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The Impacts of High-Standard Farmland Construction on Cultivated Land Improvement in China

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Abstract: The construction of high-standard farmland has emerged as a prominent strategy to increase the total arable land area and augment cultivated land quality. This paper endeavors to scrutinize the policy impacts of this measure on elevating cultivated land quality and increasing land area in China. We employ an instrumental variable model with two-way fixed effects to quantitatively analyze the impact of the construction of high-standard farmland on the area and quality of cultivated land, based on panel data from 30 sample provinces in China from 2009 to 2018. Our results indicate that for every additional 10,000 hectares of high-standard farmland construction, the cultivated land area per person increased by 0.004 hectares, and the overall quality improved by 0.004 grade. The mechanism analysis further shows that constructing high-standard farmland indirectly alleviates cultivated land quality by reducing farmers' use of chemical fertilizers, plastic film, and pesticides. The results imply that the ongoing construction of high-standard farmland remains a pivotal element in ensuring the sustainable utilization of cultivated land resources and achieving food security and agricultural modernization goals in China.

Keywords: high-standard farmland construction; land area; land quality; chemical usage



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1. Introduction

As urbanization and industrialization advance in China, the issues of a sharp decrease in cultivated land area, quality degradation, and severe pollution are becoming increasingly prominent. There was a significant reduction in cultivated land quantity and quality [1–3]. The total area of cultivated land decreased from 13.53 million hectares in 2009 to 127.87 million hectares in 2019, a decrease of 7.4667 million hectares, representing a decline of 5.6%, according to the third National Land Survey [1]. Moreover, a significant portion of high-quality cultivated land diminished year by year. The quality of cultivated land is generally low and was in continuous decline before the construction of high-standard farmland. As of 2019, the proportion of low-quality and medium-quality cultivated land was up to 68.76%. Meanwhile, soil pollution in cultivated land was also severe. The first nationwide soil pollution survey results showed that excess soil pollution on cultivated land reached as high as 19.4% in 2014. Furthermore, the utilization rates of chemical fertilizers and pesticides for grain crops were 37.8% and 38.8% in 2017, respectively, which is generally lower than the 50% level in developed countries. Overall, these data underscore the severe challenges facing China's cultivated land, and the sustainable development of cultivated land is confronted with increasingly prominent issues.

As a crucial element in agricultural production, the factors influencing the changes in the area and quality of cultivated land have been subject to in-depth research by numerous scholars. In addition to natural factors, alterations in cultivated land conditions are closely linked to urbanization, farmers' production behaviors, and land consolidation policies [2–4]. Firstly, agricultural land is requisitioned to meet the demands of urbanization, residential development, infrastructure, and industrial growth during the process of urbanization

and industrialization, directly leading to a reduction in cultivated land resources [5,6]. Meanwhile, increasing non-agricultural employment accelerates urbanization, further exacerbating the scarcity of cultivated land resources [7,8]. Farmers adopt intensively cultivated land utilization patterns to meet the substantial demand for food and ensure a domestic food supply. However, the high-intensity utilization pattern of cultivated land leads to farmers altering crop structures, overusing chemical fertilizers, pesticides, and plastic film, and engaging in inappropriate agricultural production practices, thereby altering soil composition and fertility structure [7]. These result in heavy metal residues in the soil and non-point source pollution [8], further deteriorating land quality.

The construction of high-standard farmland has become crucial to improving cultivated land area and quality in such a context so as to ensure national food security. High-standard farmland construction includes infrastructure construction projects (such as field regulation projects, field road projects, irrigation and drainage projects, farmland protection and ecological environment maintenance projects, and farmland power transmission and distribution projects) and fertility improvement projects (such as soil improvement projects). High-standard farmland construction might not only directly improve the quality level of cultivated land through soil improvement projects but also indirectly improve the quality level of cultivated land by decreasing farmers' use of fertilizers, pesticides, and plastic films. The policy implication for high-standard farmland construction for the international audience is that investing in advanced agricultural infrastructure might significantly enhance food security, promote sustainable agricultural practices, and improve rural livelihoods globally. By adopting such policies, countries can ensure more efficient use of resources, reduce environmental impacts, and foster economic development in rural areas, setting a precedent for sustainable and resilient agricultural systems worldwide.

The policy has gone through various stages, including land development and consolidation, the construction of agricultural water facilities, the transformation of low- and medium-yield fields, and the construction of high-standard farmland. In 2004, China's central government first introduced the concept of "constructing high-standard basic farmland to enhance comprehensive grain production capacity" in its No. 1 central policy document. Subsequent central policy documents in various years have reiterated and emphasized this goal. In 2015, the "13th Five-Year Plan" explicitly stated the need to "implement the strategy of storing grain in the land and enhance grain production capacity," making the construction of high-standard farmland a pivotal focus and key measure for storing grain in the land.

