Experimental Agriculture (2024), vol. 60, e28, 1–13
doi:10.1017/S001447972400022X

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

The rise of smart agriculture in China: current situation and suggestions for further development

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(Received 25 May 2024; revised 01 September 2024; accepted 27 September 2024)

Summary
Smart agriculture is based on latest technologies in communication, big data analysis, high-performance sensors, and automatic machinery to improve the effectiveness of agriculture industry. China is looking forward to achieve modernization of its agriculture industry through smart agriculture. But its unique climate, landscape, diversity in crops, and large population make this task more challenging compared to other counties. Herein, we present the current achievements regarding policies made to guide and support the development of smart agriculture, the promotion of smart techniques and smart equipment, and the cultivation of specialists in smart agriculture. Then we discussed the existing challenges that hinder further development of smart agriculture industry and proposed several feasible solutions to solve or ease the problem, including the pertinent development of smart agriculture in provinces with different resources, enrich modes of online technical support and specialist cultivation, and set a series of standards to guide research and development of novel smart systems.

Keywords Smart agriculture; bio-economy; agricultural modernization; sustainable development; local policy

Introduction

Smart agriculture combines modern technology such as wireless communication, Internet of things, big data analysis to digitalize agricultural production, in order to achieve more quantized and real-time monitoring of crops and alternatively improve efficiency of production(Tao *et al.,* 2021). Recent development has expanded to novel methods such as cloud calculation, blockchain, artificial intelligence, high-precision sensing, intelligent equipment, etc(Liu *et al.,* 2021). These smart tools offer assistance to aspects including breeding, climate, quality inspection, logistics, trades, pollution control, and other government inspection. The concept of smart agriculture, even though the name may vary in different countries, has drawn the attention of policy makers across the world. In 2015, Policy Horizon Canada (Government of Canada's center of excellence in foresight) released report <MetaScan 3: Emerging Technologies> which included satellite imagery and advanced sensors, agricultural robots, rapid iteration selective breeding, etc. In 2018, the cabinet meeting of Japan set the 'future investment strategy' to 'building the world's top-level smart agricultural system'(Li *et al.,* 2023). They followed this decision by setting up 'accelerated extension project of smart agriculture' which provides 5 billion yen to smart agriculture related research.

China is feeding one fifth of the total population on earth with only 8% of the arable land, which makes modernization of agriculture an essential issue for Chinese government (Zhang *et al.,* 2020). The size of potential market of smart agriculture in China has increased from 13.7 billion US dollars in 2015 to 26.8 billion US dollars in 2020, accompanied by an annual growth

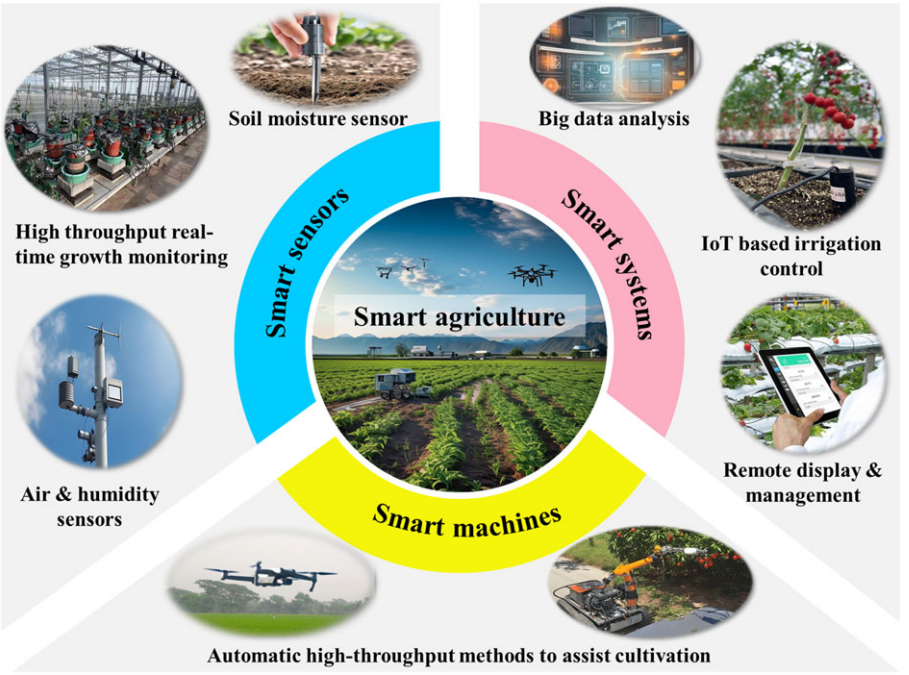

Figure 1. General introduction of smart agriculture. A smart system consists of three parts, the smart sensors to monitor agricultural traits or environmental conditions in real time, the smart systems to wireless obtain the detection results from sensors and carry out big data processing to provide advice or early warning and help make better decisions, the smart machines that automatically do hard labor work and save manpower required for agriculture activities. The combination of these parts leads to modernization of agriculture.

