World Journal of Economics and Business Research
Print ISSN: 2960-0073
Online ISSN: 2960-0081
DOI: https://doi.org/10.61784/wjebr3075

NEW PRODUCTIVITY ENABLES HIGH QUALITY DIGITAL AGRICULTURE IN JILIN PROVINCE DEVELOPMENT LOGIC AND IMPLEMENTATION COUNTERMEASURES

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Abstract: As a pioneering model driving the transformation and upgrading of traditional agriculture, digital agriculture has long been prioritized by government authorities. The new quality productive forces, characterized by technological innovation, high efficiency, and superior quality, provide robust support for the high-quality development of digital agriculture. Under the impetus of these advanced productive forces, digital agriculture will fully embrace the development concepts of innovation, openness, coordination, green practices, and sharing, thereby comprehensively empowering the high-quality development of digital agriculture in Jilin Province. However, various challenges remain in the province that urgently require resolution. To achieve sustainable development in the new era, Jilin must focus on cultivating and advancing high-quality digital agriculture as its core objective, establishing distinctive local strategies for digital agricultural advancement.
Keywords: New quality productivity; Digital agriculture; High-quality development; Jilin province

1 INTRODUCTION

During the 2024 National Two Sessions, the leaders emphasized the imperative to prioritize high-quality development and cultivate new productive forces through localized approaches. This innovative concept, first proposed during his inspection tour in Heilongjiang Province, focuses on nurturing emerging and future industries as the cornerstone of new growth drivers. By prioritizing innovation-driven development, it breaks away from traditional economic growth models characterized by high-tech, efficient, and high-quality advanced productive forces that align with modern development philosophies. Currently, these new productive forces are reshaping industrial and service sectors while extending to agriculture and rural areas, injecting strong momentum into high-quality agricultural development. As an advanced form of agricultural development, digital agriculture serves as a crucial pathway for China's transition from a major agricultural country to a global leader in farming. Against the backdrop of Northeast China's comprehensive revitalization, exploring how new productive forces can empower digital agriculture has become particularly urgent, positioning it as both a new engine and enduring driving force for high-quality development. Therefore, thoroughly analyzing the essence and requirements of new productive forces, while examining Jilin Province's development logic and implementation strategies for high-quality digital agriculture, carries significant practical implications.

2 AN OVERVIEW OF NEW QUALITY PRODUCTIVITY AND HIGH-QUALITY DEVELOPMENT OF DIGITAL AGRICULTURE

2.1 Regarding New Quality Productivity

Regarding new-quality productive forces, internationally, Barro analyzed economic growth disparities across nations through cross-country data analysis[1], examining how government policies, market conditions, and initial economic states influence productivity and economic growth. Bloom explored the paradox of declining output per unit of input despite increased inputs[2], highlighting the urgent need to address traditional productive forces 'constraints on economic development. Domestically, scholars have approached this topic from multiple dimensions since its inception. On one hand, foundational discussions include Zhou Wen' s perspective that new-quality productive forces represent an organic integration of technological breakthroughs[3], economic advancement, and industrial upgrading, where innovations in key and disruptive technologies provide stronger impetus for productivity growth. Gao Fan expanded this concept by analyzing outcomes[4], production factors, factor combinations, industrial structures, and support mechanisms. On the other hand, researchers have developed empirical evaluation frameworks. Liu Jianhua established an integrated index system encompassing laborers, means of labor, and objects of labor[5], employing entropy methods and kernel density estimation techniques tailored to China's context. Furthermore, Guo Zhaoxian conducted applied research focusing on how new-quality productive forces drive modern industrial system construction[6].

2.2 Regarding the High-Quality Development of Digital Agriculture

Regarding the high-quality development of digital agriculture, since 1997, the academicians from the National Academy of Sciences and the National Academy of Engineering—the leading representatives in the U.S. scientific and engineering communities —were the first to introduce the innovative concept of "digital agriculture[7]." This concept integrates the essence of geospatial technology with information technology, marking the transformation of agriculture towards intensive and informatized directions. Subsequently, with deeper practical exploration and theoretical expansion, the field has continued to evolve.

The concept of "agriculture" has been further defined. Research by Seelan et al. established the foundation for a narrow interpretation of digital agriculture, defining it as smart agriculture. Alm. E. emphasized that the core of digital agriculture lies in agricultural digitization[9], encompassing technologies such as big data, Internet of Things (IoT), sensors, system integration, artificial intelligence, and blockchain. Eastwood characterized digital agriculture as utilizing sensors, machinery[10], drones, and satellites monitoring animals, soil, water, plants, and human activities to interpret historical data and predict future trends. Gunasekaran and Kamble further noted in their study that digital agriculture has evolved into a new agricultural paradigm integrating computer technology[11], Geographic Information Systems (GIS), and other modern technological tools for agricultural production.