Several steps have been taken to achieve the goal of China's high-standard farmland construction: First, there has been a continuous increase in construction requirements. The scope of the project has expanded from land leveling, irrigation and drainage engineering, field road construction, and field protection to include soil improvement, farmland power distribution engineering, technological services, and management and utilization. Second, investment standards have steadily risen. Per-acre investment increased from CNY 18,000 per hectare during the 11th Five-Year Plan period, CNY 22,500 per hectare during the 12th Five-Year Plan period, and CNY 27,000 per hectare during the 13th Five-Year Plan period. It is expected to further increase to CNY 45,000 per hectare during the 14th Five-Year Plan period. Third, the scale of construction has continuously expanded. The constructed area grew from over 26.67 million hectares at the end of the 12th Five-Year Plan period (2015) to 53.33 million hectares at the end of the 13th Five-Year Plan period (2020). It is expected to reach 7.17 million hectares by the end of the 14th Five-Year Plan period (2025) and 80 million hectares by the end of the 15th Five-Year Plan period (2030). The management of farmland construction has also transitioned from being jointly managed by five government departments to only one government department (i.e., the Ministry of Agriculture and Rural Affairs). In 2018, China's State Council restructured and established the Ministry of Agriculture and Rural Affairs, fundamentally changing the previous decentralized management approach to farmland construction.

Though the central and local governments increased government spending to implement the transformation of medium- and low-yield farmland and the construction of high-standard farmland, the policy does not involve the adjustment of land ownership. Therefore, the contracted management rights of high-standard farmland after construction still belong to the original rural land contractor. The production decision process of farmers was maintained the same and the farmers were not squeezed out of agricultural production due to the construction. However, there is considerable debate about whether the already constructed high-standard farmland can effectively improve cultivated cropland quality or increase cropland area. Researchers argue that high-standard farmland construction can enhance cultivated land quality since the construction process involves intensive engineering construction and land consolidation. Comparisons before and after engineering construction have shown that the construction of high-standard farmland improves the quality grade of cultivated land [9,10]. The continuity of cultivated land, irrigation guarantee rate, channel density, and adequate soil thickness were significantly improved after engineering construction [11]. Land consolidation also could enhance farmland production capacity [12,13], normalized vegetation index [14], net primary productivity, and soil organic matter [15,16]. On the contrary, semi-structured interviews have revealed that the effectiveness of high-standard farmland construction in improving soil fertility is not very clear. The reasons for this are that the improvement in cultivated land quality was not strictly incorporated into project acceptance requirements, a shortage of construction funds led to inadequate investment in improving cultivated land quality, and the construction period for soil improvement projects was too short [17,18]. Additionally, due to factors such as mechanical compaction and non-standard construction practices, land consolidation has lowered soil quality and caused soil erosion [19]. Most studies compare and analyze the changes in cultivated land quality before and after engineering construction and between consolidation and non-consolidation areas. However, there is limited quantitative evidence regarding the impact of high-standard farmland construction on cultivated land conditions, and there is a lack of in-depth exploration of the mechanisms through which high-standard farmland construction affects both cultivated land quantity and quality, as well as their structure.

We specifically answer the question of whether the high-standard farmland construction could have alleviated the quality and increased the total area of cultivated land, and if so, what the mechanism behind the impact was. The paper first constructs a conceptual framework for high-standard farmland construction. On the one hand, it reveals the direct impact of engineering construction on cultivated land quantity and quality. On the other hand, it analyzes the influence of high-standard farmland construction on farmers' agricultural production behaviors, thus indirectly affecting cultivated land conditions. Subsequently, based on panel data from 30 provinces (municipalities and autonomous regions) in China from 2009 to 2018, this study employs a two-way fixed effects model and an instrumental variable method to analyze the impact of high-standard farmland construction on both the quantity and quality of cultivated land. Furthermore, it uncovers the mechanisms through which high-standard farmland construction affects cultivated land conditions. The remaining structure of the article is as follows: the second section presents the conceptual analysis and research hypotheses; the third section outlines the research design; the fourth section presents empirical results and analysis; and the fifth section concludes with policy recommendations.

2. The Conceptual Model

The examination of the impact of high-standard farmland construction on both the quantity and quality of farmland constitutes a focal point within the realm of scholarly inquiry and analysis. This subject delves into the intricate relationship between agricultural development policies and their tangible effects on the fundamental aspects of cultivated land resources, encompassing both their numerical abundance and inherent qualitative attributes. Besides that, the complex interaction between high-standard farmland con-

struction policies and the broader agricultural and environmental context also leads to other indirect influences, including farmers' agricultural production behaviors and other ecological and environmental aspects. Therefore, we construct our conceptual framework from the direct and indirect impact perspectives.

