Scientific and Social Research, 2026, Volume 8, Issue 3
https://ojs.bbwpublisher.com/index.php/SSR
Online ISSN: 2981-9946
Print ISSN: 2661-4332

Research on the Model Construction and Application of AI-Empowered Rural Ecological Pig Farming: A Practical Exploration Based on the "Pig–Biogas–Fertilizer–Planting" Circular System

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Abstract: Against the backdrop of rural revitalization and agricultural modernization, traditional pig farming models are confronted with multiple challenges, including low efficiency, severe environmental pollution, and food safety risks. This study takes the "Zhu" Guang Yiyi—an AI-empowered rural ecological pig farming project—as the research object, and focuses on the deep integration of artificial intelligence with ecological breeding. It proposes a trinity development model integrating intelligent farming, ecological recycling, and data-driven management. By introducing Internet of Things (IoT) sensing devices, machine learning algorithms, and big data analytics, the study realizes intelligent management throughout the entire pig breeding process, including precision feeding, environmental regulation, and disease early warning. Meanwhile, a resource recycling system of "pig–biogas–fertilizer–planting" is established to enable the energy conversion and fertilizer utilization of livestock waste, thereby promoting green transformation in agriculture. On this basis, a data platform is employed to achieve coordinated optimization of production, management, and marketing, and to extend the ecological farming industry chain toward processing, e-commerce, and agri-tourism integration. The results indicate that AI technologies can significantly improve farming efficiency and resource utilization, while reducing disease risks and environmental burdens, providing a replicable and scalable technological pathway and practical paradigm for rural industrial revitalization.

Keywords: Artificial intelligence; Ecological farming; Smart agriculture; Rural revitalization; Circular agriculture

Online publication: April 15, 2026

1. Introduction

With the upgrading of residents' consumption structure in China, pork consumption is shifting from a quantity-oriented pattern to a quality-oriented one, in which safety, nutritional value, and ecological attributes have become core concerns [1]. Meanwhile, national policies explicitly advocate the promotion of ecological breeding and the green transformation of agriculture, making it imperative for traditional farming models to upgrade toward intelligence and sustainability. However, the current pig farming sector still faces several prominent challenges: first, small-scale and dispersed farming remains dominant, with a low level of standardization [2]; second, disease monitoring and prevention measures are relatively lagging [3]; third, the treatment efficiency of livestock waste is low, resulting in serious environmental pollution [4]; and fourth, the industrial chain remains insufficiently extended, leading to low added value. Therefore, exploring the application pathways of artificial intelligence in ecological pig farming is of great significance for promoting high-quality agricultural development.

Based on an innovation and entrepreneurship project, this study systematically constructs a technical system and operational model for AI-empowered ecological pig farming, and further analyzes its application effectiveness and potential for broader dissemination.

2. Theoretical foundations and related studies

2.1. Theoretical foundations of smart agriculture and artificial intelligence

Smart agriculture is supported by a new generation of information technologies and seeks to realize the digitalization, networking, and intelligent management of the entire agricultural production process through the integration of the Internet of Things (IoT), big data, cloud computing, and artificial intelligence. Its core lies in replacing experience-based decision-making with data-driven approaches, thereby enhancing agricultural productivity and resource-use efficiency [5–6].

As a key technological pillar of smart agriculture, artificial intelligence has been widely applied in the livestock farming sector in recent years, mainly in three aspects. First, computer vision–based animal behavior recognition technologies enable real-time monitoring of pigs' feeding, movement, and abnormal behaviors [7]. Second, machine learning–based predictive models support disease risk early warning and growth trend analysis [8]. Third, intelligent control algorithm–based environmental regulation systems allow for the dynamic optimization of key parameters such as temperature, humidity, and gas concentration [9]. Relevant studies have shown that AI technologies can effectively reduce uncertainties in the breeding process and improve the level of precision management.

However, existing research has largely focused on single-technology application scenarios and lacks in-depth exploration of the integrated full-process system of "perception–analysis–decision–execution." In particular, the adaptability of such systems in small- and medium-scale farming contexts still requires further improvement.

2.2. Theoretical foundations of ecological circular agriculture

Ecological circular agriculture is an agricultural development model formed under the guidance of sustainable development principles. Its core lies in constructing a system for the recycling of materials and energy, thereby achieving coordinated development between agricultural production and the ecological environment [10–11]. This theory emphasizes the fundamental principles of "reduction, reuse, and resource recovery", and promotes the transformation of agricultural waste into reusable resources through integrated crop–livestock systems.

