Proceedings of the 9th International Conference on Economic Management and Green Development
DOI: 10.54254/2754-1169/2025.26568

Research on the Impact of Digital Empowerment in Agriculture on Farmers' Income Growth under the Background of Common Prosperity: A Case Study of Henan Province

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Abstract. Accelerating the digitalization of agriculture is a strategic key to effectively promoting the comprehensive revitalization of rural areas and an important factor in the modernization process of agriculture and rural areas. This paper selects relevant data from 18 prefecture-level cities in Henan Province from 2019 to 2023, constructs an evaluation index system, uses the entropy method to calculate the comprehensive index of agricultural digitalization development level, and selects the two-way fixed effect model to test the impact effect of the agricultural digitalization level. The research finds that the agricultural digitalization infrastructure in the agricultural digitalization development level has a significant promoting effect on rural revitalization. The agricultural digitalization development level has a significant promoting effect on farmers' income, but this effect is not obvious in the central and eastern regions. Based on this, it is proposed to strengthen the regional linkage development of agricultural digitalization, increase the training of digital technology talents, strengthen the construction of agricultural information infrastructure, and promote the level of large-scale agricultural planting. It is necessary to give full play to the leading role of Henan Province, a major agricultural province, in the process of agricultural digital transformation, and achieve common prosperity by improving the policy and institutional system of agricultural digitalization.

Keywords: Digitalization of agriculture, Farm household income, Entropy method, Digital empowerment

1. Introduction

Since the 20th National Congress of the Communist Party of China, the Central Committee has strengthened the deep integration of the digital economy and agriculture. In 2019, multiple departments including the Ministry of Agriculture and Rural Affairs issued the "Digital Agriculture and Rural Development Plan (2019-2025)", emphasizing the core of accelerating the construction of agricultural informatization and deeply integrating digital technology with the agricultural sector, aiming to achieve the goal of comprehensive digital transformation of agriculture. Leading the

DOI: 10.54254/2754-1169/2025.26568

modernization process of agriculture and rural areas through digital means has injected strong impetus into the in-depth implementation of the rural revitalization strategy. The 2024 Central Document No. 1 once again emphasized that to enhance the level of rural construction, it is necessary to continue to carry out the digital rural development action and increase farmers' income. The 2025 Central Document No. 1 proposed, "To lead the aggregation of advanced production factors with scientific and technological innovation and develop new quality productivity in agriculture based on local conditions." The modern agricultural development model that promotes agricultural digitalization is a bridge for the organic connection between farmers and agricultural modernization, and one of the new ways to promote agricultural economic development. By sorting out a series of policy documents related to agricultural digitalization, it is found that the digital economy is a new path to empower the high-quality development of agriculture in Henan Province [1]. Studying and analyzing the effect of the development level of agricultural digitalization on farmers' income is of great significance for promoting the modernization of agriculture in Henan Province.

2. Literature review

2.1. The challenges in the digital development of agriculture

In the process of agricultural digitalization, the digital transformation of agriculture is a crucial change. Heinz B and Louisa, among others, believe that there are various challenges in this process, including issues related to digital technologies and the development environment [2,3]. At present, the digitalization of agriculture in our country is in an upward stage. Wen Tao et al. believe that there is a situation of incomplete resource system construction in the construction of digital infrastructure [4], The construction of digital infrastructure and data systems is constrained by regional economic levels, especially in relatively remote rural areas [5]. Some scholars have conducted an analysis and found that by improving the influencing factors of agricultural digitalization development, the problems encountered during the process of agricultural digitalization can be solved. From the perspective of the government, it was discovered that the inadequate construction of information infrastructure has restricted the digitalization development of agriculture [6]. The main factors driving the digital development in rural areas include the following three aspects: regional economic level, dependence on information technology, and the marginalization of the actors. During the process of agricultural digital transformation, the economic development level has a positive impact on digital development, while the dependence on information technology and the marginalization of the actors has a negative impact on digital development [7].