2.1. The Direct Impact of High-Standard Farmland Construction on the Scale and Quality of Farmland

The construction components of high-standard farmland encompass the following three main aspects: field infrastructure engineering, land development engineering, and technological support engineering. Specifically, they include field block improvement projects, soil improvement projects, irrigation and drainage projects, field road projects, and farmland protection and ecological environment maintenance projects.

High-standard farmland construction exerts a profound impact on both the quantity and quality of cultivated land through the construction of the above components. First, field block improvement projects increase the quantity of cultivated land and enhance its quality by improving site conditions. These projects achieve this by flattening and merging fragmented plots, not only increasing the cultivated land area but also improving the regularity and continuity of field blocks. Second, soil improvement projects elevate cultivated land quality by enhancing soil conditions. These projects not only improve site conditions through surface soil removal and backfilling with subsoil, thus increasing the effective soil thickness, but also enhance surface soil texture, increase soil organic matter content, mitigate soil salinization, and adjust soil pH by employing methods such as plowing, using biological agents (such as leguminous plants), and chemical approaches (such as lime, gypsum, sodium chloride, and sulfuric acid for soil pH adjustment). Third, irrigation and drainage projects enhance cultivated land quality by improving utilization conditions. These projects increase irrigation reliability and improve irrigation and drainage conditions, thereby reducing the likelihood of soil salinization. Fourth, field road projects improve cultivated land quality by enhancing utilization conditions. These projects enhance field block accessibility and facilitate mechanized production, thus improving cultivated land utilization conditions by constructing field and machine access roads. Finally, farmland protection and ecological environment maintenance projects enhance cultivated land quality by improving ecological conditions. These projects strengthen natural disaster resistance by creating protective forest networks in farmland and maintaining ecological and environmental safety by constructing slope and hillside protection projects, thus elevating cultivated land quality.

We generate the following Hypothesis 1 and 2 to analyze the direct impact of the high-standard farmland construction on the farmland scale and quality.

Hypothesis 1. *The construction of high-standard farmland directly increases cultivated land area.*

Hypothesis 2. *The construction of high-standard farmland directly enhances cultivated land quality.*

2.2. The Indirect Impact of High-Standard Farmland Construction on Both the Scale and Quality of Farmland

High-standard farmland construction not only directly impacts cultivated land quantity and quality through its engineering components but also indirectly affects cultivated land quality by influencing farmers' production behaviors. The completion of high-standard farmland construction increases land parcel sizes and reduces land fragmentation, subsequently influencing farmers' willingness to use agricultural inputs. Farmers, as the central actors in rural economic activities and the basic units of agricultural production, play a pivotal role in shaping land resource utilization and management, directly affecting changes in cultivated land quality and the outcomes of grain production.

High-standard farmland construction might affect the quantity of pesticides, fertilizers, and plastic films used by farmers. According to Liu et al. [20], who utilize provincial panel data from China, the study employs a difference-in-differences approach to analyze the impact of high-standard basic farmland construction policies on per-unit area fertilizer usage. The results indicate that the high-standard farmland construction policy promotes fertilizer reduction by increasing land parcel sizes and enhancing agricultural specialization. A previous study of the Sichuan Province showed that the high-standard farmland construction significantly increased the recycling probability of the plastic film by 16% [21]. The policy could also have generated a positive effect on the reduction of pesticides [22]. Different agricultural input usage behaviors by farmers have a direct impact on cultivated land quality. Research indicates that soil quality is influenced by various factors, including farmers' land utilization practices, fertilizer use, and pesticide use [23]. Rational application of fertilizers, pesticides, and protective measures, such as plastic films, significantly affect soil organic matter content [24].

High-standard farmland construction indirectly affects cultivated land quality by influencing farmers' production behaviors, such as the use of pesticides, fertilizers, and plastic films. Rational use of pesticides and fertilizers, along with the scientific application of plastic films, contributes to reducing soil pollution, promoting soil ecological balance, enhancing soil fertility, mitigating the trend of declining soil quality, maintaining soil structure and quality, and facilitating sustainable agricultural development. Therefore, we generated Hypothesis 3 to be tested.

