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Artificial intelligence in Chinese agriculture

Applications and prospects

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EXECUTIVE SUMMARY

The rapid evolution of artificial intelligence (AI) technologies, including precision farming, machine learning, and robotics, is revolutionizing agricultural productivity and sustainability, with varying progress across regions.

Globally, North America prioritizes AI technologies for large-scale farming and supply chain automation, while Europe leverages AI to improve environmental sustainability. In contrast, China emphasizes AI applications for food security and rural revitalization.

China has emerged as a leader in adopting AI for agricultural modernization, driven by government policies and financial support emphasizing precision farming, smart irrigation, and drone-based crop management. Despite challenges like uneven technology access and skills gaps, advancements in AI applications have enhanced efficiency, reduced waste, and optimized agricultural processes.

Looking forward, China aims to further integrate AI technologies into its agricultural practices to improve productivity, enhance sustainability, and bolster food security. Key challenges such as high costs, low farmer adoption, and data integration require collaborative efforts from policymakers, industry leaders, and researchers to sustain growth and innovation in the sector.

1. Global AI applications in agriculture

1.1 AI in global agriculture

Global agriculture is facing increasing challenges such as shrinking farmland, labor shortages, and climate change, making it more difficult for traditional farming methods to support sustainable development. According to United Nations estimates, the global population is projected to exceed 9.7 billion by 2050, while arable land is expected to expand by only 4% (Molotoks et al., 2021; Xu et al., 2023). **This stark reality highlights that the solution lies not in expanding farmland for crop cultivation or livestock rearing, but in maximizing the efficiency of existing agricultural land.**

To address these critical issues, Artificial Intelligence (AI) has emerged as a transformative force in various areas of agriculture (Mark, 2019). Although early attempts to integrate AI into farming began in the early 21st century, progress was slow due to technological limitations, including restricted computing capacity (Brynjolfsson & McAfee, 2014) and the lack of sophistication in AI models (Marcus, 2020). However, recent advancements in AI have revolutionized the sector, introducing solutions such as precision farming, automated monitoring, and intelligent decision-making.

Recent improvements in large language models, like ChatGPT, have significantly enhanced capabilities in complex reasoning, text comprehension, and generation, boosting both accuracy and efficiency. Additionally, Artificial General Intelligence (AGI), which aims to develop systems capable of performing a wide range of tasks and learning autonomously, has made strides in areas such as reinforcement learning and neural network design. These AI advancements are driving the intelligent transformation of agriculture by offering tailored recommendations based on weather, soil, and crop data, thereby improving productivity (Pandu et al., 2022; Redhu et al., 2022).

Moreover, AGI is advancing the autonomy of agricultural robots, enabling them to autonomously detect and address challenges like pests and soil conditions, providing real-time support to farmers (Lu et al., 2023).

By leveraging big data analytics, machine learning, and the Internet of Things (IoT), AI has enhanced agricultural productivity while reducing resource waste and environmental impact. This has sparked widespread global interest and accelerated adoption. Despite its vast potential, the development and implementation of AI in agriculture remains uneven across regions, highlighting the need for more inclusive and accessible technological advancements.

1.2 Current situation in China

In China, the digital transformation of agriculture is a cornerstone of the nation's agricultural modernization strategy. As a country with a large population and limited arable land, food security has long been a priority. **In recent years, the Chinese government has strongly supported the integration of AI into agriculture, focusing on areas such as precision farming, smart irrigation, drone-based crop management, and agricultural supply chain optimization (Liengpunsakul, 2021).**

AI enables farmers to harness big data analytics to monitor and predict agricultural needs. For example, AI allows for real-time adjustments to irrigation systems based on field conditions, minimizing inefficiencies caused by human error. By integrating with smart machinery, AI also addresses labor shortages by reducing operation times and automating tasks such as soil monitoring, pest and weed control, irrigation, fertilization, harvesting, and storage. These technologies create a fully automated production chain that boosts efficiency and reduces waste.

China has implemented various policies and measures to accelerate agricultural digitalization, providing strong support for AI adoption. **However, challenges remain, including limited access to technology in rural areas, a shortage of skilled personnel, and gaps in data infrastructure.** Despite these obstacles, increasing policy support and rapid technological advancements are steadily expanding the role and impact of AI in Chinese agriculture, offering a model for sustainable agricultural innovation.

1.3 Current situation in Europe

In 2017, the European Agricultural Machinery Association launched the "Farming 4.0" initiative, positioning smart agriculture as the future of European farming (CEMA, 2017). **Powered by big data and AI, smart agriculture is transforming practices across the European Union (EU), ranging from soil analysis and crop management to weather monitoring and fertilizer application.** This shift is driving market growth, with the European AI agriculture market valued at USD 462 million in 2022 and projected to reach USD 2.3 billion by 2030 (Heghe & Sirois, 2023). Key applications include precision farming, drone analytics, agricultural robotics, and livestock monitoring, with precision farming leading the market in 2022 (Heghe & Sirois, 2022).

While Europe's agricultural production scale is smaller than China's, it boasts higher mechanization and technology adoption rates (Groher et al., 2020; Kendall et al., 2022). Increased government support for AI solutions has further accelerated development, fostering balanced growth across various applications. **However, strict data sharing and privacy regulations in some countries pose challenges to AI adoption, limiting integration and data efficiency.**

The development of agricultural AI within the European Union is influenced by varying levels of data privacy regulations, technological infrastructure, and policy support (Long et al., 2016). **Germany** enforces the General Data Protection Regulation (GDPR), with stringent requirements for local data storage, restricting cross-regional data sharing. Additionally, complex regulatory procedures further delay AI implementation (Vásáry, 2013). **France**, through its National Commission on Informatics and Liberty framework, imposes additional GDPR requirements, including rigorous approval processes for cross-border data transfers, which increase compliance costs (Plieninger et al., 2012). These regulatory measures, coupled with farmers' reluctance to share data, have slowed the adoption of AI technologies.

In contrast, the **Netherlands**, supported by its "Precision Agriculture Action Plan," actively promotes AI applications in agriculture by encouraging data sharing and leveraging its advanced technological infrastructure, making it a frontrunner in the field (Wolfert et al., 2017). Meanwhile, countries like **Poland**, with lower levels of agricultural digitalization, face challenges such as limited access to data collection equipment and underdeveloped network infrastructure. A lack of clear policy support further undermines farmers' confidence in AI adoption (Șerbănel, 2021).

Overall, the stringency of regulations, the maturity of infrastructure, and the willingness to share data are key factors influencing the progress of agricultural AI.

Despite these challenges, Europe continues to lead in innovative, tech-driven agriculture. In November 2018, the German Federal Government introduced its AI Strategy, aiming to position Germany as a global leader in AI research, development, and application (The Federal Government, 2020). The strategy emphasizes a human-centric approach to ensure that technological advancements align with societal values and ethical standards. To further strengthen AI initiatives, the government increased its funding commitment from €3 billion to €5 billion by 2025, focusing on talent development, research, technology transfer, application, regulatory frameworks, and public acceptance (ibid.).

The German Federal Ministry of Food and Agriculture (BMEL) actively supports the integration of AI into agriculture through targeted funding and research initiatives. In 2020, BMEL launched funding programs to advance AI technologies in agriculture, nutrition, food chains, and rural areas, receiving 82 proposals covering 305 subprojects (European Commission, 2020). Additionally, BMEL allocated over €50 million to establish 14 digital trial fields on agricultural holdings, enabling research and testing of digital technologies in crop production and animal husbandry. These initiatives aim to improve resource efficiency, environmental protection, and animal welfare through innovative digital solutions (BMEL, 2021).

1.4 Current situation in North America

North America, with its large-scale mechanized farms and advanced technological resources, faces significant agricultural challenges, including labor shortages, climate variability, and the need for sustainable practices. These pressures have fueled strong demand for AI solutions, supported by government policies, investments, and collaborations between academia, industry, and government. The National Science and Technology Council (NSTC), under the United States government, has identified agriculture as a strategic priority within its “National AI R&D Strategic Plan” (NSTC, 2023). This initiative allocates funding for long-term research aimed at advancing AI-driven agricultural innovation, positioning North America as a global leader in applying AI to enhance agricultural productivity, sustainability, and resilience.

The United States Department of Agriculture (USDA) has developed its own AI strategy to promote the application of AI in agriculture. Through the National Institute of Food and Agriculture (NIFA), the USDA supports research and innovation in AI technologies across the agricultural and food supply chain. This includes advancements in machine learning, data visualization, natural language processing, and intelligent decision support systems, all aimed at enhancing productivity and sustainability within the sector (USDA, 2024; NIFA, n.d.).