Many studies have concluded that the development of agricultural digitalization has a significant impact on the agricultural economy. It has been found that in regions with better economic development, the construction of digital infrastructure and the development of digital economy show a mutually reinforcing trend. However, there are individual differences in the informatization technical literacy of farmers, especially in areas with relatively backward economic levels, farmers have more difficulty in obtaining the benefits of agricultural digitalization, thereby hindering the development of agricultural digitalization [8,9]. From the perspective of "digital countryside", this study examines the impact of agricultural digitalization on breaking the traditional agricultural service system. It also analyzes how agricultural development, in the context of the digital economy, can increase the economic value of farmers [10]. The digital transformation of traditional agriculture can enhance the connection among different links in the agricultural value chain, thereby improving the quality and efficiency of agricultural production, and thus presenting a diversified agricultural

DOI: 10.54254/2754-1169/2025.26568

economy [11]. With the advancement of digitalized agricultural production and operation, the allocation of resources between urban and rural areas has been optimized. Through analyzing the data, they discovered that as the level of digitalized agricultural production continuously improves, its impact on the economic benefits of farmers will become increasingly significant [12,13]. Through the threshold effect model, it was found that the improvement of agricultural digitalization level can effectively narrow the income gap between urban and rural areas in China, and is conducive to achieving the strategic goal of common prosperity in our country [14]. Meanwhile, in the context of the digital economy era, the digital transformation of traditional agriculture will become one of the important means to help China achieve the goal of the rural revitalization strategy [15].

2.2. Research on the influencing factors of agricultural digitalization development

The research on the influencing factors of agricultural digitalization development mainly focuses on three aspects: First, political factors. With the development of the digital economy, the attention to agricultural digital transformation in China has been increasing. However, there are still certain problems in the policy support system during the process of agricultural digitalization development. The level of agricultural digitalization varies significantly by region, and the support from local finances will have an impact on the development status of agricultural digitalization in the local area [16]. The second factor is related to agricultural development. Through empirical research, analyzing the determinants that hinder the digitalization of agriculture revealed that a lack of close connections among agricultural production chains would lead to issues such as information asymmetry [17]. Regarding this issue, the various links of the agricultural industry, due to the lack of scientific guidance, have led to an imbalance in the supply and demand of agricultural products and technologies, resulting in an information asymmetry situation [18]. The third factor is the digital environment. Strengthening the construction of digital infrastructure in economically underdeveloped areas can help improve the allocation level of agricultural digital resources, achieving the goal of sharing digital achievements across urban and rural areas [19]. The main reason for the current lag in agricultural digitalization is the lag in digital technology. Moreover, agricultural digitalization development is a systematic project that cannot be achieved without the improvement of infrastructure and the guarantee of digital technology [20].

2.3. Research on the impact of agricultural digitalization on farmers' income

An important condition for promoting digital development in our country is to enhance the development level of the agricultural economy. During this process, agricultural digitalization inevitably leads to the emergence of unequal wealth distribution. The development of agricultural digitalization can narrow the gap brought about by the digital economy, and ensure that farmers at different income levels obtain almost the same digital dividends in the field of agricultural digitalization [21]. By constructing an empirical analysis model for the digital divide index of rural residents, it was found that the digital divide not only has a negative impact on agricultural income, but also has a more significant negative impact on non-agricultural income [22]. Some scholars have suggested that the emergence of the digital gap has a negative impact on farmers' income. Taking the "Broadband China" policy as the research starting point, it is also pointed out that reducing the digital gap between urban and rural areas is conducive to increasing the income of rural residents. The main factor causing this gap is the significant difference in information infrastructure construction. Therefore, it is proposed that the government can promote the growth of rural

DOI: 10.54254/2754-1169/2025.26568

residents' income by increasing financial support for agricultural digital infrastructure construction [23].

In conclusion, the existing literature studies have comprehensively considered the influencing factors and development challenges of agricultural digitalization. It has been found that there are still many problems in the development process of agricultural digitalization in China. The development levels of agricultural digitalization in different regions still show an imbalance, with weak infrastructure construction for information and insufficient financial support. To achieve the strategic goal of agricultural modernization in China, the country still needs to actively promote the development process of agricultural digitalization.