Regarding the understanding of high-quality development, the "endogenous growth theory" represented by Romer's model and Lucas's model in the 1980s further explored socio-economic development patterns[12-13]. These theories identified endogenous technological progress as the decisive factor for sustained economic growth. Elena proposed that economic growth is an activity of continuous quantitative accumulation[14], ultimately achieving quality improvement in economic development. Meanwhile, Mlachila and others emphasized that high-quality growth encompasses the simultaneous rapid advancement of economic levels[15], people's income levels, and social welfare standards.

However, there remains no unified definition regarding the connotation of high-quality development in digital agriculture. In academic research, some scholars define it through pathways for achieving high-quality development, such as Du Jian who posits that high-quality development entails implementing new development concepts to achieve coordinated and sustainable growth[16]. Others explore how digital agriculture can attain high-quality development by integrating it with policy contexts, like Xia Yulin who emphasizes that rural revitalization requires digital infrastructure support and agricultural technological innovation[17]. Some researchers conduct empirical analyses using urban panel data, exemplified by Yao Wen who suggests strengthening infrastructure, enhancing informatization levels[18], leveraging market mechanisms, and promoting high-quality development in digital agriculture.

2.3 Regarding the Relationship Between New Quality Productivity and the High-Quality Development of Digital Agriculture

In the exploration of the connection between new-quality productivity and digital agriculture, academia remains in its early exploratory phase, demonstrating considerable depth yet to be fully uncovered. Most scholars currently focus on the correlation between new-quality productivity and high-quality agricultural development. For instance, Li Zicheng and colleagues conducted empirical analyses based on spatial spillover effects and threshold effects[19], concluding that new-quality productivity serves as a crucial driving force for advancing agricultural high-quality development. However, with deeper research, scholars have begun exploring from different perspectives. Wang Qinmei et al. [20], for example, observed that digital technologies can deeply permeate and reshape the intrinsic structures of agricultural laborers, farming tools, and agricultural production objects, giving birth to new-quality productivity in digital agriculture. This discovery opens up fresh exploration possibilities for the future development of agriculture.

2.4 The Value of New Quality Productivity Empowering the High-Quality Development of Digital Agriculture

Through literature review, it is found that although the academic community has achieved certain results in the high-quality development of new quality productivity and digital agriculture, the achievements on how new quality productivity can empower the high-quality development of digital agriculture are still insufficient. For instance: How can new-quality productivity drive the high-quality development of digital agriculture? What strategies should be implemented to propel the transition into a high-quality development phase?

The marginal contribution of this study can be summarized in three key aspects: First, focusing on Jilin Province as the primary research subject, we clarify the crucial role of new-quality productive forces by examining their development logic, core bottlenecks, and implementation strategies for empowering high-quality digital agriculture. Second, analyzing how these innovative productive forces—emerging from traditional growth models and aligning with high-quality development requirements—empower digital agriculture through new development concepts. Third, few scholars have analyzed the implementation strategies for promoting the high-quality development of digital agriculture through new quality productivity. This article takes Jilin Province as an example, aiming to enrich the achievements in this regard.

3 THE LOGIC OF NEW QUALITY PRODUCTIVITY ENABLING HIGH-QUALITY DEVELOPMENT OF DIGITAL AGRICULTURE

As an upgraded and transcended version of traditional productive forces, new-quality productivity represents a novel form of productivity driven by technological innovation, aligning with the requirements of high-quality development. High-quality development necessitates the support of new-quality productivity. Within this framework, the core strategic focus for advancing digital agriculture's high-quality development lies in comprehensive digital innovation across all agricultural sectors. This requires not only widespread dissemination of digital technologies in agriculture but also their deep integration and penetration to stimulate innovative vitality in agricultural production. The specific content includes five dimensions: digital infrastructure construction, transformation of production and operation models, paradigm shift in development concepts, restructuring of industrial organizations, and workforce skill upgrading [21]. Among these, infrastructure construction serves as the core support, forming an indispensable component of labor objects that lays the foundation for extensive digital technology application in agriculture. Subsequently, the transformation of industrial organization further propels digital agriculture's development. As another crucial element of labor objects, it optimizes and reorganizes agricultural industry chains, providing robust organizational guarantees for deep digital integration. Building on this foundation, the digital transformation of production and operation models becomes a key application of labor materials. The adoption of intelligent agricultural equipment and precision farming technologies directly enhances agricultural productivity and quality. Meanwhile, the paradigm shift in development concepts acts as spiritual guidance for laborers, emphasizing green development and sustainable concepts under digital leadership, thereby providing clear direction and momentum for digital agriculture. Finally, the transformation of labor skills has become a specific ability guarantee for the high-quality development of digital agriculture. As an important part of the labor force, it promotes the development of digital agriculture by cultivating the digital literacy and operational skills of high-quality agricultural talents.

