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A Study on the Multidimensional Dilemmas and Collaborative Paths of Refined Management of Agricultural Production under the Background of Rural Revitalization

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Abstract: With the continuous advancement of the rural revitalization strategy, problems in the agricultural production process have increasingly emerged, and agricultural management faces a series of challenges such as coarse management, insufficient risk resistance, and low resource utilization efficiency. This paper analyzes the prominent issues in current agricultural development from three dimensions: production management, agricultural machinery and equipment, and land resources. Examples include land fragmentation limiting large-scale operations, low levels of agricultural machinery intelligence, and land quality degradation as restrictive bottlenecks. Through the analysis of these issues, this paper further explores how refined management can improve agricultural production efficiency, ensure food security, and promote high-quality agricultural development. Based on the above analysis, this paper proposes an analytical framework of "production management—technical equipment—resource base" for addressing three-dimensional dilemmas and, on this basis, constructs three types of collaborative pathways: "element integration—equipment upgrading—resource protection." It emphasizes the continuous integration of data elements (agricultural condition data, operation data, and input data) throughout the entire process, forming a closed-loop management mechanism of "monitoring—decision-making—execution—evaluation." Through measures such as land resource integration and standardized production, intelligent R&D of agricultural machinery and improvement of management systems, and cultivated land protection and sustainable use, these initiatives will effectively enhance agricultural production efficiency, ensure food security, and promote high-quality agricultural development. The paper indicates that building a refined management model with full-element collaboration is an important path for improving agricultural production efficiency and ensuring national food security.

Keywords: Rural revitalization; Agricultural production; Refined management; Agricultural machinery; Land resources

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1. Introduction

During this transition, agricultural production management faces intertwined challenges: the fragmented operations of smallholders, the atomization of service provision, and heightened exposure to risks.

Consequently, achieving "quality and efficiency enhancement" cannot rely solely on isolated technologies or individual actors; it requires holistic, fine-grained governance to coordinate land, equipment, water resources, and risk management.

Concurrently, new models such as digital agricultural machinery and smart farms have demonstrated demonstrative effects in certain regions. For instance, the use of IoT monitoring and operational data collection enables intelligent job planning and management, significantly boosting production efficiency [1]. However, shortcomings persist in network infrastructure, data standardization, and talent supply, impeding the diffusion and large-scale application of digital technologies. Moreover, the development of agricultural new quality productivity further highlights the importance of technological innovation and factor integration in promoting high-quality agricultural development [2].

2. Refined management as the inevitable path to rural revitalization

Existing literature on refined agricultural management highlights several important issues. Among them, demographic changes in rural labor forces have attracted increasing attention.

First, research addressing demographic shifts in the labor force reveals a deepening trend toward an "aging society" in rural areas, with the population aged 65 and above reaching 13.87%, and the average age of the full-time agricultural labor force rising to 51.18 years [3]. This aging workforce and the associated skill gaps further intensify the reliance of refined production on mechanization, digitalization, and socialized service systems.

3. Current status of economic-oriented management in agricultural production

Agricultural production management urgently requires refined improvements across multiple dimensions. Only through meticulous management can current bottlenecks be effectively resolved, thereby driving agriculture toward high-efficiency and sustainable development. Issues such as extensive management practices, weak risk resilience, and inefficient resource utilization have become increasingly prominent, emerging as key constraints on high-quality agricultural development.

From the perspective of operational organization, land transfer has increased the proportion of scaled entities; however, households operating more than 30 mu still account for only about 10% of the total. Agricultural production continues to exhibit a structural feature characterized by "a minority of scaled entities coexisting with a majority of smallholders." Furthermore, the integration of rural industries can effectively improve resource allocation efficiency and strengthen the linkage among production, processing, and marketing, thereby promoting agricultural modernization [4]. This leads to high organizational costs for implementing unified standards, inputs, and quality traceability [5].

From the perspective of factors and capabilities, rural aging is deepening (the population aged 65 and above accounts for about 13.87%, and the average age of full-time agricultural laborers is about 51.18 years). Coupled with a deficit in digital skills, this significantly increases the reliance of the production process on mechanization, digitalization, and socialized service systems [3].

4. Major bottlenecks confronting refined management

First, the production management dimension. Land fragmentation stands as a primary bottleneck constraining large-scale and standardized agricultural operations. It not only hinders the diffusion of agricultural technologies but also drives up labor costs. Smallholder farmers lack effective risk protection mechanisms when facing

market and natural risks, further exacerbating their vulnerability.

Second, the technological equipment dimension. The current level of intelligence in agricultural machinery remains relatively low, with significant regional disparities persisting. This renders farm machinery incapable of meeting the demands for precision and automated cultivation across diverse complex terrains and varied crops, thereby limiting the development and widespread application of advanced agricultural technologies.

