The Evolution and Potential of Precision Agriculture in China Anchored In "3S" Technology.

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Abstract. Agriculture serves as a linchpin for the national economy. With the accelerated evolution of information technology and emergent high-tech innovations, the digitization of agriculture has emerged as a pivotal trajectory for contemporary agricultural advancement. Conventional practices encompassing planting, fertilization, and harvesting are transitioning towards more quantitative, localized, and technologically-driven precision agriculture. Concurrently, with the global surge in "precision agriculture", Chinese academicians have progressively delved into its study. Over the past three decades, the "3S" technology-centric "precision agriculture" in China has witnessed commendable advancements, exemplified by innovations such as the Global Agricultural Remote Sensing Quick Report System and the Beidou Satellite Navigation System-based autonomic agricultural machinery operation. However, the modernization of Chinese agriculture exhibits certain limitations, including limited adoption, suboptimal integration, and a scarcity of high-caliber experts. Given the swift progression of Chinese scientific and economic domains, the "3S" technology is poised to surmount these challenges, enhancing the modernization of Chinese agriculture. Hence, "precision agriculture" anchored in "3S" technology retains significant growth prospects within China.

Keywords: Precision Agriculture, "3S" Technology, Agricultural Modernization, Beidou Satellite Navigation System.

1. Introduction

Agriculture holds a foundational role within China's economy. While China stands as a major agricultural nation, comprehensive assessment reveals several challenges, including suboptimal productivity, limited technological backing, and deteriorating agricultural ecology. Notably, the contribution from China's agricultural technological advancements is approximately 20% lower than that of developed nations. Current statistics indicate that China depends on imports for a significant portion of its high-end agricultural products, with patent rights predominantly held by a select number of Western enterprises [1]. Furthermore, China's efficiency in irrigation water utilization lags at 30%-40% compared to about 60% in advanced countries. Similarly, fertilizer utilization in China stands at a mere 30%, contrasting with nearly 55% in developed nations [2]. As China navigates its transition from traditional to modern agriculture, the integration of emergent electronic and information technologies becomes crucial. Precision agriculture, epitomized by the "3S" technology, has emerged as an international research focal point. Given its transformative potential for agricultural practices, it's imperative to assimilate global precision agriculture methodologies, adapt them to China's unique context, and drive forward China's agricultural sector towards precision, automation, and efficiency.

Based on the above content analysis, this paper focuses on the comparison and development of technological innovation around the research status of "3S" technology in "precision agriculture" in China. Firstly, the paper gives the traditional definition of precision agriculture and the new interpretation of precision agriculture given by modern technology, and then the paper discusses from shallow too deep on the development of domestic "3S" technology, and the current breakthrough and research in "3S" technology in China is extended to the application of various fields of large-scale agricultural production and management, and finally based on the existing problems and current development, the direction and suggestions for the future development of precision agriculture in China are put forward, in order to provide a certain reference for the development of China's agricultural modernization.

2. Definition of precision agriculture

"Precision agriculture" is a new type of modern agricultural production technology based on a series of high-tech integration development such as electronic and information science technology, bioengineering technology and agricultural engineering equipment technology, which is based on the growth and development environment of crops in the operation interval of the field unit (such as growth terrain and topography, soil internal structure, disease and pest analysis, nutrition and crop water content), fixed, regular and quantitative adjustment of soil and crop management measures, to achieve high efficiency in the timing, quantity and quality of agricultural input to the greatest extent Low-cost regulatory measures to obtain the highest crop yield and maximum economic return on benefits, while taking into account the protection of land and natural resources and the subsequent development of green agricultural ecological environment.

The main technology of "precision agriculture" consists of agricultural geographic information and farmland information acquisition system, global positioning system, remote sensing detection technology (i.e. 3S technology) and other technologies: environmental monitoring system and computer automation control technology composed of a set of highly complex integrated system. Among them, the development of "3S" technology is a strategic step to promote the modernization of Chinese traditional agriculture and enter the production of low-consumption, high-capacity, high-quality, and strong safety agricultural crops.

