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Original Research

Can High-Standard Farmland Construction Policy Promote Agricultural Green Development? Evidence from Quasi Natural Experiments in Hunan, China

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Abstract

Improving agricultural green development (AGD) has become an urgent choice for developing countries to achieve sustainable development and ensure food security. High standard farmland construction (HSFC) has improved agricultural production conditions and ecological environment through artificial improvement of farmland facilities. This study aims to evaluate the role of high standard farmland construction policy in improving agricultural green development. Based on data of rural areas in Hunan, China, this study explores quantitative impacts of HSFC on AGD by difference-in-difference model. The results are as follows: (1) The policy will significantly promote the AGD, and the results remain significant after a series of robustness tests, such as PSM-DID. (2) Mechanism analysis indicates that policies primarily promote AGD through two paths: promoting agricultural socialized services and land-scale management. (3) The results of the heterogeneity analysis indicate that differences in the driving effects of policies are present at different levels of AGD, and the policy effect is stronger in areas with high farmer income levels, large per capita arable land, and in non-grain-producing areas than in other areas. The conclusions of this study provide new empirical evidence and implementation path for developing countries to promote agricultural green development.

Keywords: high-standard farmland construction policy, agricultural green development, difference -in-difference, PSM-DID, agricultural socialized services, land scale management, quasi-natural experiment

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Introduction

Promoting agricultural green development is an effective method to achieve agricultural sustainable development, which is vital for ensuring national food security, enhancing the supply capacity of agricultural products, and promoting the healthy development of arable land [1, 2]. Green is the greatest advantage and most precious resource for agricultural development. Promoting agriculture green development is a necessary part of high-quality agricultural development and an objective need for rural revitalization. In the past, the development of agriculture in China was based on excessive resource investment in an unsustainable manner. Issues, such as agricultural non-point source pollution and declining farmland productivity, severely constrained the agricultural green development [3]. Therefore, comprehensively promoting a resource-saving and environmentally friendly green development model has become an urgent need for China's agricultural transformation and upgrading.

Promoting agricultural green development has become a key concern for governments and scholars. Over the past 40 years, the cultivated land quality in China has sharply declined, and the conflict between people and land has become increasingly prominent [4] . Moreover, strict farmland controls and constraints could not change the trend of declining quantity and quality of farmland [5]. The issue of cultivated land quality has become a key constraint on the green development of agriculture in China. However, land consolidation has played an important role in increasing farmland area, improving farmland land quality and ecological environment, and promoting agricultural productivity [6-8]. The construction of high standard farmland provides important opportunity for promoting agricultural green development by artificially leveling the land, achieving land concentration and improving supporting facilities for farmland. Scholars have analyzed the important role of high-standard farmland construction policies in alleviating rural poverty [9], reducing agricultural carbon emissions [10], improving farmland quality [11], reducing fertilizer use [12], and promoting agricultural total factor productivity [13].

In contrast, agricultural green development has also received widespread attention from researchers, who have focused on measuring and evaluating the level of agricultural green development [14-16] and have explored its key driving factors from multiple perspectives. Examples include the carbon emissions trading pilot policy [17], digital economy [18], digital agriculture [19], agricultural mechanization [20], green production technology adoption [21], and technical training [22].

Through analysis, scholars have begun to focus on the policy effects of high-standard farmland construction, but little research is present on whether high-standard farmland construction can promote agricultural green development. Therefore, this study first constructs an indicator system and then uses the entropy method to evaluate the level of agricultural green development. Second, we analyze the impact mechanism of high-standard farmland construction on agricultural green development and further explore the heterogeneity of policy effects caused by regional differences. In previous studies, the research period was limited by data availability, as they used provincial level data that were only updated until 2017 . This study focuses on the Hunan Province, the main rice-producing region of China, and adopts county panel data from 2008 to 2020. The difference-in-difference method was used for empirical analysis, and using the two paths of farmland scale management and agricultural socialized services, a two stage model analyzed high-standard farmland construction policies affecting agricultural green development. This study summarizes relevant experiences and compensates for the shortcomings in existing relevant literature and provides a reference for promoting agricultural green development.

The marginal contributions of this article are as follows: First, it compensates for the shortcomings in existing literature on the relationship between high-standard farmland construction and agricultural green development. Second, this study thoroughly analyzes the heterogeneity of policy impact effects by accounting for regional differences and proposes targeted measures to improve relevant policies. Third, this study focused on the two paths of farmland scale management and agricultural socialized services and empirically demonstrated the impact mechanism of these policies. Fourth, this study provides empirical evidence for developing countries to promote the construction of high-standard farmlands and agricultural green development.

Mechanism Analysis and Research Hypotheses

High-Standard Farmland Construction Policies and Agricultural Green Development

Agricultural green development refers to the promotion of sustainable agricultural production methods, while ensuring food security, to minimize damage to the ecological environment, improve the quality and safety of agricultural products, and promote the increase of farmers' income and rural economic development. As a major agricultural country worldwide, China's agricultural green development is a long and arduous task. Although the policy of constructing high-standard farmlands is not a natural experiment aimed entirely at the goal of agricultural green development, and according to the actual requirements of high-standard farmland construction, it can not only improve agricultural production conditions but also improve the level of existing agricultural equipment, thereby improving the efficiency of farmland resource utilization. The construction of high-standard farmlands promote a virtuous cycle and sustainable development of the agricultural ecological environment through land leveling and other means. Although a previous study has focused on the impact of high-standard farmland construction on agricultural total factor productivity [13], significant potential exists for in-depth research on the impact of high-standard farmland construction policies on agricultural green development in the current context of agricultural green development.

