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Development Strategy of Smart Agriculture for 2035 in China

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Abstract: Smart agriculture is an important component of high-quality agricultural development and rural revitalization in China. Research pertaining to smart agriculture strategies is significant for developing a medium- and long-term scientific and technological layout and clarifying the development ideas and directions of smart agriculture in China. Based on rural revitalization, this paper summarizes the macro demand for high-quality agricultural development in smart agricultural science and technologies, as well as the strategic conception, strategic tasks, and development route of China's smart agriculture development toward 2035. Our findings show that developing smart agriculture can address the low quality, low efficiency, and weak competitiveness of China's agriculture sector. Furthermore, to replace human power with machines and human brains with computers, as well as promote the independent technological competitiveness of China's agricultural sector, an industrial technology system for smart agriculture that integrates biotechnology, information technology, and intelligent equipment should be established. Furthermore, smart agriculture should be promoted in a staged manner considering different business entities and industrial requirements. Specifically, China should strengthen its top-level design, promote technological research, establish a differentiated subsidy mechanism, integrate industry and village, and encourage applied talent training.
Keywords: smart agriculture; macro demand; overall conception; technical route; smart farm; informatization

1 Introduction

The new wave of scientific and technological revolution and industrial transformation, underpinned by information technology, is focused on reconstructing global scientific and technological innovation [1]. This involves transitioning countries from the traditional industrial era to the information era and advancing agriculture into a new era of digitization and intelligence simultaneously. As a product of the deep integration of information technology with agriculture, smart agriculture is a modern agricultural production mode with information, knowledge, and advanced equipment as its core elements. Notably, smart agriculture has become the benchmark of modern competitiveness in agricultural science and technology, as well as the basis of a new business structure for future agricultural development [2].

In recent years, China deployed a series of policies and performed a number of important application projects toward the development of smart agriculture, in which breakthroughs were achieved in smart agricultural technologies, such as agricultural expert systems, agricultural intelligent equipment, and BeiDou automatic navigation and driving. However, compared with developed countries, the application level of smart agriculture in China is generally low because of the late start and weak foundation of research and development (R&D). Moreover, core technologies, such as agricultural sensors, agricultural models, and key algorithms, are controlled by foreign countries. Owing to the lack of top-level

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designs in industry, the construction level of smart agriculture in various regions is non-uniform. Improving agricultural quality, efficiency, and competitiveness, as well as establishing smart agriculture, are vital to national development. After entering the new development stage, a systematic planning and scientific layout from a strategic perspective is urgently required for high-quality smart agriculture.

At the development stage, research pertaining to smart agriculture is focused on concept analysis, technical method innovation, technical output efficiency measurement, technical progress monitoring, and technical scheme demonstration [3–13]. Progress analyses from a macroeconomic perspective on China's smart agriculture development route to 2035 are insufficient, particularly for subjects of different sizes and the path option of different industrial types. As an academic contribution to the consulting project titled "Research on Smart Agriculture Development Strategy," this paper highlights the macroeconomic requirements for smart agriculture development using novel development patterns, proposes a general strategic concept, and discusses an industrial development route with key tasks to provide basic reference for theoretical and policy studies in the field of smart agriculture.

2 Demand analysis of smart agriculture development

2.1 Necessity to improve agricultural production efficiency

Recently, China's grain output has remained above 6×10^8 t for six consecutive years. However, owing to the small scale of agricultural production, low quality of products, and lagging investment in modern production factors, the production efficiency and comparative benefits of agriculture remain low in China. In particular, the average net profit per mu of three major grain crops (wheat, rice, and corn) has been negative since 2016 (Fig. 1). In 2019, China's average agricultural labor output value was only 4%, 5% in, 15%, and 17% of that in Israel, the United States, the European Union, and Japan, respectively (Fig. 2).

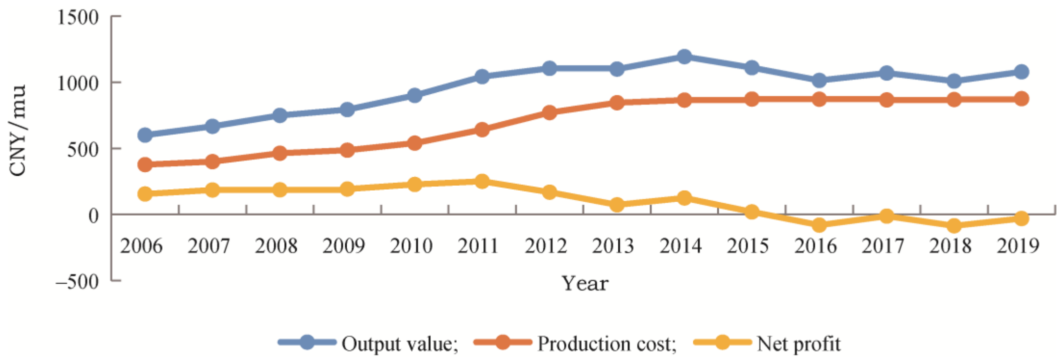

Fig. 1. Average net profit per mu of three major grain crops (wheat, rice, and corn) from 2006 to 2019.
Note: Data are source from the *Compilation of Cost Benefit of National Agricultural Products*; 1 *mu*≈666.7 m^2