The representation of the precision agriculture technological process involves an integrated harvester equipped with a positioning system and yield sensor. This harvester autonomously gathers geospatial data and the average yield metrics for the respective zones at one-second intervals. Subsequently, computer algorithms process this data to generate a crop yield distribution map. Based on spatial data maps which encompass parameters like field topography, landform, soil fertility, and barrier conditions, as well as crop growth models, input-output simulations, and an expert crop management knowledge database, a decision support system for crop management is established. Involving key decision-makers, this system produces crop management prescription maps. These maps then guide the application of varied techniques or the deployment of specific agricultural machinery for targeted interventions and precision farming in the defined zones. Notably, this precision agriculture model has been trialed and adopted in numerous developed nations, demonstrating substantial input savings, favorable economic returns, and gaining acceptance among farmers.

3. Literature and current situation analysis

3.1. Research status of precision agriculture technology in China

In the 90s of the 20th centuries, scholars began to study precision agriculture in China, and the seeds of precision agriculture began to germinate on the Chinese land. In the "Tenth Five-Year" science and technology strategic focus to develop precision agricultural technology [3]. In addition, in the "863" plan, the "agricultural precision operation technology and equipment" was launched for the first time in the direction of the production system of agriculture and orchards, and through the continuous efforts of scientific researchers, China's innovative technology in precision agricultural operations and practical products of intelligent agricultural machinery and equipment have achieved phased success [4]. In 2018, the State Council issued the "Opinions on Accelerating the Structural Reform of the Agricultural Supply Side", which proposed to accelerate the promotion of precision agriculture, promote advanced applicable technologies, and propose to promote the application of precision fertilization, precision irrigation, precision plant protection and other technologies, improve agricultural production efficiency and carry out independent innovation of precision agriculture technology [5].

Of most importance is the "3S" technology. GIS technology in farmland information visualization and thematic mapping, agricultural ecological environment research has developed greatly, it is

precision agriculture farmland information acquisition, decision-making prescription generation, The core technology of the precise variable control part; RS technology has been widely used in dynamic monitoring of crop growth, crop remote sensing yield estimation, soil erosion investigation, etc., GPS technology has been developed in intelligent agricultural machinery navigation and scheduling, pests and weeds detection systems. At present, some regions have introduced precision agriculture into production practice, established a number of precision agriculture demonstration bases, and achieved considerable economic benefits.

3.2. The development of "3S" technology and the application of "precision agriculture"

3.2.1 GIS---Geographic Information System technology

Chinese Geographic Information System started a little late, but the development momentum is quite rapid: in the seventies of the twentieth century, Chinese Geographic Information System also fully entered the experimental debugging stage, during this period, China produced the first fully computer-output all-feature map, during the eighties to nineties, the international seminar on Geographic Information System was held for the first time in Beijing, China, Geographic Information System has been applied in Chinese universities and research institutes, trying to make Chinese Geographic Information System from the beginning of experimental research, During the continuous application of local application towards practical, integrated, engineering and production, the practical application of domestic software system has been strongly supported and developed, and a series of locally optimized GIS software such as Super Map, Map GIS and Geo Star have begun to develop. In short, Chinese Geographic Information System industry has made great progress after nearly 30 years of development.

At the same time, in the field of precision agriculture, geographic information system relies on its strong ability to collect, preprocess, store, analyze, calculate and visualize geospatial information, and geographic information system is not only an independent system in precision agriculture, but a more comprehensive geographic information integrated service platform provided by integrating Remote Sensing technology and global satellite positioning system. As the core technology in precision agriculture system, Geographic Information System has been widely used in the agricultural field, such as precision agriculture fertilizer and water saving system, agricultural landscape pattern research and many other directions. In China, the physical information system is often operated in the visual mapping of spatial information in agriculture. By collecting various discrete spatial data, the graphical processing of various field information is completed, and the spatial distribution map of various field information is drawn in an intuitive and visual way such as two-dimensional plane and three-dimensional three-dimensional, which greatly facilitates the user's analysis and statistics, computing and decision-making. For example, the production of agricultural type maps such as pest and weed cover maps, crop yield distribution maps, cultivated land fertility grade maps, and agricultural climate zoning maps.