The analysis demonstrates that the high-quality development of digital agriculture driven by new productive forces primarily stems from empowering agricultural digital transformation. This process involves reshaping three fundamental elements of agricultural production: labor objects, means of labor, and workforce. Through five dimensions—infrastructure, industrial organization, production operations, development philosophy, and workforce skills—the digitalization of agricultural labor objects, means of labor, and workforce is systematically categorized. By implementing innovative development concepts, this approach achieves "quantum optimization" of basic elements, "resonance coupling" in agro-industries, "energy-level leap" in production operations, "entropy-reduction restructuring" of cognitive patterns, and "field-magnetic field reshaping" of labor resources, ultimately realizing high-quality development in digital agriculture.

3.1 Scientific and Technological Innovation: Basic Element "Quantum Optimization"

As a key driver of new productive forces, technological innovation primarily relies on data resources. In advancing these capabilities, infrastructure development focuses on 5G and F5G all-optical networks, data centers, and other foundational projects. This involves optimizing the layout, structure, functionality, and system integration of digital and intelligent infrastructure while enhancing data resource consolidation and efficient circulation. Currently, the four pillars of digital agriculture infrastructure include smart farming equipment, agricultural IoT systems, big data platforms, and communication networks. With technological breakthroughs injecting momentum into new productive forces, digital agriculture infrastructure is undergoing fundamental transformation. First, "quantum enhancement" in smart farming equipment achieves performance breakthroughs and expanded operational boundaries. These devices are now deployed in cutting-edge agricultural zones. Driven by technological innovation, their algorithms and control systems have been optimized to improve precision in sowing uniformity, irrigation accuracy, and harvesting precision. Remote operations now transcend geographical limitations, enabling real-time responses even in challenging terrains and harsh climates, significantly expanding application scenarios. Second, "quantum enhancement" in agricultural IoT systems enables efficient data acquisition and analysis. The agricultural Internet of Things (IoT) is being increasingly integrated into farming processes. By utilizing diverse sensing devices to monitor and manage critical factors like farmland environments and crop growth, technological innovation in core data collection, processing, and sharing has optimized sensor network architectures and data transmission. This enables comprehensive and high-precision monitoring of key information such as soil moisture, crop status, and climate changes, significantly improving the accuracy and real-time responsiveness of agricultural data acquisition. Thirdly, the "quantum leap" in agricultural big data platforms has achieved both expanded application scope and enhanced data security. These platforms consolidate vast agricultural data resources, leveraging advanced data processing and analytics technologies to provide precise guidance and services for farming operations. Guided by technological innovation, their applications will transcend traditional agricultural management and extend into critical fields including agricultural product quality traceability, financial services, and rural e-commerce. Through blockchain and advanced encryption technologies, these systems ensure complete protection against illegal interference and data breaches during transmission, storage, and usage. Fourthly, the "quantum upgrade" in communication infrastructure has achieved deep integration of cutting-edge technologies. The leap from 2G to 5G has dramatically increased data transmission speeds, expanded network capacity, and reduced latency, providing robust support for real-time agricultural information exchange and efficient processing. Looking ahead, continuous technological empowerment will enable the convergence of 5G, satellite IoT, and other IoT technologies, forming a more comprehensive and multi-dimensional communication network system.

3.2 Open Cooperation: Resonance Coupling of Agriculture-Related Industries

The new productive forces driven by technological innovation can further propel industrial transformation and upgrading, breaking away from traditional economic growth models to achieve low energy consumption, high efficiency, and sustainability. Traditional agricultural industries are often confined to single production stages or specific sectors, making it difficult to transcend boundaries for optimal resource allocation and full realization of value potential. As the core concept, "resonance coupling" has become a key force in building an industrial ecosystem that connects various elements and drives cross-sector collaboration, serving as a crucial driver for agriculture's future development. The deep integration of digital agriculture with cutting-edge fields like information technology, biotechnology, and intelligent manufacturing will completely dismantle barriers in traditional industries, giving birth to a new industrial ecosystem characterized by diversified complementarity and collaborative innovation. Within this ecosystem, all industrial elements interdependently reinforce each other. Through the resonance coupling mechanism, not only is precise resource allocation achieved, but the breadth and depth of value extraction are also significantly enhanced.

3.3 Coordinated Development: "Energy Level Transition" of Production and Operation

The evolution from traditional to modern agriculture fundamentally represents the widespread adoption of scientific and technological advancements in farming. As conventional agricultural practices transition to modern models, their reliance on manual labor and experience often fails to meet the dynamic demands of contemporary markets. Digital agriculture leverages advanced data analytics and AI-driven decision-making to achieve precise control and scientific management of production processes. This technology empowers farmers to accurately track market trends and production patterns, enabling them to develop scientifically sound planting plans and marketing strategies that align with market realities.