Precision farming has become a cornerstone of North American agriculture, with AI playing a key role in unlocking data insights to guide field-level decisions. In states like California, drones equipped with AI are widely used for crop monitoring, enabling farmers to analyze real-time data and take timely, precise actions to optimize yields.

However, despite these technological advancements, North American agriculture continues to face persistent challenges from extreme weather events driven by climate change (Robinson, 2021) and ongoing labor shortages (Zahniser et al., 2018), underscoring the critical need for sustained innovation and adaptive strategies.

1.5 AI applications: future trends by region

North America currently leads AI-driven agriculture, followed closely by Europe, while the Asia-Pacific region is experiencing rapid growth and is poised to emerge as a major market and innovator. Notably, China has made significant progress in recent years, with its agricultural AI market expanding steadily and demonstrating immense potential for further development.

Each region has distinct priorities for AI applications in agriculture. **China focuses on food security and productivity gains** (Liu et al., 2022), **Europe emphasizes sustainability and environmental protection** (Agovino et al., 2019), and **North America prioritizes large-scale farming and supply chain automation** (Nowak, 2021).

Looking ahead, China is expected to accelerate the development of digital infrastructure in rural areas, broaden the adoption of AI technologies, and intensify efforts to cultivate a skilled agricultural technology workforce. Europe is likely to maintain its leadership in AI innovation for sustainable agriculture, advancing eco-friendly technologies and solutions. Meanwhile, North America is poised to deepen the integration of precision farming and automation, fostering end-to-end smart agricultural systems.

Globally, AI's role in agriculture will become more comprehensive, with increasing integration of technologies such as big data and the Internet of Things (IoT). Holistic solutions combining these innovations are anticipated to address global challenges related to food security and sustainability, driving greater efficiency and resilience in agricultural systems worldwide.

2. Policy analysis

2.1 Overall guidance: integration AI into agriculture

In recent years, the application of AI in agriculture has garnered significant attention and been actively promoted through national and international policy initiatives. The **United Nations'** *Governing AI for Humanity* policy, released in September 2024, aims to harness AI for the benefit of humanity while mitigating its potential risks. The policy proposes the establishment of an International AI Science Panel to provide independent scientific evaluations and assess risks associated with AI technologies. It also advocates for a Global AI Data Framework to ensure transparency and accountability in data usage, addressing concerns about misuse and bias. Furthermore, it recommends the creation of an AI Standards Exchange Platform to align AI development and application with safety, ethical, and equity standards. To coordinate these global efforts, the policy suggests setting up a dedicated AI office within the UN Secretariat to monitor emerging risks and ensure timely governance actions (United Nations, 2024).

China has also taken significant steps to integrate AI into agriculture. In 2016, the National Development and Reform Commission, along with the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the Cyberspace Administration of China, jointly issued the *Three-Year Action Plan for "Internet+" and Artificial Intelligence* (National Development and Reform Commission et al., 2016). This plan was the first to highlight the innovative application of AI-driven smart products in key sectors, including agriculture, and proposed demand-driven demonstrations of intelligent unmanned systems to enhance their capabilities.

In 2017, the State Council released the *New Generation Artificial Intelligence Development Plan* (State Council, 2017), emphasizing the integration of AI into various industries. For agriculture, the plan prioritized piloting AI applications such as intelligent agricultural sensing and control systems, smart agricultural equipment, integrated remote sensing networks for agricultural monitoring, and data-driven decision-making systems. These initiatives laid a strong foundation for advancing smart agriculture in China.

Between 2020 and 2021, several key policy documents refined the technical requirements for integrating AI with agriculture. These included the *Guidelines for Building a National New Generation AI Standards System* (National Standardization Administration et al., 2020), the *14th Five-Year Plan for National Agricultural and Rural Science and Technology Development* (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2021), and the *14th Five-Year Plan for Promoting Agricultural and Rural Modernization* (State Council, 2021). Together, these frameworks encouraged the deep integration of AI into agricultural production and operations.

In 2022, the Ministry of Science and Technology, in collaboration with five other agencies, issued the *Guidelines on Accelerating Scenario Innovation to Promote High-Quality AI Applications for Economic Development* (Ministry of Science and Technology of the People's Republic of China et al., 2022). This document identified major priorities for smart agriculture, including autonomous navigation for agricultural machinery, geographic information engines for farming, on-demand machinery services, rubber-tapping automation, smart farms, digitalized supply chain management, drone-based crop protection, IoT-enabled agricultural production monitoring, and quality control systems for agricultural products.

Through these comprehensive policies and action plans, China has steadily deepened the application of AI in agriculture. These efforts have provided robust support for agricultural modernization, enhancing productivity while ensuring the safety and quality of agricultural products.

2.2 Targeted policies: breakthroughs in smart agriculture and robotics

(1) Smart modernization and R&D upgrades in agricultural machinery

The application of AI in agriculture has increasingly centered on enhancing and intelligently utilizing agricultural machinery and sensors, becoming a key focus of policy initiatives. In 2022, the Ministry of Science and Technology issued the *Notice on Supporting the Construction of New-Generation Artificial Intelligence Demonstration Application Scenarios* (Ministry of Science and Technology of the People's Republic of China, 2022), highlighting the development of smart agriculture. **Among the first batch of demonstration scenarios was the concept of smart farms, which targeted key operational stages—including plowing, planting, management, and harvesting**—for major crops such as rice, corn, wheat, and cotton. The policy specifically promoted the adoption of intelligent agricultural machinery capable of performing autonomous and collaborative operations.

In recent years, China's *No. 1 Central Document* has repeatedly emphasized advancements in agricultural machinery development. The 2021 *Opinions of the Central Committee of the Communist Party of China and the State Council on Fully Promoting Rural Revitalization and Accelerating Agricultural and Rural Modernization* (State Council, 2021) called for strengthening independent R&D capabilities in agricultural machinery and supported the **design and production of high-end intelligent machinery suited to hilly and mountainous regions**. Building on this, the *Opinions on Key Work for Fully Promoting Rural Revitalization in 2022* (State Council, 2022) identified gaps in agricultural machinery innovation and urged coordinated efforts to address them. Key priorities included accelerating the research and manufacturing of large-scale machinery, small-scale equipment tailored for hilly and mountainous regions, and advanced intelligent systems, supported through long-term and stable national research programs.

In 2023, the *Opinions on Key Work for Fully Promoting Rural Revitalization in 2023* (State Council, 2023) further emphasized the rapid development of large-scale intelligent agricultural machinery, small-scale equipment for hilly and mountainous areas, and specialized horticultural machinery. It also highlighted the integration of Beidou[1]-based intelligent monitoring terminals and assisted driving systems into agricultural machinery, leveraging China's satellite navigation technology to enhance precision and efficiency.

These policy measures have provided robust technical support and a strong foundation for advancing agricultural modernization and achieving rural revitalization goals.

[1] Beidou is a Chinese satellite navigation system, comparable to the GPS navigation system developed by the U.S.

(2) Breakthroughs and industrialization of agricultural robots

Agricultural robots have become integral to the advancement of intelligent agriculture. From the *2019 Digital Agriculture and Rural Development Plan* to the *2021 14th Five-Year Plan for the Development of the Robotics Industry*, policy initiatives have consistently emphasized the research, development, and application of key agricultural robotics technologies.

The *Digital Agriculture and Rural Development Plan (2019–2025)* (Ministry of Agriculture and Rural Affairs of the People's Republic of China & Cyberspace Administration of China, 2019), jointly issued by the Ministry of Agriculture and Rural Affairs and the Central Cyberspace Affairs Commission, highlights the strategic importance of developing agricultural robotics. The plan calls for the creation of a new generation of agricultural robots characterized by high adaptability, cost-efficiency, and intelligent decision-making capabilities, while accelerating efforts to standardize and industrialize these technologies.

The *14th Five-Year Plan for the Development of the Robotics Industry* (Ministry of Industry and Information Technology of the People's Republic of China and 14 other departments) further underscores the critical role of robotics in agriculture. It prioritizes the development and deployment of robots for specialized tasks, including orchard weeding, precision crop protection, pruning, harvesting, sorting, and livestock management. In livestock operations, these robots perform essential functions such as feeding, inspection, sludge removal, net cleaning, and disinfection. The plan aims to drive the evolution of agricultural robots toward greater intelligence, enhanced functionality, and broader applications.

These strategic initiatives are paving the way for the integration of robotics into agriculture, fostering innovation, and enabling the sector's transition to smarter, more efficient practices.

2.3 Financial and technical support

To drive advancements in smart agricultural technologies, the Ministry of Agriculture and Rural Affairs issued the *Guiding Opinions on Vigorously Developing Smart Agriculture* in 2024 (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2024). This document emphasizes the urgent need to accelerate research and development of technological equipment, prioritize critical issues, and establish a roadmap to address major challenges. Key focus areas include R&D efforts for agricultural sensors, specialized chips, core agricultural algorithms, and agricultural robots. The document also promotes the integration of cutting-edge technologies such as large AI models and big data analytics into the agricultural and rural sectors.