3.2.2 RS---Remote Sensing technology

Since the 1970s, alongside the evolution of Remote Sensing (RS) technology, China has increasingly recognized the significance of RS applications and initiated its exploration and development. In 1970, marking a milestone, China launched its inaugural artificial satellite, "Dongfanghong" No. 1. Following this, from 1988 to 2004, the Fengyun meteorological satellite series was introduced, culminating in the China Meteorological Satellite Service Monitoring System [6]. Presently, China has achieved numerous advancements in RS, notably the launch of the high-resolution multi-modal RS satellite "Gaofen-7", characterized by its high resolution, versatility, all-weather capability, and global reach. It finds applications in resource surveys, environmental monitoring, and disaster assessments, among others.

Agriculture has emerged as a principal beneficiary of RS technology, leveraging it for agricultural resource analysis, dynamic monitoring, crop yield forecasting, disaster surveillance, and loss evaluations. This has significantly bolstered agricultural productivity and revenue. The crop RS yield

estimation system harnesses spectral data from RS images at varying intervals. By analyzing this spectral data, a relational model linking growth information to yield is formulated, facilitating accurate crop yield predictions. The scope of this technology has expanded from exclusively monitoring winter wheat to encompassing crops like rice and corn. By the Ninth Five-Year Plan in 1998, China's indigenously developed global agricultural RS rapid reporting system, after years of refinement, positioned itself as one of the world's top three agricultural RS monitoring frameworks [7]. This system not only augments the regulation of Chinese grain crop yields but also offers evaluations of crop growth and yield metrics in up to 147 global territories, aligning with the Sustainable Development Goal of Zero Hunger. Furthermore, meteorological RS offers real-time weather insights and early alerts for climatic disturbances and agricultural ailments, such as pests and diseases. RS also finds applications in soil moisture assessments, erosion studies, and other pivotal agricultural information services.

3.2.3 GPS---Global Positioning System technology

The Beidou Navigation Satellite System (BDS) represents China's indigenous advancement in satellite navigation, purposed to deliver global positioning, navigation, and timing services. The genesis of BDS dates back to the 1980s when China initiated its quest for an autonomous satellite navigation system. By 2000, China had successfully launched its inaugural navigation satellite, symbolizing BDS's progression into operational deployment. Over subsequent decades, a sequence of satellite launches refined the BDS infrastructure. By 2020, the system's construction reached its culmination. Over its developmental trajectory, BDS has secured a pivotal stance in the global satellite navigation arena.

Spatial-temporal agricultural data forms the backbone of precision agriculture, hence, the indispensability of systems like BDS. Such systems provide accurate geospatial data for agricultural tasks, encompassing metrics like soil composition, fertility, crop dynamics, pest presence, weed proliferation, and yield. BDS aids in precise geolocation for diverse monitoring targets, facilitating enlightened agronomic decision-making. When integrated into farm equipment, BDS ensures these machines navigate pre-defined routes for tasks like fertilizing or pesticide application. This precision negates wastage and guarantees that resources like fertilizers are deployed judiciously. Supported by BDS, agricultural machinery achieves operational consistency, which cuts down labor costs, boosts operation efficiency, and enhances crop quality. Real-time monitoring and analysis of equipment operation areas, performance, and historical paths enable informed decisions about machinery deployment. Notably, China's Beidou agricultural machinery auto-navigation system has witnessed extensive application in provinces such as Xinjiang, Inner Mongolia, and Heilongjiang, covering equipment ranging from 30-350 horsepower tractors to various transplanters and harvesters [8].