Against this backdrop, the coordinated development philosophy guides agricultural production to achieve a "qualitative leap", transitioning from basic capabilities to advanced technological capabilities. This marks a fundamental transformation in agricultural production models. Farmers have shifted from relying on experience to depending on technology, while agricultural practices have evolved from extensive methods to intensive and precision-oriented approaches, achieving a qualitative leap in productivity. This transformation process not only focuses on improving production efficiency but also emphasizes close integration between agriculture and market demands, as well as synchronized optimization of ecological and economic benefits. Agricultural production can now respond more agilely to market changes, flexibly adjusting crop planting structures and sales strategies based on real-time market signals, ensuring precise alignment and efficient coordination between supply and demand.

3.4 Green development: "Entropy Reduction Reconstruction" of Thinking Mode

The cornerstone of new productive forces lies in technological innovation, with green development at its heart as the foundation of this scientific revolution. The concept of "entropy reduction restructuring" refers to harnessing technological advancement and digital transformation to eliminate inefficiencies, reduce waste, and optimize resource allocation in agricultural production systems, thereby achieving sustainable environmental outcomes. In contrast, traditional farming practices remain trapped in a vicious cycle of resource depletion, worsening pollution, and stagnant productivity growth. These entropy-increasing patterns have become major roadblocks to agricultural sustainability.

The "entropy reduction reconstruction" process manifests in two key aspects. First, it drives fundamental transformation in agricultural production methods. Traditional farming approaches often prioritized yield growth while neglecting quality and environmental balance. The new productive forces advocate a paradigm shift: ensuring stable grain production through green innovation technologies that maximize resource efficiency and minimize environmental impact, thereby achieving entropy reduction. Second, this paradigm shift propels digital agriculture to implement green "entropy reduction reconstruction". By leveraging computer systems, communication networks, and smart machinery, every link in the agricultural chain achieves precise control and significant enhancement in intelligence. This "intelligentization+" revolution reduces resource consumption and carbon emissions through precision fertilization, smart irrigation, and eco-friendly pest control measures, ultimately realizing a green transition in agricultural practices.

3.5 Shared Development: Labor Resources "Magnetic Field Remodeling"

The continuous leaps in technological innovation, the application of labor tools, and the expanding boundaries of labor objects all fundamentally rely on human effort. More crucially, the efficiency enhancement of labor tools and objects requires close collaboration with highly skilled workers to transform into tangible productivity. In this process, the high quality of workers serves as the core guarantee for new-quality productive forces. The transformation and upgrading of workforce skills lay a solid foundation for cultivating a high-caliber workforce. Particularly in the emerging field of digital agriculture, its essence lies in the close integration of digital technology and agricultural big data. This process essentially represents a profound and thorough "magnetic field restructuring" of traditional agricultural labor structures. It demands workers to achieve a leap from low-skilled to high-skilled status. This transition not only elevates individual value but also drives industry progress. The emergence of new-quality productive forces provides strong impetus for workforce skill transformation, with the ultimate goal of achieving shared development. While calling for more highly skilled professionals to join, it simultaneously guides labor migration toward digital agriculture, promoting skill structure optimization and upgrading. This ensures that the fruits of skill transformation benefit broader populations, thereby enhancing the overall workforce quality and technical proficiency across industries.