3. Policy background and theoretical analysis

3.1. The policy background for the development of agricultural digitalization

In 2007, the No.1 Central Document clearly proposed to accelerate the construction of agricultural informatization. In 2016, the No.1 Central Document stated that it was necessary to vigorously promote "Internet +" modern agriculture and improve the level of rural financial services. Since 2017, "digital economy" has frequently appeared in the government work reports. Multiple departments such as the Ministry of Agriculture and Rural Affairs released the "Digital Agriculture Development Plan (2019-2025)" in 2019, emphasizing that the core of accelerating agricultural informatization construction should be the integration of digital technology with the agricultural sector, and striving to achieve the goal of a comprehensive digital transformation of agriculture. Through digital means, the process of modernizing agriculture and rural areas can be led, injecting strong momentum for the in-depth implementation of the rural revitalization strategy. In the No.1 Central Document of 2024, it was again emphasized that for improving the level of rural construction, the digital village development action should be carried out, and farmers' income should be increased. By reviewing a series of policy documents related to agricultural digitalization, it was found that the digital economy is a new path for empowering the high-quality development of agriculture in Henan Province [1]. The digitalization development of agriculture in Henan Province has gradually shifted from the construction of the basic level of agricultural informatization to the promotion of high-quality agricultural development.

3.2. Theoretical analysis and research hypotheses

The digitalization of agriculture helps farmers obtain relevant data on agricultural production through digital networks and enables them to promptly understand the current demands of the agricultural market. It also enables them to quickly adjust to the unreasonable resource utilization issues in the agricultural production process. Through digital technology, the output of agricultural products can be more accurately matched with the consumer market, thereby achieving the goal of optimizing the operational efficiency of agricultural production and promoting the more rational use of agricultural resources. During the process of agricultural digital transformation, agricultural resources have been optimally allocated. This not only enhances agricultural production efficiency but also helps farmers increase their income. Digital technology converts tacit knowledge into explicit knowledge [24]. With the deep application of digital technology in the agricultural sector, the transfer of farmland and large-scale operations have further magnified the benefits brought by technology [25], This makes advanced digital agricultural technologies more accessible for promotion and application. It is pointed out that information asymmetry leads to problems such as

DOI: 10.54254/2754-1169/2025.26568

difficulty in selling agricultural products, high transaction costs, and low selling prices, which hinders farmers' income growth [26]. Under the collaborative theory, the government training programs and the technological transfer from enterprises form a synergy, enabling farmers to find employment opportunities more conveniently and efficiently by using digital devices and technologies. This effectively promotes the transfer of farmers to non-agricultural industries, and at the same time, after improving their educational levels, farmers can meet the demands of more job positions. Based on this, the following hypothesis is proposed: There are regional differences in the level of agricultural digitalization development, and it has a promoting effect on farmers' income.

4. Materials and methods

4.1. Data source

The research subjects of this article are the 18 prefectures in Henan Province. Considering the clear requirement in the "Several Opinions of the Central Committee of the Communist Party of China and the State Council on Persisting in Giving Priority to Agriculture and Rural Areas and Doing a Good Job in Rural Affairs" issued by the State Council in 2019 to promote the construction of digital villages and narrow the digital gap between urban and rural areas. Also considering that the development of agricultural digitalization is a dynamic process, the research scope of measuring the agricultural digitalization level of all prefectures in Henan Province is determined as from 2019 to 2023. The original data of the selected indicators come from the "China Statistical Yearbook", "China Rural Statistical Yearbook", "Henan Statistical Yearbook", relevant websites of the Ministry of Industry and Information Technology and the Department of Agriculture and Rural Areas, etc. Considering that the agricultural digitalization level is a dynamic process and considering the availability of data, for the problem of data missing, this article fills it in using the moving average method.

4.2. Variable selection

4.2.1. The explained variable

This article selects the per capita disposable income of rural residents as the indicator to measure this income level. Given that the current statistical data on the per capita disposable income of rural residents is both accurate and fair, choosing this indicator as the benchmark for explaining that farmers' income undoubtedly possesses a certain degree of objectivity.

4.2.2. Core explanatory variable

Based on the current development status of agricultural digitalization in Henan Province and the feasibility of data acquisition, an assessment framework for the development level of agricultural digitalization in Henan Province was constructed. At the same time, the comprehensive measurement indicators of agricultural digitalization development level were adopted as the core explanatory variable [27].