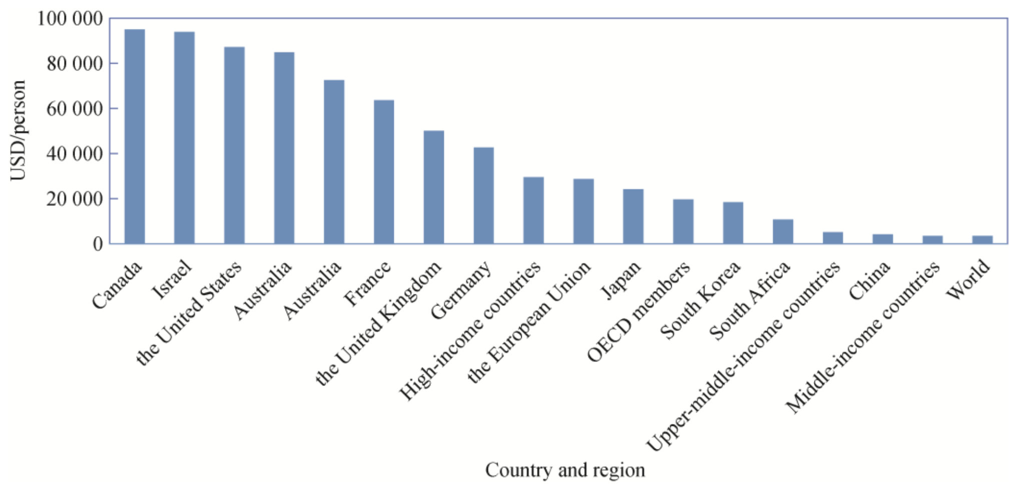

Fig. 2. Agricultural labor productivity in select countries and regions in 2019.
Note: Data are sourced from World Bank; OECD: Organization for Economic Cooperation and Development.

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Both technical demonstrations and application practices indicate that the implementation of smart agriculture affords accurate layouts, technical control, quality improvement, and increase in the efficiency of large agricultural industries. In addition, it is an effective approach for addressing low agricultural production efficiency. For example, via unmanned management of the entire growth cycle of large-scale vegetable production, the average labor input cost as well as the application amount of water, fertilizer, and pesticide at the vegetable farm at the Beijing Xiaotangshan National Precision Agriculture Research and Demonstration Base have reduced by approximately 55%, 25%, 31%, and 70%, respectively. To become a first-rate modernized agricultural country, China should accelerate the deployment of smart agriculture, promote intelligent equipment to replace labor, and improve production efficiency.

2.2 Necessity to improve utilization efficiency of agricultural resources

China's basic agricultural conditions include its large population, small land mass, uneven resource endowment, and frequent exposure to extreme climate disasters [14]. Additionally, China must control its non-point source pollution as well as prevent and control animal and plant diseases. According to the *2019 Environmental Soil Quality Report of China*, the proportion of high-quality Grade 1–3 cultivated land in China is only 27%, and the production rate of unenriched soil is approximately 50%, which is 20–30 percentage points lower than that of agriculturally developed countries. Although the Ministry of Agriculture and Rural Affairs has actively promoted conserving fertilizers and pesticides in agriculture in recent years, by the end of 2020, the utilization rate of chemical fertilizers and pesticides for China's three major grain crops had increased to more than 40%, which is 20 percentage points lower than that of agriculturally developed countries. In addition, the comprehensive utilization rate of livestock and poultry manure was over 20 percentage points lower than that of agriculturally developed countries.

Local practices demonstrate that the development of smart agriculture is conducive to improving the utilization rate of water, fertilizer, and pesticide. For example, the high-low gap precision applicator of wheat and corn can conserve 30%–40% of pesticide. China's restricted agricultural resources and environment limits its future developments. Owing to limited cultivated land and water resources, the mode of agricultural development should be changed, and the utilization efficiency of agricultural resources should be improved using smart agricultural engineering technology.

2.3 Necessity to ensure quality and safety of agricultural products

Owing to changes in lifestyle and consumption habits, the demand for high-quality, green, safe, and healthy agricultural products by urban and rural residents has increased. Food manufacturing involves multiple links and subjects, such as production, processing, circulation, and sales, which are affected by inputs, environment, technology, business models, and information asymmetry among producers, consumers, and regulatory authorities. Therefore, it is difficult to control the quality of agricultural products and the occurrence of food safety incidents despite repeated prohibitions, and this results in low public confidence in agricultural products.