Pest and weed monitoring exemplify other BDS applications in precision agriculture. Given the rapid spread and outbreak potential of pests and weeds, traditional monitoring approaches fall short. BDS empowers precision agriculture to accurately pinpoint disaster-stricken zones and evaluate disaster severity. This data is then relayed to cloud platforms, which determine the requisite intervention measures. In a notable initiative from 1992, Beijing's Plant Protection Station, in collaboration with prominent research institutions, harnessed satellite navigation aircraft for wheat insect control. This led to efficient pesticide application with a commendable aphid eradication rate of over 90% [9]. To encapsulate, BDS proves invaluable across precision agriculture's spectrum, from pre-production to production, ensuring dynamic, accurate, and real-time spatial agricultural information.

3.3. The current problems and challenges

While China stands as a major agrarian nation, it has yet to establish itself as a leading agricultural economy. The introduction of the "3S" technology (comprising GIS, GPS, and Remote Sensing) into Chinese agriculture only commenced in the late 1970s. Consequently, the nation's precision agriculture methodologies remain in their nascent stages. For context, the U.S. pioneered the incorporation of GPS into farm machinery, and Germany's agricultural production boasts nearly 100%

computer network penetration. In comparison, China possesses limited high-tech agricultural machinery, and the utilization rate is suboptimal. Although the "3S" technology is present, its integration with advanced agricultural machinery is fragmented. The application primarily revolves around the supplementary roles of the individual "S" components, rarely culminating in a cohesive, automated, and intelligent system.

To address this, it's imperative for China to amplify its commitment to modern agricultural informatization. This includes bolstering investments in "3S" research, acquiring advanced agricultural equipment, and fostering a symbiotic relationship between "3S" integration and agricultural practices. It's worth noting that genuine interest in precision agriculture's establishment and implementation in China spans a mere decade. Due to the prevalent household-based production responsibility system, Chinese agriculture predominantly operates on an individual household basis. This setup impedes the realization of unified scales, consequently hindering the adoption of advanced, large-scale agricultural machinery and the effective application of "3S" technology [10]. To circumvent this, China must hasten the transformation of agricultural production, endorse rural land circulation, expand production entities, and pivot towards large-scale, intensive, and efficient farming.

Furthermore, although "3S" is a high-tech domain demanding specialized expertise, China faces a dearth of professionals equipped to navigate and apply it in agriculture. To proliferate the "3S" footprint in agriculture, it's essential to prioritize talent development, fortify academic and research collaborations, and enlarge the cadre of agricultural specialists (Table 1).

Table. 1 Comparison of three patterns

Type	Feature	Impetus	Example	Typical region
Government-leading	Strong financial support	Government	Agricultural databases	North America
Industry self-help	Policy and famers' initiative	Association	Agricultural cooperatives	North Europe
Typical demonstration	Promote action	Government and Farmers	E-commerce, new village work	Asian

4. Conclusion

This study provides an in-depth analysis of the evolution of precision agriculture in China, with an emphasis on the pivotal "3S" technology and its research trajectory. This paper delved into the current integration and application of this technology within China's agricultural landscape while also offering insights and future projections on challenges faced by precision agriculture and the "3S" framework. In today's digitized era, precision agriculture stands as a beacon for agricultural progress both within China and globally. Serving as the foundational element of precision agriculture, the "3S" technology holds profound implications for transforming China's agricultural methodologies, ecological conservation, and its quest for attaining modern agricultural prowess. Notwithstanding the existing gaps in the fusion of "3S" technology with agricultural practices in China, the relentless march of technological and economic advancements suggests that these hurdles will be surmounted. This, in turn, will enhance China's agricultural productivity and refine its agrarian industrial framework. As a pathway forward, it is paramount to bolster large-scale agricultural operations, expedite the metamorphosis of agricultural practices, enrich the amalgamation of "3S" innovations, and prioritize the nurturing of adept agricultural technologists. Such endeavors are quintessential for the actualization of modernized agriculture and sustainable agricultural growth.

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