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Analysis on the selection of sustainable development path of smart agriculture

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Abstract. Smart agriculture is a new farm management concept, and also a path of sustainable agricultural development. The profound changes in practice have brought about both opportunities and great challenges, and agriculture in the digital age can only be called sustainable smart agriculture through overall consideration of technologies, diversity of biological systems, and various aspects of networks and institutions. Through the analysis on IoT-based smart agriculture, the options and strategies of sustainable development of smart agriculture are explored in this paper.

Keywords. Smart agriculture, IoT, sustainable development.

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1. Smart agriculture

Smart agriculture is a new farm management concept, which can promote sustainable agricultural development based on comprehensive information services in the fields of production, operation and services.

Over the past 100 years, the use of heavy machinery and industrialization of the production chain have brought about significant changes in agricultural production, which are crucial for the current development of agriculture. As a new farm management concept, smart agriculture is also a technological means of integrating computer science and information technology into traditional agriculture. Smart agriculture allows the creation of mass data, and may gradually introduce intelligence in the process of transforming intelligence into organized information. In addition, it can extract meaningful information as the final link of this virtual chain of action. The adoption of smart agriculture at all levels and scales of agricultural production can deal with the challenges of increased demand for food production and reduced labor. Smart agriculture can collect data with different types of sensors, and send and receive data via the communication network. Such data are managed and analyzed by the management information system and data analysis system, which allow the taking of necessary actions at the right time and place to minimize waste. Artificial intelligence technologies and machines can be used to predict agricultural conditions in an efficient, reliable and accurate manner, so as to reduce the corresponding production costs and environmental constraints. The data provided by smart agriculture may help to improve the productivity, and they are of great importance in modern agricultural activities.

2. IoT-based smart agriculture

As stated in Report 2018 of World Resources Institute (WRI), the goal of sustainable agriculture is to increase agricultural production to meet the grain demand of 10 billion people by 2050, while smart agriculture is a necessary path to achieve this goal [1]. Smart agriculture refers to smart economy integrating modern cutting-edge technologies and traditional agricultural methods for achieving unmanned, automated and intelligent management, which aims at improving the quality and quantity of agricultural production, and significantly reducing the invested cost. The goal of smart agriculture is to improve productivity, increase the yield and profitability, and reduce the environmental footprint with science and technology. The development of IoT can ensure the sustainable development of smart agriculture. As a key technology for smart agriculture, IoT can add values to the acquired data by automatically processing, analyzing and accessing the data flow between different devices such as sensors, relays and gateways [2]. As a result, smart agriculture can maximize the benefits of agricultural production and enables the handling of production and management practices in a timelier manner. The wireless communication technique plays a key role in the IoT system, whose structure consists of three main layers: The sensing layer for sensing, the network layer for handling data transmission, and the application layer for data storage and data manipulation.

Sensing layer: It consists of various terminal devices, sensors, wireless sensor networks, RFID tags and readers, and near field communication (NFC) devices [3]. At this layer, sensors are used to collect data such as temperature, wind speed, humidity, nutrient levels, plant pests and diseases, and then the collected data are processed by embedded devices and uploaded to higher level processors through Internet for further processing and analysis. These end devices and sensors can be used to monitor, control, identify and track farm and pasture products. The wireless sensor network is generally used for climate control, monitoring, storage and logistics facilities. RFID, as the core of the IoT sensing layer, stores data in the form of electronic product code, and then RFID readers can be used to read, trigger and operate such data. RFID radio frequency identification technology can identify data within a certain distance without a close contact with the target.

Network layer: Sensors and devices should be connected to their neighboring nodes and gateways, so as to build a

network. At this layer, sensor nodes interact and communicate with other nodes and gateways within the network, to forward the data to a remote infrastructure, and further analyze, process, and disseminate at the place where they are stored, for obtaining useful data. In terms of coverage, remote technology is the only reliable and ideal solution. As for precision agriculture, a large amount of real-time data should be transmitted and processed. 3G, 4G, LTE (Long Term Evolution) and 5G cellular communication technology are the most suitable and reliable technologies supporting precision agriculture. Compared with LTE, 5G can work at higher frequency bands, especially in rural areas, 5G can provide a higher data transmission rate and longer transmission distance in real-time connection mode, enabling remote control of devices in the farm.

Application layer: It is the highest level of the IoT architecture, with the most significant benefits and utility. For example, there are many intelligent platforms or systems at the application layer, which are mainly used for monitoring and controlling soil conditions, moisture and nutrient levels, as well as supporting early warning and management of pests, diseases and safety controllability of agricultural products.

3. Analysis on the selection of sustainable development path of smart agriculture

Agriculture has undergone dramatic revolutions such as the domestication of animals and plants thousands of years ago, crop rotation and other improvements in agricultural practices several hundred years ago, and the widespread use of breeding, artificial fertilizers, and pesticides several decades ago. It is believed in this paper that the current revolution is caused by exponential growth in the use of data and communication technologies in agriculture. In short, these technological improvements have given rise to a technological revolution, revolutionizing the agricultural production practices. These emerging technologies and equipment are applicable to agriculture in developed countries, as well as that in developing countries, because the information and communication technology infrastructure is expanding rapidly in some developing countries that are quite receptive to new devices and technologies, and they may be the framers and changers of "game rules" in the future.