In the livestock sector, a typical ecological circular model is the "livestock breeding–biogas fermentation–organic fertilizer return–crop cultivation" system. Through biological transformation processes, livestock waste is converted into energy and organic fertilizers, thereby reducing environmental pollution and improving resource-use efficiency [12]. Existing studies have shown that this model can not only reduce the use of chemical fertilizers but also enhance soil fertility and improve the quality of agricultural products.

However, in practical applications, traditional ecological circular agriculture still faces several challenges, including relatively low resource-use efficiency, insufficient system stability, and a lack of intelligent regulation. Therefore, introducing artificial intelligence technologies to optimize and control the recycling process is a key pathway for promoting the high-quality development of ecological agriculture.

2.3. Rural revitalization and agricultural industrial integration theory

The rural revitalization strategy emphasizes that industrial development is the core driving force, advocating the transformation of agriculture from a single production function to a multifunctional system integrating "production, ecology, and livelihood" [13]. The theory of agricultural industrial integration suggests that agricultural efficiency and farmers' income can be enhanced by extending the industrial chain, upgrading the value chain, and improving benefit-sharing mechanisms [14–15].

In the field of pig farming, industrial integration is mainly reflected in three dimensions. First, upstream extension involves the development of ecological feed cultivation and resource recycling. Second, downstream expansion focuses on the development of deep processing industries for meat products. Third, horizontal integration promotes the coordinated development of agriculture with sectors such as e-commerce and cultural tourism, thereby forming diversified business models.

Current research generally recognizes digital technologies as an important driving force for agricultural industrial integration. However, in practice, there is still a lack of systematic solutions for achieving coordinated optimization across production, processing, and marketing through data platforms.

3. Construction of an AI-empowered ecological pig farming system

3.1. Overall system architecture design

To achieve intelligent and refined management of the pig farming process, this study constructs an ecological pig farming system based on the integration of artificial intelligence and Internet of Things (IoT) technologies. Driven by data as the core element, the system adopts a four-layer architecture consisting of the perception layer, network layer, platform layer, and application layer.

The perception layer is primarily composed of environmental sensors, video monitoring devices, and intelligent terminals, which are used to collect real-time data on temperature, humidity, ammonia concentration in pig houses, as well as pig behavioral data. The network layer ensures stable data transmission and preliminary processing through wireless communication and edge computing devices. The platform layer relies on cloud computing and big data technologies to perform data storage, analysis, and model training. The application layer provides intelligent decision support and visualized operational interfaces for farm managers. This architecture enables a closed-loop operation from data acquisition to intelligent decision-making, offering robust technical support for ecological pig farming.

3.2. Intelligent sensing and environmental regulation subsystem

Environmental factors are critical variables affecting pig growth efficiency and health status. To address the limitations of traditional farming, where environmental regulation largely depends on human experience, this study develops an intelligent environmental regulation subsystem based on AI algorithms.

The system deploys multiple types of sensors to monitor key indicators in pig houses in real time, including temperature, humidity, and harmful gas concentrations. By integrating historical data with characteristics of different growth stages of pigs, an environmental regulation model is established. When monitored data deviates from the optimal range, the system automatically adjusts ventilation equipment, heating devices, and spraying systems to achieve dynamic regulation.

Compared with traditional manual control methods, this subsystem demonstrates advantages such as rapid response, high regulation accuracy, and strong stability. It effectively improves the pig growth environment, reduces stress responses, and enhances overall farming efficiency.

3.3. Behavior recognition–based health monitoring and disease early warning system

Disease prevention and control are critical factors constraining farming efficiency. To enhance early warning capabilities, this study introduces computer vision and machine learning technologies to construct a behavior recognition–based health monitoring system for pigs.

The system collects daily activity data of pigs through video acquisition devices and employs deep learning models to identify and analyze feeding frequency, movement trajectories, and abnormal behaviors. When behavioral patterns such as reduced appetite, decreased activity, or abnormal coughing are detected, the system automatically triggers an early warning mechanism and sends risk alerts to farm managers.

