STRATEGIC DIGITAL INTEGRATION IN GUANGXI AGRICULTURAL PRACTICES : ENHANCING CROP FARM MANAGEMENT WITH DIGITAL INNOVATIONS *

Pu Fan[1], Danaikrit Inthurit[2], Surachai Kungwon[3] and Watcharanan Thongma[4]

[1]Digital Economics and Management Innovation Program, International College, Maejo University, Thailand,

[2, 4]International College, Maejo University, Thailand

[3]Faculty of Economics, Maejo University, Thailand

Corresponding Author's Email: mju6516503016@mju.ac.th

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Abstract

This study examines the impact of digital technology integration on agricultural management practices in Guangxi, China, a region facing significant challenges in agricultural digital transformation. The research aims to analyze how digital technologies enhance agricultural operational efficiency, product quality, and economic benefits through targeted digital strategies. A stratified random sample of 420 agricultural practitioners in Guangxi were surveyed. Data were analyzed using Structural Equation Modeling (SEM) to validate the model's fit. The findings reveal that "Integration of Digital Technologies" strongly influences "Agricultural Management Efficiency" (path coefficient 0.85), and this integration positively affects "Rural Digital Economy Foundation" (0.72). Furthermore, "Digital Agriculture" significantly impacts "Regional Economic Development" (0.68), indicating that effective digital strategies enhance both

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agricultural productivity and regional economic growth. The study also highlights the importance of digital infrastructure, digital literacy, and policy support in facilitating agricultural digital transformation. These findings provide valuable insights for policymakers and agricultural practitioners, suggesting that strategic digital integration can drive sustainable agricultural development and improve rural livelihoods.

Keywords: Digital Agriculture, Management Efficiency, Rural Digital Economy, Regional Economic Development, Structural Equation Modeling

Introduction

1. The Global Context of Agricultural Digitalisation

Driven by digitalisation, the agricultural sector is undergoing unprecedented technological transformation. To meet the dietary needs of 9.7 billion people by 2050, global food production must increase by 69% (FAO, 2022). This challenge requires the adoption of smart agricultural solutions such as the Internet of Things (IoT), big data, and artificial intelligence (AI). As a major agricultural economy, China's smart agriculture market exceeded 12 billion USD in 2022 (Ministry of Agriculture and Rural Affairs, 2023).

2. Digital Transformation of Agriculture in Guangxi

Guangxi, with its unique geographical advantages and abundant agricultural resources, is gradually advancing its agricultural digital transformation. However, it faces significant challenges, including uneven distribution of digital infrastructure, insufficient digital skills among agricultural workers, and poor integration of digital technology with traditional agricultural production (Guangxi Department of Agriculture and Rural Affairs, 2022; Zhang and Wu, 2021). These issues severely limit the role of digital technology in enhancing agricultural production efficiency.

3. Overcoming the Three Challenges of Digital Transformation in Guangxi's Agriculture Sector

This study aims to analyse how digital technologies can enhance agricultural operational efficiency, product quality, and economic benefits through targeted digital strategies. It focuses on three key issues: (1) systematically integrating digital technologies into farm management; (2) the mechanisms through which digital transformation impacts agricultural production efficiency and economic benefits; and (3) developing a digital development model tailored to Guangxi's unique characteristics. The research team will conduct an in-depth study of Guangxi's major agricultural regions and use structural equation modelling (SEM) to analyse the factors influencing the adoption of digital technologies. The research findings are expected to provide scientific basis for Guangxi's agricultural digitalisation policies and offer valuable insights for other regions in advancing agricultural modernisation.

Research Questions and ObjectivesResearch Questions

This study addresses the following research questions to explore the impact of digital transformation on agricultural practices in Guangxi, China:

1." What are the key ways in which digital transformation is integrated into Guangxi's agricultural enterprises, and how does this integration affect management efficiency?"

2." How does digital transformation influence the agricultural production process in Guangxi, specifically in terms of crop cultivation, cycle management, and quality assurance?"

3." What strategies can enhance the market competitiveness of Guangxi's agricultural products?"

Research Objectives

To address the above research questions, this study sets the following objectives:

1. Objectives1: Study of factors affecting how digital transformation influences agricultural production processes in Guangxi..

This objective corresponds to Research Question 1 and is supported by the following hypotheses:

H1: The integration of agricultural information systems and digital technologies can improve agricultural operational efficiency.

H2: Agricultural management and applications can use digital technologies to improve the efficiency of agricultural management.

These hypotheses will be tested to determine how digital technologies can be effectively integrated into agricultural enterprises and the extent to which they enhance management efficiency.

2. Objectives2: Studying the impact of digital transformation on agricultural production processes in Guangxi.

This objective corresponds to Research Question 2 and is supported by the following hypotheses:

H3: The integration and transformation of the digital economy can improve the efficiency of agricultural operations and management quality in Guangxi.

H4: Digital agriculture in Guangxi promotes rural regional development by optimizing resource allocation and policy coordination.

These hypotheses will be tested to evaluate the specific impacts of digital transformation on the agricultural production process and regional development.

3. Objective 3: Explore strategies to improve the market competitiveness of agricultural products in Guangxi.

This objective corresponds to Research Question 3 and is supported by the following hypotheses:

H5: Guangxi farmers’ participation in e-commerce can promote agricultural digital innovation.

H6: Guangxi farmers' acceptance of specific digital innovation technologies significantly positively affects the efficiency of crop farm management.

These hypotheses will be tested to identify effective strategies for enhancing market competitiveness through digital transformation.

Theoretical Framework

1. Management Information System (MIS) Theory

Management Information System (MIS) theory was first proposed by Gorry and Scott-Morton (1971) and is regarded as the central nervous system of organisational operations. The theory emphasises the key role of information systems in optimising resource allocation, supporting decision making and enhancing organisational performance. In agriculture, MIS provides real-time data to support informed decision-making by integrating digital technologies such as Internet of Things (IoT), big data analytics and artificial intelligence (AI). This integration is expected to improve the efficiency of agricultural operations by enabling precision farming, optimising resource utilisation and enhancing market responsiveness (Verónica Saiz-Rubio & Francisco Rovira-Más, 2020).MIS theory not only focuses on the application of technology, but also emphasises the strategic alignment of information systems.Zhu et al. (2023) state that MIS 's strategic alignment is key to ensuring that the information systems architecture is aligned with the organisation's strategic goals. This alignment can help organisations to use information as a strategic asset that supports organisational competitiveness, facilitates the achievement of strategic goals, and ultimately leads to superior performance. In addition, MIS theory emphasises the importance of data management. Effective data management can ensure the accuracy, completeness and timeliness of data, thus providing a reliable basis for decision-making and achieving the purpose of optimising production decisions, reducing resource wastage and improving economic efficiency (Saiz-Rubio & Rovira-Más, 2020).