(1) Analysis on current development of smart agriculture

Smart agriculture can reduce the ecological footprint of agriculture. A sensor network can be established with the current information and communication technologies, which can be used for monitoring the farm on an almost continuous basis. The forecast of specific weather, prediction of yield, warning of the probability of diseases and disasters can enable the farmers to plant crops in the best way. If all data related to agriculture are recorded by automated sensors, the time required to prioritize the use of resources and perform administrative monitoring can be reduced [4]. In the precision agriculture system, the minimizing or site-specific application of materials and inputs such as fertilizers and pesticides can effectively mitigate the problem of leaching and emission of greenhouse gases. Likewise, through comparing the status of plants, animals and soil with the theoretical and practical data regarding production inputs, unnecessary resource inputs can be reduced, and farmers' capital and labor inputs can also be saved.

Smart agriculture can improve the consumers' acceptance. In principle, the analysis system of smart agriculture can increase the contents of antioxidants and other secondary metabolites, optimize management and improve product quality according to the optimum density of the orchard, or increase the amount of physiologically appropriate feed according to the individual feeding for the livestock. The products are healthier and more popular.

(2) Problems in the development of smart agriculture

Although there are ample opportunities for the development of smart agriculture, there are still many obstacles that should be resolved. The questions to be addressed mainly include: Who owns the data? Who can use and access the data? What is the proportion of the recording and statistics data, and will they cause network congestion? There are also other matters such as the recording and disclosure of resource input information and product output information that may involve intellectual property rights. Under the business model of smart agriculture, the device terminals must collect all the data and then transform the big data into information and recommendations, so as to create added values. These information and recommendations are applicable to the daily management of farmers, as well as the relevant regulatory bodies. Therefore, the government departments and relevant regulatory departments must establish a comprehensive regulatory system for ensuring the authenticity and security of the collected data, so as to increase the trust between practitioners, and thus promoting the healthy and orderly development of the industry. The use of smart agriculture technologies will increase the load on the mobile communication base stations, and the overloading will slow down the transmission rate and delay data collection, leading to a number of serious consequences. For example, the delay of the application of bactericides will result in a trace amount of bactericides on the harvested fruits and vegetables, which may fail to pass the pesticide residue testing, and also increase the risk of unsustainable development of smart agriculture. In addition, in the environment of industrialization, bactericides may delay disease outbreaks, but they would increase the risk of developing resistant strains of fungi. Once such resistant strains break through the precautionary measures, they will be even more devastating.

(3) Path of sustainable development of smart agriculture

(i) Overall planning for aggregation of resources. The sustainable development of smart agriculture requires unified

allocation of resources through integrating the technology supply system, agricultural production factors and all actors in the agricultural production sector, based on the early warnings and alerts sent by the smart agriculture system, and combined with the current local conditions. There is no single policy or approach that can achieve this vision, and the government should support and promote the appropriate use of information and communication technologies, take into account of the technological characteristics, the diversity of the agricultural system and the relevant markets and policies, on which basis, can agriculture in the digital age be developed into smart agriculture. Although the "Internet of Things" involving agricultural machinery can be used to manage standard agricultural production, the farmers still need to act as the managers and supervisors, to keep a close eye on farming. The strengthening of education and training of farmers and other technicians can enable the farmers to take the time saved by smart farming to perform pest control or monitor the conditions of the existing plots in a more personalized way [5].

(ii) Cultivating consensus and seizing opportunities. For realizing smart agriculture, all parties should continuously strengthen the innovation in agricultural technologies and overcome difficulties. The use and promotion of agricultural monitoring technologies and the increase of investment in education and training can promote the sustainable development of smart agriculture. To increase transparency, it is necessary to establish a data transmission system with different regulatory functions. For example, the administrative and production data transmitted to governments and suppliers must be transparent to farmers, and the consumers must be able to thoroughly understand the entire food production chain.

(iii) Providing government support for breakthroughs. Data management based on information and communication technology can provide a new approach for agricultural development, making environmental factors (such as soil, water, and climate) more conducive to biodiversity. In order to achieve this goal, the government should prepare the supporting policies, and provide the technical, resource, legal, financial and marketing structures required for the development of smart agriculture. For example, the policies should determine a clear legal environment, clarify the ownership and user rights, coordinate the efforts of all parties, and realize the interconnection of superior resources, so as to promote the deep integration of modern information technologies with agricultural ecosystems. In view of geographic locations, environmental factors, and the large number of stakeholders, there may not be a globally uniform and rapidly accepted agricultural system. Therefore, it is necessary to establish diverse agricultural systems. In order to achieve sustainable development of agriculture, economists must pay attention to biodiversity, establish a farming system integrating agricultural landscape diversity and diversity of species. In addition, they should also construct field testing facilities, develop new agricultural machinery, and establish an information-based management system. If the management recommendations are highly reliable and clear, even if the farmers have not planted a certain crop, they can refer to such data for farming and processing.

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