Development Status and Technical Framework of Internet-Plus Modern Agriculture

Jin LI, Chen MA*, Meirong GUO, Liangliang GAO, and Geqi GU
Beijing Research Center for Information Technology in Agriculture; National Engineering Research Center for Information Technology in Agriculture; Key Laboratory of Agri-informatics, Ministry of Agriculture; Beijing Engineering Research Center of Agricultural Internet of Things, Beijing 100097

Abstract. According to the innovative definition and connotation of “Internet-plus modern agriculture,” this study analyzes the development status of “Internet +” modern agriculture at home and abroad, as well as the development and application of agricultural sensor technology, agricultural robots, agricultural remote sensing, agricultural big data, and plant factories. The development of “Internet +” modern agriculture in China has problems such as the low level of technological innovation and immature industrial systems. A technology system of “Internet +” modern agriculture is constructed with regard to three aspects: the supporting technology level, application technology level, and software technology layer. Its application prospects and development trend are discussed.

1. Introduction
“Internet +” refers to the application of internet platforms and information communication technology to combine the Internet with various industries, including conventional ones, thus creating a new ecology for modern industrial fields. China’s 2016 “No. 1 Central Document” vigorously promoted the Internet + modern agriculture concept and the application of modern information technology, such as the Internet of Things (IoT), cloud computing, big data, and mobile internet, for transforming and upgrading the entire agricultural industry. In developed countries, significant progress has been achieved in the research and application of Internet + modern agriculture. Using cutting-edge technology, such as agricultural sensors, intelligent equipment, remote sensing, and agricultural big data, developed countries have become the pioneers of agricultural and rural information technology. At present, China’s Internet + modern agriculture includes a series of key advanced-stage information technology products and equipment for use in open-field and facility agriculture, aquaculture, and animal husbandry, as well as the seed industry, which have achieved significant results. This article presents a comprehensive analysis of the existing conditions and limitations of Internet + modern agriculture at home and abroad and proposes a technological system framework consisting of three layers: the supporting technology, software technology, and application technology. This mutually supportive and interactive system provides a strong impetus for the development of modern agriculture.

2. “Internet +” Modern Agriculture Concept
In his 2015 Government Work Report, the Prime Minister of China—Li Keqiang—presented “Internet +” as a national strategy. During the same year, China’s central government unveiled the “Internet+” action plan as the new economic development engine under the New Normal Economy. The action plan was presented as a new form of economy that relies on the Internet to optimize the allocation of
production factors and uses innovation to deeply integrate information technology with all areas of the economy and society. Its aim is to enhance the productivity and innovative performance of the real economy.

Thus far, the concept of Internet + modern agriculture has not been clearly defined. Wang Peidong [1] proposed that Internet + modern agriculture involves the innovation of production, industrial models, and management methods, resulting in ecological integration and a fundamental restructuring of the relationship among internet-based technology, the agricultural system, and the farming lifestyle. Cao Hongxin et al. [2] defined Internet + modern agriculture as agriculture supported by the information superhighway. Such agriculture promotes the use of cutting-edge science and technology, advanced industrial equipment, and modern farming management concepts and methods in the agricultural process, through the interaction and intercommunication of the human–machine–object system. Professor Li Daoliang [3] of the College of Information and Electrical Engineering, China Agricultural University considers Internet + modern agriculture to be data-based online agriculture and the cross-industrial integration of agriculture with next-generation information technology, such as mobile internet, big data, cloud computing, and the IoT.

In the present study, Internet + modern agriculture is defined as an intelligent agricultural service cloud based on a ubiquitous network and large-scale data and supported by next-generation information technology, such as mobile internet, the IoT, cloud computing, big data, and intelligent manufacturing. “Internet +” can form a smart agricultural service cloud centered on “producers, processing enterprises, and circulation consumers,” so that agricultural production and operation entities can acquire agricultural resources online and in real time, and it can automatically perceive, accurately identify, and intelligently control all elements of the agricultural industry chain. The objective is to obtain an agricultural 4.0 industrial form, which is led by information technology and characterized by intelligent production, traceable circulation, platform trading, and customized services.