What is the main logic behind promoting agricultural green development through land remediation with high-standard farmland construction? The construction of high-standard farmland is mainly divided into field infrastructure engineering, soil fertility construction engineering, and technology support engineering. The potential of these measures to promote green development in agriculture is reflected by the following aspects: First, agricultural projects aimed at achieving land leveling, centralized contiguous management, and construction of field roads that will enhance the application level of agricultural machinery; for example, mechanical deep tillage synchronous sounding fertilization technology and drone spraying technology can effectively reduce the amount of chemical inputs while improving the efficiency of fertilizer and pesticide utilization. Reducing the application of chemical fertilizers is an important aspect of agricultural green development in China [23]. Second, high-standard farmland construction policies include soil fertility construction and technology support projects. Fertility construction projects can improve soil fertility through soil improvement and cultivation, thus further reducing the use of chemical fertilizers. Furthermore, the commonly used intelligent irrigation and fertilization system for water and fertilizer integration in technology support projects can not only reduce agricultural irrigation water consumption but also achieve precise fertilization and effectively reduce fertilizer usage. Finally, the scientific and technological engineering aspects of high-standard farmland construction projects also involve two basic aspects: improving the agricultural socialized service system and improving the level of agricultural mechanization throughout the entire process. The role of mechanization in the green development of agriculture is unclear [24, 25]. Improving the agricultural socialized service system and providing specialized technical training and land trusteeship services to farmers can reduce fertilizer input [26], improve green production behavior [27, 28], and reduce agricultural carbon emissions [29]. The adoption of green production technologies has significantly improved agricultural green development [30]. The impact mechanism is shown in Fig. 1. Thus, the first hypothesis proposed in this study is as follows:

Hypothesis 1: High-standard farmland construction policies promote agricultural green development level.

Mechanism Analysis of Promoting Land Scale Management through High-Standard Farmland Construction

The construction of high-standard farmlands, with farmland engineering as the main focus, is mainly aimed at addressing the longterm challenge of farmland fragmentation in China. In practice, the construction of high-standard farmland is achieved by integrating measures, such as “small fields and large fields” to achieve centralized and contiguous cultivation of farmland. As a key measure to improve agricultural management conditions, the construction of high standard farmland has significantly improved the quality of farmland, reduced operational risks, and facilitated the continuous concentration of farmland. In theory, it helps to promote the circulation of agricultural land, thus achieving scale management. Extensive research has found that the fragmentation of arable land increases the intensity of fertilizer application by farmers [23, 31], which is highly dependent on the scale of arable land. The increase in arable land scale will significantly reduce the intensity of fertilizer and pesticide input by Chinese farmers [32, 33]. According to quantitative analysis results, for every 1 hectare increase in the average grain planting area per household, the amount of fertilizer applied per hectare will decrease by 20.6% [23]. Finally, the expansion of business scale will help

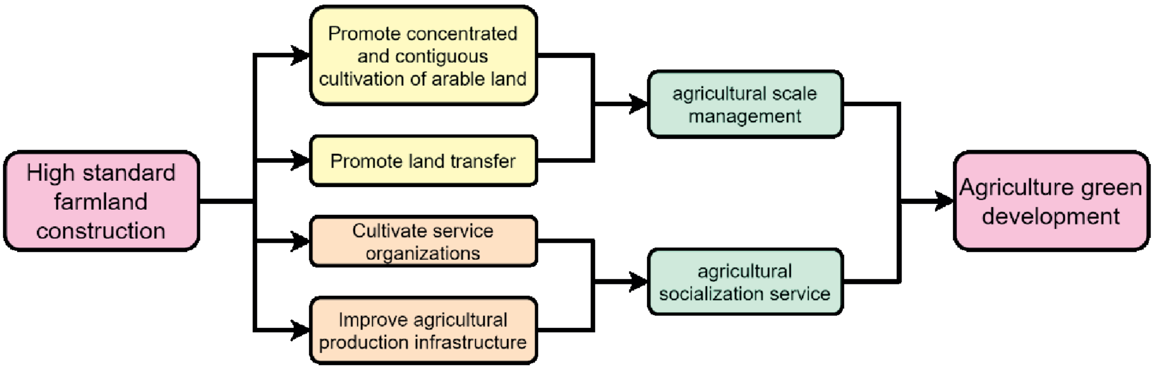

Fig. 1. The impact mechanism.

reduce the costs for farmers to adopt green production technologies and facilitate their adoption of green technologies in agricultural production processes [34, 35]. In summary, Hypothesis 2 is proposed:

Hypothesis 2: High-standard agricultural construction policies promote agricultural green development through the expansion of the arable land scale.

Mechanism Analysis of Promoting Agricultural Socialization Services through High-Standard Farmland Construction

From the above analysis, the main content of high-standard farmland construction policies not only involves farmland transformation and improvement of farmland roads but also includes the cultivation of agricultural socialized service organizations. In the practice of agricultural production in China, a group of new agricultural operators has emerged who, compared with traditional small farmers, have larger cultivated land, stronger ecological awareness, and less investment in fertilizers and pesticides [36, 37]. The implementation of high-standard farmland construction policies has promoted the concentration and connection of farmlands while also producing a group of new agricultural management entities, thereby promoting agricultural green production. In addition, the expansion of agricultural scale operation allows agricultural machinery services to promote the reduction in fertilizer and pesticide production [38].