According to the *2019 Survey Report on Urban Public Safety in China*, the Food Safety Index for Urban Residents in 2019 was only 0.4972 because approximately 66% of the respondents had experienced at least one food safety incident in the past year, and the disclosure of illegal information pertaining to food incidents was low. To ensure national food safety and optimally fulfill the multifaceted and personalized food demands of urban and rural residents, a safe and transparent supply chain for agricultural products should be established the soonest possible, and the quality and safety traceability of agricultural products should be implemented.

2.4 Necessity to enhance market competitiveness of agricultural products

Developing smart agriculture based on a dual-circulation development pattern is conducive to improving China's agricultural competitiveness in the international market. China has become the world's largest importer of agricultural products and the second largest trading country in agricultural products. However, its influence on the trading activities of global agricultural products remain insufficient (the dependence on agricultural product imports increased from 6.19% in 2001 to 13.44% in 2018 [15]). According to statistics provided by the Ministry of

Agriculture and Rural Areas, in 2019, the self-sufficiency rates of China's soybeans and edible vegetables were less than 20% and 30%, respectively. The domestic market prices of various agricultural products exceeded 30% of the international cost-insurance-freight prices. The key reason for this weak international competitiveness is the high domestic costs of producing wheat, rice, corn, and soybean, such as planting costs, which are generally 40%–70% higher than those in the international market. Therefore, it is crucial to improve the value chain of the agricultural industry using smart agricultural technology and promote the core competitiveness of China's agricultural industry to approach the level of agriculturally developed countries the soonest possible.

Another issue to consider is the domestic market. To comprehensively promote rural revitalization, promoting the connection between small farmers and modern agriculture has become the focus of research regarding agriculture, rural areas, and farmers. The proportion of small farmers in China's agricultural sector remains high. By establishing a large data intelligent service system, hundreds of millions of small farmers can be effectively linked with large markets, thereby hindering the obstruction of the urban–rural economic cycle. Hence, information services are fully exploited in agriculture to consolidate and expand the achievements of poverty alleviation and rural revitalization. Ultimately, small farmers are imbued with more confidence to increase their income.

2.5 Necessity to realize self-reliance and self-improvement of agricultural science and technology

Recently, China has implemented several science and technology projects associated with smart agriculture, thereby promoting the technical directions of BeiDou automatic navigation, smart plant factories, and unmanned aerial vehicles (UAVs) for agricultural applications to approach international benchmarks. However, a few key core technologies outside the system level are controlled by foreign countries. For example, high-end agricultural environments and life information sensing equipment are monopolized by enterprises in other countries such as the United States, Japan, and Germany. In addition, high-power and high-end intelligent equipment are primarily imported, whereas animal and plant growth models and core data are primarily based on those from the United States, Israel, the Netherlands, and Japan.

While agriculture enters the digital era, smart agriculture has become an important aspect for agricultural stakeholders to seize the commanding heights in agricultural science and technology. China should adopt this development initiative, focus on and maintain the self-reliance of science and technology, emphasize the key core technologies, which is integral in high-quality smart agriculture, conduct centralized research and demonstrate applications, promote independent control, improve the market competitiveness of domestic core products, and provide solid guarantee for agricultural and rural modernization.

3 Overall strategic concept of smart agriculture development in China

3.1 Development ideas

The period from 2021 to 2035 is a key deployment period for China to realize modernization. To accelerate the development of smart agriculture, China should implement a new development concept considering a new development stage and develop a high-quality and efficient agriculture. Hence, the priority should be directed toward the goals of ensuring national food security, ensuring ecological security, and sustainably increasing farmers' income, all of which involve a new agricultural infrastructure, smart planting and breeding, smart supply chains, smart agricultural information services, technologies associated with smart agriculture, and the general idea of prioritizing key points and improving weak links.

The following factors are equally important: highlighting the self-reliance and self-improvement of agricultural science and technology; strengthening strategic, cutting-edge, and basic research on smart agriculture; developing key common technologies; and demonstrating major science and technology projects, including projects regarding smart agriculture. In addition, key technologies must be realized, including agricultural sensors and high-end chips, agricultural big data intelligence and knowledge models, agricultural artificial intelligence (AI) algorithms, and cloud services. Moreover, key products must be developed, including high-end intelligent agricultural machinery, smart agricultural perception products, autonomous agricultural operations (robots), and smart agricultural service products. Furthermore, integrated applications should be demonstrated, including high-end products in smart

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agricultural (animal husbandry and fishery) farms, smart plant factories, smart agricultural product processing, and smart supply chain of agricultural products. Supporting industries should be established, including agricultural software development, intelligent information services, agricultural sensors and measurement/control terminals, and intelligent agricultural equipment manufacturing. Integration is important, particularly in terms of biotechnology, information technology, and intelligent equipment. Establishing a technology system for smart agriculture that adopts "AI + big data + new-generation communication technology + Internet of Things (IoT) + Beidou satellite navigation" is important for achieving the goal of realizing China as a global agricultural power. Development projects should promote the three primary changes in agriculture, namely machines replacing human resources, computers replacing human brains, and independent technological competitiveness. Moreover, efforts should be made to improve the level of smart agricultural production and networked management, strengthen the quality, efficiency, and competitiveness of agriculture, expand the space for farmers to increase their income, and facilitate rural revitalization.