To ensure robust funding support, the Ministry has implemented proactive measures. In 2021, the General Office of the Ministry of Agriculture and Rural Affairs and the Comprehensive Department of the National Rural Revitalization Administration issued the *Guidelines for Social Capital Investment in Agriculture and Rural Areas* (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2021), encouraging the extensive participation of private capital to boost smart agriculture development.

Building on these efforts, the *Smart Agriculture Action Plan (2024–2028)* (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2024) was introduced in 2024. This plan outlines a coordinated policy framework leveraging existing projects and resources to support smart agriculture. It aims to integrate various funding channels to improve smart agriculture infrastructure and accelerate technological breakthroughs in critical areas.

Table 1: Policies related to smart agriculture issued by China

Date	Department	Policy name	Main content
May 2016	National Development and Reform Commission and three other departments	Three-Year Action Plan for "Internet+" and Artificial Intelligence	This plan emphasizes the innovative use of smart products in agriculture, promoting demand-driven demonstrations of intelligent unmanned systems to enhance their capabilities.
July 2017	State Council	New Generation Artificial Intelligence Development Plan	This plan calls for integrating AI into agriculture, emphasizing pilot projects and demonstrations, such as intelligent sensing systems, smart equipment, remote sensing networks, and data-driven decision-making platforms.
January 2019	Ministry of Agriculture and Rural Affairs, Cyberspace Administration of China	Digital Agriculture and Rural Development Plan (2019–2025)	This plan focuses on accelerating the digital transformation of agriculture and rural areas, promoting intelligent upgrades in production, operations, and management. It prioritizes smart agriculture, advocating for technologies like agricultural IoT, big data, and AI.
July 2020	National Standardization Administration and four other departments	Guidelines for Building a National New Generation AI Standards System	The guidelines call for building a standard system covering AI fundamentals, key technologies, and industry applications, focusing on core technologies like smart chips and machine learning. They support application standards in areas such as smart agriculture.
February 2021	State Council	The Central Committee of the Communist Party of China and the State Council on Fully Promoting Rural Revitalization and Accelerating Agricultural and Rural Modernization	This document calls for enhancing the independent development capabilities of agricultural machinery and supporting the design and production of high-end intelligent machinery and equipment suited for hilly and mountainous regions.
April 2021	Ministry of Agriculture and Rural Affairs of the People's Republic of China	Guidelines for Social Capital Investment in Agriculture and Rural Areas	The policy encourages social capital to invest in agricultural modernization, rural infrastructure, and public services, supporting participation in projects like high-standard farmland, smart agriculture, and agricultural product processing and distribution.

November 2021	State Council	14th Five-Year Plan for Promoting Agricultural and Rural Modernization	The plan calls for accelerating agricultural technological innovation, promoting mechanization, intelligence, and digitalization of agriculture;
December 2021	Ministry of Agriculture and Rural Affairs	14th Five-Year Plan for National Agricultural and Rural Science and Technology Development	The plans calls for accelerating research and development of core robotics technologies, enhancing intelligence and high-end capabilities, and promoting the deep integration of robots in agriculture.
December 2021	Ministry of Industry and Information Technology and 14 other departments	14th Five-Year Plan for the Development of the Robotics Industry	The plan promises to firmly safeguard the two bottom lines of ensuring national food security and preventing the large-scale relapse into poverty by accelerating agricultural technological innovation and promoting agricultural mechanization, intelligence, and green development.
January 2022	State Council	Opinions on Key Work for Fully Promoting Rural Revitalization in 2022	The document vows to uphold national food security and prevent a large-scale relapse into poverty. It vows to advance rural development, construction, and governance, while accelerating agricultural innovation to promote mechanization, intelligence, and green development
July 2022	Ministry of Science and Technology and five other departments	Guidelines on Accelerating Scenario Innovation to Promote High-Quality AI Applications for Economic Development	In the agricultural sector, prioritize exploring smart applications, including autonomous agricultural machinery, agricultural geographic information engines, smart farms, digitalized industrial chain management, drone plant protection, and agricultural product quality and safety monitoring.
August 2022	Ministry of Science and Technology	Notice on Supporting the Construction of New-Generation Artificial Intelligence Demonstration Application Scenarios	The document encourages support of AI demonstration application scenarios in key sectors such as smart manufacturing, healthcare, agriculture, transportation, and cities.
January 2023	State Council	Opinions on Key Work for Fully Promoting Rural Revitalization in 2023	The document calls for ensuring stable supply of grain and essential agricultural products, accelerating innovation in agricultural science and technology, and enhancing the levels of mechanization,

			intelligence, and green development in agriculture.
October 2024	Ministry of Agriculture and Rural Affairs	Smart Agriculture Action Plan (2024–2028)	The plan seeks to promote the intelligent transformation of the entire agricultural production chain, advance the application of smart agricultural machinery and agricultural robots, and establish smart agriculture demonstration zones.
October 2024	Ministry of Agriculture and Rural Affairs	Guiding Opinions on Vigorously Developing Smart Agriculture	The document calls for enhancing agricultural production and value chain efficiency by promoting intelligent planting, breeding, and fisheries, advancing agricultural technology and equipment R&D, and establishing standardized systems to support sustainable and efficient development.

3. Global tech giants in the AI agriculture landscape

Amid the rapid expansion of digital agriculture, leading technology companies have made significant strides in the AI-agriculture sector, driving innovation and supporting sustainable development. These companies play a pivotal role in advancing technological solutions by offering cutting-edge tools that help farmers improve productivity, minimize resource waste, and transition toward green, sustainable agricultural practices. They have emerged as key drivers in accelerating agricultural modernization.

3.1 European tech innovations in AI-driven agriculture

In Europe, leading tech companies are driving innovation in smart agriculture through advanced platforms and solutions. **Bayer**, via its Climate FieldView platform, harnesses AI and big data to deliver precision farming tools. This platform helps farmers optimize planting, irrigation, and fertilization strategies, leading to higher crop yields and improved quality while minimizing resource use (Bayer, 2024). **Bosch** specializes in smart agricultural machinery and precision irrigation systems, integrating automation and sensor technologies to enhance efficiency and intelligence in field management (Quigley, 2023). The company has achieved significant success in water-saving irrigation and crop health monitoring. **Ericsson** leverages IoT and 5G technologies to develop smart agriculture solutions, enabling high-speed connectivity and real-time data analysis (Strickland et al., 2022). These solutions assist farmers with precise crop management, weather forecasting, and optimized land use. Similarly, **Nokia**, through its Nokia Smart Agriculture platform, combines sensor technology with cloud computing to enable real-time monitoring of environmental factors such as soil moisture and temperature. This facilitates precise irrigation control and crop management, advancing sustainable and efficient agricultural practices.

3.2 Chinese breakthroughs in AI agriculture

In China, leading tech companies are transforming agriculture with AI-driven solutions. **Alibaba's** Agriculture Brain uses AI and big data to help farmers optimize planting, irrigation, and fertilization, enhancing yields while reducing resource use (Alibaba Cloud, 2018). **Huawei** focuses on smart farming equipment and IoT technologies, integrating sensors and drones for precise operations such as greenhouse management and fertilization (Huawei, 2017). **DJI** applies its drone expertise to precision spraying, crop monitoring, and field mapping, increasing efficiency and reducing chemical use (DJI, 2024). **Pinduoduo** leverages AI to improve supply chains, guiding planting decisions and promoting faster delivery and product standardization (Li et al., 2021). Together, these innovations are advancing sustainable and efficient agriculture in China.

3.3 Advancements by U.S. companies in AI-driven agriculture

In the United States, companies are harnessing AI to transform agriculture. **Bayer-Monsanto**, through its Climate Corporation platform, uses AI, machine learning, and big data to provide customized precision farming solutions for farmers. The platform analyzes weather data, soil conditions, and crop cycles to optimize planting, irrigation, and fertilization, increasing crop yield and quality while minimizing environmental impact. **PrecisionHawk**, a leading agricultural tech company, employs drones and AI to capture high-resolution imagery and provide actionable insights. This technology enables precise monitoring, pest identification, and crop health assessment, enhancing farm management accuracy and responsiveness. **Google** is also advancing agricultural innovation through AI. Its Alphabet X division explores solutions to address challenges like climate change, helping farmers adapt planting, irrigation, and harvesting practices to shifting pest patterns and weather conditions. Google has also developed AI tools for soil and pest detection, as well as farming robots for seeding, cultivating, and harvesting. These innovations enhance productivity, reduce chemical use, and promote sustainable, intelligent farming practices.

