

## Postprint: Smart Farming Objectives, Key Technologies, and Regional Models for Field Crops in China

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### Abstract

Smart planting of field crops constitutes a crucial component of smart agriculture. Through analyzing the developmental trajectory of smart agriculture, this study clarifies the overarching strategic objectives and key tasks for developing smart planting of field crops, distills the essential technologies, and proposes regionally-adapted development models tailored to China's distinctive characteristics. The principal challenges confronting key technologies for smart field crop planting include: deficiencies in in-situ precision measurement technologies and agriculture-specific sensors, substantial discrepancies between crop simulation models and actual production conditions, the need for enhanced real-time performance, reliability, universality, and stability in information transmission technologies, and the imperative for smart agricultural equipment to better integrate agricultural machinery with agronomic practices. Building upon this analysis, we propose five primary-level technologies and eighteen corresponding secondary-level technologies for smart field crop planting. The five primary-level technologies encompass environmental and biological information perception technology, information mobile internet and agricultural IoT technology, cloud computing and cloud service technology, big data analysis and decision-making technology, and intelligent agricultural machinery equipment and agricultural robot technology. Based on the regional characteristics of crop cultivation in China, six distinct smart agriculture development zones are delineated: the Northeast and Inner Mongolia large-scale smart production development zone, the Beijing-Tianjin-Hebei-Shandong smart urban agriculture and water-saving agriculture development zone, the Northwest Arid Region cotton large-scale smart planting and dryland smart agriculture green development comprehensive pilot zone, the Southeast coastal circular rice smart planting comprehensive development pilot zone, the Middle and Lower Yangtze Plain smart grain and oil optimization development zone, and the Southwest mountainous region

smart characteristic agriculture development zone. Finally, development recommendations are advanced from the perspectives of infrastructure construction, technology, talent cultivation, and policy support.

## Full Text

### Goals, Key Technologies, and Regional Models of Smart Farming for Field Crops in China

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**Abstract:** Smart farming for field crops represents a crucial component of smart agriculture. By analyzing the evolution of smart agriculture, this paper clarifies the overarching strategic objectives and key tasks for smart farming development in China, distills the critical technologies involved, and proposes regionally appropriate development models tailored to China's distinctive characteristics. The principal challenges confronting smart farming for field crops include: a lack of in-situ precision measurement technologies and agriculture-specific sensors; significant discrepancies between crop simulation models and actual production conditions; the need for improvements in the real-time performance, reliability, universality, and stability of information transmission technologies; and the necessity of better integrating intelligent agricultural equipment with agronomic practices. Building upon this analysis, the paper proposes five primary technology categories encompassing eighteen corresponding secondary technologies: environmental and biological information sensing technologies; mobile internet and agricultural Internet of Things (IoT) technologies; cloud computing and cloud service technologies; big data analytics and decision-making technologies; and intelligent agricultural machinery and robotics technologies. Based on the distinctive features of China's cropping regions, six smart farming development zones are identified: the large-scale smart production development zone in Northeast China and Inner Mongolia; the smart urban agriculture and water-saving agriculture development zone in Beijing-Tianjin-Hebei-Shandong; the large-scale smart cotton farming and comprehensive green development pilot zone for dryland smart agriculture in the Northwest Arid Region; the circular smart rice farming comprehensive development pilot zone in the Southeast Coastal Region; the optimized smart grain and oil development zone in the middle and lower reaches of the Yangtze River Plain; and the characteristic smart agriculture development zone in the Southwest Mountainous Region. Finally, development recommendations are provided from the perspectives of infrastructure construction, technology, talent cultivation, and policy support.

**Keywords:** smart farming; sensing technologies; Internet of Things; intelligent agricultural machinery; unmanned farm; big data; mobile internet; smart agriculture

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## 2. Overall Development Strategy for Smart Farming of Field Crops