3. Internet + Modern Agriculture Development and Problems

3.1. Analysis of Development Conditions at Home and Abroad

The developed countries have achieved significant progress in the research, development, and application of Internet + modern agriculture, providing important scientific and technological support for the development of world agriculture. In particular, cutting-edge technology, such as agricultural sensors and robots, agricultural remote sensing, big data, and plant factories, have become important indicators of the development of intelligent agriculture. In the United States, ranches have become the leaders in the application of Internet + modern agriculture. The well-developed agricultural networks provide a base to build an entirely network-based precise agriculture model. Precision control technology, such as variable fertilization, automated weed detection, and large-scale irrigation, has already begun to be scaled up and is being applied on an industrial scale [4–6]. In Germany, a highly accurate agricultural information processing system was developed gradually, starting with the use of computers to register the type and value of each land parcel and the establishment of an information system for villages and roads and eventually leading to the application of decision-making technology for integrated pest management of crops [7–10]. In Japan, the vigorous development of precision agriculture on medium-scale farms was characterized by the use of lightweight smart agricultural machinery. Agriculture survey systems, such as rice emergence and crop leaf color detection systems, have been developed and widely used in Japan [11]. The Netherlands has developed a highly efficient greenhouse production system, in which the illumination, water, and oxygen are controlled automatically [12] and supplied regularly in fixed quantities.

Internet + modern agriculture in China has developed a series of mature information technology products and equipment for use in open-field and facility agriculture, aquaculture, and livestock and poultry breeding, as well as the seed industry. In addition, numerous technological application models have been investigated, leading to remarkable results in the development of modern agriculture. In Internet + field cultivation, major breakthroughs have been achieved in the use of Internet technology in
agricultural applications such as tillage; “four-condition” monitoring of crops; precise application of water, fertilizer, and pesticide; aerial application of crop-protection products; and machinery management and scheduling. The use of the IoT for intelligent monitoring, data collection, remote transmission, intelligent analysis, and automated control has enabled the Internet + facility agriculture in China to become a scientific production process with standardized management. The Internet-based production management of Internet + aquaculture has gradually become more standardized, achieving automated regulation of the production environment and closed-loop control of the water environment. Consequently, the output and quality of aquatic products have improved significantly, and their cost-effectiveness has increased by more than 10%. In Internet + animal husbandry, the wide use of advanced technology, such as real-time monitoring of the production environment, digitized recording, intelligent logistics management systems, and systematic quality tracing, has enabled a reduction of >30% in the average labor demand. Finally, the seed breeding cloud platform of the Internet + seed industry has been commercialized, significantly improving the breeding efficiency and quality through the comprehensive management of the entire process, from parent selection to breeding.

3.2. Existing Problems

3.2.1. Technical Level. The technical-level problems can be categorized into two major aspects. The first is the technological bottleneck problem. At present, China’s Internet + modern agriculture is still in the technology-integration stage, lagging at least 10 years behind Europe and the United States. This is manifested in the existence of many common technical problems and the lack of significant progress in the development of key equipment, which is caused by the lack of independent innovation capability. For example, the core technologies for agricultural IoT biometric sensing, intelligent control, animal and plant growth modeling, and agricultural big-data analysis and mining have not yet been developed. The second aspect is the issue of technical standards. Thus far, China has not established a standard for Internet + modern agriculture-related technology. The lack of a uniform industry standard is especially evident in the fields of agricultural IoT and intelligent equipment and in the application of information technology demonstration products and agricultural big data.