rate of 14.3% (Li and Nanseki 2022). How to set wise policies to guide healthy development of smart agriculture remains a key problem. Development of smart agriculture is vital to the transformation from traditional model to modern model, it is also very important to poverty alleviation. Its influence mainly focuses on these aspects. First, smart agriculture takes advantage of rapid robust sensing and data transferring technologies to increase the precision and decrease the response time of data collection, which results in real-time monitoring of growing status and nutrition factors of crops or detailed characterization of soil and weather, alternatively leads to more effective decision making in sowing, fertilizing or harvesting. Second, smart agriculture advocates high coverage of data acquisition and procession during the whole process of production, transportation, and trading process accompanied by assistance from artificial intelligence and big data processing methods, which will greatly help government fully understand the current situation and build more transparent commanding system to help resource allocation, quality supervision and logistics traceability. Third, smart agriculture uses specifically designed devices to realize automatic production of agri-products, which renovates the whole industry by greatly reducing man power and time required by traditional methods. Last but not least, smart agriculture contributes to sustainable development with more advanced monitoring and controlling of water or pesticide applications. Recent studies suggested a more effective way of irrigating and disinsecting, which lowers the usage of water and pesticide, and could prevent problems such as environmental pollution, soil erosion, and pesticide residues on products. A general introduction to smart agriculture is shown in Figure.1.

In this work, we start from the four aspects described above and introduce policies China has put forward to develop smart agriculture. The outcome of these policies and their achievement are

https://doi.org/10.1017/S001447972400022X Published online by Cambridge University Press

discussed from science development, popularization of novel technology and talent cultivation regarding smart agriculture industry. A comprehensive view combining agricultural science and technology and agricultural management system is provided to assess current challenges in further development, and several suggestions in political support, talent cultivation and technical standards are listed to help fulfill the goal of rural construction, common prosperity and sustainable development.

Current achievements and challenges in developing smart agriculture

The State Council of People's Republic of China consists of 26 ministries, among which the Ministry of Agriculture and Rural Affairs (MARA) is in charge of development of smart agriculture(Min 2020). Most smart agriculture related policies are made and carried out by MARA. In this section, we list the major policies and important decisions made to support development of smart agriculture and their achievements, including general support and guidance, promotion, and specialist cultivation. We also listed the existing challenges that are holding back the development of smart agriculture.

Policies to guide and support development of smart agriculture

Novel technology is the key to smart agriculture, which makes scientific research and new product development the most vital and initial step. In the past decade, China's policy makers have drawn the attention of academic and business world step by step, which resulted in the current prosperous state. China first brought up the concept of smart agriculture in 2014, corresponding to the international trend of precise farming. In the No. 1 central document of 2016, China emphasized 'Strengthen the development of a system for promoting scientific and technological innovation in modern agriculture' and 'Promote the development of modern agriculture based on 'Internet+' strategy, apply Internet of things, cloud calculation, big data, mobile Internet and other modern information technology to fully upgrade the agricultural industry chain, and remote application of smart meteorological and agricultural remote sensing technologies' (Li and Nanseki 2022. By far, smart agriculture related contents have been listed in China's major national development plans such as 'Rural Revitalization', 'Seed Industry Revitalization', 'The 14th Five Year Plan for the Development of Bio economy', and also part of the report for 'The 20th National Congress of the Communist Party of China'. From the international perspective, the United States, Japan, and Europe Union are also formulating their policies to develop and popularize smart agriculture or precision farming(Saiz-Rubio and Rovira-Más 2020; Mohamed *et al.,* 2021; Wang *et al.,* 2021).

Alongside general policies to encourage development of smart agriculture, there are more specific guide details of this massive and interdisciplinary project. In the document 'Technical guidelines for green agricultural development (2018-2030)' released by MARA, 25 primary tasks and the supporting measures to ensure these primary tasks can be completed on schedule (https://www.gov.cn/gongbao/content/2018/content_5350058.htm). 18 of these tasks were brought up in three aspects, including key R&D targets, demonstration mode and promotion channels. The other 7 tasks were about key renovation technology development, fundamental research and standardization. These detailed instructions are not mandatory for those who work in smart agriculture industry, but they gave a clear view of the foresight from the Chinese government's point of view. Companies or researchers would focus on these fields pointed out by MARA in order to get higher chance of funding or aid coming from the government. On the other hand, local governments on provincial level will also find the topics that are most suitable for their area and host events or attract investments accordingly. Here we present several examples that exhibit how the government guideline directs local government decisions or R&D progress of companies or research facilities.