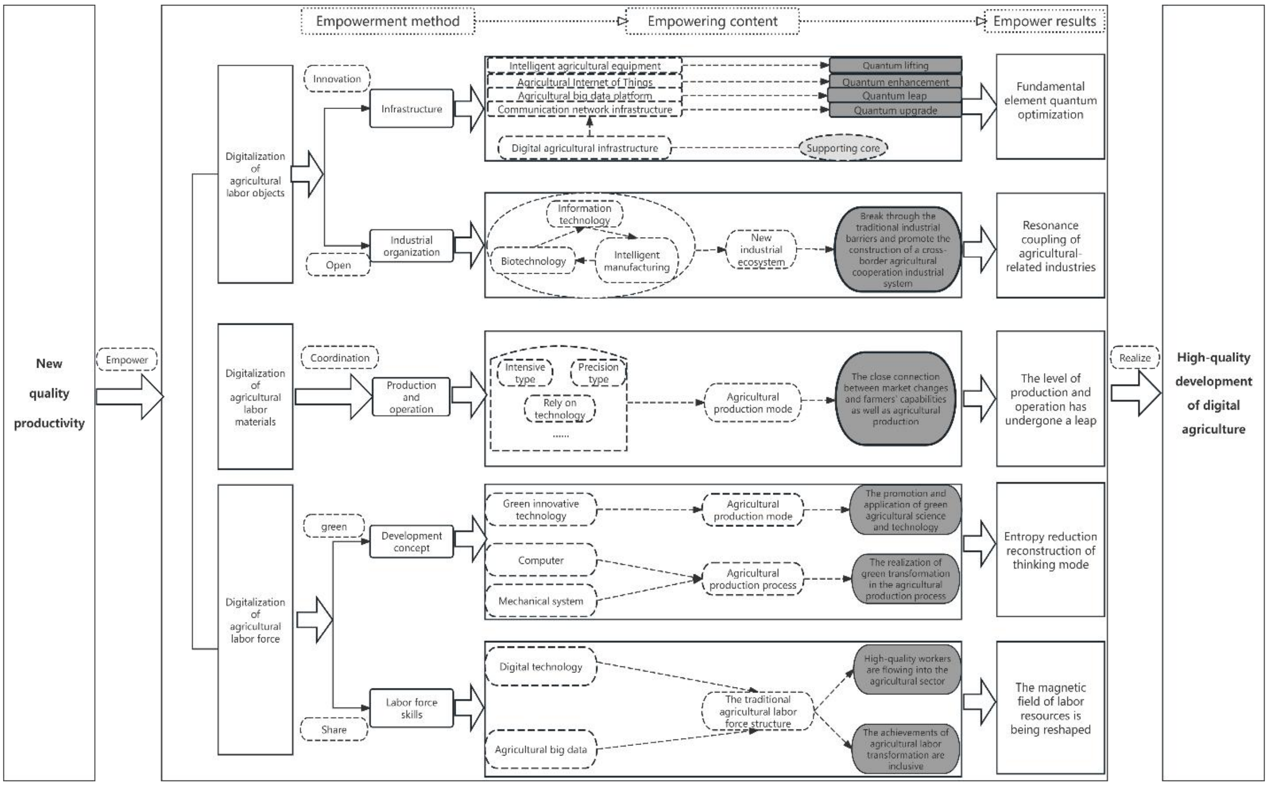


Figure 1 Logic Diagram of New Quality Productivity Empowering Digital Agriculture

4 CORE OBSTACLES TO THE HIGH-QUALITY DEVELOPMENT OF DIGITAL AGRICULTURE IN JILIN PROVINCE

As China advances its new productive forces strategy, Jilin Province—a vital hub for grain and agricultural products—must seize emerging opportunities in digital agriculture to establish a national benchmark. However, constrained by underdeveloped infrastructure and traditional farming practices, the province still faces multiple challenges in digital agriculture development. Developing localized strategies tailored to Jilin's unique conditions is crucial to achieve breakthroughs and leapfrog progress in this field.

4.1 Infrastructure Lagging Gap: Digital Connection Loosening

The development of digital infrastructure in Jilin Province is crucial, yet current progress reveals significant delays that starkly contrast with future expectations, primarily manifested through mismatches between existing facilities and actual needs. First, rural areas in Jilin lag significantly behind the national pace in communication network infrastructure adoption and upgrades. As of December 2023, while China's internet penetration rate reached 77.5%, rural coverage stood at merely 66.5%. In Jilin, only 370 out of 1,048 township-level administrative units achieved 5G network coverage in 2021, representing a mere 35.3% penetration rate. More critically, high-speed, stable communication networks remain inadequately deployed and underutilized in agriculture—a sector where such connectivity is essential for real-time data transmission and efficient processing. Second, the investment-to-output ratio of smart agricultural machinery in Jilin lags markedly. With total agricultural machinery power reaching 43.58 million kilowatts in 2022—accounting for just 3.94% of China's 1.106 billion kilowatts—this figure falls far below levels seen in agriculturally advanced regions. This indicates severe deficiencies in rural informatization infrastructure, leaving farmers unable to fully benefit from digital agricultural technologies. Third, the development of agricultural big data platforms and IoT systems requires further enhancement. Agricultural IoT in Jilin remains rudimentary, characterized by low intelligence levels and limited application scope. At the same time, the agricultural industry big data platform is also faced with the problem that data resources are scattered in different departments, enterprises and scientific research institutions, resulting in insufficient integration and sharing, difficult data acquisition, and thus affecting the application effect of the big data platform in the agricultural industry.

4.2 Industrial Structure Fragmentation: Unbalanced Development

The development of agricultural industrial chains has long been a critical challenge in Jilin Province's digital agriculture sector, significantly impacting farmers' income levels while invisibly constraining the industry's overall competitiveness and hindering its ability to stand out in fierce market competition. Three key issues require attention: First, uneven industrial development with sluggish growth in primary industries. In 2023, Jilin's primary industry added value reached 164.475 billion yuan, secondary industry 458.503 billion yuan, and tertiary industry 730.140 billion yuan. Despite rapid grain production growth, primary industry contributions accounted for merely 12.14% of total industrial output. Second, insufficient capabilities among agricultural enterprises. Only 57 enterprises were certified as provincial-level key agricultural leading enterprises in 2022—a stark contrast to Henan Province (319 certified enterprises) and Shandong Province (212 certified enterprises). Third, policy coordination challenges arise from differing interests and operational models between stakeholders and local governments. These discrepancies create regional cooperation barriers, information asymmetry undermines coordination across sectors, disrupts market dynamics, hinders information sharing, and ultimately restricts productive activities