3.2.2. Industrial Level. The following problems exist at the industrial level of production development. First, there is a lack of independent intellectual property rights for core technology products, reducing the industry’s driving force and China’s competitiveness in the international market. Second, there is a shortage of highly specialized enterprises with a background in agriculture and strong information technology skills, such as software developers, system integrators, service operators, and big-data analysis providers. Third, there is a lack of quality-testing institutions for agricultural software and electronic products. In addition, the software and hardware market is not very well supervised, leading to discrepancies between the products provided by the domestic industries and enterprises and large differences in the functionality and quality of various systems. Fourth, there is a lack of multifunctional, low-cost, easy-to-promote, and effective universal technology and equipment suitable for small-scale production and service.

3.2.3. Application Level. The following five types of problems exist at the application level. First, a user imbalance exists. Practical application occurs mostly in demonstration areas and large-scale operations, such as cooperatives and leading enterprises. Therefore, for most small-scale operations, agricultural information technology is still at the information-awareness stage. Second, the development across industries is not even. For example, the informatization of high value-added industries, such as animal husbandry and aquafarming, is more extensive. Therefore, mature technology, such as precision feeding, is more readily available in such fields. The informatization of crop farming is still dominated by facility horticulture, whereas the level of informatization of open-field cultivation remains low. Third, the application of key production links is unbalanced. Precision-work technology has been widely applied in production links, whereas it has not been popularized in seeding, post-harvest treatment, and other
similar applications. Fourth, the development level varies among different regions. For example, hilly and mountainous areas in the central and western regions have fewer applications. Fifth, the market is not mature. In various regions, the promotion process is focused on pilot demonstrations, whereas the economic performance, such as the cost–benefit ratio of equipment application, has been neglected.

4. Technological System Framework Construction

According to the combined characteristics of Internet + modern agriculture and the agricultural lifecycle activities, the present article divides the key technology system of Internet + modern agriculture into three layers: the supporting technology layer, software technology layer, and application technology layer.

![Technological framework of Internet + modern agriculture](image)

**Fig. 1** Technological framework of Internet + modern agriculture

4.1. Supporting Technology Layer

The supporting technology system of Internet + modern agriculture includes the agricultural IoT, agricultural big data, cloud computing, artificial intelligence, virtual reality, and agronomic professional technology. The supporting technology system is combined with the software technology system to provide support for the application technology system. The combination of these three systems forms the complete technological system of Internet + modern agriculture, which provides technical support for modern agricultural development.
4.2. Software Technology Layer
The software technology system of Internet + modern agriculture refers to a system architecture based on system software and platform software and is used to develop software systems for practical applications. It is composed of three parts: system software, platform software, and application software.

4.3. Application Technology Layer
The application technology system of Internet + modern agriculture refers to the actual application of key technology in such areas as open-field cultivation, facility agriculture, animal husbandry, the fishing industry, agricultural product processing, agricultural e-commerce, and agricultural and rural information service.
Fig. 4 Application technology system of Internet + modern agriculture

Informatization application technology of open-field cultivation aims to improve the informatization level of agricultural production in areas such as information-technology-based plant breeding [14], intelligent germination systems for rice [15], soil testing for formulated fertilization [16], water and fertilizer-integrated precision irrigation [17], and aerial application [18]. Facility agriculture informatization application technology aims to improve the level of automated production through the use of intelligent equipment technology, such as facility environment monitoring [19], intelligent control [20], harvesting robots [21], and grafting robots [22]. Animal husbandry informatization application technology focuses on improving the level of information-based breeding of the most popular species, i.e., pigs, cattle, and chickens. Examples of such technology include animal vital-sign monitoring [23], animal identification [24], precision feeding [25], automatic waste disposal equipment [26], and network-based breeding systems [27]. The aim of fishery informatization application technology is to improve the quality of aquaculture through the use of information-based technology and equipment, such as real-time water quality monitoring [28], automated precise feeding, disease monitoring and early-warning systems, water-circulation equipment control, and net cage lifting control [29]. Informatization application technology of agricultural products processing concentrates on improving the information management system of processing facilities. Its main focus is the big-data platform technology of primary processing facilities, such as grain dryers, fruit and vegetable storage, and post-harvest commercial processing facilities to improve the data integrity of agricultural product quality and safety control [30, 31]. The goal of agricultural e-commerce informatization application technology is to forge new types of agricultural business operations, such as the basic infrastructure for rural networking, processing, packaging, logistics, cold-chain, warehousing, and payment [32]. Agricultural and rural informatization service technology aims to establish a new type of comprehensive information service system. It includes technologies such as agricultural big data, cloud computing, information push, virtual reality, and network information security [33, 34].