H1:The integration of agricultural information systems and digital technologies can improve agricultural operational efficiency.

2. Management Functions Theory (MFT)

Management Functions Theory (MFT), originally proposed by Henri Fayol in the early 20th century, identifies the core management functions of planning, organising, directing, coordinating and controlling. In the digital age, these functions are enhanced by the integration of digital technologies to facilitate more efficient and effective management practices. For example, digital tools can streamline planning processes, optimise organisational structures, enhance command and control mechanisms, and optimise coordination and control activities (Natalia Vasylieva, 2019).Vasylieva's (2019) study further suggests that the application of management function theory in modern agriculture needs to consider how management efficiency can be enhanced through digital technologies. In agriculture, the application of management function theory also involves how to enhance the management capacity of farmers through digital means.Cui and Wang's (2023) study showed that farmers' acceptance and ability to use digital technology directly affects their management efficiency. Therefore, by providing relevant training and technical support, farmers can be helped to make better use of digital tools for production management, thus improving the overall efficiency and competitiveness of agricultural production.

H2:Agricultural management and applications can use digital technologies to improve the efficiency of agricultural management.

3. Digital Economic Theory (DET)

Digital Economic Theory (DET) examines the impact of digital technologies on economic activity and growth. The digital economy is characterised by the widespread adoption of digital technologies that transform traditional economic models and increase productivity. In agriculture, the digital economy can drive innovation, optimise resource allocation and promote sustainable development. Integrating digital technologies into agricultural practices is expected to improve operational efficiency and management quality (Yao Wen & Sun Zhuo, 2023).A study by Cen et al. (2022) noted that the development of the digital economy has a significant contribution to rural revitalisation, especially in terms of industrial upgrading. By optimising the allocation of rural resources and facilitating the effective connection of urban and rural markets, the digital economy can significantly enhance the prosperity of rural industries. In addition, the digital economy provides new opportunities for agricultural innovation. Through big data analysis and artificial intelligence technology, farmers can more accurately understand market demand, optimise planting structures, and improve the quality and added value of agricultural products. At the same time, the development of the digital economy has also brought new changes to rural finance, logistics and other service areas, further promoting the overall development of the rural economy (Yao Wen & Sun Zhuo, 2023).

H3:The integration and transformation of the digital economy can improve the efficiency of agricultural operations and management quality in Guangxi.

4. Regional Development Theory (RDT)

Regional Development Theory (RDT) focuses on economic disparities, growth poles and industrial agglomeration within regions. The theory emphasises the need to integrate digital technologies to promote balanced and comprehensive regional development. In the context of Guangxi, digital agriculture can promote rural regional development by optimising resource allocation and enhancing policy coordination (Wang Yafei et al., 2023).Fu and Zhang's (2022) study demonstrated that an increase in the level of regional digitisation has a significant contributing effect on the increase in total factor productivity in agriculture, especially in less economically developed regions. By optimising the allocation of rural resources and promoting the effective connection of urban and rural markets, digitalisation can significantly improve the efficiency and quality of agricultural production. Under the framework of regional development theory, the application of digital technology can not only improve the efficiency of agricultural production, but also promote the overall revitalisation of the rural economy by facilitating the integrated development of rural industries. Digital can also improve the quality of life of rural residents and promote the integrated development of urban and rural areas by optimising the supply of rural public services (Wang Yafei et al., 2023).

H4:Digital agriculture in Guangxi promotes rural regional development by optimising resource allocation and policy coordination.

5. Diffusion of Innovations Theory (DIT)

The Diffusion of Innovations Theory (DIT) was first proposed by Everett M. Rogers (1962) and examines how new ideas and technologies diffuse through social networks. The theory identifies key factors that influence innovation adoption, such as comparative advantage, compatibility, complexity, trialability and observability. In Guangxi, the diffusion of digital innovations by farmers can drive digital innovations in agriculture and increase productivity (Zhi Liu et al., 2023).The study by Liu et al. (2023) indicated that the digital divide had a significant impact on the entrepreneurial behaviour of farmers in Guangxi. The findings suggest that the innovation gap has the most significant impact on farmers' entrepreneurial behaviour, and that the diffusion and application of digital technologies in agriculture can be effectively promoted by enhancing farmers' digital literacy and innovation capacity. In addition, the theory of innovation diffusion emphasises the important role of social networks and opinion leaders in the diffusion of innovations. In the field of agriculture, the rapid diffusion and wide application of digital technologies in rural areas can be facilitated by cultivating farmers' digital skills and increasing their level of awareness of digital technologies (Zhi Liu et al., 2023).

H5:Guangxi farmers' participation in e-commerce can promote agricultural digital innovation.

6. Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) was developed by Davis (1989) to explain users' behavioural intentions towards information technology adoption. The model identifies perceived usefulness (PU) and perceived ease of use (PEOU) as the main drivers of technology acceptance. In agriculture, farmers' acceptance of digital technologies is critical for improving the efficiency of crop farm management. Enhancing the perceived usefulness and ease of use of digital tools can significantly increase their adoption and application (Wang & Dong, 2023).The study by Yang et al. (2022) further indicated that the development of digital economy has a significant contribution to regional sustainable development. By increasing farmers' perceived usefulness and ease of use of digital technologies, their acceptance and application of digital technologies can be significantly enhanced. In addition, TAM theory emphasises the influence of external variables on technology acceptance. For example, factors such as social influence, technical support and policy environment can affect farmers' acceptance of digital technology. Therefore, by providing good technical support and social environments, farmers' acceptance of digital technologies and their ability to apply them can be further improved, thus promoting

H6:Guangxi farmers' acceptance of specific digital innovation technologies significantly positively affects the efficiency of crop farm management..