In addition, by establishing individual health records, the system enables dynamic tracking and data accumulation throughout the entire life cycle of pigs, providing data support for disease diagnosis and prevention. This system can significantly shorten response times to disease outbreaks and reduce the risk of epidemic spread.

3.4. Precision feeding and growth optimization subsystem

In the landscape of modern swine production, feed expenditures constitute the most significant variable cost, accounting for a substantial proportion of total farming expenses. Consequently, maximizing feed utilization efficiency is paramount for enhancing overall economic viability and profit margins. To address this critical challenge, this study develops a sophisticated precision feeding model underpinned by advanced AI algorithms, designed to achieve dynamic, real-time optimization of pig growth management.

The system functions by comprehensively integrating and analyzing a wide array of multi-dimensional data points, including real-time body weight trajectories, specific age stages, and comprehensive health status indicators. Based on this deep analysis, the system automatically calibrates both feed composition and daily feeding quantities, facilitating flexible management strategies that can be precisely tailored to either individual pigs or specific groups. Concurrently, a continuous data feedback mechanism is utilized to iteratively refine the underlying model. This self-learning capability ensures that feeding strategies evolve over time to become increasingly scientific, rational, and adaptive to changing environmental or biological conditions.

The deployment of this subsystem delivers significant multifaceted benefits to the farming operation. It not only substantially reduces feed waste and associated operational costs but also effectively accelerates average growth rates and improves uniformity across the herd. Consequently, these improvements lead to enhanced slaughter efficiency and superior end-product quality, thereby strengthening the overall market competitiveness and sustainability of the pig farming enterprise.

3.5. Ecological circulation and resource utilization subsystem

To address environmental pollution caused by livestock farming, this study incorporates the concept of ecological circulation into system design, forming a resource utilization subsystem. Centered on the “pig–biogas–fertilizer–

planting” pathway, this subsystem enables the recycling of farming waste.

Specifically, livestock manure is converted into biogas through anaerobic fermentation, which is used as an energy source for daily farm operations. The resulting biogas residue and slurry are utilized as organic fertilizers for crop cultivation, partially replacing chemical fertilizers. The crops produced are further used as feed resources, thus forming a closed-loop cycle that supports the farming process.

On this basis, intelligent monitoring technologies are applied to optimize the fermentation process and fertilizer application, improving resource conversion efficiency and reducing environmental risks, thereby establishing a green and low-carbon farming model.

3.6. Data platform and intelligent decision support system

To ensure the coordinated operation of multiple subsystems, this study develops an integrated data management and decision support platform. The platform consolidates data from environmental monitoring, feeding management, and health monitoring subsystems, and utilizes data mining and analytical techniques to achieve comprehensive visualization and intelligent decision-making for the farming process.

The platform’s main functions include production process monitoring, cost–benefit analysis, slaughter cycle prediction, and market demand analysis. By establishing data models, the system can anticipate potential risks in advance and provide optimization recommendations for managers.

In addition, the platform supports access via mobile terminals, enabling managers to monitor farming conditions in real time, thereby improving management efficiency and response speed.

4. Industrial model and application expansion

4.1. AI-empowered collaborative development model for the entire industrial chain

Based on the deep integration of artificial intelligence and ecological farming, this study constructs a collaborative development model for the entire industrial chain centered on pig farming. Guided by the main framework of “intelligent production, value-added processing, and digitalized sales”, the model facilitates the transformation from primary agricultural production to a high value-added industrial system.

At the production end, AI-driven intelligent farming systems are employed to enhance pig growth efficiency and product quality, thereby ensuring a stable supply of high-quality raw materials. At the processing end, the development of deep-processing industries for meat products, such as cured meat and sausages, extends the industrial chain and increases product value. At the sales end, e-commerce platforms and digital marketing strategies are utilized to establish an integrated online–offline multi-channel sales system.

This model breaks away from the traditional “single-production” structure, enabling organic linkage and coordinated optimization across all stages of the industrial chain, and thereby improving overall economic performance and risk resilience.

4.2. A Composite development path of “ecological farming + circular agriculture”

Guided by the concept of ecological circular agriculture, the project further develops a composite development path integrating ecological farming with circular agriculture, deeply coupling livestock production with crop cultivation systems.