### 2.1 Strategic Objectives

Field crop production constitutes the primary component of China's agricultural sector. Given the country's large population and relatively limited arable land, the Chinese government has consistently prioritized grain production to ensure food security. In 2021, national grain output reached approximately 682.85 million tons, an increase of 13.36 million tons (2.0% growth) compared to 2020, with cereal production totaling 632.76 million tons, up 16.02 million tons (2.6% growth) from the previous year [?]. Smart agriculture represents a new concept for sustainable agricultural development, emerging against the backdrop of rapid advancement in new-generation information technologies [?, ?]. During the early to mid-1990s, developed countries introduced the concept of Precision Agriculture, promoting agricultural production informatization and sustainable development based on information technology [?]. Smart agriculture builds upon precision agriculture through deep integration with modern information technologies, requiring not only faster, more accurate, cost-effective, and diversified information sharing mechanisms, but also comprehensive analysis integrating regional agricultural and biological resources, environment, ecology, and socio-economic conditions, while leveraging producers' wisdom to make scientific, cost-effective, and efficiency-enhancing management decisions based on objective data. In 2013, the Food and Agriculture Organization of the United Nations published the CSA-Climate-Smart Agriculture monograph [?], which comprehensively discussed smart agricultural development pathways under climate change conditions. Subsequently, smart agriculture, particularly new agricultural concepts for field crops, has rapidly disseminated and developed worldwide.

In recent years, China's central government has attached great importance to smart agriculture development. The 2021 No. 1 Central Document, "Opinions of the CPC Central Committee and the State Council on Comprehensively Promoting Rural Revitalization and Accelerating Agricultural and Rural Modernization," called for developing smart agriculture and establishing a big data system for agriculture and rural areas to promote deep integration of new-generation information technologies with agricultural production and operation. In the same year, the Ministry of Agriculture and Rural Affairs issued "Implementation Opinions on Implementing the Key Work Deployment of the CPC Central Committee and the State Council on Agriculture and Rural Affairs in 2021," proposing to strengthen high-standard farmland construction, fight the battle

for seed industry revitalization, vigorously promote agricultural mechanization, enhance agricultural science and technology support services, and accelerate smart agriculture development. The 2022 No. 1 Central Document continued to focus on rural revitalization, proposing to advance smart agriculture development and promote the integrated application of information technology with agricultural machinery and agronomy.

As urbanization accelerates and the agricultural workforce ages, labor costs continue to rise, presenting agriculture with the critical question of “who will farm and how to farm well,” alongside multiple challenges including low quality and efficiency of field crops and weak international competitiveness. Modern information technologies can provide unprecedented new momentum for field crop production, making the deep integration of these technologies with smart production of field crops and the vigorous development of smart farming a crucial national strategy. Achieving agricultural modernization constitutes a major component of the “Two Centenary Goals,” with smart farming for field crops representing one of the primary development directions for modern agriculture.

The overall development objective for smart farming of field crops is to achieve integrated multi-source precision perception across “space-air-ground” dimensions, intelligent equipment for fine operations, deep integration of smart production knowledge systems, and efficient connectivity of technical equipment throughout the smart production process, while constructing a comprehensive cloud service system to elevate the intelligence level of field crop farming into the international advanced ranks. This involves building a technical system for field crop smart farming based on unmanned farms and forming a highly intelligent decision-making management and service system for field crop production.

Socio-economic development and changes in domestic and international situations have placed higher demands on China’s field crop production, which must now emphasize not only high and stable yields but also food quality, nutrition, safety, and environmental protection. The development of smart agricultural technology systems provides technical support for healthy development of field crop production in the new era, meeting food security and national economic development needs. Additionally, cross-sector technology applications from non-agricultural fields create new opportunities for innovation in smart agriculture’s key core technologies [?], making research on the development strategy for smart farming of field crops essential.

The year 2025 marks the conclusion of the 14th Five-Year Plan and will be the first year to see initial results following the 20th Party Congress. The year 2035 represents the midpoint between the beginning of the 14th Five-Year Plan and the 100th anniversary of the founding of the People’s Republic of China in 2049, when the goal of basically achieving modernization and building a prosperous, strong, democratic, and civilized socialist country will be realized. Therefore, this paper focuses on these time nodes to study the key tasks for each stage, targeting the major needs of agricultural and rural modernization and rural revitalization strategies.

**(1) Key tasks through 2025.** Focusing on achieving automation, informatization, and intelligence in field crop production (robots replacing manual labor), priority should be given to research on key technologies for improving quality and efficiency in field production. This includes accelerating the application of agriculture-specific sensor technologies in field crop farming, with emphasis on breakthroughs in sensor stability across different application scenarios to develop reliable sensing equipment, create advanced sensor brands with agricultural characteristics, and establish a standard system for agriculture-specific sensors to revolutionize farmland information perception technology and achieve important progress in rural revitalization.