Agricultural socialized service organizations load modern production factors, such as knowledge, technology, capital, and management, into the agricultural production process through service outsourcing and effectively promoting the modernization of small farmers' agriculture [39, 40]. Agricultural socialized services mainly promote agricultural green development through two paths. First, compared with those of small farmers, agricultural socialized service organizations have stronger green production capabilities. Through service outsourcing, green production behavior is directly introduced into the agricultural production process of small farmers, thereby achieving agricultural green development [28, 41]. Agricultural socialized services have a significant positive impact on farmers' adoption of soiltesting formula fertilization, straw returning technology, and organic fertilizer application [42]. Furthermore, the outsourcing of mechanical services has had a significant positive impact on farmers' adoption of notillage, organic fertilizer application, and straw return technologies [27]. Second, the involvement of socialized service organizations improves land production efficiency [43, 44], and directly reduces fertilizer input [26, 45], agricultural nonpoint source pollution [46], and agricultural carbon emissions [29, 47-49] through the introduction of advanced technology and the implementation of service scale management, thereby positively impacting agricultural green development. Based on this discussion, Hypothesis 3 is proposed:

Hypothesis 3: High-standard farmland construction policies promote agricultural green development by promoting the development of agricultural socialized services.

Materials and Methods

Study Areas

Located in the middle of China and the middle reaches of the Yangtze River, Hunan Province, one of the big agricultural province in central China, is facing a long-term trade-off between agricultural development and severe non-point source pollution of cultivated land. In recent decades, the social economy in this province has developed rapidly, the land use structure has changed drastically, and the pressure on farmland conservation continues to increase. Since 2011, Hunan Province has adhered to the construction of high standard farmland as an important lever to ensure food security, and has promoted the construction of high standard farmland on a large scale. Through land consolidation, farmland infrastructure has been significantly improved, and the comprehensive agricultural production capacity has been continuously enhanced. As of the end of 2021, the reserve of high standard farmland in Hunan Province was 2.41 million hectare, driving the total grain yield to reach 30.745 million tons, a new high in nearly six years. The Hunan region, which has the most severe farmland pollution and actively promotes the policy of high standard farmland construction, is a typical representative research area. Taking Hunan Province as an example, this research can provide a reference and insight for the design and improvement of high standard farmland construction policies promote agricultural green development. It is worth noting that Hunan Province has only released the "Hunan Rural Statistical Yearbook" since 2008. Considering the availability of data, the research range of this article is from 2008 to 2020.

Model

Measurement of Agricultural Green Development Level: This study adopts the common practice of existing literature [15, 16] and measures the level of agricultural green development through an evaluation index system. In a basic study that comprehensively considers the availability of data in each county, we constructed an agricultural green development evaluation index system based on three dimensions: agricultural resource conservation, agricultural environment governance, and agricultural production benefit, with eight three-level indicators (see Table 1).

In indicator processing, the third-level indicators in this study underwent range standardization to

Table 1. Evaluation Index System for Agricultural Green Development Level.

Index		Indicator Meaning and Unit	Indicator direction	Third level indicator weight	Second level indicators weight
Second-level indicators	Three-level indicators				
Agricultural resource conservation	Per capita cultivated land area	Total sown area of crops/total population (hectare/person)	+	0.1380	0.2658
	Proportion of effective irrigation area	Effective irrigation area/total planting area of crops (%)	+	0.1278	
Agricultural environment governance	Use of pesticides per unit sowing area	Pesticide usage/total planting area of crops (kg/ha)	-	0.1279	0.4443
	Fertilizer usage per unit sowing area	Fertilizer application amount/total planting area of crops (kg/ha)	-	0.1250	
	Machinery input per unit of agricultural output value	Total power of agricultural machinery/total agricultural output value (kW/10000 yuan)	-	0.0965	
	Input of agricultural film per unit of agricultural output value	Agricultural film usage/ total agricultural output value (kg/10000 yuan)	-	0.0949	
Agricultural production efficiency	Per capita agricultural output value	Gross Agricultural Product/ Agricultural Employment (10000 yuan/person)	+	0.1015	0.2899
	Average grain yield per mu	Total grain yield/total planting area of crops (kg/ha)	+	0.1884	

obtain dimensionless data with the same influence and comparability. This study used the entropy method to determine the weight of indicators (see Table 1 for the weight of indicators at all levels) and calculated the level of agricultural green development in each region based on their weights.