Hypothesis 3. *The construction of high-standard farmland indirectly affects cultivated land quality by reducing the use of agricultural inputs, e.g., fertilizers, pesticides, and plastic films.*

3. The Empirical Specifications

To quantitatively analyze the impact of high-standard farmland construction on cultivated land quality, this paper constructs the following IV regression with two-way fixed effects:

$$Y_{it} = \alpha_1 + \beta_1 H_{i(t-1)} + \lambda X_{i(t-1)} + \eta_{1i} + \gamma_{1t} + \varepsilon_{1it} \quad (1)$$

$$H_{it} = \alpha_2 + \beta_2 Z_{i(t-1)} + \lambda X_{i(t-1)} + \eta_{2i} + \gamma_{2t} + \varepsilon_{2it} \quad (2)$$

where Y_{it} are the scale or quality of cultivated land i th province (including municipalities and autonomous regions) in t th year; H_{it} is the construction of high-standard farmland in i th province (including municipalities and autonomous regions) in t th year; $Z_{i(t-1)}$ is the instrumented variable of the construction of high-standard farmland in i th province (including municipalities and autonomous regions) in previous year; $X_{i(t-1)}$ are the control variables in i th province (including municipalities and autonomous regions) in previous year; η_i , γ_t , and ε_{it} are individual fixed effect, time fixed effect, and random error term, respectively; and α , β , and λ are the parameters to be estimated.

3.1. Model Identification

Endogeneity issues can lead to biased estimates of the impact of the construction of high-standard farmland on cultivated land quality. The sources of endogeneity problems stem from two aspects: omitted variables and reverse causality. Omitted variables are unobservable factors that may change over time but are not included in the econometric model. Reverse causality arises because areas with initially better-cultivated land quality are more likely to be selected for high-standard farmland construction. We first use a two-way fixed effects model with time and regional fixed effects to mitigate the problem of omitted variables that do not vary over time. And we also employ the instrumental variable (IV) method to address reverse causality and the potential omission of unobservable variables that change over time.

3.2. Key Variables

3.2.1. Dependent Variables

Scale: The cultivated land scale (see Table 1, Row 1) is measured using the per capita cultivated land area, which comes from the *China Statistical Yearbook* for 30 provinces from 2009 to 2018. The average per capita allocation of farmland measures 0.33 hectares from 2009 to 2018 (See Table 1, Row 1).

Q: The weighted average quality (see Table 1, Row 2) of cultivated land is calculated using Equation (3) as follows, using data from the Ministry of Land and Resources (excluding Tibet and the Hong Kong–Macau–Taiwan regions), ranging from 1st grade to 15th grade, with 15th grade being the lowest level.

$$Q_{it} = \frac{\sum_{j=1}^{15} j \times A_{itj}}{\sum_{j=1}^{15} A_{itj}} \quad (3)$$

where A_{itj} represents the area of cultivated land in i th province classified of quality level j . There are 15 different levels of farmland quality ranging from 1st grade to 15th grade; The 1st grade is the farmland with the highest quality level, while the 15th grade is the lowest. Meanwhile, the farmland quality is classified by the Ministry of Land and Resources in China into the following four levels, including superior-grade cultivated land (1st grade to 4th grade), high-grade cultivated land (5th grade to 8th grade), medium-grade cultivated land (9th grade to 12th grade), and lower-grade cultivated land (13th grade to 15th grade), and calculated separately the farmland area of these categories. The average weighted quality is 9.52 from 2009 to 2018 (See Table 1, Row 2).

The measurement of arable land quality by the government is often questioned. Previous studies frequently used specific, small-scale indicators to construct arable land quality indices. Different levels of arable land quality evaluation indicators focus on different aspects, and their basic evaluation units and framework systems may vary. Consequently, the evaluation procedures, methods, and application of evaluation results also differ. Therefore, this paper adopts the county-level land area-weighted average land grade as the representative of provincial-level land quality, as it better reflects changes in land quality at the provincial level. Additionally, China's national land quality grading is a standardized land survey organized and implemented in accordance with regulations. These evaluation methods are scientific and standard, covering 202.3 million mu of cultivated land and selecting multiple key indicators (such as soil physical and chemical properties, nutrient status, etc.) for a comprehensive evaluation. Despite being organized by the government, this approach ensures national comparability of measurement methods. Compared to previous small-scale measurements, this method offers higher comparability for research and cross-regional comparisons and could be a good option for our quantitative analysis.

The cultivated land area decreased from 0.023 hectares per capita in 2009 to 0.021 hectares per capita in 2018. The quality of cultivated land decreased from a 9.80 grade in 2009 to a 9.96 grade in 2018 (See Figure 1).