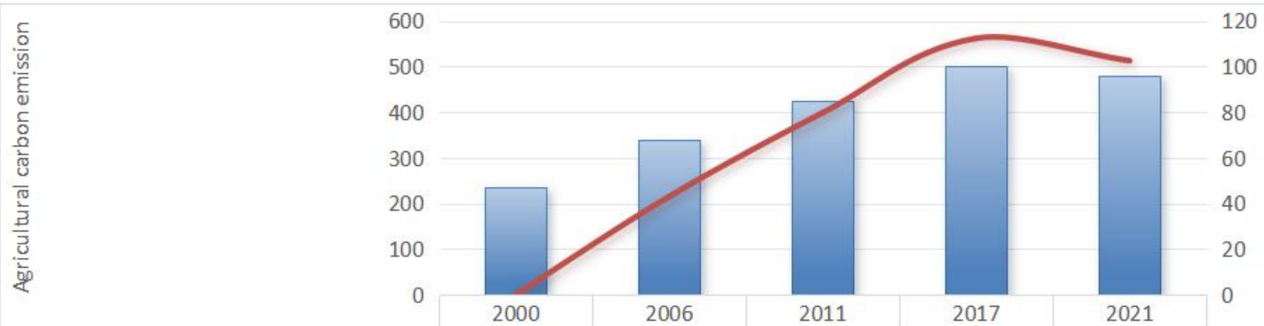
4.3 Traditional Agricultural System Dominates: The Rupture of The Coordination Mechanism between Business and Innovation

The integration of digital technology with agriculture can significantly enhance market transparency, boost agricultural productivity, and improve distribution efficiency. However, this digital transformation also imposes specific requirements on production capabilities and economic scale for agricultural operators [11]. In China's agricultural landscape, where 98% of farming households are small-scale farmers, the "large country with small-scale farming" phenomenon remains prevalent. Under these circumstances, Jilin Province still relies heavily on traditional agricultural models that depend on heavy manual labor and rudimentary machinery, resulting in low efficiency and poor adaptation to modern agricultural development needs.

With the continuous outflow of rural labor and accelerated population aging, the traditional farming system's heavy reliance on human labor has become unsustainable. Between 2014 and 2023, Jilin Province witnessed a significant decrease in rural population, dropping from 11.41 million to 8.25 million, accounting for 35.28% of the total population. Meanwhile, the elderly population surged from 3.02 million to 4.35 million (aged 65+), representing 18.63% of the total population. This labor-dependent model is becoming untenable. In 2022, Jilin Province planned to cultivate 25,000 high-quality farmers, yet this accounted for merely 3.31% of China's national initiative to train 753,900 skilled agricultural workers. Most farmers lack essential skills and knowledge to master modern farming techniques, hindering the establishment of integrated business-farming mechanisms. Compounded by deep-rooted traditional farming concepts, many farmers remain skeptical about modern technologies and prefer conventional cultivation methods. Under these circumstances, innovation in production models faces challenges, and the gap between traditional farming systems and modern agricultural development continues to widen.

4.4 Heavy Carbon Emission Load: Signs of Environmental Degradation are Prominent

The CPC Central Committee and the State Council emphasized in their "Strategic Guidelines on Revitalizing Northeast China and Other Old Industrial Bases" the importance of establishing a robust ecological security barrier in northern China and creating a green homeland with clear mountains, clean waters, and livable environments. The document stresses that environmental quality is closely tied to public welfare and serves as an essential component of livelihood protection. It advocates unwavering commitment to green development principles, calling for complete abandonment of any practices or models that harm natural ecosystems. The goal is to realize the vision of bluer skies, greener mountains, and clearer waters in Northeast China, ultimately building a sustainable region with harmonious ecology and improved living conditions. However, Jilin Province's traditional agricultural structure and production methods have led to significant environmental degradation. Carbon emissions from agriculture stand out as a prominent environmental issue. Since 2000, agricultural carbon emissions in Jilin have steadily increased from 2.3672 million tons to 5.0272 million tons in 2017, representing a peak growth rate of 112.37%. After a decline to 4.7952 million tons by 2021, emissions still rose by 102.6%, doubling the province's total carbon emissions over two decades [22]. Although emissions have slightly decreased in recent years, the overall increase remains substantial. If this trend continues, Jilin's ecosystem will struggle under such heavy pressure, potentially undermining agricultural foundations and jeopardizing regional ecological balance and sustainable development.