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In the task 'develop low energy consuming intelligent agricultural equipment', they key R&D targets concluded 22 different purposes of the preferred equipment including water saving irrigation equipment. Following this guidance, Laiwu city developed an industrial cluster of water-saving irrigation equipment which consisted of more than 100 companies that are producing over 33% of the irrigation equipment in China. Another example is the task 'green mode based on crops to improve production and efficiency'. One of the suggestions is to use plants as a measure to lower carbon emission. Right after this document was released, Chinese government gave official notice to allow three cities to construct 'National Sustainable Development Agenda Innovation Demonstration Zone' as a way to encourage sustainable development. After a few years' preparation, Zaozhuang city has successfully applied for such honor in 2022. They also announced future plans for 'Sustainable, low-carbon and high quality development of agriculture', including how to effectively recycle waste, build industrial chain, realize digitalization, provide trade centers (both online and offline) or financial aid. Similarly, Wuhai city initialized its own low carbon project as well. The city government set up 'natural resource smart agriculture research demonstration project' with a newly constructed zero-carbon high-tech agriculture industrial park. The whole industrial park achieved internal circulation of clean energy and waste recycle, resulting in an environmental friendly system that generates zero external waste. Last but not least, many objectives in promoting digitization in agriculture were presented in the task 'smart agriculture technique mode'. Jinlin province, one of the most important agricultural areas in China, has released an official document in October 2022 regarding 'advices towards implementation of smart agriculture'. According to this document, the provincial government has addressed the task of optimizing the existing digitalized cloud platform for agriculture purpose to the Provincial Department of Agriculture and Rural Affairs, Provincial Bureau of Government Services and Provincial Bureau of Digitization. Moreover, in the section on overall objectives the government specified that by the end of 2022 this cloud platform should be fully functional in all departments that are related to rural affairs, regardless of their administration level. With the help of such a strong push by the government, a great sum of 5G base stations were installed along with multiple big-data processing center. In addition, the document also announced the government will set the standards for 'digitized agriculture demonstration base' and appraise ten of the best villages as demonstration base as reward for their efforts.

Besides the items listed in the above mentioned document, there are many other achievements obtained following this 'top-down' chain of command. For instance, the No. 1 central document of 2023 instructed that idle paddy fields in winter should be utilized for oilseed rape production. This instruction has taken into account the cold resistance, nutrition balance between two crops and soil, economic benefit and the outcome of previous application demonstration. This idea was demonstrated in at least three villages in 2022. By the end of 2023, we are able to find more than twenty villages reported in local news that they applied such arrangements following the No. 1 central document.

The promotion of smart agriculture

Besides the policies made to guide and support smart agriculture, China has made efforts in many other forms to promote smart agriculture.

One of the most effective methods is to set 'model smart agriculture village' for as a way to demonstrate how smart agriculture can improve people's lives. Instead of verbal recommendation or bibliographic education, setting a direct example is more intuitive. Moreover, these villages are usually designed based on the natural resources and climate conditions, which also act as guidance to those villagers who are not able to choose the correct developing model on their own (Zhang and Zhang 2020). Jilin province is organizing model villages that combine clean energy with smart agriculture. Jilin province is famous for its development in promoting clean and renewable energy (Zhang *et al.,* 2014; Li, Pan, and Zhang 2023). Such combination not only solves the problem of

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power supply and transfer in large-scale farmland but also integrates local businesses to achieve greater profit. In some other cases, the village government invites universities to try out their latest research projects and collaborate in construction of a new concept smart village. Shanmei village in Guangdong province collaborated with Guangdong University of Petrochemical Technology to construct an agriculture experimental base that focuses on special local products, such as cherry tomato, peanut, sesame, etc. The university is providing fertilizers and pesticides they developed to the experimental base as well as guidance in controlling the optimal dosage. In return, they will get data and feedback for further research.

There are other factors that eased the promotion of smart agriculture, even though their primary goal was not related to agriculture industry. For instance, China has put great effort into telecommunication in rural areas. By the end of 2021, more than 99% of villages were covered by 4G network (Li and Nanseki 2022). The construction of such infrastructure is vital to establish internet related tools for smart agriculture.