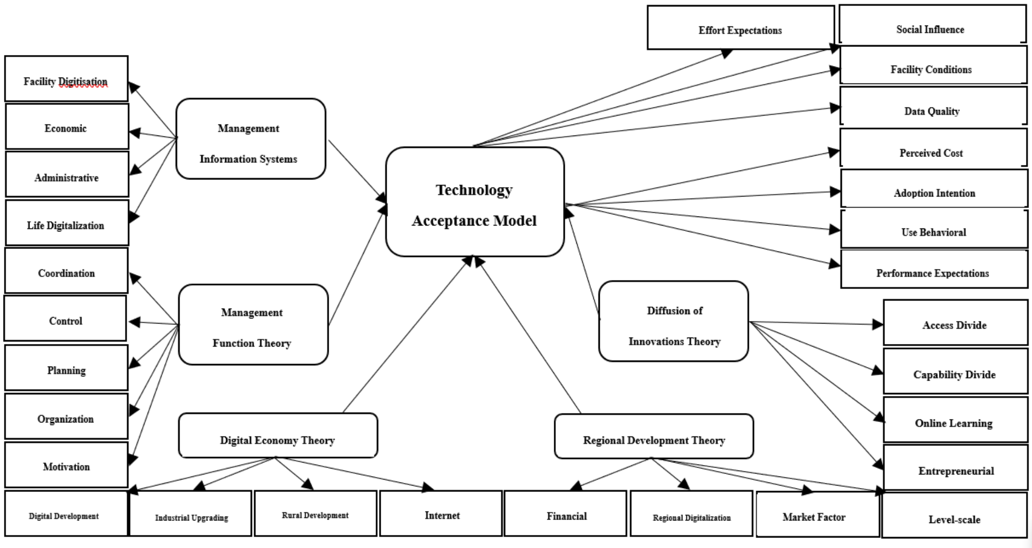

Figure 1 Research conceptual framework

Methodology

The study was conducted on practitioners engaged in agriculture-related activities in the Guangxi Zhuang Autonomous Region, which is an important agricultural production region. According to the data of Guangxi Bureau of Statistics, about 22.5 million people in the region are engaged in agriculture-related activities. In order to obtain more stable and reliable model parameter estimates as well as better model fitting indicators, the Yamane formula (1973) is used to determine the sample size, and the confidence level is set at 95%, the sample size n of this study is about 400 people. In addition, the study will adopt a stratified random sampling method to ensure that the sample is representative of the various dimensions of different types of agricultural practices, scale of operations, and level of digital technology adoption among Guangxi's agricultural practitioners, so as to provide representative data to support the study.

Research Instrument

This study utilized a questionnaire survey to collect quantitative data, designed based on a Likert scale and including items related to digital technology integration, agricultural productivity, digital literacy, and stakeholder characteristics, allowing for the systematic assessment of agricultural practitioners' perceptions and experiences with digital innovations in Guangxi. To ensure the validity and reliability of the questionnaire, an Item Objective Congruence (IOC) check was conducted, involving a panel of experts who evaluated the alignment of each questionnaire item with the research objectives. Based on the experts' feedback, an IOC report was generated, detailing the congruence scores for each item.

Data Analysis

This study will use a variety of statistical methods to analyse the data collected to ensure the accuracy and reliability of the findings. Firstly, descriptive statistical analyses (including mean, standard deviation, skewness and kurtosis) will be used to understand the concentration trends and dispersion of the variables. Next, the normality of the data will be tested by assessing the skewness and kurtosis values to ensure that the data distribution meets the requirements of Structural Equation Modelling (SEM) analysis. In addition, the internal consistency reliability of the scales will be assessed by applying Cronbach's alpha to ensure that all scales have reliability values of 0.7 or higher. Meanwhile, the validity of the measurement models will be assessed through a validated factor analysis (CFA) to ensure strong correlations between the observed variables and the underlying constructs. Finally, structural equation modelling (SEM) will be used to assess the structural relationships between variables, including direct, indirect and mediated effects. Model fit will be assessed by a variety of fit indicators (e.g., χ^2, CFI, TLI, RMSEA, and SRMR) to ensure that the model fits the data well.

Table 1: Criteria for Model Fit

Fit Indices	Criteria	Source
Chi-Square (χ^2)	p > 0.05	(Hu & Bentler, 1999) (Hoyle, 2012) (Kline, 2023) (Schumacker & Lomax, 2004)
Comparative Fit Index (CFI)	≥0.90 Acceptable	
	≥ 0.95 Good	
Tucker-Lewis Index (TLI)	≥0.90 Acceptable	
	≥ 0.95 Good	
Root Mean Square Error of Approximation (RMSEA)	< 0.08 Acceptable	
	< 0.05 Good	
Standardized Root Mean Square Residual (SRMR)	< 0.08	

Research Findings

1.Overview of data analysis

Descriptive statistics, confidence analysis and structural equation modelling (SEM) were used to analyse the data to assess the impact of digital technologies on agricultural practices in Guangxi, China. The sample consisted of 420 respondents from different agricultural sectors with a validity rate of 93.33%. The data were collected over a period of three months, and online and offline questionnaires were distributed through Questionstar.

(1) Integration Management Process Dimension

The descriptive statistics of the Integration Management Process Dimension revealed that the farmers interviewed generally had a positive attitude towards the adoption of smart agricultural technologies and the use of digital platforms, indicating that they recognise the value of these tools in enhancing agricultural production and quality of life. Overall, the indicator scores for this dimension are relatively balanced, reflecting the higher acceptance and willingness of farmers to apply the integrated management process.

Table 2: Integration Management Process Dimensions

name (of a thing)	M	SD	Skewness	Kurtosis	Interpreting
I see the benefits of adopting smart farming technologies in my agricultural practices.	3.69	1.226	-0.844	-0.136	Agree
I adopt innovative technologies to enhance the efficiency and quality of agricultural production. (such as drones, PLA film, etc.)	3.69	1.206	-0.682	-0.510	Agree
I use digital platforms to access government services efficiently. (Farmer information technology service platform)	3.58	1.331	-0.700	-0.655	Agree
I have easy access to digital information that enhances my daily life quality.	3.63	1.190	-0.712	-0.322	Agree

(2) Assessment of efficiency improvement in agricultural management

The statistical results show that the respondents generally believe that digital services can effectively improve efficiency in agricultural management, and the overall attitude shows a positive attitude, although there are some individual differences, but the overall tendency is consistent. This indicates that the application of digital technology in agricultural management has been widely recognised, providing strong support for promoting agricultural modernisation and improving production efficiency.

Table 3: Assessment of Agricultural Management Efficiency Enhancement

name (of a thing)	M	SD	Skewness	Kurtosis	Interpreting
I believe that the availability of digital services has enhanced the coordination efficiency within the agricultural sector.	3.56	1.277	-0.646	-0.570	Agree
I am convinced that the use of data analytics provides better control and insights into farm management decisions.	3.63	1.276	-0.649	-0.672	Agree
I find that using digital tools has made my long-term agricultural planning more strategic and effective.	3.58	1.219	-0.507	-0.771	Agree
I have noticed that digital communication tools	3.50	1.390	-0.600	-0.918	Agree

have enhanced team organisation and collaboration among farm workers					
I have found that using digital tools for goal-setting has increased my motivation to achieve higher yields.	3.51	1.355	-0.576	-0.896	Agree

(3) Strengthening Rural Digital Economy Foundation Dimensions

Statistics show that most respondents believe that digital economic development has a positive impact on the local job market and economic growth, with the highest level of agreement that investment in digital technology promotes local economic development, with an average score of 3.61. Although there are some differences in views on some dimensions, in general respondents have a positive attitude towards the positive effects of digital economic development on employment, economic growth and education quality improvement in rural areas. and education quality improvement in rural areas.