Policy background and econometric models: The construction of high-standard farmland is an important component of land consolidation in China, which aims to promote and ensure food security and agricultural sustainable development [13]. The definition of high-standard farmland in the High-Standard Farmland Construction Standard (TD/T1033-2012) is as follows: within a certain period, basic farmland formed through rural land remediation is centralized and contiguous, with supporting facilities, high and stable yield, good ecology, strong disaster resistance, and suitability for modern agricultural production and management methods. As agricultural environmental issues have become increasingly prominent, the connotation of comprehensive land development has shifted from an initial focus on stabilizing the decline in the amount of cultivated land caused by industrialization and urbanization to a focus on stabilizing the amount of cultivated land, thereby improving its quality of cultivated land and the ecological environment. To promote the reform of high-standard farmland construction, in 2015, the Hunan Provincial Government issued the "Pilot Work Plan for Comprehensive Reform of High-Standard Farmland Construction." The plan was designed to conduct pilot projects for high-standard farmland construction policies in 13 counties, including Liuyang and Xiangxiang. Since then, these policies have officially entered the stage of standardized implementation and have gradually advanced counties, forming a quasi-natural experiment. To identify the impact of high-standard farmland construction policies on agricultural green development, this study constructed a difference-in-difference (DID) model [17]. The model settings were as follows:

$$y_{it} = \alpha + \beta treat_i \times time_t + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

In formula (1), y_{it} is the agricultural green development level in county i during period t, and $treat_i = 1$ is the disposal group, that is, the counties selected for the high-standard farmland pilot; $treat_i = 0$ represents the counties that did not conduct the pilot; $time_t$ is a dummy variable for the policy implementation time; and the separation point between the two was set to 2015. In addition, α are constant terms, β and δ are parameters to be evaluated; X_{it} is a control variable that changes over time; μ_i is a fixed effect at the county level; γ_t is the fixed effect of the corresponding year; and ε_{it} is a random error term.

Parallel trend test: The prerequisite for DID analysis is that the data should satisfy the parallel trend test, which this study sets as follows:

$$y_{it} = \alpha + \sum_{t=-3}^{3} \beta_t treat_i \times d_t + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

In formula (2), d_t is a year dummy variable, which represents the time from the implementation of the policy; for example, -3 represents 3 years before the implementation of the policy, and 3 represents three years after the implementation of the policy. The remaining variables were set using Equation (1). If the high-standard farmland construction pilot policy can promote agricultural green development, before the implementation of the policy, the variables of the coefficient β_t should tend to be stable, but it will show differences after the implementation of the corresponding policy.

Mechanism validation model settings: This study used a two-stage method [50] to verify the impact mechanism of the implementation of high-standard farmland construction policies on agricultural green development. The details are as follows:

$$M_{it} = \alpha + \beta treat_i \times time_t + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it}$$
$$y_{it} = \alpha + \beta treat_i \times time_t + \varphi M_{it} + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{3}$$

In formulas (3) and (4), M_{it} is the mechanism variable set in this study; they are farmland-scale management and agricultural socialized services, and the other variables are the same as that in formula (1).

Variable Selection

Explained Variable: The explanatory variable in this study was the level of agricultural green development, which was calculated using the index system constructed earlier with the entropy method. Taking into account the availability of relevant data from various counties, this article constructs an indicator system for agricultural green development level from three dimensions: agricultural resource conservation, agricultural environmental governance, and agricultural production efficiency.

Agricultural resource conservation refers to the conservation and utilization of natural resources in the agricultural production process. Among them, the per capita arable land area represents the per capita ownership of arable land resources. The higher the value, the more arable land resources per capita can be utilized, so the indicator direction is positive. The proportion of effective irrigation area refers to the proportion of farmland that can be irrigated normally in the current year. Effective irrigated farmland is usually equipped with water-saving irrigation projects or equipment, which can effectively save irrigation water and is an important indicator reflecting the drought resistance ability of farmland. The larger the value of this indicator, the higher the degree of protection for arable land resources and irrigation water consumption in a region, which is more conducive to green agricultural development. Therefore, the direction of the indicator is positive.

Agricultural environmental governance refers to the management of environmental pollution during agricultural production processes. The more pesticides and fertilizers used per unit sowing area, the less conducive it is to agricultural environmental governance, so the direction of relevant indicators is negative. The mechanical input per unit of agricultural output value represents the use of agricultural machinery. Although improving the level of mechanization is beneficial for agricultural production, it will emit a large amount of exhaust gas during use, resulting in air pollution that is not conducive to green agricultural development. The direction of this indicator is negative. The larger the value of the amount of agricultural film used per unit of agricultural output value, the more dependent agricultural production is on the use of agricultural film. The use of agricultural film generates a large amount of residue and pollutes the environment, so the direction of this indicator is negative.

Agricultural production efficiency represents the agricultural production situation in a region. The green development of agriculture not only needs to protect the ecological environment, but also ensures agricultural production. Among them, the higher the per capita agricultural output value and the higher the per mu crop yield, the better the agricultural production situation, and the indicator direction is positive.

Core explanatory variables: The core explanatory variable of this study is the high-standard farmland construction policy, which reflects the impact of high-standard farmland construction policies on agricultural green development, the interactive term representation of $treat_i \times time_t$ is used.

Control variable: To minimize the bias caused by missing variables in the regression, this study uses a series of control variables in the model as follows. (1) The number of agricultural employees (Labor), represented by the number of employees in the primary industry, is used to measure the impact of rural labor resources on agricultural green production [51]. (2) The proportion of the primary industry (Instr) is used to control the impact of regional development on the degree of dependence on the primary industry [52]. (3) Planting structure (Str), measured by the total planting area of grain crops/total planting area of crops, is used to control the impact of planting structure on agricultural production [53]. (4) The degree of labor transfer (Ltrans) [54], expressed by the proportion of employment in the secondary and tertiary industries among the agricultural workforce, is used to control the impact of the relative shortage of labor resources on agricultural green production in the context of the gradual disappearance of the demographic dividend.

Mechanism variable: Cultivated land scale (CLS) and agricultural socialized services (ASS) were the two mechanism variables in this study. (1) Given the availability of data, the cultivated land size is represented by the total sown area of crops/total rural

Table 2. Descriptive statistical results.