The cultivation of specialists in smart agriculture

Smart agriculture combines the most recent and advanced technologies in multiple fields, which greatly raised the bar for its practitioners. On the other hand, the promotion of smart agriculture requires a great deal of high level specialists in the grass root level of agriculture industry, so that agriculturists could refresh and update their perception in all stages of cultivation. Hence, the huge need for specialists is one of the most limiting factors in developing smart agriculture industry. The current methods of cultivating specialists can be divided into education of next generation experts and training of existing agriculturists.

The education of next generation experts provides future personnel in smart agriculture. Thanks to various promoting policies put forward by Chinese government, many universities have established novel majors in smart agriculture or are preparing to do so. The number of master theses or Ph.D. dissertations that mentioned 'smart agriculture' in its title, abstract or key words in the past decade was enlisted in Figure 2. The data was accessed from China National Knowledge Infrastructure (CNKI, www.cnki.net) in August 2024. CNKI is the official database for research paper, thesis and dissertation published in Chinese. We could see a rapid growth in the number of theses or dissertations, which suggests more and more research groups are getting involved in this field. It is important to point out that CNKI do not publicly display all of the theses, some works are protected by non-disclosure agreement. The real number of students working in smart agriculture will be higher than the ones reported here. The most commonly mentioned key words are displayed in Figure 3, which could provide an overall view of the general interests in research topic. It shows that the most heated research topics in smart agriculture are 'internet of things', 'deep learning' and 'ZigBee' (a kind of wireless communication technology). Jilin Province, one of the most fertile and capacious provinces in the northeast of China, is the only geographic name that appears on this list, which suggests its determination and befitting natural conditions in promoting smart agriculture.

It is necessary to mention the novel education model established in Hainan province. The climate of Hainan displays typical tropical monsoon features. Hainan has sufficient sunshine and rainfall accompanied with high temperature which allows more growing cycles of crops throughout the year and can accelerate the speed of breeding and research(Gao *et al.,* 2022). As a result, students who wish to work in smart agriculture industry could greatly benefit from these conditions. Eight agricultural universities across China have allied to educate some of their students in Hainan province. This alliance is further supported by MARA and Ministry of Education, those students who work in Hainan province will not be accounted in the total number of students allowed to enroll for these universities.

On the other hand, post-graduate education may contribute to the development of novel technologies, but based on employment status, those students who process master or Ph.D.

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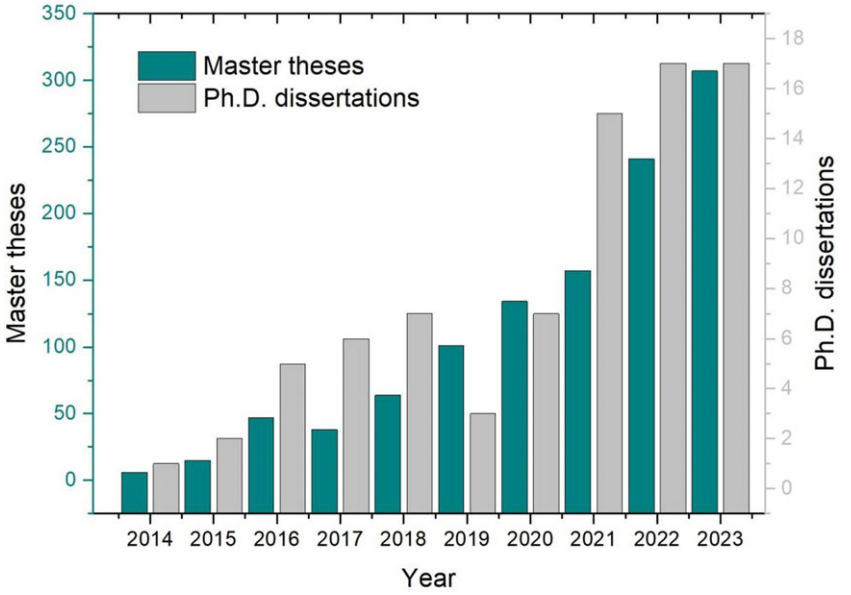

Figure 2. The number of master theses (left Y axis) or Ph.D. dissertations (right Y axis) that mentioned "smart agriculture" in their title, abstract or key words recorded in CNKI database from 2014–2023.