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Table 1. Evaluation index system for the development level of agricultural digitalization in Henan Province

Primary indicator	Secondary indicator	Third-level indicators	Attribute	Attribute
Agricultural digital infrastructure construction	The intensity of fiscal support for agriculture	Expenditure on agriculture, forestry and water resources	+	0.036
		Agricultural science and technology funding	+	0.052
	Scale of information infrastructure	Scale of agricultural meteorological observation stations	+	0.097
		Mobile phone users	+	0.049
		Rural electricity consumption scale	+	0.037
		Rural digital base stations	+	0.123
Agricultural digital production	Green production situation	Effective irrigated area	+	0.033
		Fertilizer application volume for agriculture	-	0.061
		Plastic film usage in agriculture	-	0.035
	Agricultural machinery production situation	Agricultural production machinery level	+	0.041
	Degree of agricultural technological progress	Scale of agricultural science and technology personnel	+	0.046
		Agricultural electrification level	+	0.046
		Agricultural labor productivity	+	0.052

DOI: 10.54254/2754-1169/2025.26568

Table 1.(continued)

Agricultural Digital Circulation	The digitalization level of agricultural products	Express delivery volume	+	0.086
	The scale of agricultural product e-commerce	Online order amount of agricultural products	+	0.052
		Total level of agricultural express delivery services	+	0.031
		Agricultural innovation base	+	0.123

4.2.3. Control variable

To ensure the scientific and rigor of the research analysis and to prevent the influence of factors other than the level of agricultural digitalization development on farmers' income, it is necessary to control these interfering factors. Reference study [28-29], The following control variables were selected: the number of employees in the primary industry(ω), the urbanization level(φ) , the scale of grain cultivation (α), and the economic development level(γ). The descriptive statistics of each variable are presented in Table 2.

Table 2. Descriptive statistics of variables

Variable	Mean	Standard Deviation	Minimum Value	Maximum Value
Farmers' income (Y)	18620.265	3827.280	9799.100	30383.000
Level of agricultural digitalization development (X)	0.232	0.117	0.089	0.652
Employees in the primary industry (ω)	80.183	55.380	4.230	295.530
Urbanization level (φ)	0.556	0.084	0.411	0.800
Scale of grain cultivation (α)	0.753	0.071	0.605	0.870
Economic development level(γ)	58861.905	19468.789	34961.190	113138.870

4.3. Model selection

Based on the above analysis and assumptions, to further analyze the impact of agricultural digitalization on farmers' income, the following baseline regression model is constructed:

$$lnY_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 ln\omega_{it} + \beta_3 \varphi_{it} + \beta_4 \alpha_{it} + \beta_5 ln\gamma_{it} + city_i + year_t + \varepsilon_{it} \tag{1}$$

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In Equation (1), lnY_{it} represents the per capita disposable income of rural residents, X_{it} represents the level of agricultural digitalization development, $city_i$ represents the individual fixed effect, $year_t$ represents the time fixed effect, ε_{it} represents the random disturbance term, $t=(2019,2020,\ldots,T)$ represents each year, and i represents the 18 prefecture-level cities in Henan Province.

5. Results

5.1. Baseline regression analysis

To further explore the impact of the digitalization development level of agriculture in Henan Province on farmers' income, a two-way fixed effect model was used for regression analysis on the influence of the digitalization development level of agriculture on farmers' income, as shown in Table 3. Among them, column (1) is the benchmark regression result without control variables. The regression coefficient of the digitalization development level of agriculture shows a significant positive impact at the 1% level, indicating that the digitalization development of agriculture in Henan Province can significantly promote the growth of farmers' income. Columns (2) to (5) are the benchmark regression analysis results after adding control variables successively. The regression coefficient of agricultural digitalization development shows a fluctuating trend within the range of 0.1. The digitalization development level of agriculture in Henan Province still has a significant positive impact on farmers' income at the 1% level. This fully demonstrates that the digitalization development level of agriculture in Henan Province can effectively promote the growth of farmers' income.