3.4 Global leaders in sustainable AI agriculture

Large tech companies worldwide are embracing the wave of AI-powered agriculture with unprecedented enthusiasm. Their efforts are driving rapid advancements in digital agricultural technologies and providing strong support for the transformation of farming into a more intelligent, sustainable, and efficient industry. From Europe to Asia and the Americas, these innovators are making a global impact. By focusing on precision agriculture, smart farming equipment, efficient irrigation systems, drone monitoring, and supply chain optimization, they are not only boosting crop yields and quality but also reducing resource consumption and environmental impact. These developments are paving the way for sustainable agricultural practices on a global scale.

4. Application of artificial intelligence in agriculture

4.1 AI applications in crop production

AI is being applied in several key areas of crop production, including smart farming, precision agriculture, pest and disease management, and intelligent breeding. These innovations have significantly enhanced the efficiency and productivity of crop production (Javaid et al., 2023).

(1) Smart farming and precision agriculture

AI has enabled the development of smart technologies, transforming precision agriculture into a practical reality (Ampatzidis et al., 2020). The **FarmSight system, developed by John Deere**, integrates AI, drones, and ground sensors to provide farmers with real-time soil analysis, fertilization recommendations, and irrigation optimization (John Deere, 2013). This technology has helped reduce fertilizer usage, boost yields, and minimize environmental pollution in the U.S. Midwest's soybean and corn regions.

In the European Union, **COPA-COGECA** is working to promote precision agriculture (Copa-cogeca, n.d.), enabling farmers to optimize irrigation, fertilization, and planting strategies. This has led to a 25% reduction in fertilizer use, a 30% reduction in water consumption, and a 10-15% increase in crop yields (Getahun et al., 2024).

Microsoft's Azure Data Manager for Agriculture facilitates the integration and analysis of diverse agricultural data sources, supporting precision farming, supply chain optimization, and sustainability monitoring (Microsoft, 2024). By leveraging sensors, satellite imagery, and weather data, the platform enables farmers to optimize planting, irrigation, and fertilization strategies. It also enhances supply chain transparency by tracking agricultural products from farm to market and monitoring storage conditions.

Tencent's iGrow model utilizes IoT sensors, AI algorithms, and agricultural expertise to improve precision farming, optimize resource usage, and promote sustainable practices (Tencent, 2020). The model offers real-time environmental data monitoring and provides actionable insights for optimized planting and cultivation strategies. Successfully piloted in solar greenhouses in Liaoning, China, iGrow demonstrated increased yields and profitability (Cao et al., 2022).

Alibaba Cloud's ET Agricultural Brain is a digital agricultural management platform that integrates AI, IoT, and big data technologies (Alibaba Cloud, 2018). It supports smart planting, full lifecycle traceability, and data-driven decision-making, empowering farmers to boost efficiency and foster sustainability. In collaboration with Haisheng Group, the platform helped reduce costs by over 2,000 RMB per mu[2] in apple orchards while improving management efficiency. In pig farming, image recognition technology lowered piglet mortality by 3%, thereby enhancing overall farming productivity and operational outcomes (Alibaba Cloud, 2018).

(2) Pest and disease management

AI has significantly improved pest and disease management, making farm operations more efficient. The **Plantix app, developed by the German company PEAT**, uses AI and deep learning (Tibbetts, 2024). By capturing images of plant diseases with a smartphone, the app can diagnose the issue and suggest solutions. It is widely used in India, where it has helped farmers reduce crop losses by 20%. In China, the **"Tianzhi-1" project** combines satellite remote sensing with AI to predict the spread of pests and diseases (Wang et al., 2024). This allows farmers to take preventive measures in advance. In 2019, the system successfully predicted an outbreak of rice planthopper in Yunnan Province. This early warning helped reduce losses and safeguard food security.

(3) Smart breeding

AI has optimized breeding techniques, allowing for more precise development of new crop varieties. The **Corteva Agriscience platform, developed by DuPont Pioneer**, uses AI to analyze climate, soil, and planting history data (DuPont, 2019). Based on these analyses, the platform has developed drought-resistant and disease-resistant seed varieties. In trials in Texas, the new corn variety increased yields by 15%, even under extreme drought conditions. In China, **AI-assisted gene editing for rice breeding, developed by a team from Huazhong Agricultural University**, is used to identify key genes that impact rice yield (Zhu et al., 2024). This technology has enabled the development of high-yield, high-quality rice varieties.

[2] Mu is a unit of area measurement used primarily in China. It is equivalent to 1/15 of a hectare, or approximately 666.67 m².

4.2 AI applications in animal husbandry

(1) Smart livestock farms

Smart management has significantly enhanced the efficiency and profitability of livestock farms (Melak et al., 2024). Dutch company **Lely's milking robots** monitor cow behavior in real time (Lely, n.d.). AI analyzes the data to assess health and adjust milking frequency, ensuring optimal conditions. This technology is widely used in dairy farms across Europe, **increasing milk production by 20%**. In China, **JD Agriculture uses AI cameras to monitor pig farms** (Wee and Chen, 2019). The system tracks changes in weight, behavior, and health, and alerts staff if abnormal behavior is detected, enabling timely intervention. This helps control disease spread and reduces economic losses. In Chile, **BioMar Chile**, a marine biotechnology company, uses AI, underwater cameras, and sensors to monitor salmon behavior (Hagedorn, 2021). The system optimizes feeding times and amounts, improving fish quality and saving over 15% on feed costs annually.

(2) Animal health monitoring

AI-based health monitoring systems help reduce the risk of diseases in animals. The **See Tree platform from Israel**, initially designed for fruit tree monitoring, has been adapted for animal health management (Atar, 2022). Its multispectral cameras detect subtle changes in animal skin, predicting potential health risks. In dairy farms, See Tree has helped identify early cases of mastitis, enabling treatment to begin two weeks earlier. The system can also detect respiratory diseases early, allowing for timely intervention.

(3) Feed management

AI optimizes feed distribution, reducing costs and improving efficiency. **Cargill's AI system** adjusts feed ratios based on animal weight, metabolic needs, and weather conditions (Byrne, 2022). It is widely used in cattle farms across South America, helping farmers **reduce feed usage by 12% while maintaining production**. **Chia Tai Group**, an investment holding company of Thailand's Charoen Pokphand Group, uses AI in its poultry farms (International Monetary Fund, 2023). The system collects data on chicken behavior, body temperature, and environmental conditions through cameras and sensors. This data helps identify individual chickens and their growth stages. Using nutritional models, the system predicts the nutritional needs at each stage and adjusts the feed formula accordingly. It also tracks body weight and feed conversion rates to assess and improve performance, enhancing both farming efficiency and economic returns.

4.3 AI in agriculture: a holistic impact

The application of AI in agriculture has had far-reaching effects. AI has improved crop and livestock yields and quality through precision agriculture and smart management. It has optimized production processes, helping farmers achieve higher economic returns. AI has also enhanced resource efficiency; precision irrigation and feed management have reduced the waste of water, fertilizers, and feed, supporting sustainable and green agriculture. Additionally, AI has strengthened agricultural risk management by providing real-time monitoring and forecasting, reducing losses from pests, diseases, and other risks. AI has accelerated the breeding and adoption of new crop varieties, offering innovative solutions to food security and agricultural modernization. These developments are driving agriculture toward greater efficiency, intelligence, and sustainability.

Beyond improving productivity and profitability, AI has also made significant contributions to resource conservation, risk management, and technological innovation. These changes are accelerating the transition from traditional to modern agriculture. AI is providing strong support for global food security, environmental protection, and sustainable socio-economic development. AI-driven agriculture will be a crucial pillar in addressing future challenges. However, the rapid rise of AI in the agricultural sector has also raised several concerns. Chapter 5 will provide an in-depth analysis of the challenges currently facing AI development in this field.

Table 2: Overview of the environmental impacts of smart technologies in agriculture

Technology	Function	Environmental impacts
Intelligent planting and precision agriculture	Conduct targeted, timely, and precise fertilization; monitor soil and crop water needs in real-time, enabling precise control of water usage and optimization of irrigation schedules.	Prevent resource waste and environmental pollution caused by excessive fertilization; conserve water resources and improve resource utilization efficiency.
Pest and disease control	Accurately identify pests and diseases for targeted pesticide application; predict the spread of pests and diseases before outbreaks to provide proactive prevention recommendations.	Issue early warnings to minimize crop losses and reduce resource waste; decrease pesticide usage to lower the environmental impact of chemical substances.
Smart breeding	Utilize gene selection tools to precisely identify target genes; develop drought-resistant and disease-resistant varieties through targeted breeding.	Enhance breeding efficiency; reduce the use of fertilizers and pesticides, thereby minimizing environmental pollution.
Animal health monitoring	Enable early warning and prevention of diseases; reduce the use of antibiotics and other medications through precise administration of drugs and vaccines.	Enhance production efficiency while minimizing chemical residues in soil and water by reducing feed waste; curb the overuse of medications and lowering animal mortality associated with diseases.
Smart feeding management	Precisely control the amount and timing of feed delivery; optimize feeding strategies using historical data and predictive models.	Reduce feed waste and greenhouse gas emissions during livestock farming; optimize the use of feed and water resources, lowering the environmental impact of livestock waste.