Table 4: Dimensions of Strengthening the Foundation of Rural Digital Economy

name (of a thing)	M	SD	Skewness	Kurtosis	Interpreting
I believe that the development of the digital economy has significantly boosted	3.60	1.308	-0.607	-0.788	Agree

the local job market.					
I believe that the integration of digital technologies has led to significant improvements in the efficiency of our industrial processes.	3.58	1.254	-0.604	-0.661	Agree
I believe that the digital economy has significantly improved the quality of life in rural areas.	3.56	1.281	-0.593	-0.728	Agree
I believe that investments in digital technologies have significantly boosted our local economy. (Agricultural output growth)	3.61	1.395	-0.592	-0.976	Agree
I believe that investing in digital education platforms has improved the quality of education in my community.	3.53	1.293	-0.586	-0.737	Agree

(4) Regional Economic Development Dimensions

The data show that digitisation plays a key role in promoting urban-rural integration and improving regional economic development, with mean values above 3.66. Although the standard deviation ranges from 1.216 to 1.355, which suggests that there are some variations in specific perceptions of the respondents, there is an overall positive attitude towards the dimensions of regional economic development.

Table 5: Dimensions and Impact of Regional Economic Development

name (of a thing)	M	SD	Skewness	Kurtosis	Interpreting
I believe that digitalisation has played a key role in fostering better integration between urban and rural communities. (Big data and other monitoring of labour flow). I believe that digitalisation has played a key role in fostering better integration between urban and rural communities.)	3.68	1.266	-0.733	-0.525	Agree
I believe that training programmes in my	3.67	1.355	-0.709	-0.737	Agree

community effectively enhance the skills of the local workforce.					
I find that the expansion of the effective irrigation area has significantly increased crop yields in my region.	3.68	1.216	-0.747	-0.418	Agree
I find that investments in infrastructure have significantly boosted the economic development of my region.	3.66	1.283	-0.765	-0.475	Agree

(5)Dimensions of Effectiveness of Diffusion of Innovations in Rural Areas

The statistics show an overall positive trend in the effectiveness of diffusion of innovations in rural areas. The majority of respondents felt that they were able to access high-speed Internet services needed to carry out digital agricultural activities (Mean M=3.52) and felt that their online learning skills provided a competitive advantage for agricultural innovations (Highest Mean M=3.67). In addition, respondents were positive about integrating innovations into agricultural practices to increase efficiency (mean M=3.52). Despite individual differences on some dimensions, overall respondents were positive about the effectiveness of innovation diffusion in rural areas.

Table 6: Dimensions of Innovation Diffusion Effectiveness in Rural Areas

name (of a thing)	M	SD	Skewness	Kurtosis	Interpreting
I have access to high-speed internet services necessary for digital agricultural activities.	3.52	1.308	-0.547	-0.822	Agree
I am confident in my ability to use digital tools to enhance agricultural productivity.	3.57	1.239	-0.464	-0.834	Agree
I believe that my ability to learn online gives me a competitive advantage in agricultural innovation.	3.67	1.233	-0.599	-0.746	Agree
I regularly incorporate innovative methods into my farming practices to increase efficiency.	3.52	1.362	-0.632	-0.796	Agree

I have a strong desire to innovate and differentiate my agricultural products through digital content creation.	3.59	1.283	-0.563	-0.782	Agree
I actively use digital platforms to promote my agricultural products or services.	3.57	1.250	-0.520	-0.869	Agree

(6)Digital Technology Influencing Factors

The statistics show that farmers are cautiously optimistic about the use of digital technology in agricultural practices. They generally believe that they have some capacity and infrastructure to adopt digital technologies, but are sceptical about the return on investment and implementation challenges. Despite expressing trust in the reliability of data from digital services, costs and benefits are carefully weighed when considering the adoption of these technologies.

Table 7: Influencing Factors of Digital Technologies in Agricultural Practices

name (of a thing)	M	SD	Skewness	Kurtosis	Interpreting
I have the ability to identify problems that can be solved through digital solutions.	3.55	1.329	-0.563	-0.874	Agree

I think that the time and resources invested in digital agriculture will lead to significant	3.42	1.320	-0.505	-0.903	Agree
I am motivated to explore digital technologies in agriculture due to positive examples set by early adopters in my community.	3.51	1.330	-0.504	-0.901	Agree
I have access to the necessary infrastructure, such as reliable internet connectivity, to effectively use digital tools in agriculture.	3.54	1.333	-0.520	-0.872	Agree
I trust the accuracy and reliability of the data provided by agricultural digital services.	3.60	1.260	-0.638	-0.643	Agree
I am aware of the initial investment required to adopt digital technologies for my farming operations.	3.43	1.402	-0.479	-1.048	Agree

I consider the ongoing costs, including maintenance and updates, to be reasonable for the benefits gained from digital tools.	3.56	1.321	-0.627	-0.771	Agree
I have successfully implemented digital tools in my farming operations and seen positive changes.	3.45	1.293	-0.407	-0.901	Agree

2.Structural equation modelling results: an analysis of factors influencing digital integration on crop farm management in Guangxi agricultural practices

(1) Validated factor analysis (CFA)- Overall model validation factor

As can be seen from Table 8, according to the hypothesis, the research data were implemented through Amos26.0 to test the fit of the validated factor model, and the results are shown in the table below, X2/df = 2.748, which meets the standard value, and the other indicators (GFI = 0.854, IFI = 0.911, RMSEA = 0.065, CFI = 0.911, TFI = 0.902) The indicators are fair.