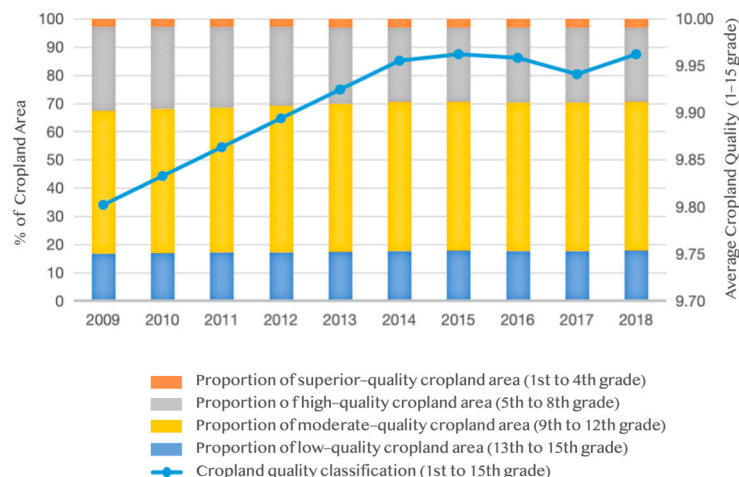


Figure 1. The evolvement of land quality in China from 2009 to 2018. Figure 1 illustrates each category of the cropland's proportion to the total cropland area and the line chart presents the average cropland quality from 2009 to 2018. Sources: *China Statistical Yearbook* and the Ministry of Land and Resources.

3.2.2. Mechanism Variables

Agricultural Input Variables: Theoretical analysis suggests that the construction of high-standard farmland could improve the quality of cultivated land by reducing farmers' usage of fertilizers, plastic film, and pesticide. Therefore, by verifying how high-standard farmland construction affects fertilizer, plastic film, and pesticide usage, we can determine whether farmers' agricultural production behaviors serve as an essential channel through which high-standard farmland construction influences cultivated land quality. Previous research has demonstrated that significantly reducing the use of fertilizers, chemical pesticides, and plastic films can enhance soil fertility and structure, thereby improving soil quality and increasing its capacity to support sustained agricultural productivity [25–27]. Consequently, we examine the relationship between the area of high-standard farmland construction and farmers' usage of fertilizers, plastic film, and pesticides (See Table 1, Row 3–5). If the construction of high-standard farmland leads to a decrease in the usage of these inputs, the indirect mediation effect through this channel is validated.

For grain sowing, both fertilizer and plastic film increased from 0.55 tons per hectare and 0.027 tons per hectare in 2009 to 0.63 tons per hectare and 0.035 tons per hectare, respectively. While for grain sowing, pesticide use was decreased from 0.020 tons per hectare in 2009 to 0.018 tons per hectare in 2018.

3.2.3. Key Independent Variables

H: We utilize the total area of the upgrade of low- and medium-yield farmland and the construction of high-standard farmland at the provincial level from 2009 to 2018 in the *China Financial Yearbook* to construct the key independent variable (See Table 1, Row 6). The total area of the upgrade of low- and medium-yield farmland and the construction of high-standard farmland increased from 1.03 million hectares in 2009 to 1.48 million hectares in 2018.

3.2.4. Instrumental Variable

Pattern: We use the farmland pattern from the *China Agricultural Yearbook* as our instrumental variable. The paper uses the relative importance of cultivated land (i.e., the proportion of cultivated land area in each region to the total national cultivated land area) as the instrumental variable for the level of high-standard farmland construction (See Table 1, Row 7). The choice of this instrument is based on two factors: On one hand, regions with greater relative importance of cultivated land are more likely to undergo the policy of the construction of high-standard farmland. On the other hand, the relative importance of

cultivated land alone does not directly determine cultivated land quality levels. There is tiny change in the proportion of cultivated land area to the total cultivated land area in the country.

3.2.5. Control Variables

As for data availability and referring to existing studies, we selected urbanization, industrialization, infrastructure construction, agricultural land requisition, farmland irrigation facilities, natural disasters, and meteorological factors as control variables (See Table 1, Row 8–15). The data collected for the empirical estimation is from the *China Urban Statistics Yearbook*, the *China Urban Construction Statistics Yearbook*, the *China Population and Employment Statistics Yearbook*, the *China Land and Resources Yearbook*, the *China Statistical Yearbook*, and the *China Rural Statistics Yearbook*.

Urbanization: Urban expansion leads to a reduction in cultivated land area and a decline in cultivated land quality. Urbanization includes three types: land urbanization, population urbanization, and in situ urbanization. Land urbanization is measured by the proportion of urban built-up area to the administrative area of the province. Population urbanization is measured using the year-end urban population proportion by region. In situ urbanization is measured using the proportion of rural private enterprise employment plus individual employment to the rural population.

Industrialization: We utilize the sum of the values of the secondary and tertiary sectors as a proportion of regional GDP.

Infrastructure: We obtain the proportion of land used for transportation and transportation-related purposes to the total construction land area from the *China Statistical Yearbook* to indicate the infrastructure construction level.

