involvement, and involve modern production factors through service methods while further promoting efficiency improvement and introducing modern green production technology into the production and operation process of small farmers.

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