5. Future opportunities and challenges

5.1 Future opportunities

(1) Government policy guidance and support

Governments around the world are actively promoting the use of AI in agriculture and have introduced a range of policies to accelerate the development and deployment of agricultural AI technologies (Bhat & Huang, 2021). On one hand, governments provide direct financial subsidies to reduce research and development costs and market risks for agricultural technology companies. These subsidies cover areas such as technology development, equipment procurement, market promotion, and user training, ensuring smooth implementation and widespread adoption of the technology. Special funds have also been established to support startups and innovative projects in agricultural AI, encouraging more private investment in the sector.

On the other hand, governments offer tax incentives and loan subsidies to alleviate the financial burden on agricultural technology companies. For example, qualifying companies benefit from income tax reductions and VAT exemptions. Financial products such as low-interest loans and risk compensation funds help reduce financing costs and stimulate innovation. Furthermore, governments are promoting the creation of AI innovation platforms and public-private partnerships. These initiatives facilitate collaboration between agricultural technology companies, universities, and research institutions, helping to integrate AI technologies into agricultural production. Through field demonstrations, technical training, and result showcases, governments are guiding farmers to adopt new technologies, thereby enhancing agricultural productivity and quality and laying a strong foundation for the digital transformation of agriculture.

Looking ahead, to address challenges posed by AI in areas such as employment, data privacy, and intellectual property, governments should establish clear regulatory frameworks. These frameworks will ensure the fair use of technology and protect the rights of farmers and small and medium-sized enterprises. To safeguard data security and privacy, governments can strengthen oversight mechanisms to prevent misuse and monopolistic practices, thus protecting the interests of smallholder farmers. Through these actions, governments will create a solid foundation for achieving efficient, green, and sustainable agricultural development.

(2) International cooperation and exchange

International cooperation is essential for advancing agricultural AI technologies. As globalization progresses, agricultural technology companies around the world are seeking cross-border partnerships to address technological challenges and share best practices. **An example of this is the "China-Germany Agricultural Modernization Demonstration Farm" project in Yancheng, Jiangsu province**, which concluded in 2022. This initiative brought advanced German agricultural technologies and management practices to China, showcasing the potential of AI in precision farming, smart irrigation, and pest monitoring. Through this project, Chinese agricultural companies were able to learn from Germany's expertise and apply it to local practices. This not only elevated the technological level of Chinese agriculture but also promoted the localization and innovation of AI technologies.

Additionally, both countries have strengthened cooperation through agricultural innovation forums and technical workshops. These events have provided a platform for sharing new technological achievements and facilitated deeper collaboration in areas such as technology standards, talent development, and market expansion. Through these efforts, China and Germany have contributed to the global exchange and optimal allocation of agricultural innovation resources, helping to foster the growth of smart agriculture worldwide.

(3) Market demand and consumer upgrades

As living standards improve, consumers are placing increasing emphasis on the safety and quality of agricultural products. There is also a growing demand for efficient, sustainable, and environmentally friendly agricultural practices. AI plays a crucial role in meeting these demands (Saha et al., 2024). When combined with blockchain technology, AI ensures the traceability of agricultural products. Machine vision systems help assess the maturity of produce, ensuring quality and safety to meet consumer expectations for high-quality goods. Additionally, AI is boosting agricultural efficiency through precision farming, smart machinery, and the recycling of agricultural waste. These innovations reduce the use of fertilizers and pesticides, promote ecological balance, and pave the way for more sustainable agricultural development.

(4) Labor shortages

As urbanization accelerates in China, rural labor continues to migrate to urban areas, resulting in a decline in the agricultural workforce and an aging population. This shift poses a significant challenge to agricultural production due to labor shortages. In response, AI provides innovative solutions. Through the use of smart machinery, automated irrigation systems, and AI-powered management platforms, farmers can perform tasks such as planting, fertilizing, and harvesting more efficiently, reducing the need for manual labor. These advancements help alleviate labor shortages, boost overall agricultural productivity, and bring new momentum to agricultural modernization.

5.2 Key challenges in AI agriculture

(1) Technology maturity

While AI has made notable progress in agriculture, particularly in areas like pest and disease detection and precision farming, several technological challenges remain. These include improving accuracy, enhancing management efficiency, and addressing the complexities of diverse agricultural environments. Additionally, as technology evolves rapidly, AI systems are frequently updated. This creates a need for farmers to continuously learn and adapt to new technologies, which can be a significant challenge for many.

(2) High costs and long investment payback periods

Implementing AI in agriculture requires significant financial investment, covering costs such as technology development, equipment, system integration, and ongoing maintenance. For agricultural producers, especially small-scale farmers, these expenses can be a heavy burden. Additionally, the cyclical nature of agricultural production, combined with the early-stage adoption of AI, results in long payback periods for investments. This can be challenging for investors who are seeking short-term returns. The extended payback period also increases investment risks, making some producers hesitant to invest in AI technologies.

(3) Low acceptance among farmers and lack of skills

Some farmers, influenced by traditional beliefs, are slow to adopt new technologies, particularly AI. This reluctance creates a barrier to the widespread implementation of AI in agriculture. Additionally, many farmers have limited education and lack the necessary skills to fully utilize AI. As a result, they struggle to apply these technologies effectively, which limits their ability to improve productivity and quality. In recent years, the Chinese government has prioritized agricultural innovation, actively promoting the integration of AI with traditional farming practices to improve efficiency and competitiveness. AI has helped increase productivity, conserve resources, protect the environment, and enhance crop quality, driving sustainable agricultural development.

(4) Reduction in employment opportunities

The widespread adoption of AI and automation technologies may replace some agricultural labor, particularly in rural areas, potentially exacerbating employment pressures and triggering social instability. Balancing technological progress with the protection of jobs, and ensuring that farmers are not marginalized during this technological transformation, has become a critical issue that requires urgent attention from both the government and society.

(5) Technological restrictions and international competition

As global technological competition intensifies, the rivalry between China and the United States in areas such as semiconductors, digital technologies, and AI continues to escalate. Technology restrictions and export controls may impact the promotion and application of AI in agriculture. For example, limited access to advanced chips could delay the development and widespread adoption of smart agricultural equipment, slowing the pace of agricultural modernization. To address this, fostering domestic innovation, strengthening research and development of core technologies, and localizing industrial supply chains are crucial strategies. Additionally, enhancing international cooperation and dialogue, as well as overcoming technological barriers, are key to achieving breakthroughs and advancing the intelligent transformation of agriculture.

(6) Data compatibility and system integration

During the process of agricultural modernization, data compatibility and system integration present significant challenges. Agricultural sensors, devices, and software often come from different manufacturers, each with varying data formats and system architectures. This makes data integration and coordination difficult. For example, integrating GPS navigation systems, weather data, and soil monitoring data into a single AI platform remains a key technical issue that still needs to be addressed.

(7) Data security and privacy protection

In smart agriculture, the collection, storage, processing, and analysis of data involve large amounts of sensitive information, including crop growth data, soil conditions, and agricultural machinery operation records. While this data is vital for agricultural production, it also raises concerns about personal privacy and business confidentiality. In China, challenges regarding data security in smart agriculture are notable. Existing security measures often struggle to counter increasingly complex cyberattacks, and rural areas have relatively weak network infrastructure, heightening the risk of data breaches. Furthermore, data transmission in smart agriculture requires multiple protocols to work together, but some of these lack specialized data protection mechanisms, leading to potential security risks during data transfer to agricultural big data platforms.

At the same time, the development of smart agriculture raises ethical concerns. First, the ownership and usage rights of data are often unclear, potentially leading to the misuse or unauthorized use of farmers' data and infringing on their rights. Second, farmers frequently lack a full understanding of how their data will be used or shared, and insufficient transparency may erode trust. Additionally, large technology companies or platforms could monopolize agricultural data resources due to their technological advantages, increasing market inequality and disadvantaging small farmers. Lastly, the leakage of data privacy could be exploited for improper purposes, such as business competition or fraud, putting farmers' privacy and security at risk.

The application of AI in agriculture offers unprecedented opportunities for the development of modern agriculture, but it also presents numerous challenges. From government policy guidance and international cooperation to market demand, AI is driving improvements in agricultural productivity, resource efficiency, and product quality. However, challenges remain, including insufficient technology maturity, high investment costs, low farmer acceptance, job reductions, international technological competition, data compatibility issues, and concerns over data security and privacy protection. These challenges require collective efforts from governments, businesses, and society to address.