	2000	2006	2011	2017	2021
Agricultural carbon emissions（wt）	236.72	338.46	425.46	502.72	479.52
Growth rate（%）	0	42.97	79.73	112.37	102.6

Figure 2 Map of Agricultural Carbon Emissions in Jilin Province

4.5 Significant Dissipation of Human Resources: Market Supply and Demand Mismatch has Intensified

Jilin Province is grappling with a critical mismatch between its talent development mechanisms and rapidly expanding agricultural demands during its push for industrial growth. The first challenge lies in the disconnect between talent cultivation systems and fast-growing industry needs. Despite extensive training initiatives implemented across 50 cities and counties in 2022—encompassing 1,738 family farm operators, 1,376 farmer cooperative leaders, 425 agricultural service organization directors, 263 enterprise executives, 512 technical specialists, and 120 professional managers—all aimed at building a diversified and specialized agricultural workforce—the provincial government's work report reveals a striking contrast: while the number of farmer cooperatives surged to 81,000 and family farms reached 146,000 households, the demand for high-caliber professionals has skyrocketed. This surge coincides with the continuous expansion of agricultural bases and accelerated technological innovation, creating unprecedented pressure for skilled agricultural talent. The second issue stems from outdated recruitment strategies. Jilin's current talent acquisition policies lack flexibility and innovation, making them less attractive than their counterparts in more economically developed regions. Compounded by geographical constraints and economic disparities, the province struggles to retain top-tier professionals through conventional incentives alone.

5 NEW QUALITY PRODUCTIVITY ENABLES THE HIGH-QUALITY DEVELOPMENT STRATEGY OF DIGITAL AGRICULTURE IN JILIN PROVINCE

The deep integration of new productive forces in empowering digital agriculture is gradually demonstrating its strategic position as the core driver for high-quality agricultural development. This comprehensive empowerment provides robust support for Jilin Province to achieve its goal of becoming a leading agricultural province. Specifically, it manifests through multiple dimensions: building resilient infrastructure, developing diversified industrial ecosystems, nurturing new-generation agricultural innovators for the digital era, shaping green circular and low-carbon innovation ecosystems, and implementing targeted talent recruitment with regional collaboration. These efforts collectively propel the high-quality advancement of digital agriculture in Jilin Province.

5.1 Building a Resilient Development Framework for Infrastructure: Bridging the Gap

Establishing a resilient development framework for infrastructure is crucial for advancing digital agriculture modernization, narrowing the digital divide, and enhancing agricultural productivity and quality in Jilin Province. First, building a digital agriculture platform. By strategically increasing investment in intelligent agricultural machinery—particularly considering Jilin's northeastern location with extreme winter temperatures—farmers should prioritize cold-resistant equipment through low-freezing-point fuels, coolants, and insulation materials. Advanced technologies like autonomous driving and precision farming should be widely adopted to expand their applications. Policy incentives and fiscal subsidies will encourage farmers to adopt smart machinery while establishing agricultural equipment leasing and sharing systems to lower adoption barriers. Additionally, creating a unified agricultural big data platform will consolidate fragmented resources such as Jilin Statistical Yearbook and provincial agricultural data, enabling cross-system data sharing to support intelligent decision-making. Second, constructing a "Smart Network" for digital agriculture. To strengthen information accessibility, Jilin needs to accelerate rural communication infrastructure upgrades, especially 5G network coverage and high-speed broadband. Through IoT integration, deploying smart sensor networks will enable real-time monitoring of farmland conditions and crop growth, ensuring data accuracy and timeliness. Furthermore, deepening collaboration between IoT, big data, cloud computing, and AI technologies will create efficient communication networks, enabling smart interconnection and coordinated operations across agricultural equipment, ultimately forming a comprehensive smart agriculture ecosystem.

5.2 Developing Diversified Industrial Ecology: Restructuring the Pattern

The development of Jilin Province's diversified industrial ecosystem is primarily driven by the deepening integration and cross-sector collaboration within agricultural value chains. First, enhancing cross-regional cooperation in agricultural supply chains through establishing Northeast Asia agricultural cooperation platforms helps overcome limitations caused by the limited number of agribusiness enterprises. As a strategic hub in Northeast Asia, Jilin's unique geographical advantages enable it to break regional barriers through agricultural exhibitions and trade fairs. This facilitates strengthened agricultural exchanges with neighboring countries and regions, promotes trade cooperation, establishes collaborative mechanisms, and drives joint R&D efforts. Such initiatives achieve resource sharing and complementary advantages, thereby boosting the competitiveness and stability of the entire industrial chain while stimulating innovation across its upstream and downstream sectors. Second, leveraging its strengths in market intelligence and coordination, the Jilin provincial government has transformed traditional administrative functions into flexible industrial governance frameworks. This approach optimizes resource allocation and dynamic integration of production factors, strengthens policy support, funding mechanisms, interdepartmental coordination, supervision, and performance evaluation to eliminate institutional barriers in resource circulation.