**(2) Key tasks through 2035.** Focusing on achieving smart management, intelligent production, and smart services in field crop farming (machines replacing human brains), priority should be given to research on key technology innovation and demonstration for smart farming. This involves accelerating the application of smart agricultural technologies and intelligent control equipment in field crop production, with emphasis on breakthroughs in interconnectivity, sharing, and security of farmland and crop information across all domains and processes to form stable and reliable national maps of cultivated land and crop production. The goal is to create a full-industry-chain cloud service platform with Chinese characteristics, establish a dedicated smart service system for field agriculture, and promote major reforms in the national food security guarantee system. The construction of the unmanned farm technical system should be basically completed, enabling factory-style agricultural production supported by intelligent agricultural machinery and robotics.

**(3) Key tasks through 2050.** The objective is to establish a smart/intelligent production system for field crop farming, achieving comprehensive and full-process smart/intelligent production with adjustable and controllable production processes and product quality, fundamentally solving food safety and security issues through the smart agricultural production system and technology.

### 3. Key Technologies for Smart Farming of Field Crops

Smart farming represents an integrated system based on deep integration of new-generation Information and Communications Technology (ICT) with agricultural modernization in the information economy era. Its technical core can be summarized as five main components: “Sensing, Mobile, Cloud, Big, and Smart.” “Sensing” refers to efficient perception technologies, including advanced agricultural information sensing and agricultural sensors. “Mobile” refers to mobile communication and mobile internet technologies for real-time agricultural information transmission and production regulation. “Cloud” refers to cloud computing and cloud services that support agricultural production digitalization and informatization. “Big” refers to big data technology—agricultural data forms the foundation of smart farming, and agricultural big data technology serves as the tool for data mining and application in the smart agriculture era. “Smart” encompasses both wisdom and intelligence, including smart manage-

ment decision-making for field crop farming, intelligent equipment, and other core elements of smart agriculture. As modern agriculture develops, “Sensing-Mobile-Cloud-Big-Smart” technologies play a central role in the smart agriculture domain.

### 3.1 Existing Challenges

From the perspective of industrial transformation, upgrading, and high-quality development needs for smart farming of field crops, the “Sensing-Mobile-Cloud-Big-Smart” framework still faces several problems and challenges.

**(1) Information acquisition technology.** There is a lack of in-situ precision measurement technologies and agriculture-specific sensors. Field crop farming operates in environments heavily influenced by meteorological conditions and regional differences, with significant time constraints during farming seasons, creating urgent demand for in-situ precision measurement technologies. However, most research achievements are only applicable to certain crops or regions, lacking universality and causing deviations in the information sources that smart agriculture relies upon, thereby affecting subsequent data analysis and control decisions.

**(2) Information transmission technology.** Real-time performance, reliability, universality, and stability need improvement. The characteristics of agricultural production environments and the technical requirements of low-power sensors impose higher demands on data transmission for agricultural IoT in terms of real-time performance, reliability, universality, and stability [?]. The lack of standards and specifications limits the standardized application of IoT in this field [?].

**(3) Information processing and decision-making.** Simulation models show significant differences from actual production. While substantial progress has been made in agricultural knowledge models, pattern recognition, knowledge representation, and machine learning for agricultural pest and disease diagnosis [?, ?], some models and algorithms are still insufficient to fully reflect objective reality and have limitations in guiding precision agricultural production [?]. A major challenge for agricultural big data technology is transforming big data into intelligent data that is accessible and usable for farmers, providing knowledge support for precision and smart agriculture research and practice.

**(4) Intelligent agricultural equipment application.** Further integration of agricultural machinery with agronomy is needed. Agricultural operations involve living organisms such as soil, plants, and animals with systematic organizational structures and biological activity. Only through cross-disciplinary integration, penetration, and fusion with agricultural science and biological/life science and technology can intelligent agricultural equipment meet the technical requirements of modern agricultural production processes. The compatibility between agricultural machinery and agronomy still requires further exploration [?].

### 3.2 Key Technologies

“Sensing, Mobile, Cloud, Big, and Smart” constitute the key components of the smart farming technology system for field crops. This paper focuses on these five components to analyze and select key technologies for smart farming, ultimately identifying five primary technologies and eighteen corresponding secondary technologies. The five primary technologies are: environmental and biological information sensing technology; mobile internet and agricultural IoT technology; cloud computing and cloud service technology; big data analytics and decision-making technology; and intelligent agricultural machinery and robotics technology. A mind map of the key technologies list for smart farming of field crops is shown in Figure 1 [Figure 1: see original paper].