Variable name		Variable code	n	Mean	SD
Explained Variable	Agriculture green development level	AGD	1144	0.388	0.047
Core explanatory variables	Treat*time	did	1144	0.068	0.252
Control variable	Agricultural employees*	Labor	1144	3.396	0.590
	The proportion of the primary industry	Instr	1144	0.199	0.078
	Planting structure	Str	1144	0.591	0.088
	Labor transfer	Ltrans	1144	0.421	0.116
Mechanism variable	Cultivated land scale	CLS	1144	3.818	1.315
	Agricultural socialized services*	ASS	1144	6.770	1.246

Note: Variables with * indicate logarithmization processing.

population. (2) Agricultural socialized services refer to various services provided by social and economic organizations related to agriculture to meet the needs of agricultural production. The development level of agricultural socialized services is represented by the total output value of agriculture, forestry, animal husbandry, and fishing services/total sown area of crops.

Data Sources and Descriptive Statistical Analysis

The data in this study were compiled from the "Hunan Statistical Yearbook" (2008-2021) and "Hunan Rural Statistical Yearbook" (2008-2021). Some missing data were filled in through county-level statistical yearbooks or county-level statistical bulletins for each region, and missing data that could not be obtained from official compilations were acquired using the imputation method. Descriptive statistics for each variable are presented in Table 2.

Results

Green Development Level of Agriculture

Use Geoda software to draw a heat map of the level of agricultural green development (see Fig. 2). It can be seen that the level of agricultural green development in various counties in Hunan Province is relatively low, but it is continuously improving over time. It can be seen that the green transformation of agriculture is imperative. Before the policy pilot, the development level of agricultural green development in each county was slow. However, after the start of the pilot policy in 2015, the level of agricultural green development was rapidly improved in 2016, especially with 23 counties with development levels above 0.5 in 2020. Intuitively, it can be believed that there is a positive causal relationship between the high standard farmland pilot policy and the green development of agriculture, which will be confirmed in the following text.

Prior Parallel Trend Testing

Satisfying the parallel trend test hypothesis is a prerequisite for applying the DID method, which requires that no significant difference should be present between the treatment and control groups before policy implementation. Fig. 3a) shows the changing trends in the agricultural green development levels of the experimental and control groups. The results showed that before the implementation of the policy, the two groups had the same change trend, which satisfied the basic requirements of the parallel trend test. Later, an event study was conducted to analyze the dynamic effects of the policy.

Benchmark Regression Results

This study verified the impact of high-standard farmland construction policies on agricultural green development. The benchmark regression results are presented in Table 3. Regression (1) controls for regional fixed effects and time-fixed effects without adding control variables. Regressions (2) and (3) add control variables based on regression (1), where regression (2) uses ordinary standard error, and regression (3) uses robust standard error. The results show that regardless of the standard error, land improvement with high-standard farmland construction as the main content significantly improved the level of agricultural green development at a significance level of 1%. According to the results of regression (3), the agricultural green development level in the pilot areas for implementing high-standard farmland construction increased by approximately 2% compared with the areas that did not implement a high-standard farmland construction pilot. In summary, Hypothesis 1 is supported.

Post Event Dynamic Effect Analysis

The post-event dynamic effect analysis shows the differences in the effects between different years after the implementation of the intensity policy. Significant

Table 3. Benchmark regression results.

Variable	Agriculture green development		
	(1)	(2)	(3)
did	0.058***(0.007)	0.020***(0.005)	0.020**(0.009)
Labor		-0.073***(0.019)	-0.073**(0.036)
Instr		-0.418***(0.030)	-0.418***(0.057)
Str		-0.134***(0.028)	-0.134***(0.048)
Ltrans		0.232***(0.022)	0.232***(0.045)
Constant	0.383***(<0.001)	0.698***(0.071)	0.698***(0.117)
Regional fixed effects	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes
n	1144	1144	1144

differences indicate that the policy implementation will have a sustained effect. Fig. 3b) shows the test charts for the prior parallel trend testing and post-event dynamic effects. The results show that the policy effects are significant in both the current and subsequent years of policy implementation, indicating the sustainability of the policy. However, in the years before the implementation of the policy, the policy effect was not significant, again verifying the assumption of satisfying parallel trends.

Robustness Analysis Results

The robustness of the benchmark regression was not verified. This study uses the following four methods to test robustness: (1) changing the time node of policy implementation to conduct a placebo test, (2) replacing the dependent variable, (3) Using PSM-DID for reestimation, and (4) considering the impact of other relevant policies.

Change the timing of policy implementation: We changed the implementation date of the policy to 2012 and excluded samples from the policy implementation period after 2015 for placebo testing.