5. Application Prospects and Future Development
5.1. Deep Integration of Intelligent Sensing, Human–Computer Interaction, and Intelligent Service-Based Artificial Intelligence into Agricultural Field

Having already achieved mechanization and automation, China’s agriculture is advancing toward intelligence-based Agriculture 4.0, which demands “complete-process, fully automated, large-scale, and integrated” intelligent sensing, precise analysis, and highly efficient application of agricultural information, such as animal and plant physiological data, growth data, moisture and nutrient data, and production yield and variability data. Artificial intelligence employs machine vision, image recognition, algorithms, and natural language processing as its core technology and will become the “main force” in the application of modern agriculture in the future.

5.2. Accelerated Development that Promotes Green, Ecological, and Unmanned Agriculture Through Precise and Intelligent Equipment Technology

At present, China’s agricultural development is confronted with the problems of the deteriorating climate, accelerating urbanization, and shortage of resources, such as arable land, water, and labor, increasing the urgency to accelerate innovation in fields such as agricultural biotechnology, information technology, and equipment technology. With the use of intelligent sensing equipment, sensor networks, the Internet, and intelligent information processing, the IoT will become a gateway to a new-generation management system based on quantitative analysis, intelligent decision-making, variable inputs, and positioning operation in the agricultural production process. This management system will be widely applied in the field of agriculture.

5.3. Domination of Agricultural Information Chain by Agricultural Big-Data Industry with Cloud Computing and Big-Data Technology

As cloud computing and big-data technology become mature and with the development and application of knowledge models, all components of the agricultural information chain, including information collection, pre-processing, storage, processing, and analysis, will be dominated by agricultural big data, such as germplasm data, bioinformation data, environmental data, agricultural production data, market data, and statistical data. In addition, through the integration of software and hardware resources, technologies such as intelligent search engines, intelligent multimedia agriculture service robots, and big-data platforms based on Internet + modern agriculture will be used to innovate the big-data service model, thus forming an important industrial ecology of modern agriculture.

6. Conclusion and Discussion

In accordance with the “Internet +” strategy, China’s “Internet +” modern agriculture has made great progress in field planting, facility agriculture, aquaculture, animal husbandry, and the modern seed industry. However, compared with developed countries such as Europe and the United States, there are problems, such as the low level of technological innovation, immature industrial system, and unbalanced application. The framework of the “Internet +” modern agricultural technology system comprises the supporting technology layer, software technology layer, and application technology layer, and its future application prospects and technology are examined. In the future development of “Internet +” modern agriculture in China, we should encourage government leadership, enterprise participation, and market operation; develop a standard for agricultural big data; build a modern agricultural industrial ecosystem; foster industrial application innovation; and vigorously promote human intelligent technology and virtual reality technology. Driving technology, blockchain technology, and other modern agricultural technology should be promoted to ensure the sustained, rapid, and healthy development of “Internet +” modern agriculture.