#### 3.2.1 Environmental and Biological Information Sensing Technology

This primary technology includes four secondary technologies: soil fertility information sensing, crop growth information sensing, crop phenotypic information sensing, and crop pest and disease information sensing.

Soil forms the foundation of agriculture. Existing field rapid detection equipment cannot meet the demands for multi-parameter in-situ rapid soil detection in terms of sensitivity, precision, and accuracy [?], and core components are primarily imported. Therefore, there is an urgent need to develop and promote core hardware and integrated technologies for multi-parameter rapid soil detection with independent intellectual property rights.

Real-time monitoring technology for field crop growth and development can monitor and predict various growth status indicators, providing practical guidance for field management, yield prediction, quality detection, and harvesting [?, ?]. Crop phenotyping measurement targets primarily common grain and economic crops such as wheat, maize, sorghum, barley, and legumes. Automated high-throughput measurement of morphological and physiological parameters through phenotyping technology provides critical information for smart breeding and management [?]. Crop pests and diseases constitute significant biological disasters affecting grain yield and quality during agricultural production. Early warning and control of pests and diseases are crucial for reducing chemical pesticide usage and residues, with important strategic significance for promoting ecological environment and agricultural product safety, as well as for formulating China’s grain trade strategies and socio-economic development [?].

**3.2.2 Mobile Internet and Agricultural IoT Technology** This primary technology includes three secondary technologies: IoT technology, 5G technology, and smartphone agricultural applications.

China has developed multiple IoT application models for field crop farming [?], covering crops such as rice, wheat, maize, cotton, fruit trees, and mushrooms. These application models include single-domain IoT systems for intelligent irrigation, soil moisture monitoring, and pest control, as well as composite IoT

systems covering the entire process from seedling cultivation, planting, harvesting, to storage.

The new-generation mobile internet technology based on 5G plays a vital role in field crop farming [?]. Leveraging 5G's high bandwidth and low latency characteristics enables unmanned agricultural machinery operations, including autonomous tractors, transplanters, and harvesters. Smartphones are gradually becoming important modern agricultural equipment, enabling functions such as farmland information acquisition, agricultural machinery control, and agricultural product e-commerce through dedicated apps.

**3.2.3 Cloud Computing and Cloud Service Technology** This primary technology includes two secondary technologies: field crop and environmental simulation modeling technology, and cloud computing and cloud service platform technology.

Crop growth models simulate crop photosynthesis, respiration, transpiration, and nutrient mechanisms based on variety characteristics, meteorological conditions, soil conditions, and crop management practices using mathematical models. These models can accurately simulate crop growth and development over time and yield formation dynamics at single-point scales [?]. Crop and environmental simulation modeling technologies provide powerful tools for cloud computing and cloud service platforms in smart farming. Taking crop identification as an example, inputting crop growth models and various parameters into cloud servers enables identification of different crops or growth stages and differentiation between weeds and crops to optimize herbicide application schemes through the platform's powerful analytical capabilities [?].

**3.2.4 Big Data Analytics and Decision-Making Technology** This primary technology includes two secondary technologies: data mining and machine learning technology, and UAV remote sensing application and disaster prevention and control technology.

Agricultural big data technology includes cleaning, integration, fusion, and mining to discover hidden data value and provide guidance and services for smart agriculture development. Machine learning, a core field of artificial intelligence, provides techniques for data mining to analyze agricultural big data. The synergy between these complementary technologies promotes the development of big data analytics and decision-making technology for smart farming [?, ?].

Using UAVs to monitor soil before crop planting plays a crucial role in pre-planting planning. UAV-based crop growth monitoring during the growing season provides reliable foundational data for smart field management. Agricultural plant protection using UAVs has become one of the fastest-growing emerging fields in China and represents a major future development direction [?].

### 3.2.5 Intelligent Agricultural Machinery and Robotics Technology

This primary technology includes seven secondary technologies: agricultural machinery automatic navigation technology, electric agricultural machinery, precision irrigation equipment, grain automatic yield monitoring technology, field operation robotics technology, water-fertilizer-pesticide integration technology, and unmanned farm technology.

The completion and application of the BeiDou Navigation Satellite System ensures the reliability and healthy development of automatic navigation technology for agricultural machinery in China. Automatic navigation systems are primarily applied to operations requiring high straightness and precision, such as seeding, ditching, ridging, inter-tillage cultivation, and spraying. The maturation of electric motor and battery technologies, particularly low-speed high-torque electric motors, provides a foundation for developing electric agricultural equipment. Precision operations such as irrigation, harvesting, and integrated water-fertilizer-pesticide application, along with agricultural robotics, exemplify the deep integration of modern information technology with modern agriculture, driving agricultural production toward high quality, high yield, low pollution, water conservation, energy efficiency, intelligence, and modernization.