Table 3. Results of baseline regression analysis

	(1)	(2)	(3)	(4)	(5)
The level of digitalization in agriculture development (X)	0.892*** (4.067)	0.768*** (4.263)	0.873*** (3.216)	0.766*** (3.216)	0.782*** (4.838)
Employees in the primary industry ($ln\omega$)		-0.101*** (-3.986)	-0.084*** (-3.678)	-0.164*** (-2.583)	-0.094*** (-4.126)
Urbanization level (φ)			0.0958** (1.973)	0.138** (2.027)	0.085** (1.981)
The scale of grain cultivation (α)				0.046 (1.236)	0.032 (1.531)
Economic development level ($ln\gamma$)					0.090 (1.140)
Individual fixed effect	Yes	Yes	Yes	Yes	Yes
Fixed effect of time	Yes	Yes	Yes	Yes	Yes
Constant	0.982** (3.427)	0.796** (4.862)	0.782** (4.403)	0.428** (3.239)	0.542** (4.251)
R^2	0.843	0.894	0.921	0.792	0.873

Note: The dependent variable is the income of farmers(lnY),***, **, and * indicate significance at 1%, 5%, and 10% levels respectively. The values in parentheses are t-values, and the same applies below.

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5.2. Robustness test

To eliminate the endogeneity problem possibly caused by reverse causality, this paper conducts robustness tests through three methods. First, the agricultural digital development level is lagged by one period and denoted as($L.X$).Column (1) shows that even when the agricultural digital development level is lagged, its regression coefficient still presents a significant positive correlation at the 1% level. Second, this study removes the data of Zhengzhou City, Jiyuan City, and Jiaozuo City, and re-regresses the remaining samples. As shown in column (2) of Table 4, even after removing the data of some cities, the impact of agricultural digital development on farmers' income remains positive and significant at the 1% level. Third, two additional control variables, namely the degree of agricultural disaster($lnADL$)and the added value of the primary industry ($lnAVA$),are further included. As shown in column (3) of Table 4, the regression coefficient of the agricultural digital development level is still significantly positive at the 1% level, indicating that the promoting effect of agricultural digital development in Henan Province on farmers' income has not been affected by the new variables and still shows a significant positive impact. This paper fully considers the endogeneity problem, thus making the conclusion more reliable.

Table 4. Results of robustness test

	Variable lag processing	Exclude special samples	Add control variables
	(1)	(2)	(3)
The level of digitalization in agriculture development (X)		0.792*** (4.018)	0.779*** (3.198)
The level of agricultural digitalization development lags behind by one year ($L.X$)	0.872*** (3.203)		
Employees in the primary industry ($ln\omega$)	-0.131*** (-4.051)	-0.167*** (-3.105)	-0.097*** (-4.296)
Urbanization level (φ)	0.131** (2.265)	0.094** (2.196)	0.107** (2.273)
The scale of grain cultivation (α)	0.085 (0.867)	0.053 (0.897)	0.067 (0.983)
Economic development level ($ln\gamma$)	0.064 (0.947)	0.103 (0.783)	0.078 (0.968)
The extent of agricultural damage($lnADL$)			0.174** (3.138)
Value added of the primary industry ($lnAVA$)			0.362** (3.337)
Constant	1.298*** (4.473)	0.864*** (4.198)	0.969*** (3.317)
Individual fixed effect	Yes	Yes	Yes
Fixed effect of time	Yes	Yes	Yes
R^2	0.706	0.698	0.716

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5.3. Heterogeneity analysis

This article divides Henan Province into five regions: the eastern part of Henan, the western part of Henan, the central part of Henan, the northern part of Henan, and the southern part of Henan. Regression tests are conducted on each of these regions to analyze whether the development of agricultural digitalization has regional heterogeneity in its impact on farmers' income. The regression results are shown in Table 5. There are significant regional differences in the development of agricultural digitalization in Henan Province and its impact on farmers' income. However, there is a significant positive correlation in all regions. Among them, the three regions of western Henan, southern Henan, and northern Henan have a more significant effect on increasing farmers' income. The impact of agricultural digitalization level in Henan Province on farmers' income shows regional differences. From the coefficient size, the influence of agricultural digitalization development level on farmers' income in the northern region is significantly higher than that in the southern, western, eastern, and central regions. The development of agricultural digitalization in Henan Province has a more significant effect on the farmers' income of the northern, southern, and western regions than that of the eastern and western regions. However, the effect of agricultural digitalization level also varies. Its effect is the most significant on the northern region and the weakest on the central region.