5.3 Incubating New Agricultural Craftsmen in the Digital Era: Upgrading and Transformation

With the shrinking rural workforce in Jilin Province, it is imperative to transform labor-dependent agricultural practices and boost both crop yields and market sales. Two key strategies should be implemented: First, establishing a multi-dimensional cultivation framework to develop digitally savvy farmers who can mitigate the demographic decline. Provincial authorities should design specialized training programs leveraging resources from institutions like Jilin Agricultural University and Jilin Academy of Agricultural Sciences. These courses should cover core areas including modern farming techniques, business management, and marketing strategies, adopting a blended learning model that combines online instruction with hands-on field training. Customized services should address regional needs while enhancing farmers' proficiency in digital tools and platforms, improving their technical expertise, market insight, and innovative thinking to maximize training effectiveness. Second, restructuring agricultural operations to achieve seamless integration with market demands. As most regions adopt cutting-edge technologies like big data analytics, IoT, and AI, digitally literate farmers can master these innovations and effectively implement the "Internet + Agriculture" model. By expanding sales channels through e-commerce platforms and social media, they can break free from traditional limitations, build distinctive local brands, increase product value, and enhance market competitiveness. This deep integration of agriculture with e-commerce will help offset production and sales challenges caused by declining traditional farming populations.

5.4 Shaping a Green, Circular and Low-Carbon Innovation Ecosystem: Ecological Restoration

With the core focus on reducing agricultural chemical inputs, we aim to maximize synergistic effects in pollution and carbon reduction. From 2000 to 2021, agricultural carbon emissions in Jilin Province were primarily attributed to farmland utilization (72%), straw burning (23%), rice cultivation (4%), and livestock farming (1%) [28]. To advance decarbonization efforts, the province must develop region-specific strategies that align with local conditions, ensuring effective establishment of green circular and low-carbon innovation ecosystems. Firstly, cities with extensive cultivated land should prioritize the adoption of green agricultural technologies. Given that carbon emissions mainly stem from fertilizers, pesticides, plastic mulch, and machinery use, while straw burning and rice cultivation emissions correlate positively with land area, four regions—Changchun, Baicheng, Songyuan, and Siping—which account for 71% of the province's total arable land—should become key zones for green technology implementation. These areas could adopt advanced methods including biological control techniques, precision soil testing and formula fertilization systems, and eco-friendly pesticides. This will guide farmers to transition from traditional resource-intensive production models to environmentally sustainable practices, fostering the growth of organic and green agriculture. Secondly, comprehensive management of agricultural non-point source pollution requires establishing a deeply integrated circular symbiosis system that combines crop cultivation with livestock farming. Taking key livestock breeding zones such as Yanbian Yellow Cattle, East Feng County, and Shuangyang District's sika deer herds as examples, innovative closed-loop agricultural green ecosystems have been designed. Centered on efficient resource recycling, these systems achieve reduced agricultural waste and pollution-free processing. This approach effectively cuts carbon emissions and various pollutants at the source during farming processes, driving comprehensive pollution reduction and carbon mitigation in agriculture.

5.5 Targeted Talent Recruitment and Regional Progress: Gathering Talents

Jilin Province is currently formulating its "Talent Policy 4.0". Confronted with relatively lagging economic development, the province cannot solely rely on high salaries and abundant job opportunities to attract external talents. Therefore, the policy formulation should shift focus to deeply exploring and cultivating local talent resources. First, deepen local sentiment and precise positioning. By refining the talent classification system and comprehensively considering multiple factors such as origin, educational background, and career trajectory—such as whether candidates are locally born, educated locally, or remain after graduation—the province can accurately identify and nurture agricultural professionals with a sense of hometown belonging and mission. This reduces policy externalities and enhances talent identification and responsibility towards Jilin. Second, establish regional agricultural talent hubs. Jilin should actively strengthen cooperation with neighboring cities and regions like Shenyang, Dalian, and Harbin to jointly explore new pathways for coordinated regional agricultural talent development. Through sharing agricultural talent resources, technical expertise, and information networks, the province can break down geographical barriers, promote free flow and optimal allocation of agricultural talents and technologies, leverage its strengths, and create complementary win-win development patterns with partners.

6 CONCLUSION

In advancing high-quality digital agriculture development in Jilin Province, new productive forces serve as the core driving force. Through multidimensional advancements in technological innovation, open collaboration, coordinated development, green growth, and shared benefits, these efforts comprehensively enhance the overall efficiency and competitiveness of digital agriculture. Examining the current landscape of digital agriculture development in Jilin, it becomes evident that multiple challenges—such as lagging infrastructure construction, fragmented industrial structures, entrenched traditional farming systems, heavy carbon emission burdens, and significant talent drain—are becoming bottlenecks hindering further progress. To address these complex issues, Jilin should establish resilient infrastructure frameworks, develop diversified industrial ecosystems, cultivate new-generation digital-era agricultural artisans, build green circular and low-carbon innovation ecosystems, and implement targeted talent recruitment strategies for regional advancement. These measures will inject momentum into the province's digital agriculture development.

Looking ahead, agricultural research in Jilin Province should focus more on the in-depth exploration and efficient utilization of new quality productivity. Through scientific and rigorous methods and practices, we will thoroughly investigate the practical application effects of new quality productivity in agriculture and rural areas, so as to take more solid and powerful steps on the path of high-quality development of digital agriculture.

COMPETING INTERESTS

The author has no relevant financial or non-financial interests to disclose.

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