Through the “pig–biogas–fertilizer–planting” circular system, livestock waste is transformed into energy and organic fertilizers, which are then applied to feed crop cultivation and ecological agricultural production, forming a closed-loop resource utilization mechanism. In this process, AI technologies are employed to dynamically monitor and optimize manure treatment, fermentation processes, and fertilizer application, thereby improving resource-use efficiency and system stability.

This development path not only effectively reduces environmental pollution and production costs but also promotes the virtuous cycle of agricultural ecosystems, providing a feasible paradigm for green agricultural development.

4.3. Digital marketing and brand value construction

Against the backdrop of consumption upgrading, competition in agricultural product markets is gradually shifting from price-based competition to competition based on brand and quality. Accordingly, this study establishes a data-driven digital marketing system.

On the one hand, big data analytics are used to analyze consumer behavior and market demand, enabling dynamic adjustment of product structures and precise supply. On the other hand, new media tools such as short videos and live streaming are utilized to visually present the farming process, thereby enhancing consumer trust and engagement. Meanwhile, a product traceability system is established to ensure transparency throughout the entire process from farming to sales, strengthening brand credibility.

In addition, a membership-based operation mechanism is introduced, incorporating measures such as reward points and customized services to enhance user loyalty and repurchase rates, thereby facilitating the continuous accumulation of brand value and the improvement of market competitiveness.

4.4. Multi-industry integrated development model

Beyond basic farming and product sales, the project further explores a multi-industry integrated development path, promoting the coordinated development of agriculture with the service and cultural sectors.

First, the integration of “agriculture + cultural tourism” is realized through the establishment of sightseeing farms and experiential agricultural bases, offering activities such as parent–child interaction, study tours, and ecological experiences, thereby expanding the social service functions of agriculture. Second, the integration of “agriculture + e-commerce” leverages online platforms and social media to achieve both product sales and brand promotion. Third, the integration of “agriculture + education” enhances farmers’ digital farming capabilities through technical training and demonstration programs, facilitating technology dissemination.

The integration of multiple industries not only broadens revenue sources but also enhances the comprehensive value and sustainability of the agricultural system.

5. Conclusions and prospects

5.1. Research conclusions

This study focuses on AI-empowered rural ecological pig farming and addresses key challenges in traditional pig production, including low efficiency, heavy environmental pollution, and extensive management practices. It proposes a comprehensive development model integrating intelligent farming, ecological recycling, and data-driven decision-making. The main conclusions are as follows:

First, the introduction of artificial intelligence technologies has significantly improved the level of refined management in the farming process. Through technologies such as environmental monitoring, precision feeding, and behavior recognition, the system enables a transition from experience-driven to data-driven management, effectively enhancing production efficiency and reducing disease risks.

Second, based on the “pig–biogas–fertilizer–planting” ecological circular system, the resource utilization and energy conversion of livestock waste are realized, substantially reducing environmental pollution and improving the ecological benefits and sustainability of the agricultural system.

Third, the data platform–based collaborative model across the entire industrial chain promotes the deep integration of farming, processing, and marketing, enhancing industrial added value and market competitiveness, while expanding multifunctional agricultural development pathways.

Fourth, through modular technological design and standardized system construction, the proposed AI-enabled ecological pig farming model demonstrates strong replicability and scalability, providing a feasible, practical paradigm and technical support for rural industrial revitalization.

Overall, the deep integration of artificial intelligence and ecological farming offers a new pathway for the transformation and upgrading of traditional animal husbandry, with significant implications for advancing agricultural modernization and green development.

5.2. Research limitations

Despite the systematic construction and analysis of the AI-empowered ecological pig farming model, this study has several limitations. On the one hand, it primarily relies on phased project implementation and sample data, lacking long-term continuous data support; thus, the sustained evaluation of system stability and economic performance remains insufficient. On the other hand, the adaptability of AI models in complex and dynamic real-world farming environments requires further improvement, and variations in application effectiveness exist across regions and farm scales. In addition, constraints such as underdeveloped digital infrastructure in some rural areas and uneven levels of digital literacy among farmers pose practical challenges to the widespread adoption and implementation of intelligent systems.