Acknowledgements

This work was funded by the Beijing Social Science Fund (17XCA002); the Beijing Academy of Agriculture and Forestry Science and Technology Innovation Capacity Building Special (KJCX20180501, QNJJ201822); and the Engineering Consulting Project (2018-ZD-02-04-03).
References

[1] WANG Peidong. Four dimensions of "Internet plus" to boost the development of modern agriculture [J]. The Farmers Consultant, 2016, 2016(05): 6-7. (in Chinese with English abstract)

[2] CAO Hongxin, GE Daokuo, CAO Jing, et al. Theoretical analysis and ideas for development of internet-plus modern agriculture [J]. Jiangsu Journal of Agricultural Sciences, 2017, 33(2): 314-321. (in Chinese with English abstract)

[3] LI Daoliang. On How Agricultural Modernization Gains Momentum from the "Internet Plus" [J]. People's Tribune Frontiers, 2016, 2016(10): 89-94. (in Chinese with English abstract)

[4] Daberkow S G, Mcbride W D, Robert P C, et al. Adoption of precision agriculture technologies by U.S. farmers[C]/International Conference on Precision Agriculture, Bloomington, Minnesota, USA, 16-19 July. 2015.

[5] Schimmelpfennig D E. Farm Profits and Adoption of Precision Agriculture [J]. Economic Research Report, 2016.

[6] Spiertz J H J, Kropff M J. Adaptation of knowledge systems to changes in agriculture and society: The case of the Netherlands [J]. NJAS-Wageningen Journal of Life Sciences, 2011, 58(1/2): 1-10.

[7] Noguchi N. Monitoring of wheat growth status and mapping of wheat yield’s within-field spatial variations using color images acquired from UAV-camera system [J]. Remote Sensing, 2017, 9(3): 289.

[8] Paustian M, Theuvsen L. Adoption of precision agriculture technologies by German crop farmers [J]. Precision Agriculture, 2017, 18: 701-716.

[9] Gerhards R, Oebel H. Practical experiences with a system for site-specific weed control in arable crops using real-time image analysis and GPS-controlled patch spraying [J]. Weed Research, 2006, 46(3): 185-193.

[10] Philipp I, Rath T, Nordmeyer H. Automatic weed mapping in sugar beet by use of image processing [J]. Journal of Plant Diseases & Protection, 2002, 109(4): 429-436.

[11] Shibysawa S. Innovation in precision agriculture [J]. Journal of the Society of Instrument and Control Engineers, 2009, 48 (2):151-156.

[12] Jansen R, Hofstee J W, Bouwmeester H, et al. Automated Signal Processing Applied to Volatile-Based Inspection of Greenhouse Crops [J]. Sensors, 2010, 10(8): 7122-7133.

[13] FLAIG Dorothee, RUBIN Ofir, SIDIDIG Khalid. Imperfect competition, border protection and consumer boycott: The future of the dairy industry in Israel [J]. Journal of Policy Modeling, 2013, 35(5).

[14] LIU Zhongqiang, WANG Kaiyi, ZHAO Xiangyu, et al. Research on Information Model of Plant Breeding under Cloud Environment [J]. Journal of Agricultural Mechanization Research, 2017, 2017(03): 7-11. (in Chinese with English abstract)

[15] WU Jianwei, XIN Ying, WANG Cheng, et al. Design of the Intelligent Germination System for Rice[J]. Journal of Agricultural Mechanization Research, 2013, 2013(11): 168-170. (in Chinese with English abstract)

[16] YIN Xin, ZHANG Mingxiang, HU Ronggui. Contribution of soil testing for formulated fertilization to N2 O mitigation in Hubei Province [J]. Acta Scientiae Circumstantiae, 2016, 36(4): 1351-1358. (in Chinese with English abstract)

[17] XU Gang, CHEN Liping, ZHANG Ruirui, et al. Application of Internet of things for precision irrigation [J]. Journal of Computer Research and Development, 2010, 47(S2): 333-337. (in Chinese with English abstract)

[18] WANG Jihuan, ZHAO Chunjiang, WANG Xiu, et al. Design and Test of an Analog Rotorcraft Electrostatic Spraying Pesticide Deposition Apparatus [J]. Journal of Computer Research and Development, 2016, 2016(01): 95-100. (in Chinese with English abstract)