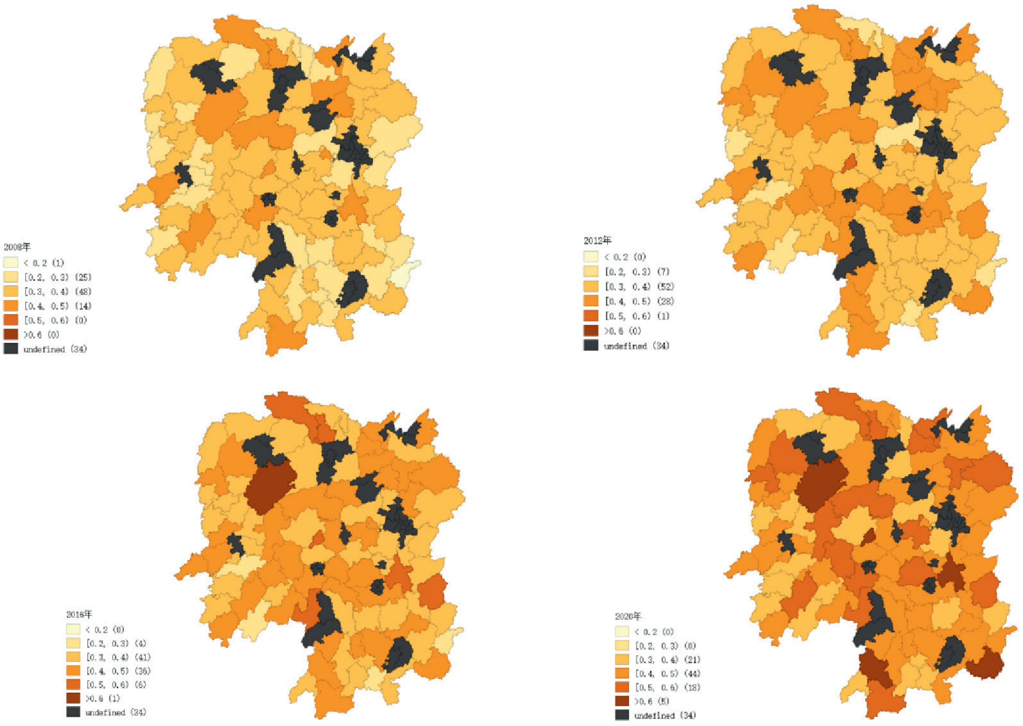

Fig. 2. Regional Map of Agricultural Green Development Level.

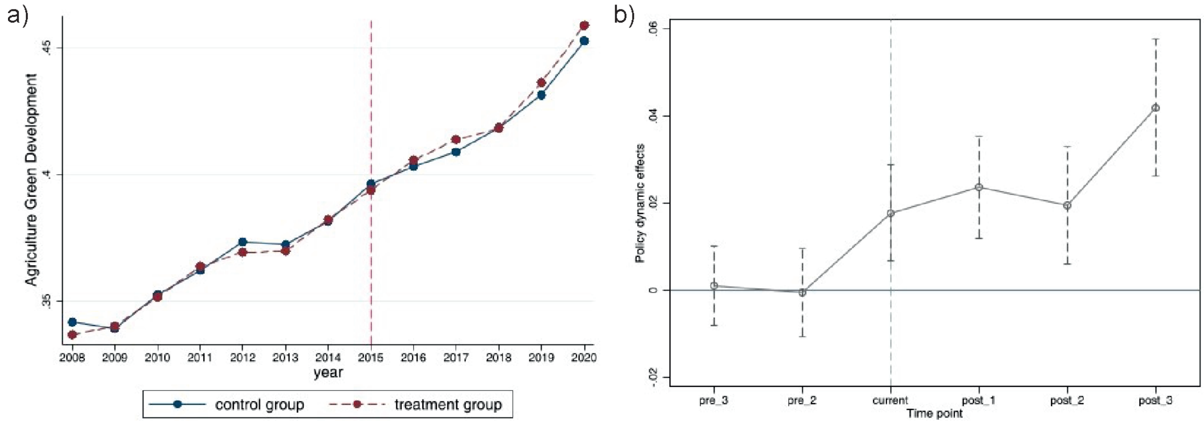

Fig. 3. Parallel Trend Testing a) and Policy Dynamic Effects b).

The regression results in Table 4 (1) show that the policy implementation effect is not significant, indicating that no policy effect existed before policy implementation. This finding verifies the robustness of the policy effects to a certain extent.

Replacement of the dependent variable: Using a super-efficiency model with unexpected outputs to calculate agricultural ecological efficiency as a proxy indicator for the level of agricultural green development, seven input indicators are used, including labor input represented by primary industry employees, land input represented by total crop planting area, fertilizer input, pesticide input, agricultural film input, agricultural machinery power input, and irrigation input represented by effective irrigation area. The expected output indicator is the total agricultural output value, whereas the non-expected output value is represented by agricultural carbon emissions.

In combination with relevant research [49, 55, 56], six indicators were selected to estimate carbon emissions from the unexpected output of agriculture, namely fertilizers, pesticides, plastic sheeting for agricultural use, agricultural diesel, agricultural irrigation, and agricultural cultivation, whose emission coefficients were 0.896, 4.934, 5.180, 0.593, 20.476, and 312.6 kg/ha, respectively.

As shown in Table 4 (2), when agricultural ecological efficiency was used to measure the level of agricultural green development, the policy passed the test at a significance level of 1%; the effect of the policy shows that the agricultural ecological efficiency in the pilot area was 7.5% higher than that in the area without the pilot, which further explains the robustness of the benchmark results.

Re-estimation using PSM-DID: Before using the double-difference method, kernel matching was performed based on three variables: per capita GDP, per capita grain yield, and agricultural development level, and then re-estimates were made on this basis. The results in Table 4 (3) show that the pilot policy for high-standard farmland construction significantly improved the level of agricultural green development,

Table 4. Robustness test results.