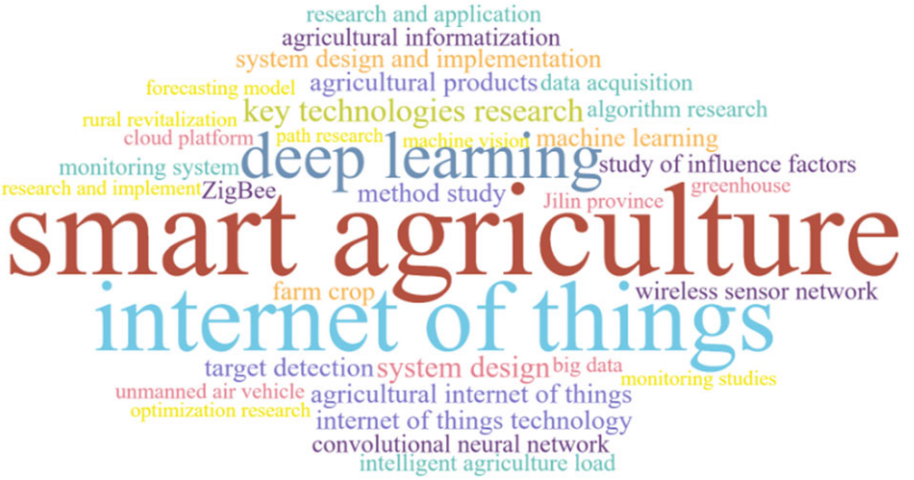

Figure 3. A word cloud that displays the most frequently mentioned key words in 932 theses or dissertations recorded in the database of CNKI.

degrees are less likely to work directly in agriculture business. For this reason, specialized undergraduate programs dedicated to the course of smart agriculture are essential. In 2020, the Ministry of Education of China first granted enrollment of smart agriculture major, including some of the top universities in agriculture. For instance, Huazhong Agricultural University set up its smart agriculture major with core curriculum covering machine learning, breeding, Python, internet of things, bioinformatics, supply chain management, etc. By the time of 2022, the programs have expanded to 12 different majors covering various aspects of smart agriculture, including breeding science, breeding techniques, earth science and technology, biomass science

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and technology, ecological restoration, construction and management of national parks, smart agriculture, agricultural intelligent equipment, food nutrition and health, veterinary public health, rural governance and global agriculture development. These majors are not limited to research of novel technologies, but also take into consideration of public health, sustainable development and management. The challenge in hosting undergraduate programs in brand new majors lies in the lack of appropriate textbooks. In order to help universities across the country, the MARA released the plan of compiling a series of smart agriculture related textbooks and the universities and publishing presses taking charge of each subject. This series of textbooks consists of 47 different curriculums related to modernized agriculture, animal husbandry, aquaculture, etc. These revolutions are not confined to agricultural universities, many comprehensive universities (based on definition of Ministry of Education of China, comprehensive university refers to large scale university that offers a wide range of academic disciplines, including philosophy, humanities, sciences, engineering, management, law, medicine, agriculture and forestry, economics, education, arts, etc.) are establishing majors and courses for smart industry that covers the field of agriculture. In 2021, 13 universities established new smart agriculture major, including 3 comprehensive universities. Thanks to the interdisciplinary nature of comprehensive universities, it is easier to organize teaching staff in programming, automate, data transmission, mechanical design, etc.

Despite many efforts being made to cultivate specialists in smart agriculture, the process still takes a very long time and could not provide the vacancy in personnel shortage. Many courses and training camps were hosted across the country to prepare the in-services agriculturists for the coming changes. These lectures or training camps were either government hosted or in some cases hosted by companies who wished to sell their products. In addition to this, China is also promoting practical education as part of the 'rural revitalization' policy. The Communist Youth League Committee is organizing programs in various forms to send students from college level to primary school level to leave the city and visit villages nearby to have an intuitive impression of the modernized village under construction. These programs aim to provoke the interest of younger generation in devoting to agriculture industry.

Challenges in further developing smart agriculture

Despite the above mentioned efforts to promote smart agriculture in China, many challenges still exist in further development. Herein we summarize these challenges into three categories, the localization of policy making process, the shortage of technique and personnel in several key fields, and the lack of technical standards to formalize the market.

Urgent need for more customized policies according to local resources

We enlisted some of the policies to promote smart agriculture in section 2.1, but these are macroeconomic policies on national level. Due to China's large area and distinct conditions, policy makers on provincial level should consider and take advantage of local resources to achieve more effective results. The factors that need to be taken into account include the landscape, local agri-products, climate, academic resource, industry structure, local economy, etc.