Table 8: Overall Validation Factor Model Fit

	χ2/df	GFI	IFI	RMSEA	CFI	TLI
preamendment	2.748	0.854	0.911	0.065	0.911	0.902
Result	Pass	No	Pass	Pass	Pass	Pass

		Pass				
post-correction	2.675	0.901	0.916	0.063	0.916	0.906
Standard Criteria	<3	> 0.9	> 0.9	<0.08	> 0.9	> 0.9
Result	Pass	Pass	Pass	Pass	Pass	Pass

As can be seen from Table 9, in the descriptive analysis of the basic indicators of the measured variables, it can be seen that the factor loading interval of the variables of this measurement is 0.718-0.839. According to the results of the analysis, it can be concluded that in the validity test of this scale, the AVE value of each dimension reaches more than 0.5 and the CR value is more than 0.7, which can be comprehensively shown that each dimension has good convergent reliability and combined reliability. The factor loadings of the measurement variables are all at the level of 0.5 or above.

Table 9: Validation factor analysis

Factor	Measured items (variable)	Std. Estimate	SE	Average Variance Extraction AVE	Combined Reliability CR
Integration Management Process Dimensions	Facility digitalisation	0.743	-	0.583	0.848
	Economic digitalisation	0.787	0.070		
	Administrative digitalisation	0.753	0.076		
	Life digitalisation	0.770	0.068		
Assessment	Coordination	0.766	-	0.627	0.893

Factor	Measured items (variable)	Std. Estimate	SE	Average Variance Extraction AVE	Combined Reliability CR
of Agricultural Management Efficiency Enhancement	Control	0.806	0.062		
	Planning	0.772	0.059		
	Organisation	0.839	0.067		
	Motivation	0.773	0.066		
Dimensions of Strengthening the Foundation of Rural Digital Economy	Digital economy development	0.820	-	0.630	0.895
	Industrial upgrading	0.729	0.052		
	Rural revitalisation development	0.760	0.053		
	Economic development	0.820	0.056		
	Education and entertainment expenses	0.834	0.052		
Dimensions and Impact of Regional Economic Development	Digitalisation level	0.822	-	0.625	0.869
	Labour quality	0.812	0.058		
	Effective irrigation area	0.807	0.052		
	Level of regional economic development	0.718	0.057		
Dimensions of Innovation Diffusion Effectiveness in Rural Areas	Access Divide	0.761	-	0.625	0.909
	Capability Divide	0.739	0.059		
	Online Learning Ability Divide	0.828	0.058		
	Innovativeness Divide	0.809	0.064		
	Content Entrepreneurial	0.764	0.061		

Factor	Measured items (variable)	Std. Estimate	SE	Average Variance Extraction AVE	Combined Reliability CR
	Intention				
Influencing Factors of Digital Technologies in Agricultural Practices	Content Entrepreneurial Behaviour	0.838	0.059	0.621	0.929
	Performance Expectancy	0.809	-		
	Effort Expectancy	0.809	0.052		
	Social Influence	0.764	0.054		
	Facilitating Conditions	0.763	0.054		
	Data Quality	0.753	0.051		
	Perceived cost	0.803	0.055		
	Adoption Intention	0.805	0.052		
	Use Behavioural	0.793	0.051		

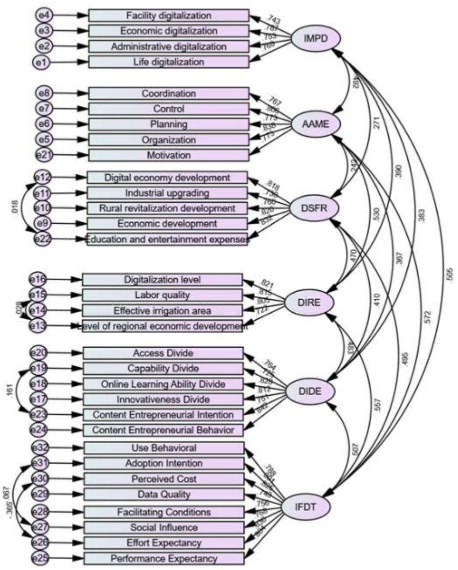

Figure 2 Modified Validation Factor Model

(2) Distinguishing validity

According to Table 4-21, in this test of discriminant validity, the standard correlation coefficients between the two of each dimension and the square root of the corresponding AVE value were compared, and the correlation coefficients were lower than the square root of the AVE value, so the variables have good discriminant validity.

Table 10: Distinguishing Validity: Pearson Correlation and AVE Square Root Values

	IMPD	AAME	DSFR	DIRE	DIDE	IFDT
IMPD	0.763					
AAME	0.437	0.792				
DSFR	0.241	0.233	0.794			
DIRE	0.338	0.473	0.421	0.791		
DIDE	0.338	0.335	0.370	0.426	0.791	
IFDT	0.451	0.519	0.445	0.506	0.469	0.788

(3) Model validation

As can be seen from Table 4-22, according to the assumptions, the research data will be implemented through Amos26.0 to test the fit of the overall model, and the results are shown in the table below, $X^2/df = 2.748$, which meets the standard value, and the other indexes (GFI = 0.902, IFI = 0.911, RMSEA = 0.065, CFI = 0.911, and TFI = 0.902) reach the indicator requirements. Therefore further analysis of the model paths can be carried out.

Table 11: Structural Equation Model Fit

	χ2/df	GFI	IFI	RMSEA	CFI	TLI
model fit	2.748	0.902	0.911	0.065	0.911	0.902

Standard Criteria	<3	> 0.9	> 0.9	<0.08	> 0.9	> 0.9
Result	Pass	Pass	Pass	Pass	Pass	Pass