	Taking 2012 as the implementation date of the policy	Replace dependent variable	PSM-DID	Consider interference from other relevant policies
	(1)	(2)	(3)	(4)
did	0.005 (0.005)	0.075***(0.026)	0.027***(0.009)	0.019** (0.009)
Industrial integration policy				0.017* (0.009)
Control variable	Control	Control	Control	Control
Regional fixed effects	Yes	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes	Yes
Constant	0.498***(0.110)	1.068***(0.462)	0.594***(0.149)	0.686*** (0.118)
n	616	1144	929	1144

and the impact of the policy was greater than that of the benchmark regression. This finding indicates that regional differences in policy efficiency must be considered. The following section presents an in-depth analysis of this issue.

Impact of relevant policies: The policy of integrating rural industries has positively impacted agricultural green development. The results in Table 4 (4) show that after excluding the impact of this policy, the effect of the high-standard farmland construction policy remained significant, indicating that the benchmark regression results of this study are robust.

Heterogeneity Analysis

This study also analyzes the heterogeneity of the policy effectiveness of high-standard farmland construction caused by four factors: different quantiles of agricultural green development level, economic development level, differences in farmland scale, and whether the county is a major grain-producing county.

Heterogeneity at different quantile levels: Table 5 shows the results at different quantiles. All other quantiles, except for the 0.5 quantile, passed the significance test. The policy has the strongest effect at the 0.75 percentile, followed by the 0.9 percentile; The policy effect at the 0.1 and 0.25 quantiles is relatively smaller. A possible reason for this observation is that in areas with relatively high levels of agricultural green development, ecological consciousness is ingrained in farmers' production behavior, and the implementation of high-standard farmland policies can further promote regional agricultural green development. In areas with low levels of agricultural green development, farmers still adopt traditional production methods to avoid risk, resulting in relatively weak policy driving effects. However, regions with moderate levels of green development already have a certain level of green production capacity, and the policy has a limited driving effect, resulting in a non-significant driving effect of high-standard farmland construction policies. Therefore, focusing on the courage and coordination of policies and high-standard farmland construction policies is vital in regions with moderate levels of agricultural green development for successful promotion.

Heterogeneity under different income levels: According to the environmental Kuznets curve, rural residents were grouped according to their mean income level during the sample period to verify the heterogeneity of the impact of differences in farmers' income levels on policy effectiveness. Samples above the mean represent high-income groups, whereas samples below the mean represent low-income groups. Table 6 (1) and (2) present the regression results. The policy effect on the high-income group was stronger than that on the low-income group, and both groups passed the significance test . This difference may be because farmers with high income levels pay attention to the quantity and quality of agricultural products, forcing the green transformation of agriculture from the demand side, thus strengthening the driving effect of policies.

Heterogeneity of cultivated land scale: This study examined the impact of high-standard farmland construction on agricultural green development. The implementation of this policy directly affects the per capita arable land scale, and small-scale management due to agricultural land fragmentation is a major challenge faced by China's agricultural green development [57]. Because it is necessary to consider the heterogeneous impact of differences in cultivated land scale . Table 6 (3) and (4) show the differences in policy effectiveness among different cultivated land scales. The policy effect in areas with little cultivated land was non-significant, whereas the driving effect of policies in areas with relatively large cultivated land was significant at the 1% level. A possible reason for this discrepancy is that in the current context of a relatively small proportion of high-standard farmland construction areas, the effectiveness of policy mobilization has not yet been highlighted in areas with a relatively small per capita arable land scale. In contrast, areas with large per capita arable land have achieved a certain degree of moderate-scale operation, and the promotion effect of policies has also become prominent.

Heterogeneity based on grain producing ability: To further analyze the heterogeneous impact of policies,

Table 5. Different quantiles of agricultural green development level

	0.1 quantile	0.25 quantile	0.5 quantile	0.75 quantile	0.9 quantile
	(1)	(2)	(3)	(4)	(5)
did	0.025***(0.008)	0.022***(0.006)	0.010 (0.019)	0.056*** (0.014)	0.038*** (0.013)
Control variable	Control	Control	Control	Control	Control
Regional fixed effects	Yes	Yes	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	0. 289*** (0.021)	0. 322***(0 .016)	0.392***(0.022)	0.482*** (0.025)	0.552*** (0.051)
n	1144	1144	1144	1144	1144

Table 6. Heterogeneity analysis under different conditions.

	Income level of rural residents		Per capita cultivated land area		Major grain-producing countie	
	(1)	(2)	(3)	(4)	(5)	(6)
did	0.016* (0.009)	0.021** (0.011)	0.014 (0.014)	0.030*** (0.004)	0.024*** (0.004)	0.019 (0.011)
Control variable	Control	Control	Control	Control	Control	Control
Regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.357*** (0.179)	0. 914** (0.193)	0.468** (0.190)	0.872*** (0.186)	0.541** (0.234)	0.880*** (0.165)
n	674	470	657	487	564	580

analyzing the differences caused by the agricultural planting structure in a region is crucial. We established regions with a higher proportion of grain crops than the average as major grain-producing counties, and vice versa as non-major grain-producing counties. The regression results are presented in Table 6 (5) (6). The policy driving effect of non-grain-producing counties is significant, whereas the driving effect of grain-producing counties did not pass the significance test. A possible reason for these results is that the amount of chemical fertilizer and pesticide input in grain production is less than that in cash crops [58], and the construction of high-standard farmland is conducive to the grain displacement adjustment of the regional planting structure [50]; thus, the driving effect is stronger.