[19] LIU Jun, TAO Jianping, MENG Lili, et al. Design of a greenhouse environment monitoring system based on Internet of things technology [J]. Journal of Chinese Agricultural
Mechanization. 2016, 37(12): 179-182. (in Chinese with English abstract)

[20] MA Wei, WANG Xiu, LI Yunlong, et al. Sixty-six of the greenhouse smart equipment series-A mobile greenhouse electric wind delivery disinfectant device [J]. Agriculture Engineering Technology, 2015, 2015(04): 20-21. (in Chinese with English abstract)

[21] ZHANG Junxiong, HE Fen. Research progress of facility agricultural picking robot [J]. Agriculture Engineering Technology, 2015, 2015(25): 31-34. (in Chinese with English abstract)

[22] TONG Junhua, JIANG Huanyu, JIANG Zhuohua, et al. Experiment on parameter optimization of gripper needles clamping seedling plug for automatic transplanter [J]. Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE), 2014, 30(16): 8-16. (in Chinese with English abstract)

[23] GU Jingqiu, WANG Zhihai, GAO Ronghua, et al. Recognition Method of Cow Behavior Based on Combination of Image and Activities [J]. Transactions of the Chinese Society of Agricultural Machinery, 2017, 48(06): 1-14. (in Chinese with English abstract)

[24] GUO Wei, QIAN Dongping, WANG Hui, et al. Anti-collision technique in the radio-frequency identification system for dairy cattle [J]. Transactions of the CSAE, 2009, 25(11): 222-225. (in Chinese with English abstract)

[25] MA Mingxin, WANG Shuijie, WANG Xue, et al. Diet control for accurate feeding of dairy cows [J]. China Dairy Cattle, 2014, 2014(21): 56-58. (in Chinese with English abstract)

[26] LI Wenzhe, XU Minghan, LI Jingyu. Prospect of Resource Utilization of Animal Faeces Wastes [J]. Transactions of the Chinese Society of Agricultural Machinery, 2013, 44(05): 135-142. (in Chinese with English abstract)

[27] LI Shigong, XU Houqiang, LONG Guorong, et al. Study on construction of livestock and poultry germplasm resources library and information database in Guizhou [J]. Guangdong Agricultural Sciences, 2013, 2013(13): 183-186. (in Chinese with English abstract)

[28] DU Yancheng, CHEN Wei, CAO Dianguo. The Design of Aquiculture Water Quality Monitoring and Control System Based on Internet of Things [J]. Electronic Technology, 2013, 2013(12): 35-38. (in Chinese with English abstract)

[29] HUANG Yayu, E Xu, YANG Fang, et al. Research on Integration of Internet of Things System and Security Early Warning in Aquaculture [J]. Computer Technology and Development, 2017, 27(09): 201-204. (in Chinese with English abstract)

[30] MAO Lin, CHENG Tao, CHENG Weili, et al. Construction and application of intelligent terminal system for safety tracing of agricultural product quality [J]. Jiangsu Journal of Agricultural Sciences, 2014, 30(01): 205-211. (in Chinese with English abstract)

[31] LUO Bin. The present situation and Prospect of China's agricultural product quality safety traceability system construction [J]. Quality and Safety of Agro-products, 2014, 2014(04): 3-6. (in Chinese with English abstract)

[32] TAN Bengang, FANG Yong, CHEN Zhaosan. Thinking on the construction of the demonstration project for the application of the Internet of food and transportation supervision and transportation in Shenzhen, Guangzhou and Nanning [J]. China Grain Economy, 2015, 2015(12): 49-53. (in Chinese with English abstract)

[33] LUO Zhiqing, WU Yaling, CHEN Pinting, et al. Research on application of cloud computing in information service platform service and peasant [J]. Journal of Chinese Agricultural Mechanization, 2017, 38(03): 62-65. (in Chinese with English abstract)

[34] WANG Wensheng, GUO Leifeng. Agricultural big data and its application prospect [J]. Jiangsu Agricultural Sciences, 2015, 43(09): 1-5. (in Chinese with English abstract)