Land requisition: We utilize the proportion of agricultural land requisitioned to the total agricultural land area.

Irrigation: The level of irrigation facilities can alleviate pressure on cultivated land [11]. It is measured as the proportion of effectively irrigated cultivated land area to the total cultivated land area.

Disaster: Natural disasters can reduce cultivated land quality. It is measured as the proportion of the affected area to the total sown area of crops.

Table 1. Descriptive statistical analysis of key variables.

Variables	Variables Definition	Mean	S.D.
Scale	Average cultivated land area per labor (hectares/person)	0.33	0.35
Q	Quality level of cultivated land based on area-weighted method, with 1 being the highest quality while 15 the lowest.	9.52	2.25
Fertilizer	Fertilizer usage for crop planting area (tons/hectare)	0.59	0.26
Plastic film	Plastic film usage for crop planting area (tons/hectare)	0.03	0.03
Pesticide	Pesticide usage for crop planting area (tons/hectare)	0.02	0.02
H	Total construction area of high-standard farmland (hectares)	128.93	81.83
Pattern	Proportion of cultivated land area in each region to the national cultivated land area (%)	3.32	2.43
Land urbanization	Proportion of urban built-up area to the administrative area of the province (%)	1.98	3.39
Population urbanization	Proportion of urban permanent residents to the total population (%)	55.07	13.31
In situ urbanization	Proportion of employment in private enterprises and individual employment in rural areas to the rural population (%)	17.84	23.04

Table 1. *Cont.*

Variables	Variables Definition	Mean	S.D.
Industrialization	Sum of the output value of the secondary and tertiary industries as a percentage of the regional GDP (%)	89.55	5.40
Infrastructure	Proportion of land area for transportation to the total construction land area (%)	9.09	2.14
Land requisition	Proportion of requisitioned agricultural land area to the total agricultural land area (%)	0.08	0.14
Irrigation facilities	Proportion of effective irrigation area to cultivated land area (%)	52.47	23.01
Disaster	Proportion of crop-affected area to the total sown area of crops (%)	19.54	13.70

4. Results and Discussions

The estimated coefficient of the instrumental variable (i.e., farmland pattern) on the endogenous variable (i.e., high-standard farmland construction) is 21.830, and it is statistically significant at the 1% confidence level (see Table 2, Column 1), indicating regions with a relatively large proportion of cultivated land in the whole country are more likely to carry out the policy of the construction of high-standard farmland.

4.1. The Direct Impact of High-Standard Farmland Construction on Cultivated Land Quality

Table 2 reports the overall impact of high-standard farmland construction on both the quantity and quality of the cultivated land. In the first-stage estimation (see Table 2, Column 1) using the IV-2SLS model, the Kleibergen–Paap statistic is significantly larger than the critical value for the F-statistic at the 10% bias level (i.e., 16.38) as specified by Stock and Yogo (2005). This indicates the absence of weak instrument problems when using the farmland pattern, which is the relative importance of cultivated land (i.e., the proportion of cultivated land area in each region to the national cultivated land area). The F-statistics in Table 3 are statistically significant at least at the 1% confidence level, indicating a good model fit for analyzing the impact of high-standard farmland construction on both the quantity and quality of the cultivated land.

Table 2. The impacts of high-standard farmland on the quantity and quality of cultivated land.

	First-Stage Regression	Second-Stage Regression	
	1	2	3
	High-Standard Farmland	Cultivated Land Area	Cultivated Land Quality
High-standard farmland	— —	0.004 *** (0.001)	−0.004 ** (0.002)
Pattern	21.830 *** (5.324)	— —	— —
Land urbanization	4.322 (6.220)	−0.014 (0.018)	−0.021 (0.041)
Population urbanization	0.391 (1.397)	0.002 (0.005)	−0.007 (0.009)
In situ urbanization	−0.150 (0.406)	0.001 (0.001)	−0.004 * (0.003)
Industrialization	−0.352 (1.315)	0.004 (0.005)	0.013 (0.011)

Table 2. Cont.

	First-Stage Regression	Second-Stage Regression	
	1	2	3
	High-Standard Farmland	Cultivated Land Area	Cultivated Land Quality
Infrastructure	−4.572 (2.810)	0.006 (0.009)	0.001 (0.024)
Land requisition	37.792 ** (14.104)	−0.187 *** (0.065)	0.347 *** (0.127)
Irrigation	0.694 *** (0.219)	−0.004 *** (0.001)	−0.002 (0.003)
Disaster	0.085 * (0.048)	−0.0002 (0.0001)	−0.0001 (0.001)
Constant	34.036 (131.305)	— —	— —
Individual fixed effect	Controlled	Controlled	Controlled
Time fixed effect	Controlled	Controlled	Controlled
F statistic	17.84 ***	6.45 ***	3.95 ***
Kleibergen–Paap statistic	—	16.874	16.874
# of observations	300	300	300

Note: ***, ** and * indicates the statistical level of 1%, 5% and 10%. Clustering robust standard error in provincial level are in parentheses. The Stock–Yogo weak ID test critical value (10% maximal IV size) is 16.38.