In the future, through enhanced technological innovation, improved policy support, strengthened international cooperation, better farmer skills development, and the establishment of robust data security and ethical oversight mechanisms, AI in agriculture can contribute to achieving efficient, green, and sustainable development, while balancing technological progress with social equity. This will inject new momentum into global agricultural modernization.

6. AI in agriculture: case studies from China

Case 1: Sheng Mu Organic Dairy in China

China Sheng Mu Organic Dairy Co., Ltd. (中国圣牧有机奶业有限公司) is a leading producer of organic dairy products in China, with a robust foundation in ranching resources. The company focuses on the production and supply of high-quality organic milk, and in response to increasing consumer demands for food safety and quality, Sheng Mu has actively pursued digital transformation. **By introducing AI and big data analytics, the company has optimized its ranch management processes, improved operational efficiency, and ensured high milk quality.** This digital transformation has not only enhanced Sheng Mu's competitiveness but also set a model for the smart development of the dairy industry.

(1) Big data platform and AI technology

Sheng Mu has partnered with Tencent Cloud to build an integrated management system based on a big data platform, incorporating AI and blockchain technologies. This system enables 360-degree intelligent monitoring and traceability throughout the dairy production process, from breeding to output. It collects and analyzes real-time data on cow health, milk production, and feed consumption, empowering managers to make informed decisions. For instance, the system automatically adjusts milking schedules based on each cow's milk production curve to ensure stable milk quality. Additionally, blockchain technology enhances food safety traceability, allowing consumers to scan product QR codes to trace the entire production process. This system has improved ranch management efficiency, optimized resource allocation, reduced operational costs, and increased both milk yield and quality. Overall, it has strengthened operational effectiveness and enhanced market competitiveness.

(2) Intelligent feeding and health monitoring

Sheng Mu has introduced AI visual technology for ranch management, which automatically identifies cows and integrates the data with other business systems. This technology enables the system to match milk production information accurately, addressing issues such as statistical errors caused by cows being misaligned or incorrectly positioned. Additionally, Sheng Mu is developing various AI models for disease early warning, body condition scoring, calving prediction, and feed intake analysis. These models allow for comprehensive, real-time monitoring and management of cow health. For example, by analyzing body temperature, activity levels, and feed intake, the system can provide early alerts for diseases such as mastitis, enabling timely intervention. This technology has improved ranch management intelligence, enhanced cow health, and boosted milk production efficiency.

(3) Digital management platform

Sheng Mu has deployed the advanced **SAP-ERP system** and the latest **SAP HANA/4 system**, integrating logistics, cash flow, and information flow to standardize internal management. In supply chain management, the company has reduced overall inventory through better production and sales coordination, resulting in an 8.6% improvement in inventory turnover. In production management, the system automates the collection and analysis of herd structure and feeding data, while also calculating daily feeding costs.

This helps managers identify and address issues promptly. In financial management, the integration of procurement, production, and sales processes has automated 90% of financial report consolidation, improving time efficiency by 50%. This digital management platform has not only enhanced ranch operational efficiency but also provided reliable data for strategic decision-making (Economic Daily, 2023).

(4) Smart ranch environmental control

With the integration of big data and AI technologies, Sheng Mu has made significant strides toward comprehensive intelligent management of its ranches. The ranch is equipped with intelligent ventilation and cooling systems, automatic spraying systems, and automated environmental control systems that can monitor and adjust critical parameters such as temperature and humidity in real time, ensuring an optimal environment for the cows. For example, when the system detects high temperatures, it automatically activates the cooling spray system to ensure the cows remain comfortable. With AI technology, the ranch has achieved precise feeding and constant monitoring of cow health, improving both milk quality and yield. The use of these smart systems has not only improved the cows' living conditions but also reduced energy consumption, supporting the sustainable development of the ranch.

China Sheng Mu Organic Dairy has successfully achieved digital transformation by integrating AI, big data, and blockchain technologies into its ranch management. The company's big data platform and AI technology have enabled intelligent management across the entire production chain, improving operational efficiency and decision-making accuracy. The intelligent feeding and health monitoring system has optimized cow management, enhanced milk production efficiency, and reduced costs. The digital management platform integrates supply chain, production, and financial processes, improving operational effectiveness. Lastly, the smart environmental control system has created a more comfortable environment for the cows, enhancing milk quality and contributing to sustainable ranch development. Sheng Mu's digital transformation not only strengthens its competitiveness but also provides a replicable model for the dairy industry's smart upgrading, demonstrating the potential of technology in empowering agriculture.

Case 2: JD Farm's AI agricultural practices

As a leader in China's e-commerce industry, **JD Group is implementing multiple strategies to drive rural revitalization through e-commerce, smart logistics, and smart farming**. JD Farm, an important initiative aimed at empowering agricultural development with technology, is playing a key role in transforming modern agricultural production. By leveraging JD Group's expertise in big data, IoT, and AI, **JD Farm** is gradually driving the digital and technology-driven transformation of agriculture. The project is centered around the concept of "ecological agriculture, healthy dining," with the goal of establishing modern agricultural bases across the country. By promoting scientific planting, standardized production, and efficient transportation, it seeks to create a high-quality agricultural product supply chain.

(1) Precision farming

Precision farming is one of the core components of JD Farm's efforts to modernize agriculture. By integrating remote sensing technology, weather data, and soil monitoring, JD Farm has developed a digital model of the farmland, enabling precise management from planting to harvest. Remote sensing technology, including satellites and drones, captures high-resolution images of the farmland, providing real-time data on crop growth, soil moisture, and pest distribution. This data supports farm management decisions. Weather data, combined with forecasts and historical information, helps predict the impact of weather changes on crop growth, enabling farmers to optimize planting plans and mitigate risks from natural disasters. Additionally, JD Farm deploys soil sensors to monitor key parameters such as moisture, temperature, and nutrient content in real time, providing a scientific basis for accurate fertilization and irrigation. Using the digital model, JD Farm employs smart machinery for precise planting, variable fertilization, and intelligent irrigation, maximizing resource use, reducing waste, and promoting sustainable agricultural practices.

(2) Intelligent management

JD Farm has deployed IoT devices and AI algorithms to enable real-time monitoring and intelligent management of crop growth environments. Various sensors installed in the fields collect data on temperature, humidity, light, and carbon dioxide levels. This data is transmitted via wireless networks to the cloud, forming a comprehensive data network for the farm. Using machine learning and big data analytics, JD Farm analyzes the collected data to predict pest and disease outbreaks and track crop growth trends, providing farmers with scientific decision-making support. Based on AI analysis, JD Farm has developed early warning systems for pests and diseases, allowing farmers to take preventive actions in advance and reduce losses. Additionally, through intelligent control systems, JD Farm can automatically adjust the temperature, humidity, and light levels in greenhouses, optimizing conditions for crop growth and improving the efficiency and stability of agricultural production.

(3) Efficient operations

JD Farm uses blockchain technology and intelligent logistics systems to enable full traceability and efficient operations from farm to table. Blockchain is applied across all stages of planting, processing, transportation, and sales, recording information at each step to ensure data transparency and immutability. Consumers can scan QR codes to access complete product information, enhancing trust in product quality. Additionally, JD Farm leverages JD's extensive logistics network and AI algorithms to optimize delivery routes, ensuring that products reach consumers quickly and minimizing losses during transport. By analyzing market demand using big data, JD Farm optimizes inventory management and production planning, reducing operating costs and improving supply chain efficiency. This allows JD Farm to offer fresh, safe, and high-quality products to consumers while generating higher economic benefits for farmers.

By deeply integrating AI technology into agricultural production, JD Farm has not only improved production efficiency and product quality but also supported the increase of farmers' income and promoted rural revitalization. In the future, JD Farm is expected to become a major force in advancing the modernization of Chinese agriculture.

As outlined, the successful cases of JD Farm and China Sheng Mu Organic Dairy demonstrate the pivotal role of AI technology in advancing agricultural modernization in China. JD Farm has used digital tools to achieve precision planting, intelligent management, and brand marketing of agricultural products, setting a high-quality model for agricultural development. Meanwhile, China Sheng Mu has achieved intelligent ranch management through digital transformation, providing safer and higher-quality dairy products to consumers and offering valuable insights for the green transformation of animal husbandry. As AI technology continues to mature and its applications expand, Chinese agriculture is poised to enter a new era of smarter, more precise, and more efficient development.

References

1. Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. WW Norton & Company.

2. Marcus, G. (2020). The next decade in AI: Four steps towards robust artificial intelligence. *arXiv preprint* arXiv:2002.06177.