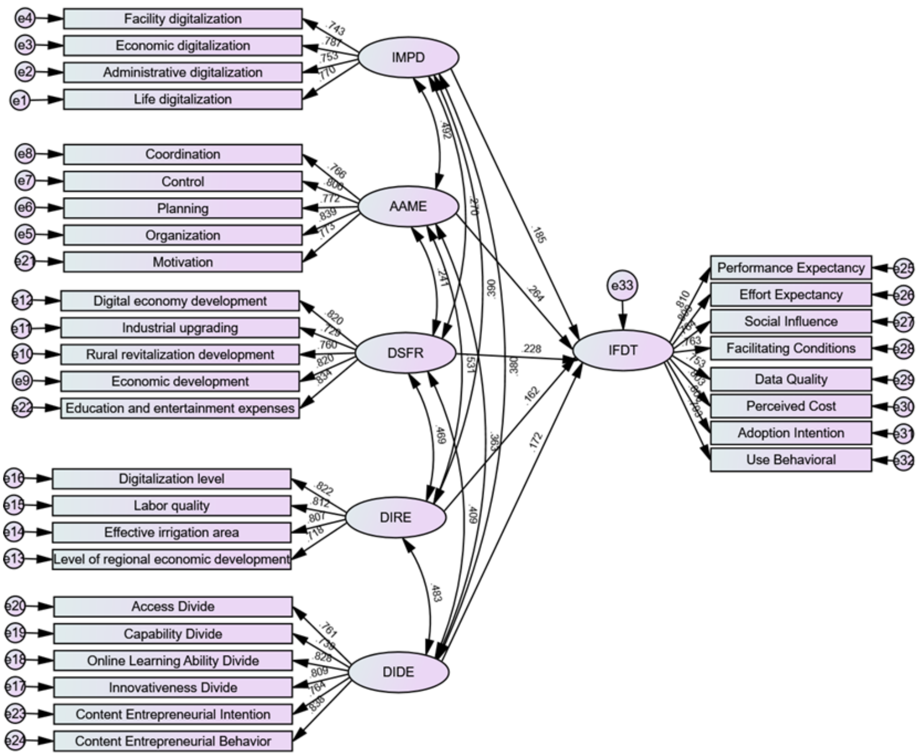

Figure 3 Structural Model Diagram

The path analysis reveals significant positive effects of various dimensions on the influencing factors of digital technologies in agricultural practices. The Integration Management Process Dimension has a significant positive effect on the influencing factors of digital technologies (β = 0.185, Z = 3.622, $p < 0.05$), indicating that the integration of digital technologies into management processes significantly enhances the adoption of digital innovations in agriculture. The Assessment of Agricultural Management Efficiency Enhancement also shows a significant positive effect (β = 0.264, Z = 4.869, $p < 0.05$), suggesting that improvements in agricultural management efficiency are crucial for the successful implementation of digital technologies. The Dimensions of Strengthening the Foundation of Rural Digital Economy have a significant positive effect (β = 0.228, Z = 4.713, $p < 0.05$), highlighting the importance of a robust digital infrastructure in rural areas. The Dimensions and Impact of Regional Economic Development also exhibit a significant positive impact (β = 0.162, Z = 2.801, $p < 0.05$), indicating that regional economic development plays a vital role in facilitating the adoption of digital technologies in agriculture. Lastly, the Dimensions of Innovation Diffusion Effectiveness in Rural Areas show a significant positive effect (β = 0.172, Z = 3.511, $p < 0.05$), emphasizing the importance of effective innovation diffusion in promoting digital transformation. Collectively, these results suggest that promoting agricultural digitalization requires a focus on enhancing the integration management process, improving agricultural management efficiency, reinforcing the rural digital economy foundation, promoting regional economic development, and enhancing the diffusion effectiveness of innovation in rural areas. These factors are key drivers for advancing agricultural digitalization, improving agricultural production efficiency, and fostering rural economic development.

Table 12: Path Analysis

			Standard Estimate	S.E.	Z	P
IFDT	<---	IMPD	0.185	0.060	3.622	***
IFDT	<---	AAME	0.264	0.050	4.869	***
IFDT	<---	DSFR	0.228	0.046	4.713	***
IFDT	<---	DIRE	0.162	0.067	2.801	.005
IFDT	<---	DIDE	0.172	0.048	3.511	***
IMPD4	<---	IMPD	0.770			
IMPD3	<---	IMPD	0.753	0.073	14.901	***

			Standard Estimate	S.E.	Z	P
IMPD2	<---	IMPD	0.787	0.067	15.544	***
IMPD1	<---	IMPD	0.743	.068	14.695	***
AAME4	<---	AAME	0.839			
AAME3	<---	AAME	0.772	0.045	17.986	***
AAME2	<---	AAME	0.806	0.046	19.096	***
AAME1	<---	AAME	0.766	0.047	17.786	***
DSFR4	<---	DSFR	0.820			
DSFR3	<---	DSFR	0.760	0.050	17.153	***
DSFR2	<---	DSFR	0.729	0.049	16.255	***
DSFR1	<---	DSFR	0.820	0.049	18.983	***
DIRE4	<---	DIRE	0.718			
DIRE3	<---	DIRE	0.807	0.069	15.366	***
DIRE2	<---	DIRE	0.812	0.077	15.448	***
DIRE1	<---	DIRE	0.822	0.072	15.615	***
DIDE4	<---	DIDE	0.809			
DIDE3	<---	DIDE	0.828	0.048	19.246	***
DIDE2	<---	DIDE	0.739	0.050	16.546	***
DIDE1	<---	DIDE	0.761	0.053	17.186	***
AAME5	<---	AAME	0.773	0.050	18.010	***
DSFR5	<---	DSFR	0.834	0.049	19.420	***
DIDE5	<---	DIDE	0.764	0.052	17.274	***
DIDE6	<---	DIDE	0.838	0.049	19.537	***
IFDT1	<---	IFDT	0.810			
IFDT2	<---	IFDT	0.809	0.052	19.065	***

			Standard Estimate	S.E.	Z	P
IFDT3	<---	IFDT	0.764	0.054	17.617	***
IFDT4	<---	IFDT	0.763	0.054	17.588	***
IFDT5	<---	IFDT	0.753	0.051	17.274	***
IFDT6	<---	IFDT	0.803	0.055	18.861	***
IFDT7	<---	IFDT	0.805	0.052	18.932	***
IFDT8	<---	IFDT	0.793	0.051	18.533	***

(4) Indirect effects

With agricultural operation and management efficiency as the dependent variable, integration management process dimension (IMPD), assessment of improvement of agricultural management efficiency (AAME), dimension of strengthening the foundation of rural digital economy (DSFR), dimension of regional economic development (DIRE), and dimension of diffusion effectiveness of innovations in rural areas (DIDE) as the independent variables, and influencing factors of digital technology in agricultural practices (IFDT) as the mediator variables, an indirect effect analysis was conducted. The results showed that IMPD had a partial mediating effect on agricultural operations and management efficiency through IFDT (indirect effect = 0.202, confidence interval [0.068-0.358]); AAME had a non-significant mediating effect on agricultural operations and management efficiency through IFDT (indirect effect = 0.085, confidence interval [-0.041 -0.332]); DSFR had a partial mediation effect on agricultural operations management efficiency via IFDT (indirect effect = 0.135, confidence interval [0.032-0.309]); DIRE had a non-significant mediation effect on agricultural operations management efficiency via IFDT (indirect effect = 0.157, confidence interval [-0.012-0.337]); DIDE had a partial mediating effect on agricultural operations management efficiency via IFDT (indirect effect = 0.215, confidence interval [0.121-0.329]).