Further Analysis: Impact Mechanism

Based on the theoretical analysis mentioned earlier, the policy of high-standard farmland construction promotes the green development of agriculture through two paths: expanding the scale of arable land and driving agricultural socialized services. The following sections validate this hypothesis using the previously constructed two-stage model (Table 7).

The role of expanding land scale: The regression results in Table 7 (1) show that the high-standard farmland construction policy substantially improved the land scale and was significant at the 1% level. Based on the results in column (3) of Table 7, the expansion of arable land scale positively promotes agricultural green development and the coefficient of promoting agricultural green development by high-standard farmland construction policies has decreased compared with that in the benchmark regression. Both coefficients were significant. Combined with the two-stage model, policies promote agricultural green development by expanding the land scale. Thus, Hypothesis 2 was verified.

Role of agricultural socialized services: The results in Table 7 (2) show that high-standard farmland construction policies promote the development of agricultural socialized services and pass the significance test . The results in Table 7 (4) indicate that agricultural socialized services have positively promoted agricultural

Table 7. Impact mechanism results.

	Land scale	Agricultural socialized services	Agriculture green development	
	(1)	(2)	(3)	(4)
did	0.398***(0.139)	0.741***(0.194)	0.018** (0.009)	0.007 (0.008)
Land scale			0.019*** (0.004)	
Agricultural socialized services				0.022*** (0.004)
control variable	Control	Control	Control	Control
Regional fixed effects	Yes	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes	Yes
Constant	2.975*** (0.184)	6.304** (2.846)	0.571*** (0.124)	0.285** (0.134)
n	1144	1144	1144	1144

green development, and the effect of high-standard farmland construction policies was no longer significant. Based on the two-stage model, we concluded that high-standard farmland construction policies promote agricultural green development by driving agricultural socialized services. Furthermore, Hypothesis 3 proposed in this article was validated.

Discussion

Based on the above discussion and analyses, we conclude that high-standard farmland construction policies can effectively promote agricultural green development. Regarding the policy effects of high-standard farmland construction, previous research focused on alleviating rural poverty [59], improving agricultural total factor productivity [13], reducing agricultural carbon emissions [10], and promoting the protection and improvement of farmland quality [11]. It can be found that the measurement of policy effects focuses on rural poverty reduction, agricultural carbon reduction, and the improvement of farmland quality. Research has confirmed the beneficial impact of policy implementation on agricultural and rural development. In the context of agricultural green development, this study enriches relevant research on agricultural green development from the perspective of policy evaluation. It also provides new empirical evidence for developing countries to promote agricultural green development. Unlike previous related studies, previous studies have been based on provincial-level data in China until 2017, whereas this study focuses on county-level data from the Hunan Province, the main rice-producing area, with updated data till 2020. In addition, unlike this paper, research in this field focuses on continuous DID models. In terms of policy evaluation methods, the causal forest in machine learning and the synthetic DID model, due to their unique advantages, can be applied in future research in this field.

Although this study revealed some important findings, some limitations existed. First, we constructed an evaluation index system for agricultural green development based on three aspects: agricultural resource conservation, agricultural environment governance, and agricultural production benefits. Compared with relevant studies [14, 16], because of the feasibility of county-level data, the coverage of the evaluation index system did not involve all aspects of agricultural production. Secondly, this study only analyzed county-level data in Hunan Province, and in the future, it may be considered to expand the research area to make the research conclusions more representative. Finally, high-standard farmland construction policies promoted agricultural green development by promoting land transfer [60] and promoting green production behavior [61]. However, owing to limited data availability, empirical testing was not conducted on these two paths. In addition,drawing on relevant research paradigms [62], microsurvey data should be obtained by designing questionnaires to enrich relevant research in this field. For example, promoting small-scale farmers to engage in green production, and reducing fertilizer application.

Conclusions

Under the realistic background of promoting the agricultural green development, we used high-standard farmland construction policies as a quasi-natural experiment. This study verifies the importance of high standard farmland construction policies for green agricultural development, enriches research in related fields. Our study can provide lessons for agricultural green development in developing countries. In this study, we constructed an evaluation index system for agricultural green development, used the entropy method to determine the index weight, employed county panel data of Hunan Province from 2008 to 2020, and used the DID method and the PSM-DID model to empirically test the impact of the high-standard farmland construction policy with land consolidation as the main content on agricultural green development. The conclusions drawn from this study are as follows.

(1) The high-standard farmland construction policy significantly promoted the green development of agriculture, and the results remained significant after a series of robustness tests. Under unchanged conditions, compared with the pilot areas, the green development level of agriculture in the pilot areas of the high-standard farmland construction policy increased by 2% on an average, and the agricultural ecological efficiency increased by 7.5% on an average.

(2) The dynamic effect of the policies showed that their implementation effect of policies is sustainable.

(3) Heterogeneity analysis showed that differences were present in the driving effects of policies at different levels of agricultural green development. Furthermore, the promotion effect of policies was stronger in areas with high income levels for farmers, large per capita arable land areas, and non-grain-producing counties.

(4) The impact path of the two-stage model test indicated that high-standard farmland construction policies mainly promoted agricultural green development through two paths: promoting agricultural socialized services and expanding farmland scale.

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Conflict of Interest

The authors declare no conflict of interest.

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