Unmanned farms represent the most advanced agricultural productivity, integrating all the aforementioned key technologies including IoT, big data, AI, 5G, intelligent agricultural machinery, and robotics to complete all farm production and management tasks in an all-weather, full-process, and full-space unmanned operation mode. Unmanned farms will lead the development of smart farming for field crops [?].

## 4. Regional Development Models for Smart Farming of Field Crops

China's vast territory exhibits significant regional differences in natural conditions, crop types, and characteristics, even within the same region. Therefore, this paper proposes six regional development models for smart farming of field crops based on different regional features.

### 4.1 Northeast China and Inner Mongolia—Large-Scale Smart Production Development Zone

The three northeastern provinces serve as China's grain "ballast stone," with the Sanjiang Plain being a nationally important commodity grain base where per capita grain output is four times the national average. In recent years, smart agriculture development in the Sanjiang Plain has been a national leader, with smart farm demonstrations and "enterprise + modern agriculture" model explorations of unmanned farms providing feasible models for advanced agricultural regions in China. The Songnen Plain and Liaohe Plain region, dominated by maize and soybean production, features fertile land including the Northeast Black Soil, one of the world's three major black soil zones, making it an impor-

tant grain production base in China. Based on regional characteristics, this area is suitable for developing large-scale farmer planting models and family farms to continue playing a vital role in ensuring China's food security.

Inner Mongolia is also an important grain production base and major pastoral area in China. The region has natural advantages for forage production, which is suitable for large-scale operation. Therefore, Inner Mongolia should adopt a large-scale model to develop smart forage production.

#### **4.2 Beijing-Tianjin-Hebei-Shandong–Smart Urban Agriculture and Water-Saving Agriculture Development Zone**

The Beijing-Tianjin-Hebei-Shandong region is located in the North China Plain (also known as the Huang-Huai-Hai Plain). Beijing and Tianjin, as municipalities, will primarily focus on developing smart urban agriculture, while Hebei and Shandong provinces, with similar natural conditions in the Huang-Huai-Hai Plain, have long faced water scarcity as their biggest agricultural challenge. Developing smart water-saving agriculture is the only path to sustainable agricultural development in these provinces. Hebei and Shandong should adopt agricultural cooperatives, family farms, and large-scale agricultural models, focusing on water-saving and efficient agriculture supported by smart agriculture key technologies, and promote modern agricultural technologies such as IoT-based soil moisture monitoring, crop growth monitoring, and drip irrigation to ensure sustainable agricultural development.

#### **4.3 Northwest Arid Region–Large-Scale Smart Cotton Farming and Comprehensive Green Development Pilot Zone for Dryland Smart Agriculture**

The Northwest Arid Region (a non-administrative division) includes Xinjiang, Qinghai, Gansu, Ningxia, Shaanxi, and Shanxi. Except for the Guanzhong Plain in Shaanxi, which enjoys favorable weather and fertile land, other areas face harsh climate conditions, particularly water shortages, belonging to dryland agricultural zones. Cotton is the main crop in Xinjiang (including the Xinjiang Production and Construction Corps). With support, subsidies, and guidance from national, autonomous region, and corps authorities, cotton production in Xinjiang has rapidly developed toward mechanization, digitalization, precision, and intelligence. Under new domestic and international situations, the demand for developing smart farming in Xinjiang's cotton region will become more urgent, making the "enterprise + modern agriculture" model an inevitable choice for smart agriculture development.

Beyond the Guanzhong Plain and Xinjiang cotton region, other agricultural areas in the Northwest Arid Region share similar natural conditions with complex topography, presenting interwoven spatial patterns of irrigated agriculture, dryland farming, pastoral areas, and desert Gobi zones. Dryland agriculture in the Northwest Arid Region has achieved remarkable results, with modern agri-

cultural technologies such as plastic film mulching, under-film drip irrigation, and conservation tillage playing important roles. Therefore, developing water-saving and efficient agriculture as the core and adopting “farmer + cooperative,” family farm, or large-scale farmer planting models to develop smart agriculture represents the direction for modern agricultural development in this region.