3.2 Development route and objectives for 2025

The objective set for 2025 is the implementation of breakthroughs in common key technologies relevant to agricultural big data, such as agricultural big data integration and governance, big data cognitive analysis, and big data in-depth learning. Another objective is the construction of agricultural big data standards and specifications as well as a digital agricultural and rural big data center to provide support for data discovery and knowledge acquisition. Other objectives include developing high-end plant protection UAVs and automatic equipment for the harmless treatment of dead livestock and poultry; promoting the independent innovation of agricultural machinery and equipment; strengthening basic R&D for agricultural AI, agricultural virtual reality (VR), and other technologies; and developing man–machine collaborations, smart agricultural systems, man–machine hybrid intelligent interactions, and virtual technologies. Additional objectives include studying phenotypic information analysis technologies based on agricultural augmented reality/VR and adopting VR technologies to design the ideal phenotypic structure of animals and plants to provide the basis for breakthroughs in agricultural knowledge models (Fig. 3).

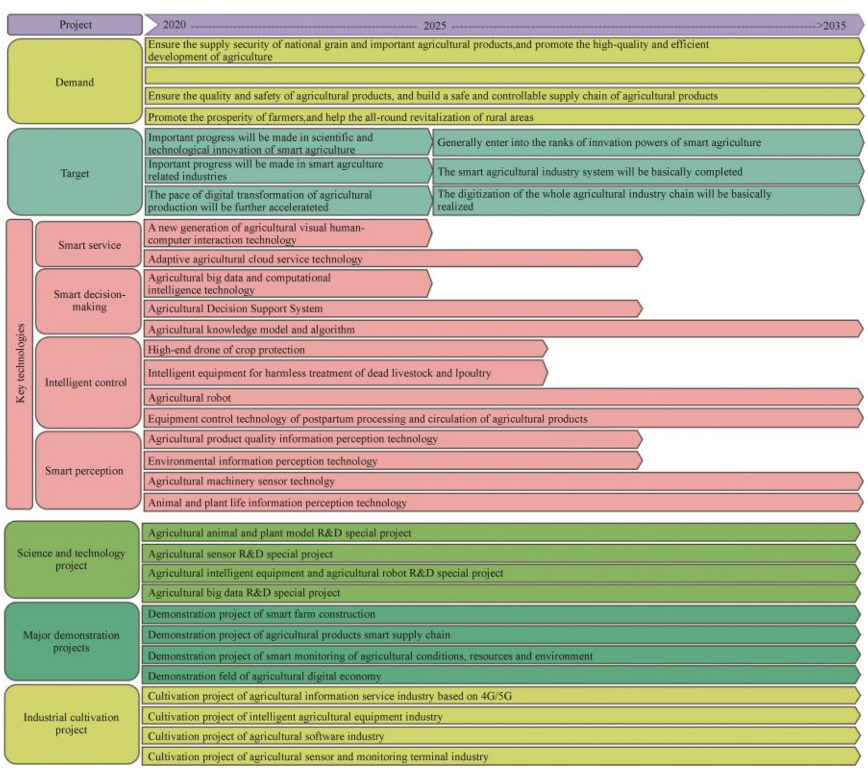

Fig. 3. Smart agricultural technology roadmap of China toward 2035.

By 2025, China's digital transformation in agriculture is expected to progress significantly. Digital technology is integrated with industrial systems for agricultural production and management. In addition, large-scale planting facilities, standard horticultural parks, and large-scale healthy animals (pigs, poultry, dairy cows, and fish) breeding demonstration farms can be used to realize digital transformation. Accordingly, the scientific and technological innovation system of smart agriculture as well as the industrial system of smart agriculture will improve, and smart agriculture will facilitate a phased progress in agricultural and rural modernization. Specifically, the digital levels of field, facility, livestock, poultry, and aquatic production are 25%, 45%, 50%, and 30%, respectively. The cold chain circulation rate of fresh agricultural products is expected to exceed 40%, the proportion of agricultural products that realize quality and safety traceability exceeds 25%, and the proportion of the agricultural digital economy in the gross domestic product (GDP) of the primary industry exceeds 15%. The coverage of e-commerce sites in administrative villages should not be less than 85% (Table 1).