The differences in landscape and climate lead to highly localized agri-product selection, which means the requirement of basic elements sensor, machine, algorism, and processing system is different in each province. This has made it very difficult for policy makers to directly learn from the success of other district. Blindly following other district's policies may cause severe outcomes. On the other hand, this has also increased the difficulty of research for corresponding smart equipment. The various needs of sensors toward different traits also cause the problem of low credibility in the sensing results, which will affect the outcome of the whole system.

Financial problem is also vital in this discussion. The implementation of smart agriculture requires a great sum of money. The development of smart agriculture related technologies

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strongly depends on governmental projects, whereas the promotion of smart agriculture mostly relies on local Academy of Agricultural Sciences (AAS, a kind of institute that exists in most of the major cities of China and is dedicated to development and promotion of novel agriculture technology), which is also government related agricultural research facility. However, those provinces that depend on agriculture are usually not thriving in economy and are facing difficulty in attracting investment from more wealthy provinces. Moreover, provinces that excel in agriculture but lack economic prosperity tend to have large scale of fields whereas wealthy provinces do not depend on agriculture have limited area of fields, which makes it more difficult to promote smart agriculture. This problem not only hinders the promotion of smart equipment but also exists during the procedure of increasing capital construction related to the internet, transportation, etc.

Last but not least, the willingness to try new technology of farmers in different provinces varies greatly. Li *et al.,* (2020) set up a hybrid model to analyze key factors affecting farmers decision making in the matter of adopting smart agriculture, the factors include education, finance, size of the farms, local labor cost, etc.

Shortage of specialists in front-line work

Smart agriculture covers the latest work in multiple scientific fields and has high requirement for fusion of these technologies. Although Chinese government has made great efforts to cultivate specialists in smart agriculture, there is still shortage of specialists in front-line work. This is mainly due to two reasons. First, the duration of cultivation through college is at least four years, which takes a long time to cover the current shortage. Second, many of these students who graduate from smart agriculture related majors want to pursue further education so that they could earn a job in the office instead of doing hard labor work in the fields. The shortage of specialists not only influences the yield of smart systems, it also inhibits the promotion of smart technologies since old-school front-line farmers tend to refuse or are unwilling to adopt novel systems (Shaheb, Sarker, and Shearer 2022).

In order to help cover the current shortage in specialists, the ideal solution is to direct host training sessions to front-line farmers and update their knowledge. The difficulties lie in the low educational background and old age of front-line farmers. Based on previous research, a group of 782 farmers in Jiangsu province was selected to study their preference in farming techniques (Chen and Zhou 2023). The average age of this group was 53 years old, which accords with the usual description of labor force in agriculture. One could imagine the difficulty of promoting smart agriculture methods to this group of front-line farmers. The education methods in front-line need to be modified to better suit this group of audience as well. Despite many new media platforms being used to propagate smart agriculture, these platforms do not reach the audience in front-line due to their old age and low usage of smart phones. For the moment, the propagation of smart agriculture in front-line mostly relies on posters, broadcasts, and television, but the outcome is not as good as expected. Moreover, these front-line farmers represent small companies or an even family-based small farming group, which makes it impossible to directly command them to change their way of farming. The change should be induced through rational designed policies, which is still in exploration.

Lack of standards to guide technical and administrational details

The lack of standards specifically targeting smart agriculture system or equipment is also the main obstacle standing in the route of development. We analyzed 3037 national standards and 4721 industry standards under the category of agriculture enlisted in "National public service platform for standard information" database (https://std.samr.gov.cn/), the official site for all the Chinese standards in practice. The comparison was listed in Figure 4, whereas numbers of standards in

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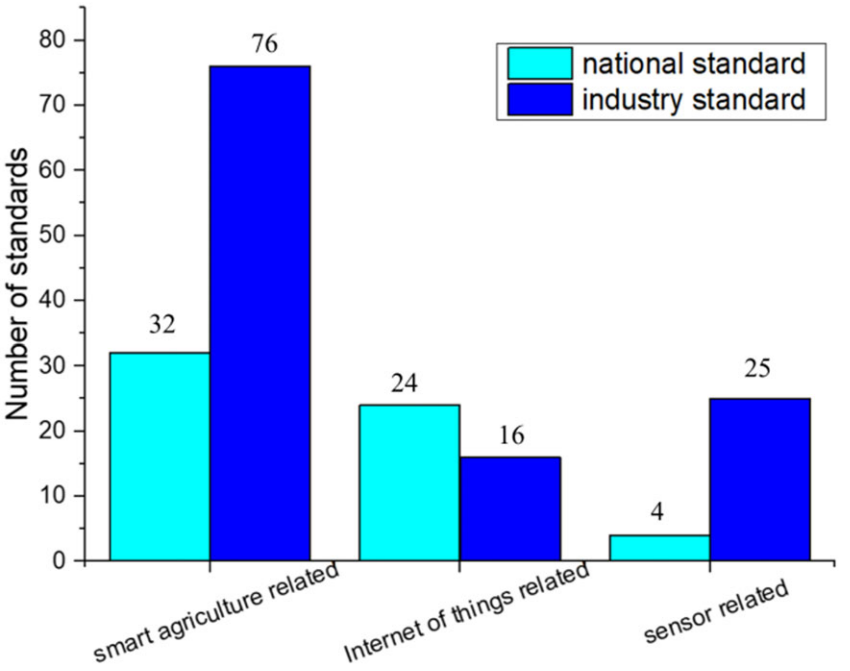