Firstly, the construction of high-standard farmland increases the cultivated land area. The estimated coefficient for the impact of high-standard farmland construction on per capita cultivated land area is 0.004, and it is statistically significant at the 1% confidence level (see Table 2, Column 2). This suggests that for every additional 10,000 hectares of high-standard farmland construction, the per capita cultivated land area increased by 0.004 hectares per person. The result rejected our null hypothesis of Hypothesis 1, indicating that the high-standard farmland construction could have indeed increased the scale of cultivated land. This might be attributed to the land leveling project, which increases cultivated land quantity through the consolidation of scattered land parcels. Between 2009 and 2017, the average increase in high-standard farmland was 1.2893 million hectares, cumulatively resulting in an increase in land area per person of 0.51 hectare, which is 1.6 times the average farmland scale level, indicating a significant land consolidation effect of the policy.

Secondly, the high-standard farmland construction enhances cultivated land quality. The estimated coefficient for the impact of high-standard farmland construction on cultivated land quality levels is −0.004, and it is statistically significant at the 5% confidence level (see Table 2, Column 3). This indicates that for every additional 10,000 hectares of high-standard farmland construction, cultivated land quality improves by 0.004 grade. This improvement is attributed to soil improvement, irrigation and drainage, field road construction, farmland protection, and ecological conservation projects, which contribute to improving cultivated land conditions regarding location, soil quality, utilization, cultivation, and ecological factors. Though the coefficient is minimal, the real effect could be economically significant. The official evaluation by the Chinese government indicates that an improvement in arable land quality by one to two grades corresponds to an increase in grain yield of 1500 kg per hectare. In the study, the coefficient is 0.004, which translates to an additional increase of 3 to 6 kg in average grain yield per hectare for every 10,000 hectares of high-standard farmland constructed. Between 2009 and 2017, the average increase in high-standard farmland was 1.2893 million hectares, cumulatively resulting in an increase in grain yield of 386.8 to 773.6 kg per hectare. Given that China’s grain yield in

2018 was 5,621 kg per hectare, the construction of high-standard farmland has contributed to a 6.9% to 13.8% increase in the country's grain yield. Hence, we validate our Hypothesis 2 that the high-standard farmland construction could have enhanced the quality of the cultivated land.

Our findings align with previous research, demonstrating that the construction of high-standard farmland can improve land quality. Multifaceted benefits of high-standard farmland development in China, highlighting its positive impact on agricultural productivity, rural socio-economic conditions, and ecological sustainability [28]. However, their use of indicators lacks causal identification and cannot be quantified for analysis. Our results are also consistent with prior land consolidation studies, which showed an increase in arable land area. Land consolidation in China significantly increases agricultural productivity and expands the cultivated land area. Our primary contribution lies in conducting a quantitative analysis within a causal identification framework, using the actual area of high-standard farmland construction rather than a binary indicator variable. Therefore, our results hold economic significance and could be employed consistently if the construction of high-standard farmland continues to be one of the major agricultural production policies in China.

4.2. The Indirect Impact of High-Standard Farmland Construction on Cultivated Land Quality: Reduced Use of Fertilizers, Plastic Films, and Pesticides

Table 3 reports the effects of high-standard farmland construction on the usage of fertilizer, plastic film, and pesticide for grain production. First, high-standard farmland construction could have significantly reduced farmers' fertilizer usage (see Table 3, Column 1). The estimated coefficient for the impact of high-standard farmland construction on fertilizer application for grain production is -0.0058 at the 1% significance level. For each additional hectare of high-standard farmland construction, fertilizer application for grain production decreases by 0.0058 tons per hectare. Second, high-standard farmland construction might have also reduced the usage of plastic film (see Table 3, Column 2). The estimated coefficient for the impact of high-standard farmland construction on plastic film application for grain production is -0.0003 at the 1% significance level. For each additional hectare of high-standard farmland construction, plastic film usage for grain production decreases by 0.0003 tons per hectare. Finally, pesticide usage for grain production might also have been significantly decreased due to the high-standard farmland construction. The estimated coefficient for the impact of high-standard farmland construction on pesticide application for grain production is -0.0001 at the 5% significance level (see Table 3, Column 3). Pesticide usage for grain production decreases by 0.0001 tons per hectare with each additional hectare of high-standard farmland construction.