Table 1. Main prediction index of smart agriculture in China forecast toward 2050.

Main Index	Base period value	Predicted value		
		2025	2035	2050
Rural Internet penetration	55.9% (2020)	⩾ 70%	⩾ 90%	⩾ 98%
Digital level of field planting	17.4%	⩾ 25%	⩾ 50%	⩾ 80%
Digital level of protected cultivation	41.0%	⩾ 45%	⩾ 70%	⩾ 85%
Digital level of livestock and poultry breeding	32.8%	⩾ 50%	⩾ 75%	⩾ 90%
Digital level of aquaculture	16.4%	⩾ 30%	⩾ 75%	⩾ 90%
Cold chain circulation rate of fresh agricultural products	31.8% (2018)	⩾ 40%	⩾ 50%	⩾ 80%
Proportion of agricultural products with quality and safety traceability	17.2%	⩾ 25%	⩾ 50%	⩾ 90%
Proportion of online retail sales in total agricultural product transactions	10%	⩾ 15%	⩾ 30%	⩾ 60%
Proportion of agricultural digital economy in primary production GDP	8.2%	⩾15%	⩾ 70%	⩾ 300%
E-commerce site coverage of administrative village	74.0%	⩾ 85%	⩾ 95%	⩾ 98%

Note: The base period values are from the end of 2019 unless otherwise specified.

3.3 Development route and objectives for 2035

The key problems to address include the technical directions of high-quality, high-precision, high-reliability, and low-power agricultural environment information perception; agricultural product quality information perception; high-end animal and plant life information perception; and special sensors for agricultural machinery and equipment. Meanwhile, the following objectives are equally important: independent control of agricultural sensors and high-end chips and alleviation of the problems pertaining to high-throughput information acquisition in smart agriculture. Other objectives include implementing scientific and technological innovation in agricultural robots; developing a new generation of agricultural robots with high labor intensity, strong adaptability, high cost performance, and smart decision-making; improving the technical level of grafting, weeding, pollination, pesticide spraying, and electric operation robots in greenhouse facilities; and demonstrating and promoting intelligent (unmanned or less populated) farm integration technologies. To realize implementations and promote the intelligent level of agricultural big data, research pertaining to the following key technologies is crucial: agricultural, animal, and plant knowledge models, core algorithms, and decision support systems. Adaptive agricultural cloud service technology can be developed using the concept of software as a service to significantly reduce the operation and maintenance costs of smart agriculture and provide convenient customized services for numerous users.

By 2035, the digitization and networking of the entire agricultural industry chain as well as landmark progress will be realized in smart agriculture, and China will become a global agricultural power. Breakthroughs will manifest in terms of new infrastructure, new theories, new technologies, new equipment, new products, and new

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formats of smart agriculture. Additionally, the ability and level of independent innovation will improve comprehensively, and the discipline and innovation teams of smart agriculture will reach the world-class level. The digitization of the main links of agriculture will shift to the digitization and networking of the entire agricultural industry chain and all links. Less-manned or unmanned smart agricultural (animal husbandry and fishery) farms in batches will be constructed, and a smart agricultural industry system for software definition, data-driven, equipment support, and industrial integration will be established. The scale of agricultural sensors, measurement/control terminals, smart agricultural manufacturing equipment, agricultural software, and other industries will increase, and the core competitiveness of the smart agriculture industry will reach an internationally advanced level. Specifically, the digital level of fields, facilities, livestock and poultry, and aquatic production are projected to be 50%, 70%, 75%, and 75%, respectively. The proportion of the agricultural digital economy in the GDP of the primary industry will exceed 70%.

4 Key development tasks associated with smart agriculture in China

4.1 Deploying new infrastructure in agriculture to provide solid foundation for smart agriculture

The primary development tasks are to promote new infrastructure construction in agriculture and rural areas as well as develop a new agricultural information infrastructure system that is ubiquitous, advanced, open, and shared. The secondary development tasks involve the accelerated construction of a new infrastructure, such as 5G networks, data storage centers, and the cold chain; the upgrade of a national agricultural and rural big data center; and the development of agricultural big data standardization technologies and data exchange mechanisms. Furthermore, an agricultural knowledge map based on big data should be constructed to transform data into practical values to ensure the accuracy and intelligence of agricultural information services.