Figure 4. The number of standards in different fields related to smart agriculture. The number of smart agriculture related standards refers to those works that are closely related to smart equipment and their parts, which includes internet of things and sensor related standards. The sensor related standards not only cover the structure of sensor but also how to harness sensing data.

four categories were presented, readers could find details of these standards in the ESI. We could see that only a few standards were closely related to smart agriculture. Moreover, we also counted 502 national standards and 434 industry standards for farm machinery (transportation machines eliminated). Even though the number is relatively higher than smart systems, the contents mainly focus on tractors or planters, which are quite mature in machine design. There are two sides to this issue. On one hand, the emergence of smart technologies is quite recent and various approaches were applied to realize similar functions, blindly setting high level technical standards will suppress the creativity of researchers. On the other hand, the lack of standards is also causing extra trouble in developing novel systems. For instance, the data harvesting, transmission and processing processes could be realized through diversified protocols. This means parts designed by different companies are not compatible and it is impossible to assemble a custom designed system with optimal performance.

Data storage is also a key concern in developing new smart agriculture systems. The sensors are constantly generating data and massive of data will be produced during the whole planting cycle. Any fault in data storage may cause untrustworthy data analysis, but more importantly, the safety of these data is vital to the government since they represent the production capability and food security of the nation, video or images used to assist smart machines may also contain private information of the farmers (Tao *et al.,* 2021). It is difficult to store all these data in private companies. In theory, the government should build an official data base to protect these data, but the expenses associated with its creation and upkeep pose a substantial financial burden for the government. In some cases, block chain or anti-counterfeiting code is used to make sure authenticity of agri-products in transportation, which requires unitive standards across the country.

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Suggestions for the policy making process of smart agriculture development

Pertinently design policies for smart agriculture

As mentioned before, the conditions in each province are different and the government should not use the same set of policies to promote smart agriculture. Without careful and pertinently design, these policies may lead to investment with low profit rates or even cause huge losses. The ideal strategy is to set two to three batches in achieving modernization of agriculture. Those provinces that have large farming area but not strong in economy should consider promoting well-established smart systems in order to make sure the money is well-spent. Those provinces that are strong in economy but do not have large farming area is suitable for the testing and demonstration of novel smart systems. The only exception is Jiangsu province, which has both large farming area and good economy. It could act as the transition between two developing modes. Before a new system is widely promoted, it could have a first trial run in Jiangsu province to rule out the possible hidden troubles and keep a good investment profit rate in other provinces. The policy concerning talent introduction should also differ from provinces. Some advantages in promotion, title competition or research funding application should be added to agriculture based provinces so that the most talented specialists will consider working in those areas instead of fighting for better treatment in big cities such as Beijing and Shanghai.

Another way to help make pertinently designed policies is to build typical models of different climates and landscapes and let the rest of the country follow their corresponding model. Zhejiang province stands out among all the provinces due to its special complexity. Located on the southeast coast of China, Zhejiang province is quite complicated in landscape that includes mountains, hills, and plains. Its climate could also be divided into costal area (mild and humid), inland area (dry, hot in summer and cold in winter), and mountainous area (cool with sufficient rainfall). This special property has made Zhejiang very important in the great task of achieving "common prosperity", since it acts as a simulation area for testing different models and methods for eliminating poverty(Xu, Liu, and Sun 2023). For the same reasons, Zhejiang could play an important role in helping the development of smart agriculture systems and set demonstrations for new methods or systems. In addition to this, Zhejiang is also a wealthy province (with 8260 billion RMB reported GDP in 2023, ranking 4th in all provinces), which could afford the cost of testing these models and methods. It is beneficial to set special policies to set experimental models of smart agriculture in Zhejiang.