3. Pandu, U., Desai, K., Krupashree, R., Theerthana, T., & Raddy, G. (2022). A review on artificial intelligence and robots in agriculture. *Mysore Journal of Agricultural Sciences*, 56(2).

4. Redhu, N. S., Thakur, Z., Yashveer, S., & Mor, P. (2022). Artificial intelligence: A way forward for agricultural sciences. In *Bioinformatics in Agriculture* (pp. 641-668). Academic Press.

5. Lu, G., Li, S., Mai, G., Sun, J., Zhu, D., Chai, L., ... & Liu, T. (2023). Agi for agriculture. *arXiv preprint* arXiv:2304.06136.

6. CEMA. (2017). *Agriculture 4.0: Digital farming and the future of European farming*. European Agricultural Machinery Association. Retrieved from https://www.cema-agri.org/priorities/agriculture-4-0

7. Europe Artificial Intelligence in Agriculture Market Forecast to 2030 - Regional Analysis. Available at https://www.giiresearch.com/report/tip1567905-europe-artificial-intelligence-agriculture-market.html.

8. Christine Sirois. (2022). Global AI in Agriculture Market Size study, by Application (Weather Tracking, Precision Farming, Drone Analytics), by Deployment (Cloud, On-premise, Hybrid), and Regional Forecasts 2022-2032. Retrieved from https://www.giiresearch.com/report/bzc1490953-global-ai-agriculture-market-size-study-by.html.

9. Groher, T., Heitkämper, K., Walter, A., Liebisch, F., & Umstätter, C. (2020). Status quo of adoption of precision agriculture enabling technologies in Swiss plant production. *Precision Agriculture*, 21, 1327-1350.

10. Kendall, H., Clark, B., Li, W., Jin, S., Jones, G. D., Chen, J., ... & Frewer, L. J. (2022). Precision agriculture technology adoption: A qualitative study of small-scale commercial "family farms" located in the North China Plain. *Precision Agriculture*, 1-33.

11. Long, T. B., Blok, V., & Coninx, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: Evidence from the Netherlands, France, Switzerland, and Italy. *Journal of Cleaner Production*, 112, 9-21.

12. Vásáry, V. (2013). Simplification and Better Regulation in EU's Agricultural Policy. Available at SSRN 2237918.

13. Plieninger, T., Schleyer, C., Schaich, H., Ohnesorge, B., Gerdes, H., Hernández-Morcillo, M., & Bieling, C. (2012). Mainstreaming ecosystem services through reformed European agricultural policies. *Conservation Letters*, 5(4), 281-288.

14. Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–a review. *Agricultural Systems*, 153, 69-80.

15. Șerbănel, C. I. (2021, December). A panorama of digitalization tendencies in the European agriculture sector. In *Proceedings of the International Conference on Business Excellence* (Vol. 15, No. 1, pp. 352-363).

16. The Federal Government. (2020). *Artificial Intelligence Strategy of the German Federal Government*. Retrieved from http://www.ki-strategie-deustschland.de/files/downFortschreibung_KI-Strategie_engl.pdf?utm_source

17. European Commission AI Watch. (2020). *Germany AI strategy report*. Retrieved from https://ai-watch.ec.europa.eu/countries/germany/germany-ai-strategy-report_en

18. German Federal Ministry of Food and Agriculture (BMEL). (2021). More than 50 million euros for digital trial fields in the agricultural sector. Retrieved from https://www.bmel.de/EN/topics/digitalisation/digital-trial-fields.html?utm_source

19. National Science and Technology Council. (2023). *National artificial intelligence research and development strategic plan: 2023 update*. The White House. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2023/05/National-Artificial-Intelligence-Research-and-Development-Strategic-Plan-2023-Update.pdf

20. USDA. (2024). *USDA AI Compliance Plan FY2024*. Retrieved from https://www.usda.gov/sites/default/files/documents/usda-ai-compliance-plan-fy2024.pdf

21. National Institute of Food and Agriculture (NIFA). (n.d.). Artificial Intelligence. Retrieved from https://www.nifa.usda.gov/artificial-intelligence

22. Robinson, W. A. (2021). Climate change and extreme weather: A review focusing on the continental United States. *Journal of the Air & Waste Management Association*, 71(10), 1186-1209.

23. Zahniser, S., Taylor, J. E., Hertz, T., & Charlton, D. (2018). Farm labor markets in the United States and Mexico pose challenges for US agriculture.

24. Liu, X., Xu, Y., Sun, S., Zhao, X., Wu, P., & Wang, Y. (2022). What is the potential to improve food security by restructuring crops in Northwest China?. *Journal of Cleaner Production*, 378, 134620.

25. Agovino, M., Casaccia, M., Ciommi, M., Ferrara, M., & Marchesano, K. (2019). Agriculture, climate change, and sustainability: The case of EU-28. *Ecological Indicators*, 105, 525-543.

26. Nowak, B. (2021). Precision agriculture: Where do we stand? A review of the adoption of precision agriculture technologies on field crops farms in developed countries. *Agricultural Research*, 10(4), 515-522.

27. United Nations. (2024). *Governing AI for Humanity*. Available from https://www.un.org/sites/un2.un.org/files/governing_ai_for_humanity_final_report_en.pdf

28. Ampatzidis, Y., Partel, V., & Costa, L. (2020). Agroview: Cloud-based application to process, analyze, and visualize UAV-collected data for precision agriculture applications utilizing artificial intelligence. *Computers and Electronics in Agriculture*, 174, 105457.

29. Bhat, S. A., & Huang, N. (2021). Big Data and AI Revolution in Precision Agriculture: Survey and Challenges. *IEEE Access*, 9, 110209-110222.

30. National Development and Reform Commission. (2016). *Three-Year Action Implementation Plan for 'Internet Plus' Artificial Intelligence*. Retrieved from https://www.gov.cn/xinwen/2016-05/23/content_5075944.htm.

31. State Council. (2017). *Next Generation Artificial Intelligence Development Plan*. Retrieved from https://www.gov.cn/zhengce/zhengceku/2017-07/20/content5211996.htm.

32. National Standardization Administration. (2020). *Notice on the implementation of AI standards*. Retrieved from https://www.cnki.net

33. Ministry of Agriculture and Rural Affairs of the People's Republic of China. (2021). *Notice on the National Agricultural and Rural Science and Technology Development Plan for the 14th Five-Year Plan Period*. Retrieved from https://www.gov.cn/zhengce/zhengceku/2022-01/07/content_5666862.htm.

34. State Council. (2021). *Notice on the National Agricultural and Rural Science and Technology Development Plan for the 14th Five-Year Plan Period*. Retrieved from https://www.gov.cn/zhengce/content/2022-02/11/content_5673082.htm.

35. Ministry of Science and Technology of the People's Republic of China. (2022). *Guiding Opinions on Accelerating Scenario Innovation to Promote High-Quality Economic Development through High-Level Application of Artificial Intelligence*. Retrieved from https://www.gov.cn/zhengce/zhengceku/2022-08/12/content_5705154.htm.

36. Ministry of Science and Technology of the People's Republic of China. (2022). *Notice on Supporting the Construction of New Generation Artificial Intelligence Demonstration Application Scenarios*. Retrieved from https://www.gov.cn/zhengce/zhengceku/2022-08/15/content_5705450.htm.

37. State Council. (2021). *Opinions on Comprehensively Promoting Rural Revitalization and Accelerating the Modernization of Agriculture and Rural Areas.* Retrieved from https://www.gov.cn/gongbao/content/2021/content_5591401.htm.

38. State Council. (2021). *Opinions on Advancing the Key Tasks of Comprehensively Promoting Rural Revitalization in 2022.* Retrieved from https://www.gov.cn/gongbao/content/2022/content_5678065.htm.

39. State Council. (2021). *Opinions on Advancing the Key Tasks of Comprehensively Promoting Rural Revitalization in 2023.* Retrieved from https://www.gov.cn/zhengce/2023-02/13/content_5741370.htm.

40. Ministry of Agriculture and Rural Affairs of the People's Republic of China. (2019). *Digital Agriculture and Rural Development Plan (2019-2025).* Retrieved from https://www.cac.gov.cn/2020-01/21/c_1581145429704893.htm.

41. Ministry of Industry and Information Technology of the People's Republic of China. (2021). *14th Five-Year Plan for the Development of the Robotics Industry.* Retrieved from https://www.gov.cn/zhengce/zhengceku/2021-12/28/content_5664988.htm.

42. Ministry of Agriculture and Rural Affairs of the People's Republic of China. (2019). *Digital Agriculture and Rural Development Plan (2019-2025).* Retrieved from http://www.moa.gov.cn/gk/tzgg_1/tz/202001/t20200120_6336316.htm.