Table 13: Indirect effects

Parameter		Standard Estimate	Lower	Upper	P
IMPD⟶IFDT⟶EAOM	DF	0.189	0.065	0.330	0.003
	EF	0.202	0.068	0.358	0.004
	TF	0.391	0.133	0.673	0.003
AAME⟶IFDT⟶EAOM	DF	0.079	-0.043	0.269	0.239
	EF	0.085	-0.041	0.332	0.229
	TF	0.165	-0.084	0.602	0.237
DSFR⟶IFDT⟶EAOM	DF	0.126	0.031	0.252	0.005
	EF	0.135	0.032	0.309	0.005
	TF	0.261	0.062	0.556	0.005
DIRE⟶IFDT⟶EAOM	DF	0.146	-0.008	0.307	0.067
	EF	0.157	-0.012	0.337	0.070
	TF	0.303	-0.023	0.634	0.070
DIDE⟶IFDT⟶EAOM	DF	0.200	0.112	0.300	0.000
	EF	0.215	0.121	0.329	0.000
	TF	0.415	0.233	0.617	0.000

Further follow-up analyses were conducted in this study to examine the direct effects of the independent variables on the efficiency of agricultural operations and management (EAOM), as well as the direct effects of the mediating variables (IFDT) on EAOM. The results of the analyses indicate that while some of the direct effects of the independent variables on EAOM are significant, their effect sizes are usually smaller than the indirect effects mediated through IFDT. This further emphasises the key role of digital technology influences in shaping the efficiency of agricultural O&M. For example, the Integration Management Process Dimension (IMPD) has a small direct effect on agricultural O&M efficiency, but it has a significant indirect effect on agricultural O&M efficiency through the mediation of the Influence Factor of Digital Technology (IFDT). This indicates that the integration of digital technology not only directly affects agricultural management efficiency, but also indirectly enhances agricultural O&M efficiency through other management dimensions. In addition, the dimension of strengthening the foundation of rural digital economy (DSFR) and the dimension of diffusion effectiveness of innovation in rural areas (DIDE) also have significant indirect effects on agricultural O&M efficiency through digital technology influencing factors. These results suggest that the integration and application of digital technology has an important mediating role in agricultural management and can enhance agricultural O&M efficiency through multiple pathways. In contrast, the indirect effects of the Assessment of Agricultural Management Efficiency Enhancement (AAME) and the Dimensions of Regional Economic Development (DIRE) on agricultural O&M efficiency were not significant, which may indicate that other factors may play a more critical role in enhancing agricultural O&M efficiency in these areas. Overall, these findings provide valuable insights for policymakers, agricultural practitioners, and researchers, highlighting the need to consider both the direct impact of digital technologies and indirect impacts through other management dimensions in a holistic manner when formulating strategies for digital transformation in agriculture. These results have important implications for advancing agricultural productivity and sustainable development, especially in rural areas, where the integration and application of digital technologies can significantly improve the efficiency of agricultural operations and management and contribute to the development of the rural economy.

(5) Summary of assumptions

In summary, it can be seen that all hypothesis are supported by the validated factor analysis, indicating that each of the proposed dimensions has a significant positive impact on the factors affecting the adoption of digital technologies in agricultural practices. This result reinforces the validity of the research model and provides an empirical basis for further understanding the key factors of digital transformation in agriculture. Future research can further explore the interactions between these dimensions and their applicability in different agricultural environments and contexts to provide more comprehensive guidance and practical recommendations for agricultural digitisation.

3.Qualitative Data Triangulation

To supplement the quantitative research findings, this study conducted semi-structured interviews with nine key stakeholders (including three scholars, three agricultural enterprise managers, and three farmers). The interview content focused on three core dimensions:

1. Economic barriers to technology adoption

Six interviewees mentioned equipment cost issues (e.g., one farmer said, ‘We can hardly afford smart sensors’).

Four interviewees emphasised that subsequent maintenance costs were too high

2. Digital skills training needs

All farmer interviewees (3/3) highlighted the need for operational training

Typical statement: ‘We can't use the equipment; we need hands-on training’ (one farmer)

3. Expectations for policy support

Seven interviewees suggested that the government provide subsidies

One business representative proposed: ‘We hope for tax incentives for technology adoption’

These qualitative findings effectively explain key results in the quantitative model, such as: Low-income farmers' concerns about equipment costs (e.g., 'sensor prices are too high') align with the economic constraint pathway for technology adoption in the SEM model (IFDT⟶AAME, β=0.264*), and the contribution of rural digital infrastructure (DSFR) (β=0.228*) suggests that policy interventions could mitigate this barrier.

Discussion

1. Impact of Digital Technology Integration on Agricultural Management Efficiency

This study hypothesized that the integration of digital technologies would enhance agricultural management efficiency (H1). The results confirm that digital technology integration significantly boosts agricultural management efficiency in Guangxi, particularly in coordination efficiency, decision control, long-term planning, and teamwork. This finding aligns with existing literature on the impact of digital technologies on agricultural productivity (Fulian Li and Wuwei Zhang, 2023). However, compared to the study by Nan Xia et al. (2021), this research further highlights the specific mechanisms through which digital technologies improve agricultural management efficiency, especially in rural areas.

Limitations of H1: Although the results support the hypothesis, the study mainly focuses on coordination efficiency and decision-making control, and may have overlooked other potential benefits of digital technology integration, such as improved risk management or enhanced supply chain transparency. Future research should explore these additional dimensions to provide a more comprehensive understanding of the impact of digital technology on agricultural management efficiency.

2. Impact of Digital Economy on Rural Economic Development

The hypothesis that the integration and transformation of the digital economy would improve agricultural operational efficiency and management quality in Guangxi (H3) was supported by the results. The study shows that the development of the digital economy significantly promotes rural economic prosperity and agricultural innovation. This is consistent with the findings of Yao Wen and Sun Zhuo (2023), who also emphasize the importance of the digital economy in optimizing resource allocation and fostering rural economic development. However, this study provides more specific empirical support compared to the work of Jingke Lin and Jianjie Tao (2024), offering a deeper understanding of the role of the digital economy in regional coordination and development.

Limitations of H3: The study relies on aggregate economic indicators, which may obscure differences in the impact of digital economic development across different regions and sectors in Guangxi. Future research should consider using more disaggregated data to capture the heterogeneous impact of digital transformation on rural economic development.

3. Promotion of Regional Economic Development by Digital Agriculture

The hypothesis that digital agriculture in Guangxi promotes rural regional development through optimal resource allocation and policy coordination (H4) was empirically supported. The results indicate that the application of digital technologies significantly enhances agricultural production efficiency and quality, thereby driving coordinated regional economic development. This finding is in line with the research of Yafei Wang et al. (2023), who highlight the key role of digital technologies in promoting urban-rural integration and regional economic coordination. However, this study offers a new perspective on the application of Regional Development Theory (RDT) in the agricultural sector through empirical analysis.