4.2 Promoting digital transformation of production and constructing smart farms in batches

To improve capabilities in monitoring and information services for agricultural resources and environments, a space–sky–terrestrial information acquisition network must be developed for multiscale agricultural resources and environments, as well as an intelligent, multitemporal, multidimensional, high-precision information service platform for agricultural resources and environments. The following tasks are equally important: addressing the bottleneck technology of field and horticultural crop sensors, accelerating the construction of digital agricultural conditions, and forming an integrated technical system for the construction and operation of intelligent greenhouse facilities. For large-scale farmlands and greenhouses, the following tasks are important: promoting technical equipment for plant environment monitoring and control, precise application of water, fertilizer, and pesticide, and intelligent management of soil crops. Additionally, building unmanned (or less populated) farms and plant factories in batches are crucial. Other critical tasks include developing breeding equipment, applying specific sensors (for aquaculture inputs, breeding processes, and product quality), and developing a knowledge model of modern animal growth and production processes. Furthermore, the development of intelligent breeding machinery, breeding dynamic feed formulas, and breeding technology based on big data are equally important. Additionally, establishing a big data platform for farm group optimization management and decision-making, developing operation robots in key links of breeding, and building unmanned (or less populated) pasture and unmanned (or less populated) fishing grounds in large-scale livestock and poultry aquaculture farms in batches are crucial.

4.3 Constructing transparent supply chain and quality and safety defense line

To significantly improve efficiency, the following tasks are crucial: establishing an intelligent ecosystem for the supply chain of agricultural products, developing intelligent equipment for post-harvest processing and the cold chain, and developing a new operation mode for the agricultural supply chain. Moreover, key technologies for smart equipment driven by clean energy and intelligent control technologies for cold storage should be developed, and the agricultural cold chain should be transformed and advanced. In the agricultural supply chain, blockchain, big data, and AI technologies should be applied to comprehensively control information from the numerous links of the entire agricultural supply chain (agricultural materials, production, processing, storage, and transportation), a digital twin of the agricultural supply chain should be constructed, and the quality and safety traceability of agricultural products should be improved [16]. Furthermore, the data alliance chain should be investigated to establish a new supply chain cooperation network to reduce the trust cost of the supply chain, as well as to support the use of green, intelligent, efficient, and open technologies in the agricultural supply chain.

4.4 Accelerating process of technology industrialization

This category involves several essential tasks, i.e., closely monitoring the development trend of global smart agricultural science and technology, cultivating major industrial projects, and balancing potential technology demand, industrial growth potential, product competitiveness, and technology-driven leadership [17]. The following three key innovation fields should be prioritized: intelligent agricultural equipment, agricultural sensors and measurement/control terminals, and agricultural software and emerging information services. Within these fields, the following tasks are essential: implementing industrial technology projects associated with smart agriculture, promoting the accurate docking of smart agricultural innovation and industrial chains, and ensuring that agriculture, rural areas, and farmers benefit from smart agricultural technologies and products. In addition, the application-level maturity of the following technologies is required: AI, 5G, edge computing, human–computer interaction, and other information technologies associated with intelligent agricultural machinery, agricultural sensors, and agricultural software. Improvement in the support ability of smart agricultural software and hardware products is equally important. Other crucial tasks include developing intelligent agricultural production and operation equipment, intelligent agricultural operation robots, and other key intelligent agricultural machinery; standardization and industrialization of a new generation of agricultural sensors with wide adaptability, high performance, and intelligent decision-making; and establishing an ecology and industrial cluster for the agricultural software industry.

4.5 Prioritizing concept of green ecology toward carbon peaking and carbon neutrality

To fulfill the target requirements of carbon peaking and carbon neutrality, green ecology should be prioritized. Therefore, the following tasks are essential: applying digital technologies to enable green agriculture; reducing carbon emissions from chemical fertilizers, livestock, and poultry breeding; and constructing a smart green agriculture demonstration area to lead the development of high-quality green agriculture with high energy efficiency. In addition, the following tasks are equally important: implementing smart transformation of cultivated land, promoting the application of efficient water-saving irrigation technologies, and improving the utilization efficiency of agricultural water and soil resources. The following components of smart green agriculture are recommended: precise regulation of animal and plant growth, smart prediction of environmental changes by integrating big data and multi-omics, establishment of a modern smart agricultural production system to adapt to climate change, precision planting and breeding, and reduction of carbon emissions from agricultural systems. Additionally, the following tasks are equally important: establishing smart ecological protection and restoring demonstration areas; realizing dynamic monitoring, early warning, and smart supervision of the ecology.

5 Classified promotion path of smart agriculture with Chinese characteristics

5.1 Promotion path for different production and operation entities

5.1.1 Small farmers

To promote effective connections between small farmers and modern agriculture, a regional intelligent service platform with optimal functions should be established using agricultural big data, information regarding village and household projects, and the national agricultural science and education cloud platform. This intelligent platform can provide convenient, efficient, and accurate agricultural knowledge to deliver accurate and personalized agricultural services to small farmers. In addition, all types of socialized service organizations and information enterprises should be considered to identify a new mode for intelligent voice interactive services, to provide small farmers with professional and personalized agricultural science and technology information, production trusteeship, equipment sharing, and other services, as well as to reduce the application cost of intelligent agricultural technology products and services. The “Internet Plus” project for rural villages should be continued. Similarly, support should be extended to the new mode of electricity supply and agricultural research

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jointly investigated by e-commerce enterprises and scientific research institutions. Hence, the following outcomes will be achieved: a docking platform for production, marketing for small farmers, production and marketing linkage of high-quality and special agricultural products, and cost competitiveness.