Third, the resource base dimension. Arable land protection faces immense pressure. Long-term irrational fertilization and tillage practices have led to soil degradation, threatening the sustainability of agricultural production. Furthermore, trends toward "non-agriculturalization" and "non-grainification" of farmland, coupled with unreasonable land planning, exacerbate the risks of resource misallocation and ecological environmental deterioration, thereby jeopardizing national food security. In addition, inefficient land resource management and unsustainable land-use practices may further aggravate ecological pressure and constrain long-term agricultural development [6].

5. Countermeasures and suggestions: Integrated pathways for refined agricultural management

Addressing the three-dimensional dilemmas of "production management, technological equipment, and resource base," synergistic progress can be achieved through three pathways: factor integration, equipment upgrading, and resource protection. This will establish a replicable and scalable model for refined management. At the same time, improving agricultural insurance mechanisms can enhance farmers' ability to cope with production risks and contribute to agricultural modernization [7].

First, integrate production factors. Promote contiguous operations through land transfer and "merging small plots into large fields," combined with digital plot filing and grid-based operation management, facilitating the shift from "fragmented operations" to "process-controllable scaled operations."

Second, strengthen technological and equipment support. Advance machinery renewal and intelligent upgrades across the entire cycle of plowing, planting, managing, and harvesting, while refining training, maintenance, and operational standards to enhance the substitution capacity of machinery for an aging workforce.

Third, uphold resource and environmental bottom lines. Constrained by the cultivated land protection system and leveraging water-saving technologies and smart irrigation, build a refined resource management system featuring "monitoring–scheduling–evaluation" to reduce resource consumption per unit of output.

Fourth, the wider adoption of water-saving irrigation technologies should be encouraged to improve resource-use efficiency and alleviate water constraints in agricultural production [8]. Refine risk and income adjustment mechanisms. Supported by agricultural insurance, credit access, and contract farming, stabilize farmer incomes and ensure sustainable input.

Only through the coordinated advancement of these pathways can the goals of rural revitalization be achieved: ensuring food security while enhancing agricultural efficiency, rural vitality, and farmers' incomes.

6. Conclusion

In summary, against the backdrop of rural revitalization, refined management in agricultural production must center on "whole-factor synergy," employing multidimensional measures to resolve current pain points:

First, integrate production factors. Achieve scaled operations through land transfer and the consolidation of small plots into large fields. Unify the procurement of agricultural inputs and establish standardized planting

protocols to enhance product quality control and operational efficiency. Simultaneously, leverage agricultural insurance as a safety net to strengthen the risk resilience of smallholder farmers.

Second, reinforce technological support for agricultural machinery. Meanwhile, it is essential to improve agricultural machinery management systems and strengthen technical guidance for farmers to ensure the efficient use of agricultural equipment [9]. Develop multi-functional machinery tailored to China's diverse terrains and crops. Improve management systems covering usage, maintenance, and overhaul. Reduce the barriers to adoption and alleviate the financial burden for farmers through talent service networks and fiscal subsidies.

Third, utilize land sustainably. Strictly enforce cultivated land protection (demarcating permanent basic farmland red lines) and promote techniques such as soil testing-based formulated fertilization and green manure crop rotation to mitigate soil degradation. Align these efforts with county-level topographic planning to develop characteristic agricultural planting structures.

Future efforts must further integrate local practices, refining operational procedures for each link—such as land transfer negotiation mechanisms for farmers and hierarchical responsibility divisions in machinery management—to transition refined management from theoretical exploration to practical implementation. This will provide robust support and safeguards for high-quality agricultural development and food security. Regarding future research, this paper argues that focus should be placed on safeguarding farmers' rights and interests during land transfer and on incentivizing farmers to adopt smart agricultural machinery technologies, thereby further advancing the practice of refined management models. Resolving these specific issues is essential for truly realizing the modernization of agricultural production, promoting the Rural Revitalization Strategy, and providing solid support for the sustainable development of China's agriculture.

Furthermore, refined management should be regarded as a comprehensive governance framework rather than merely a technological tool but as a governance scheme oriented toward the goals of rural revitalization: using data as a nexus to integrate factors such as land, labor, capital, and technology; lowering the participation threshold for smallholders through standardized operations and socialized services; upholding resource and environmental bottom lines through water conservation, efficiency enhancement, and cultivated land protection; and bolstering farmers' risk resilience via insurance, credit, and public service systems.

In future practical implementation, a "local-context adaptation" approach must be upheld: major plain producing areas should prioritize scaled operations and digital platform construction; hilly and mountainous regions should focus on small, adaptable machinery and entrusted service models; and water-scarce regions should emphasize irrigation system reform and the diffusion of water-saving technologies. This will forge refined management pathways that are replicable, scalable, and evaluable. The analytical framework of "factor mobility–functional synergy–spatial resilience" in county-level urban-rural integration can serve as a reference point for refining institutional and service provision at the county level [10].

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