43. Ministry of Agriculture and Rural Affairs of the People's Republic of China. (2014). *Guiding Opinions on Vigorously Developing Smart Agriculture.* Retrieved from https://www.gov.cn/zhengce/zhengceku/202410/content_6983051.htm.

44. Ministry of Agriculture and Rural Affairs of the People's Republic of China. (2021). *Guidelines for Social Capital Investment in Agriculture and Rural Areas (2021).* Retrieved from https://www.gov.cn/zhengce/zhengceku/2021-05/08/content_5605362.htm.

45. Ministry of Agriculture and Rural Affairs of the People's Republic of China. (2024). *National Smart Agriculture Action Plan (2024-2028).* Retrieved from https://www.gov.cn/zhengce/zhengceku/202410/content_6983057.htm.

46. Bayer. (2024). Smart Solutions for a Sustainable Future. Retrieved from https://www.bayer.com/en/agriculture/digital-farming.

47. Quigley, N. (2023). Bosch BASF Smart Farming and AGCO announce joint development and commercialization of smart spraying capabilities. Retrieved from https://www.basf.com/global/en/media/news-releases/2023/04/p-23-159.

48. Strickland, S., Dalgleish, R., & Modesto, N. (2022). Making the 5G precision agriculture connection: Ericsson assumes a leadership role in advocating for the 5G networking that powers this revolutionary shift. Retrieved from https://www.ericsson.com/en/blog/north-america/2022/making-the-5g-precision-agriculture-connection.

49. Alibaba Cloud. (2018). Alibaba Cloud Launches ET Agricultural Brain at the Shanghai Computing Conference. Retrieved from https://www.alibabacloud.com/en/press-room/alibaba-cloud-launches-et-agricultural-brain-at-the-shanghai-computing?_p_lc=1.

50. Huawei. (2017). Feeding the world with connected farming. Retrieved from https://www.huawei.com/en/huaweitech/publication/winwin/plus-intelligence/feeding-the-world-connected-farming.

51. DJI. (2024). Agricultural Drone Industry Insight Report. Retrieved from https://www1.djicdn.com/cms_uploads/ckeditor/attachments/9171/03e81f9a23cf4df447b66c91c43d929a.pdf.

52. Li, M., Tsai, C., & Tran, L. T. T. (2021, August). A Case Study of Pinduoduo Strategy Based on SWOT Analysis. *In 1st International Symposium on Innovative Management and Economics (ISIME 2021)* (pp. 337-346). Atlantis Press.

53. John Deere. (2013). John Deere FarmSight: The future of farming is in your sight. Retrieved from https://www.crossimplement.com/upload/files/resources/john_deere_literature_rack/John%20Deere%20Farmsite%20Literature.pdf.

54. Copa-Cogeca. (n.d.). Smart / Precision Farming. Retrieved from https://copa-cogeca.eu/smart_farming

55. Getahun, S., Kefale, H., & Gelaye, Y. (2024). Application of Precision Agriculture Technologies for Sustainable Crop Production and Environmental Sustainability: A Systematic Review. *The Scientific World Journal*, 2024(1), 2126734.

56. Microsoft. (2024). World Agri-Tech 2024: Pioneering Agriculture Resilience with AI. Retrieved from https://www.microsoft.com/en-us/industry/blog/sustainability/2024/04/02/world-agri-tech-2024-pioneering-agriculture-resilience-with-ai/

57. Tencent. (2020). Tencent Harnesses AI for Smart Agriculture. Retrieved from https://www.tencent.com/en-us/articles/2201057.html

58. Cao, X., Yao, Y., Li, L., Zhang, W., An, Z., Zhang, Z., & Luo, D. (2022, June). iGrow: A Smart Agriculture Solution to Autonomous Greenhouse Control. *Proceedings of the AAAI Conference on Artificial Intelligence,* 36(11), 11837-11845.

59. Alibaba Cloud. (2018). Alibaba Cloud Launches ET Agricultural Brain at the Shanghai Computing Conference. Retrieved from https://www.alibabacloud.com/en/press-room/alibaba-cloud-launches-et-agricultural-brain-at-the-shanghai-computing?_p_lc=1

60. Alibaba Cloud. (2018). Alibaba Cloud Launches ET Agricultural Brain at the Shanghai Computing Conference. Retrieved from https://www.alibabacloud.com/en/press-room/alibaba-cloud-launches-et-agricultural-brain-at-the-shanghai-computing?_p_lc=1

61. Tibbetts, J. H. (2018). From Identifying Plant Pests to Picking Fruit, AI is Reinventing How Farmers Produce Your Food. Retrieved from https://www.eco-business.com/news/from-identifying-plant-pests-to-picking-fruit-ai-is-reinventing-how-farmers-produce-your-food/

62. Wang, G., Wan, G., Su, Z., Wang, Y., Jia, Y., Li, G., & Liang, S. (2024). High-Performance On-Orbit Intelligent Computing and Real-Time Services for Remote Sensing Satellites Based on Space Large-Scale Computing Power. *Aerospace Engineering,* pre-print.

63. DuPont. (2019). Corteva Agriscience™, Agriculture Division of DowDuPont, Provides Pipeline Update. Retrieved from https://www.investors.dupont.com/news-and-media/press-release-details/2019/Corteva-AgriscienceTM-Agriculture-Division-of-DowDuPont-Provides-Pipeline-Update/default.aspx

64. Zhu, W., Han, R., Shang, X., Zhou, T., Liang, C., Qin, X., ... & Li, L. (2024). The CropGPT Project: Call for a Global, Coordinated Effort in Precision Design Breeding Driven by AI Using Biological Big Data. *Molecular Plant,* 17(2), 215-218.

65. Lely. (n.d.). T4C Management System. Retrieved from https://www.lely.com/farming-insights/t4c-management-system/

66. Wee, S.-L., & Chen, E. (2019). China's Tech Firms Are Mapping Pig Faces. Retrieved from https://www.nytimes.com/2019/02/24/business/china-pig-technology-facial-recognition.html

67. Hagedorn, E. (2021). BioMar Chile Unveils New AI Service for Salmon Fillet Quality. Retrieved from https://www.aquafeed.com/newsroom/news/biomar-chile-unveils-new-ai-service-for-salmon-fillet-quality/

68. Atar, N. (2022). Leveraging Big Data Through Digitization: A Fruit Orchard Use Case. Retrieved from https://www.seetree.ai/blog/leveraging-big-data

69. Byrne, J. (2022). Cargill Leveraging AI Tools to Optimize Broiler Production. Retrieved from https://www.feednavigator.com/Article/2022/01/12/Cargill-leveraging-AI-tools-to-optimize-broiler-production/

70. International Monetary Fund. (2023). F&D Artificial Intelligence: AI in Practice. Retrieved from file:///C:/Users/%E5%88%98%E5%A5%A5/Downloads/ai-in-practice-case-studies-horn.pdf

71. Javaid, M., Haleem, A., Khan, I. H., & Suman, R. (2023). Understanding the Potential Applications of Artificial Intelligence in the Agriculture Sector. *Advanced Agrochem*, 2(1), 15-30.

72. Karunathilake, E. M. B. M., Le, A. T., Heo, S., Chung, Y. S., & Mansoor, S. (2023). The Path to Smart Farming: Innovations and Opportunities in Precision Agriculture. *Agriculture*, 13(8), 1593.

73. Liengpunsakul, S. (2021). Artificial Intelligence and Sustainable Development in China. *The Chinese Economy*, 54(4), 235-248.

74. Mark, R. (2019). Ethics of Using AI and Big Data in Agriculture: The Case of a Large Agriculture Multinational. *Orbit Journal*, 2(2), 1-27.

75. Melak, A., Aseged, T., & Shitaw, T. (2024). The Influence of Artificial Intelligence Technology on the Management of Livestock Farms. *International Journal of Distributed Sensor Networks*, 2024, 1-12.

76. Molotoks, A., Smith, P., & Dawson, T. P. (2021). Impacts of Land Use, Population, and Climate Change on Global Food Security. *Food and Energy Security*, 10(1).

77. Saha, S., Ghimire, A., Manik, M. M. T. G., Tiwari, A., & Imran, M. A. U. (2024). Exploring Benefits, Overcoming Challenges, and Shaping Future Trends of Artificial Intelligence Application in the Agricultural Industry. *The American Journal of Agriculture and Biomedical Engineering*, 6(7), 11-27.

78. Xu, Y., Li, C., & Wang, J. (2023). How Does Agricultural Global Value Chain Affect Ecological Footprint? The Moderating Role of Environmental Regulation. *Sustainable Development*, 31(4), 2416-2427.

79. Economic Daily. (2023). China Shengmu Organic Dairy Co., Ltd.: Digital Empowerment Builds Smart Pastures. Retrieved from https://finance.sina.com.cn/jjxw/2023-11-20/doc-imzvhhxq9305237.shtml

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