#### **4.4 Southeast Coastal Region—Circular Smart Rice Farming Comprehensive Development Pilot Zone**

The Southeast Coastal Region includes Zhejiang, Fujian, Guangdong, Hainan, and Guangxi. This eastern region at lower latitudes enjoys superior natural conditions with abundant heat and precipitation, creating favorable conditions for developing characteristic agriculture, regional agriculture, and circular agriculture. Smart agriculture development provides technical support for establishing circular agricultural systems. Unmanned farm experiments in rice cultivation conducted in Guangdong have significantly improved labor productivity and resource utilization efficiency. UAV-based intelligent plant protection operations enable precise and controllable pesticide use, creating conditions for developing circular agriculture. Developing a smart agricultural system featuring circular agriculture in the Southeast Coastal Region, adopting “farmer + cooperative” or family farm models, represents an optimal choice.

#### **4.5 Middle and Lower Reaches of the Yangtze River Plain—Optimized Smart Grain and Oil Development Zone**

The middle and lower reaches of the Yangtze River Plain include Shanghai, Jiangsu, Anhui, Hunan, Hubei, and Jiangxi, where agriculture is well-developed with high land reclamation indices, forming an important production base for grain, oil, and cotton in China. Promoting green agricultural development in this region holds significant importance for achieving overall green development in the Yangtze River Economic Belt, the Yangtze River Basin, and even the entire nation. To achieve this goal, precision agriculture must be developed to improve water and fertilizer efficiency. The region needs to fully capitalize on the current historical opportunity of “digital transformation” in modern agriculture, vigorously develop modern agricultural models such as precision agriculture and smart agriculture, construct a characteristic smart production system for grain and oil crops in the middle and lower reaches of the Yangtze River Plain, improve the utilization efficiency of various resources including water and fertilizer, and accelerate regional agricultural green development.

#### **4.6 Southwest Mountainous Region—Characteristic Smart Agriculture Development Zone**

The Southwest Mountainous Region includes Sichuan, Chongqing, Yunnan, Guizhou, and the Tibet Autonomous Region. This region features extensive mountainous and hilly terrain with small, scattered cultivated land areas, where sloping farmland accounts for over 70% of all cultivated land. The land

in China' s Southwest Mountainous Region is relatively infertile with serious soil erosion, and these objective natural conditions have resulted in consistently low crop yields. Developing modern agriculture should adopt farmer-based or “farmer + cooperative” models to promote characteristic smart agriculture development. Active efforts should be made in breeding superior grain and oil varieties, characteristic fruits, specialty edible fungi, and plateau vegetables to provide variety support for characteristic industry development.

## 5. Summary and Recommendations

Smart farming development for field crops should be incorporated as an important component of rural revitalization and agricultural modernization strategies into relevant development plans and overall planning. Based on the current development status of China' s field crop farming, it is essential to deeply understand the constraints restricting industrial development, plan smart field industry clusters, design complete industrial chains from top-level perspectives, and formulate roadmaps and timelines.

From an infrastructure perspective, developing smart farming for field crops requires strengthening infrastructure construction for smart field crop production. This includes incorporating field crop production-specific sensors, high-speed and stable information transmission systems, and intelligent agricultural machinery into the national new infrastructure construction agenda, building applicable cloud platforms to provide efficient smart services, supporting agricultural producers in adopting advanced technologies and equipment including mobile phones, and establishing sharing mechanisms between smart field service enterprises and new types of agricultural operators as well as small-scale farmers.

From a technological perspective, priority should be given to breakthroughs in information acquisition-specific sensing technologies for field operations, crop phenotypic information and growth requirement relationship models, improving the reliability of sensors and intelligent equipment, resolving bottleneck common key technologies, forming a complete set of industry standards for common key technologies, and enhancing the international competitiveness of field crop farming industry development.

From a talent perspective, it is necessary to strengthen the cultivation of high-level innovative talents and teams, enhance discipline system construction and promotion, improve interdisciplinary integration among agronomy, agricultural engineering, informatics, and other fields, and perfect talent incentive systems to cultivate interdisciplinary talents [?].

From a policy perspective, developing smart farming for field crops requires fully leveraging the “industry-university-research-application” cooperation model of collaborative construction, sharing, mutual benefit, and co-creation, strengthening the cultivation of high-level innovative talents and teams, and enhancing national-level innovation platform construction. International exchange and co-

operation should be strengthened to enhance the international competitiveness of smart field crop farming.

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