5.1.2 Family farms

To improve the operation and management of family farms and to achieve the best economies of scale, appropriate scale standards should be developed for smart agricultural demonstration farms, support should be extended to family farms in primary grain-producing areas, and advantageous areas of bulk agricultural products and modern agricultural demonstration areas should be further developed to create smart agricultural demonstration farms. Using the China agricultural socialized service platform, guidance and support should be extended to all types of socialized service organizations to provide the menu-type, whole process production, and trusteeship smart agricultural socialized services for family farms. Furthermore, market players are encouraged to develop applicable data products, provide customized technical packages, and application schemes for family farms, as well as support targeted production scheduling plans.

5.1.3 Cooperatives, leading enterprises, and other large-scale business entities

Applicable standards should be formulated for the technology application modes of unmanned ecological farms in different regions and industries. Considering the National Modern Agricultural Industrial Park as the major carrier, support to large-scale grain, vegetable, pig, cow, egg, and poultry farms or settled enterprises (cooperatives) should be prioritized to construct national unmanned (animal husbandry) demonstration farms in batches and promote the integrated application of unmanned autonomous operation in stages, levels, fields, and echelons. An ecological and unmanned production technology system should be developed to promote China’s status as a major agricultural country. In addition, social capital should be encouraged to participate in the construction of’ new infrastructure, such as 5G network farms, data centers, basic data resource systems, and digital supply chains of agricultural products associated with the goal of “new infrastructure” agricultural cases, as well as the construction of smart countryside, smart plant factories, smart pastures, smart fisheries, smart orchards, and smart processing workshops of agricultural products in batches. The exemplary effects of these initiatives are highlighted herein.

5.2 Promotion path for different industrial subjects

5.2.1 Smart planting

The demand for stable production and supply, quality improvement, and increased efficiency for grains and vegetables can be achieved by directing “space–sky–terrestrial” integrated smart monitoring and accurate services toward large-scale grain and vegetable production bases. Smart climate agricultural projects, such as the smart climate agricultural model in main grain-producing areas and the grassland smart climate management model in Northwest China, can enhance the adaptability of crop production to climate change. Demonstration projects focused on integrating agricultural machinery, agronomy, and intelligence can address the incomplete coverage of precision operations and the low cooperation efficiency of intelligent equipment. Furthermore, unmanned or less populated fields can be utilized by building unmanned (or less populated) farms and unmanned plant factories in batches, wherein grafting, weeding, spraying, and picking are conducted using electric operation robots in greenhouses.

5.2.2 Smart economic animal industry

To achieve smart animal farming, focus should be directed toward large-scale breeding farms for pigs (more than 1×10^4 heads), dairy cows (more than 500 heads), and chickens (laminated building scale: exceeding 1×10^5 heads; scale of three-dimensional free-range house: exceeding 5×10^4 heads); integrated application of software and hardware in livestock and poultry breeding; and various technologies, including dynamic feed formula, smart breeding, accurate environmental control, accurate feeding equipment, smart management, and intelligent treatment of fecal pollution. In addition, the following infrastructure should be developed: land-based breeding factories (area: exceeding 7×10^7 m³), caged farms (shallow water: exceeding 1.4×10^6 cages; deep sea: exceeding than 2×10^4 cages), marine ranch demonstration areas, and other large-scale aquaculture bases. Furthermore, application of the following technologies should be promoted: intelligent perception, reliable transmission, accurate prediction, decision-making, and control of unmanned (or less populated) fishing grounds. Finally, a smart fishery system that considers the entire process of aquaculture, fishing, aquatic circulation, and processing should be developed.

5.2.3 Smart supply chain of agricultural products

First, in the major producing areas of fresh agricultural products and characteristic agricultural product-advantage areas in Hainan Province, Shandong Province, Chongqing City, Hebei Province, Guizhou Province, and Jiangsu Province, a smart processing workshop for the non-destructive quality testing of agricultural products and the sorting of graded products should be established and commissioned for operation. Second, regional cold chain logistics nodes and backbone networks should be established in these areas, where conditions permit, and accurate regulation and control of the storage and transportation environments should be maintained. Meanwhile, in the pilot county of big data of single variety whole industry chain, a supply-chain traceability platform based on blockchain technology for the chain management of agricultural products which using data alliance chain should be demonstrated and applied; consequently, data monitoring and traceability management can be achieved for the entire lifecycle of high-end agricultural products. Furthermore, the following areas should be investigated: smart supervision of the agricultural supply chain in the main national sales areas; integration of visual information display, agricultural product traceability, and blockchain of smart agricultural trade systems; and maintenance of early warning, rapid response, and source traceability of major food safety events.