Table 3. The impact of the construction of high-standard farmland on the usages of fertilizer, plastic film, and pesticide.

	Fertilizer	Plastic Film	Pesticide
	1	2	3
High-standard farmland	-0.0058^{***} (0.0018)	-0.0003^* (0.0002)	-0.0001^* (0.0001)
Land urbanization	-0.0223 (0.0470)	-0.0007 (0.0035)	0.0017^* (0.0009)
Population urbanization	-0.0226^{***} (0.0073)	-0.0017^{**} (0.0008)	-0.0006^{**} (0.0002)
In situ urbanization	-0.0039^* (0.0021)	-0.0002 (0.0001)	-0.0001 (0.0001)
Industrialization	0.0080 (0.0054)	0.0010 (0.0006)	-0.00003 (0.0002)

Table 3. Cont.

	Fertilizer	Plastic Film	Pesticide
	1	2	3
Infrastructure	−0.0098 (0.0170)	0.0007 (0.0015)	−0.0006 (0.0005)
Land requisition	0.6693 *** (0.1585)	0.0409 ** (0.0165)	0.0271 *** (0.0075)
Irrigation	0.0010 (0.0018)	−0.0001 (0.0001)	−0.0001 (0.0001)
Disaster	0.0001 (0.0004)	0.00002 (0.00002)	0.000003 (0.00001)
Individual fixed effect	Controlled	Controlled	Controlled
Time fixed effect	Controlled	Controlled	Controlled
F statistic	12.51 ***	5.46 ***	3.31 **
Kleibergen–Paap statistic	16.874	16.874	16.874
# of observations	300	300	300

Note: ***, ** and * indicates the statistical level of 1%, 5% and 10%. Clustering robust standard error in provincial level are in parentheses. The Stock–Yogo weak ID test critical values (10% maximal IV size) is 16.38.

Farmers’ agricultural production behavior is the channel through which high-standard farmland construction could have affected cultivated land scale and quality. After the construction of high-standard farmland, there is a significant reduction in the usage of fertilizer, plastic film, and pesticides for grain production, which subsequently ensures an improvement in soil natural fertility and an increase in cultivated land area quality. Empirical studies indicate that the use of chemical fertilizers, pesticides, and plastic mulch films can degrade the quality of cultivated land. Research has demonstrated that excessive use of chemical fertilizers disrupts the natural nutrient balance of soil, leading to reduced organic matter and impeding long-term soil fertility [29]. Studies have identified that the extensive use of pesticides in agriculture is a major source of non-point source pollution, contributing to soil degradation and water contamination, which negatively affects land quality [30]. Evaluations of the long-term effects of plastic mulching have highlighted its role in disrupting soil structure, reducing water infiltration, and contributing to microplastic accumulation in soils, all of which lead to reduced soil quality [31]. Based on this, we verified our Hypothesis 3.

5. Conclusions and Policy Implications

As the construction of high-standard farmland has been implemented nationwide in China, there is a noticeable trend of decreasing the quantity and quality of cultivated land. Whether the constructed high-standard farmland can significantly improve the quality of cultivated land has sparked considerable debate. To address this issue, based on panel data from 30 provinces in China during 2009 to 2018, this study employs a two-way fixed effects model based on the instrumental variable method to empirically analyze the impact of the construction of high-standard farmland on the quantity and quality of cultivated land. The findings are as follows: On one hand, the construction of high-standard farmland can significantly increase the cultivated land area. For each additional 10,000 hectares of high-standard farmland, the area of cultivated land increases by 0.004 hectares per labor. On the other hand, the construction of high-standard farmland can significantly enhance the average quality of cultivated land by influencing farmers’ behaviors and reducing the usage of fertilizers, pesticides, and plastic films for grain production. For each additional 10,000 hectares of high-standard farmland constructed, the quality of cultivated land will improve by a grade of 0.004.

Based on the research findings presented above, this paper offers some empirical evidence of the high-standard farmland on the land scale and quality. Though limited in the

investigation as the paper is only on the provincial level and examines several input factors, it might still provide the following four policy implications: First, because the coverage rate of high-standard farmland construction is less than 40%, the central government could consider accelerating the progress of high-standard farmland construction. Second, local government could enhance the quality of high-standard farmland construction projects. It is a critical need to improve the project quality of high-standard farmland construction, thus further enhancing the quality levels of cultivated land. Third, the policymaker could implement diversified types of high-standard farmland construction models tailored to local conditions. Finally, the government might strengthen the post-construction management mechanism to ensure the sustainability of the policy, which will help further reinforce the quality of cultivated land.

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