Provide technical aid and cultivation of specialists through various paths

The existing cultivation mode cannot fulfill the cavity of specialists in smart agriculture, especially in the front-line work. There are two suggested approaches to help this matter. First, encourage the use of online software or artificial intelligence tools to provide technical aid to front-line farmers. Second, the cultivation mode of specialists in smart agriculture should be altered or enriched so that the graduates could directly engage in front-line work.

The current problem is that front-line farmers do not possess the knowledge to operate smart agriculture systems on daily basis, especially when it comes to emergency situations such as massive spread of contagious pathogens or plant diseases. With the development of digital construction and online business software, the specialist could provide their experience through internet instantly. Several news were reported in the past few years that the specialists in AAS helped farmers in other provinces to solve the problems during mushroom growing process through online methods. Much like the current medical system in China, where doctors in small cities that lack patents during daytime could offer online assistance to patients who are confused in pharmacies, the specialists in AAS could also be encouraged to help front-line work in their office. The government or MARA should coordinate between different provinces to build database

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of specialists and sort by the crop or vegetable of their expertise and provide an official platform to establish connection between academy and front-line.

The government should also consider setting new job positions in front-line work and limiting the applicant to graduates in smart agriculture majors. This would greatly encourage students to engage in front-line work instead of continuing for further education. The aim of bringing in these young and well educated graduates is to guide the transition between traditional farming and modernized farming. As a matter of fact, rudiment of this idea already exists in local government policy. Nanchang city has announced a "directed education mode" for front-line workers in agriculture industry. The students choosing this mode will be specifically cultivated for front-line positions, so they won't have to worry about job searching and will be better suited for the job. It is a highly effective way to connect university and front-line, but the collaboration between wide range of government agencies is hard to achieve on large scale.

Build a series of standards to establish a mature system

Although the setting of technical standards will limit the path of developing novel smart technologies, it also facilitates the formation of mature market. Two suggestions are posed for this matter.

First, instead of setting high level standards in a rush, it is wiser to start with local standard and group standard. This approach makes sure that the standards are set according to the needs of local agriculture industry and won't create problems in other provinces. It also gives new technologies a test run and can be easier altered based on feedback in front-line. The well verified standards could be upgraded into national or industry standards. The setting of these standards could accelerate the formation of technical standard alliance (Wang, Zhou, and Wang 2023). Such alliance combines the strong points of companies and increases the efficiency of research and development.

Second, the government should propel the setting of standards in data transmission and storage. As discussed before, the diversity of data harvesting, transmission and storage protocol makes it impossible to integrate parts designed by different companies. The companies also tend to use the difference in these aspects as a way to eliminate competition or repel self-assembled systems by the customers. More importantly, these parts are not vital to the functions of smart systems. If the government sets a series of standards to unite the protocols and make it easier to assemble products from different companies, it could greatly guide competition to the quality and practicability of smart machines or sensors and boost the formation of reliable smart system.

Conclusion

To sum up, the development of smart agriculture in China has achieved respectable results in promoting new technologies and cultivating specialists. But the shortage of local policies, front-line specialists and technical standards is hindering further development of smart agriculture in China. After a thorough analysis of current situation, we proposed several suggestions in policy designs to help solve or ease these problems. The provinces could be divided into two groups, one for large scale application of mature and well-tested smart systems, the other one for exploration of new systems, whereas Jiangsu province could act as the transition between two groups. Zhejiang province is an ideal province to develop new systems due to its complex climate and landscape, and could set developing models for villages across the country. Online assistance should be provided to the front-line farmers so that the specialist could advise their decision making. New methods such as artificial intelligence are also promising in providing technical aid to front-line farmers. New cultivation mode of specialists should direct and encourage undergraduates to look for jobs in the front-line instead of blindly pursuing higher degrees and waste all the talents in lab and office. The government should establish a series of standards regarding data harvesting,

https://doi.org/10.1017/S001447972400022X Published online by Cambridge University Press

transmission and storage to make sure smart equipment developed by different companies is compatible with each other. New local standards or group standards should be encouraged for verifying new systems and forming technical standard alliances. These measures should help policy makers to guide the rational and rapid development of smart agriculture industry.

Author contributions. Wei Wu and Xiaorui Feng were in charge of original draft writing, Chenze Lu was in charge of the whole structure of this work and the editing of original draft.

Funding statement. This paper is funded by Basic Public Welfare Research Program of Zhejiang Province (LTGN23C020003) and NSFC (32201254).

Competing interests. The authors declare no conflict of interest.

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Cite this article: Wu W, Feng X, and Lu C. The rise of smart agriculture in China: current situation and suggestions for further development. *Experimental Agriculture*. https://doi.org/10.1017/S001447972400022X