5.3. Future prospects

In the future, the development of AI-empowered ecological pig farming should be advanced from multiple dimensions, including technological optimization, model innovation, and practical application. At the technological level, efforts should focus on improving algorithm accuracy and system stability, as well as promoting the application of low-cost intelligent devices and edge computing technologies to enhance system accessibility and scalability. In terms of development models, further integration of agriculture with the digital economy is needed, alongside the improvement of data-driven full industrial chain coordination mechanisms, to promote the upgrading of the pig farming industry toward scale, standardization, and branding. Meanwhile, exploring the integration of ecological farming with carbon reduction mechanisms is essential to facilitate the transformation of ecological value into economic value. At the application level, it is necessary to establish comprehensive technical service and training systems to enhance farmers’ digital competencies, thereby accelerating the large-scale replication and regional dissemination of AI-enabled ecological farming models and contributing to high-quality agricultural development and the implementation of the rural revitalization strategy.

Funding

University-level Project of the 2025 College Students’ Innovation and Entrepreneurship Training Program (Project Number: CXCY2025012).

Disclosure statement

The authors declare no conflict of interest.

References

[1] Cui KY, Hong YF, Li Y, et al., 2025, Research Status, Hotspots and Trends in AI of Technologies in the Field of Animal Husbandry—A Bibliometric Visualization Analysis. Heilongjiang Xumu Shouyi, 2025(12): 166–173.

[2] Li JL, Li Y, Zhao SJ, et al., 2025, Research on the Application of Intelligent Technologies in Pig Farming. Ji Lin Chu Mu Shou Yi, 46(11): 49–51.

[3] Zhong ZH, 2025, Application of Green Livestock Breeding Technologies in Ecological Pig Farming. Chu Mu Ye Huan Jing, 2025(22): 146–147.

[4] Zhu XM, 2025, Analysis of the Impact of the New Normal on Pig Farming and Green Development Strategies from an Environmental Protection Perspective. Shan Dong Chu Mu Shou Yi, 46(5): 29–30.

[5] Yan H, Wei L, Li S, 2025, Research on the Application and Development Trends of Large AI Models in the Agricultural Sector. Agricultural Economy, 2025(10): 10–12.

[6] Feng YY, 2022, Artificial Intelligence Empowering High-Quality Development of Smart Agriculture. Mian Hua Xue Bao, 34(6): 560.

[7] Lu R, Dong YN, Yin M, et al., 2025, Research Progress on the Application of Artificial Intelligence in the Livestock Industry. Heilongjiang Xumu Shouyi, 2025(11): 21–25.

[8] Ding HH, Song XD, Dong GJ, et al., 2025, Applications and Prospects of Artificial Intelligence in the Food Industry. Journal of Chinese Institute of Food Science and Technology, 25(10): 397–412.

[9] Dai DL, Liu ZH, Zhao C, et al., 2021, Research Advances on Application of Artificial Intelligence Technology in Animal Husbandry. Chu Mu Yu Si Liao Ke Xue, 42(5): 112–119.

[10] Zou BL, Yu FW, 2026, Ecological Restoration Agriculture: Conceptual Features, Development Logic, and Promotion Strategies. Zhong Guo Nong Cun Jing Ji, 2026(3): 26–45.

[11] Shen XX, Duan JY, Peng C, 2026, Theoretical Foundations and Practical Logic of Realizing the Value of Rural Ecological Products. Xi Bei Nong Lin Ke Ji Da Xue Xue Bao (She Hui Ke Xue Ban), preprint, 1–12.

[12] Ning ZS, Liu Z, Zhang ZY, et al., 2025, The Impact of Environmental Regulations on the Resource Utilization of Livestock and Poultry Farming Waste: A Literature Review. Nong Ye Nong Cun Bu Guan Li Gan Bu Xue Yuan Xue Bao, 16(4): 58–70.

[13] Jie W, Qin W, 2026, Regionalized Promotion of Rural Revitalization: Context of Emergence, Mechanism of Action and Practical Paths. Wei Lai Yu Fa Zhan, preprint, 1–7.

[14] Wang XY, Liu H, Li S, 2026, Realistic Challenges, Pathway Exploration, and International Experience in Promoting Urban-Rural Integrated Development: A Review of the 2025 Annual Conference of the China Society of Foreign Agricultural Economics. Zhong Guo Nong Cun Jing Ji, 2026(3): 189–200.

[15] Liao Y, Tang WY, Zhang SL, 2026, Regional Public Brands of Agricultural Products—Industrial Collaborative Agglomeration and Rural Industry Revitalization: Evidence from China's Provincial Panel. Hong Guan Zhi Liang Yan Jiu, preprint, 1–13.