Table 5. Results of heterogeneity test

Variable	Eastern Henan region	Western Henan region	Central Henan region	Southern Henan region	Northern Henan region
The level of digitalization in agriculture development	0.768**	1.013***	0.534**	1.293***	1.639***
(X)	(2.365)	(3.069)	(2.216)	(3.927)	(3.218)
Employees in the primary industry	-0.123***	-0.225***	-0.316***	0.011	-0.053***
($ln\omega$)	(-3.137)	(-2.979)	(-4.215)	(0.745)	(-3.414)
Urbanization level	1.056**	0.523***	1.056**	1.042***	0.997**
(φ)	(2.254)	(4.393)	(2.106)	(4.051)	(2.187)
The scale of grain cultivation	0.280**	0.178***	0.280**	0.178***	-0.786
(α)	(2.346)	(4.113)	(2.129)	(3.063)	(0.053)
Economic development level	0.187	0.056	0.167	-0.056	-0.036
($ln\gamma$)	(0.219)	(0.971)	(0.119)	(0.035)	(0.021)
Individual fixed effect	Yes	Yes	Yes	Yes	Yes
Fixed effect of time	Yes	Yes	Yes	Yes	Yes
R^2	0.923	0.733	0.658	0.891	0.871

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The values in parentheses are t-values.

6. Conclusions and policy implications

This paper constructs an evaluation system for the level of agricultural digitalization development and uses the entropy method to calculate the level of agricultural digitalization development in Henan Province. It also conducts a heterogeneity analysis of different regions' cities. The results show that in recent years, the overall development level of agricultural digitalization in each city of Henan Province has been continuously improving, but there are significant differences. In

DOI: 10.54254/2754-1169/2025.26568

conclusion, the Henan region has shown remarkable achievements in agricultural digitalization transformation, and it clearly points out that promoting the agricultural digitalization process has a positive effect on increasing farmers' income. In the context of the deep integration of digital technology and agriculture, accelerating the digital transformation of agricultural industries is not only a key strategy to help agriculture enter the modernization process, but also can significantly reduce production costs and improve efficiency, becoming a reliable path to steadily increase farmers' economic income.

First, in the process of promoting the coordinated development of agricultural digitalization in Henan Province, narrowing the gap in the level of agricultural digitalization development among different regions is of paramount importance. One is for the government to take the lead in strengthening regional collaboration and increasing investment in agricultural digitalization in the central and eastern regions of Henan Province, promoting agricultural digitalization cooperation among different regions. The second is to establish digital economic development funds and implement digital population development strategies in the central and eastern regions of Henan Province, set up special funds to support agricultural digitalization demonstration projects and network cooperation platforms in the central and eastern regions of Henan Province, and alleviate the imbalance in agricultural digitalization development in Henan Province.

Second, enhancing the professional quality of farmers themselves, to lay a solid talent support foundation for the development of agricultural digitalization in different regions of Henan Province. Stimulate current agricultural operators to join the agricultural digitalization transformation, and through the cultivation of digital technology, become the cornerstone of agricultural digitalization progress. Introduce high-quality talents, improve their literacy and skills in digital technology application, enabling them to calmly cope with agricultural digitalization transformation. Attracting more outstanding talents to gather, effectively stimulate their enthusiasm for participating in agricultural digitalization construction, and fully mobilize their inherent potential. Build an agricultural talent cultivation framework with deep integration of industry, academia, and research.

Third, formulate a strategic development plan for agricultural information infrastructure construction. Information infrastructure is the cornerstone of agricultural digitalization development, and its importance is self-evident. Improve network coverage conditions, enhance the intelligent level of agricultural production labor, expand the employment absorption effect of agricultural digitalization in the field of agriculture, thereby creating broader career development space and more job opportunities. Build an agricultural digital information service platform. Promote cross-industry innovation cooperation and information sharing and resource integration, promote the diversified development of agricultural digitalization, and fully release greater "digital dividends".

Fourth, improve the agricultural land transfer system. The government should formulate land transfer policies suitable for each region, encourage farmers in different regions to combine their own needs, and actively explore suitable agricultural scale development models for their regions. Actively promote rural land transfer, improve the level of agricultural scale planting. To further promote agricultural digitalization transformation, promote agricultural mechanization production, promote the application of agricultural digital technologies, enhance the scale effect of agricultural digitalization, expand the influence of agricultural digitalization on scale planting, and make significant contributions to creating a larger space for agricultural economic development. Promote the deep integration of agricultural digitalization and traditional agriculture, achieve sustainable development of agriculture, and promote farmers' income increase.

DOI: 10.54254/2754-1169/2025.26568

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