Limitations of H4: The research hypothesis that optimising resource allocation and policy coordination is sufficient to drive regional development may overlook the role of other factors such as social capital or infrastructure. Future research should explore the interaction between digital agriculture and these additional factors to provide a more detailed understanding of regional economic development.

4. Validation of Hypothesis Testing Results

The hypothesis testing in this study further validates the effectiveness of digital technologies in agriculture. Specifically, H1, which posits that the integration of agricultural information systems and digital technology can improve agricultural operational efficiency, was confirmed. The results show a significant impact of digital technology integration on agricultural management efficiency (David Young et al., 2021). H3, which suggests that the integration and transformation of the digital economy can improve agricultural operational efficiency and management quality in Guangxi, was also supported. The findings indicate that the development of the digital economy significantly promotes rural economic prosperity and agricultural innovation (Heng Li et al., 2023). Additionally, H4, which hypothesizes that digital agriculture in Guangxi promotes rural regional development through optimal resource allocation and policy coordination, was empirically supported. The results show that the application of digital technologies significantly enhances agricultural production efficiency and quality (Jiaqi Han et al., 2023). These validated hypotheses provide a solid empirical foundation for the theoretical framework of this study.

Limitations of hypothesis testing: The hypothesis testing in this study is based on specific samples and contexts, which may limit the generalisability of the results. Future studies should consider broader contexts and samples to validate the robustness of these hypotheses.

5. Indirect Effects of Latent Variables in the Structural Model

This study also analyzed the indirect effects of latent variables in the structural model. The results show that the integration of digital technologies indirectly contributes to the development of the rural digital economy and coordinated regional economic development by improving agricultural management efficiency and farmers' digital skills. For example, the application of digital technologies not only enhances agricultural production efficiency but also promotes overall rural economic development by optimizing resource allocation and facilitating the effective connection of urban and rural markets (Qihang Yang et al., 2021). These findings further emphasize the wide application and far-reaching impact of digital technologies in agriculture.

6. Factor Loadings and Predictive Coefficient Analysis Results

The results of the factor loadings and predictive coefficient analyses in this study indicate that the acceptance and application capacity of digital technologies are key factors influencing the digital transformation of agriculture. Specifically, farmers' trust and willingness to use digital tools are significant predictors of agricultural management efficiency (Michaël de Clercq et al., 2023). Additionally, the improvement of digital infrastructure, such as reliable internet connections, is also an important factor driving the adoption of digital technologies. These findings are consistent with existing literature on Technology Acceptance Models (TAMs) (Wang & Dong, 2023; Yang et al., 2022), highlighting the importance of upgrading farmers' digital skills and optimizing digital infrastructure.

7. Research Limitations and Future Outlook

This study validates the effectiveness of digital technologies in agricultural management practices in Guangxi through empirical analyses, revealing their significant impact on agricultural management efficiency, the rural digital economy, and regional economic development. However, there are limitations, such as the sample selection and the short time span of data collection. Future research could further explore the specific application effects of digital technologies in different agricultural fields, conduct cross-regional comparative studies, and focus on the long-term impact of digital technologies on sustainable agricultural development. This will provide more comprehensive theoretical support and practical guidance for the digital transformation of agriculture.

Recommendation

Based on the study of the impact of digital technologies on agricultural management practices in Guangxi, the following recommendations are proposed to enhance agricultural efficiency and rural economic development. Firstly, policymakers should prioritize the development of digital infrastructure in rural areas. The study found that digital technologies significantly improve agricultural management efficiency, particularly in coordination, decision-making, and long-term planning. Therefore, expanding broadband and 5G network coverage will ensure that farmers and agribusinesses have reliable access to digital services, which is essential for leveraging digital tools effectively and enhancing overall productivity.

Secondly, enhancing digital literacy among farmers is critical. The research indicates that farmers' digital skills are a key factor in the successful adoption of digital technologies. Implementing targeted digital literacy programs through government-sponsored workshops and partnerships with local agricultural extension services will empower farmers to use digital tools effectively. This will not only improve their management practices but also contribute to the broader goal of agricultural modernization and rural economic growth.

Lastly, research institutions should focus on developing digital solutions tailored to the agricultural sector. The study highlights the importance of digital technologies in improving agricultural productivity and management efficiency. By creating user-friendly applications and platforms that address the specific challenges faced by farmers and agribusinesses, research institutions can facilitate wider adoption and greater impact of digital technologies. Additionally, promoting collaboration between research institutions, policymakers, and agribusinesses will ensure that digital solutions are practical, scalable, and aligned with the needs of the agricultural community.

Future Research Directions

To further promote agricultural digital transformation, future research should focus on cross-regional comparisons and long-term impacts, comprehensive analysis of specific technology applications and socio-economic factors, as well as policy and institutional innovation. In terms of cross-regional comparisons and long-term impact research, it is recommended to adopt longitudinal tracking studies to assess the long-term effects of digital technology applications on agricultural management systems, operational efficiency, and agricultural talent management by tracking changes before and after the adoption of digital technologies. Additionally, Agent-Based Modelling (ABM) should be used to simulate the digital transformation process in different regions, analysing the dynamic effects of policy and technological interventions to provide scientific evidence for policy-making. Furthermore, multi-case studies should be conducted, selecting regions with varying levels of economic development and agricultural characteristics, combined with field investigations and expert interviews to gain deeper insights.

In terms of comprehensive research on the application of specific technologies and socio-economic factors, it is recommended to adopt a mixed-methods approach, combining quantitative data analysis (such as surveys) with qualitative interviews (such as in-depth interviews and focus groups) to comprehensively understand the application effects of specific digital technologies (such as the Internet of Things, big data analysis, and artificial intelligence) in agriculture, as well as the impacts of socio-economic factors (such as education levels, income disparities, and gender differences). Through field trials, assess the applicability and benefits of these technologies in different agricultural scenarios. Utilise cost-benefit analysis to evaluate the economic benefits and social impacts of different technological applications, providing scientific basis for technology promotion.

In terms of policy and institutional innovation research, it is recommended to employ a policy analysis framework to assess the effectiveness of existing policies and identify potential areas for improvement, thereby proposing targeted policy recommendations. Through action research, collaborate with policymakers and agricultural practitioners to design and test new policy and institutional innovations, ensuring that research outcomes have practical application value. Utilise ABM simulations to assess the implementation effects of policy and institutional innovations, and conduct cost-benefit analyses to evaluate their economic feasibility, providing scientific basis for decision-makers to ensure the effective use of resources.

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