6 Countermeasures and suggestions

6.1 Preparation of medium- and long-term planning outline for smart agriculture

First, an outline for the national smart agriculture development strategy (2021–2035) should be prepared based on the requirements of the National Rural Revitalization Strategy and the *Outline of the Digital Rural Development Strategy*. Second, the digital transformation of agricultural production, transparent supply chain of agricultural products, and intelligent services using agricultural big data should be prioritized. Furthermore, smart agricultural projects should be conducted in counties (cities) with superior production areas, national agricultural science and technology parks, and national modern agricultural industrial parks to demonstrate the results of smart agriculture.

6.2 Implementing key core technologies of smart agriculture

First, to upgrade the agricultural industry and high-quality agricultural development based on self-reliance and self-improvement in science and technology, focus should be directed toward short-board technologies and weak links, such as agricultural sensors and information acquisition systems, high-end intelligent agricultural machinery and equipment, agricultural robots, agricultural big data and computational intelligence, and agricultural models and algorithms, as well as the layout and implementation of key core technology research projects. Second, the following should be prioritized to effectively improve independent R&D capacities and provide more usable, affordable, and optimal software and hardware products for industrial users: constructing industrial promotion platforms, such as the National Smart Agricultural Innovation Centre and key laboratories; demonstrating and promoting the major "Smart Agricultural Science and Technology Innovation 2035" project. Finally, commendable leadership should be reflected when establishing a national smart agricultural innovation and development pilot zone for conducting novel technology verification and accelerating the transformation and application of achievements in key areas, such as the Bohai Rim Economic Zone, the Yangtze River Delta, the Great Bay area of Guangdong, Hong Kong, Macao, and Chengdu Chongqing economic circles, and a number of cities with an optimal modern agricultural foundation.

6.3 Establishing differentiated smart agricultural subsidy mechanism

Complete sets of agricultural IoT devices and control terminals for intelligent tractors are included in the scope of agricultural machinery purchase subsidies. Meanwhile, the subsidy standard for the purchase of intelligent high-end agricultural machinery should be improved accordingly. Considering regional and industrial differences, the following differentiated subsidy mechanism should be established to support the application of smart agriculture technology by farmers of various scales: provide smart mobile terminal subsidies and network access fee reduction

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for small-scale farmers, providing quota subsidies or proportional subsidies to the appropriate scale operators based on the production scale, and offering hosting service subsidies to smart operation service providers based on the service area. In addition, a pilot subsidy scheme should be implemented for smart livestock and poultry breeding in large pigs, cow, and poultry breeding counties. For operations in the Northeast, Inner Mongolia Autonomous, and Xinjiang Uygur Autonomous regions, subsidies are provided for the purchase of intelligent power equipment and special operation equipment associated with field grains and open-field vegetables. For standard vegetable gardens and aquaculture demonstration farms, subsidies should be extended to enable the purchase of complete sets of agricultural IoT equipment and solutions.

6.4 Coordinating development of smart agriculture and digital village

The integrated design and construction of smart agriculture and digital villages with the county (city) should be conducted to achieve the objective of "'high-quality and high-efficiency agriculture, rich and affluent farmers, and liveable and professional countryside." Additionally, the following initiatives should be supported: introduction of a new infrastructure for agricultural and rural areas into the national rural construction action, construction of agricultural and rural big data centers in counties, "space–sky–terrestrial" integrated observation systems, digital transformation of agricultural production bases and rural logistics facilities, pilot 5G and Internet protocol version 6 (IPv6), narrowband IoT, and other network collaborative applications. To ensure the inclusive application of agricultural and rural digitization and intelligence, qualified counties (cities) should be supported to realize "rural brains" and coordinate the development of the agricultural and rural digital economy, environmental digital governance, and rural digital governance.

6.5 Cultivating applied talents

The technology promotion concept of "industry oriented and special service" should be highlighted, and the service capacity improvement plan of rural science and technology commissioners and agricultural technicians should be implemented based on the existing farmers' education and training systems. Trained people are vital to the digital and standardized transformation of agricultural production bases, operation procedures, and processes of smart agricultural information technology; operation and management of agricultural machinery and intelligent equipment; and the application and maintenance of application systems and platforms. Specific training for applied talents in smart agriculture should be performed, whereby the advantages of talent are rapidly realized to consolidate the endogenous driving force of smart agriculture; this will provide intellectual guarantee for the application, promotion, and effectiveness of smart agriculture projects.

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