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Review

Precision Fertilization and Irrigation: Progress and Applications

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Abstract: The transformation and upgrading of traditional agriculture are required to address its shortcomings and deficiencies, which have resulted in environmental pollution or water problems. Precision agriculture emerged at the historic moment to solve the current problems. Field information collection, information management and decision-making, and execution systems are the three key links of precision fertilization and irrigation. The technical principle and application of field information acquisition systems are analyzed. The information management and decision-making system describes the management and summary of information in crop growth. The execution system combines the knowledge of various disciplines and experts for targeted applications to specific crops. It further focuses on the core implementation system, that is, variable fertilization technology and variable spraying technology that can realize variable operations. Major contributions from different countries, institutions, corresponding authors, and journals are presented in detail. This study proposes several suggestions and ideas based on the research status and progress of the three key systems to provide a theoretical basis and technical support for the research and development of key technologies and innovative devices of precision agricultural fertilization and irrigation.

Keywords: facility agriculture; agricultural equipment; precision agricultural machinery; variable operation; fertilization and irrigation

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1. Introduction

The environmental and resource problems caused by fertilization and irrigation in traditional agriculture have become increasingly serious, thereby hindering the realization of sustainable agricultural development goals in China. In the context of changing international situations and frequent natural disasters, traditional agricultural production methods are in urgent need of transformation and upgrading driven by emerging technologies, such as artificial intelligence, Internet of Things, and cloud platforms [1,2]. Precision fertilization and irrigation technology is emerging as the times require and is becoming an effective means to achieve green and efficient global agriculture. Precision fertilization and irrigation technology, supported by information technology, is a new type of agriculture that comprehensively integrates information technology and agricultural production by positioning, timing, and quantitative implementation of a set of modern agricultural operation and management systems in accordance with spatial variation [3,4].

Food security depends on agriculture, and agricultural security depends on water security and fertilizer security. Irrigation water resources are scarce, and fertilizer pollution is serious [5]. In the current greenhouse production process, excessive consumption of pesticides, fertilizers, and irrigation water leads to a low utilization rate of resources and a high content of liquid nitrate discharged from irrigation, resulting in the pollution of groundwater resources [6,7]. Fertilizers with low efficiency are used heavily in many areas to increase crop yields [8]. Although yields are relatively high, crop quality and income are low in some cases, and excessive fertilization causes a large amount of wastewater and pollution [9]. Precise irrigation management requires data and information from crop growth conditions, soil physical and chemical properties, weather factors, and the interaction among these factors. The effective implementation of precision irrigation requires a comprehensive decision support system to process and integrate data and information at different levels [10].

The growth of crops mainly depends on the supply of nutrients and water. Precision fertilization and precision irrigation have always been a research hotspot. With the progress of science and technology, precision fertilization and precision irrigation have emerged after in-depth research. Field information collection, information management and decision-making, and execution systems are the necessary links to realize precision agricultural machinery. Field information collection technology is the first step to achieve precision agricultural fertilization and irrigation. The principles and applications of a grid format survey, Global Positioning System (GPS) monitoring, remote sensing monitoring, and wireless sensor automatic monitoring technologies are analyzed. The above technologies are used to collect information on crop survival environments and growth conditions for grasping the dynamic changes in crop growth and using the information rationally. Information management and decision-making systems are at the heart of precision fertilization and irrigation. Their principles and applications are analyzed in terms of precision decision making and management technologies, respectively. These systems are responsible for the rational analysis and integration of the collected information and making decisions based on the information. The execution system is an important component of precision fertilization and irrigation. Variable fertilizer application and variable spraying technologies are the two essential technologies of this system, and their principles and applications are analyzed. The above technologies are applied to achieve the final variable fertilization and irrigation operation of the crop. The above three links are used sequentially, interlocked, reasonably regulated, and coordinated with each other to realize precision fertilization and irrigation, as shown in Figure 1.

At present, the traditional operation mode is costly, inefficient, and may lead to the decline of crop yield, low quality, and environmental pollution. The application of variable technology and equipment in crop production can greatly improve crop yield and resource utilization and reduce environmental pollution. The supporting devices of field information acquisition, information management and decision-making, and execution systems are an important basis for the development of intelligent agricultural machinery industry. However, the variable technology and device level of intelligent agricultural machinery in China lag behind compared with developed countries. To improve the technical level of China's intelligent agricultural machinery variable technology, Chinese researchers from domestic agricultural machinery departments and various colleges and universities have analyzed and studied foreign advanced agricultural machinery variable technology. They independently innovated and designed relevant mechanical equipment that has been preliminarily applied in production, but they cannot produce large-scale benefits. No mechanical equipment is available to support the intelligent agricultural machinery in China, and many key technologies need further study.

This study summarizes and reviews systematically the system mechanisms and applications corresponding to each of the three key aspects of precision fertilization and irrigation: field information collection, information management and decision-making, and execution systems. The main contributions from different countries, institutions, corresponding authors, and journals are presented in detail. They are expected to provide a theoretical basis and technical support for the development of key technologies and innovative devices for precision fertilization and irrigation.

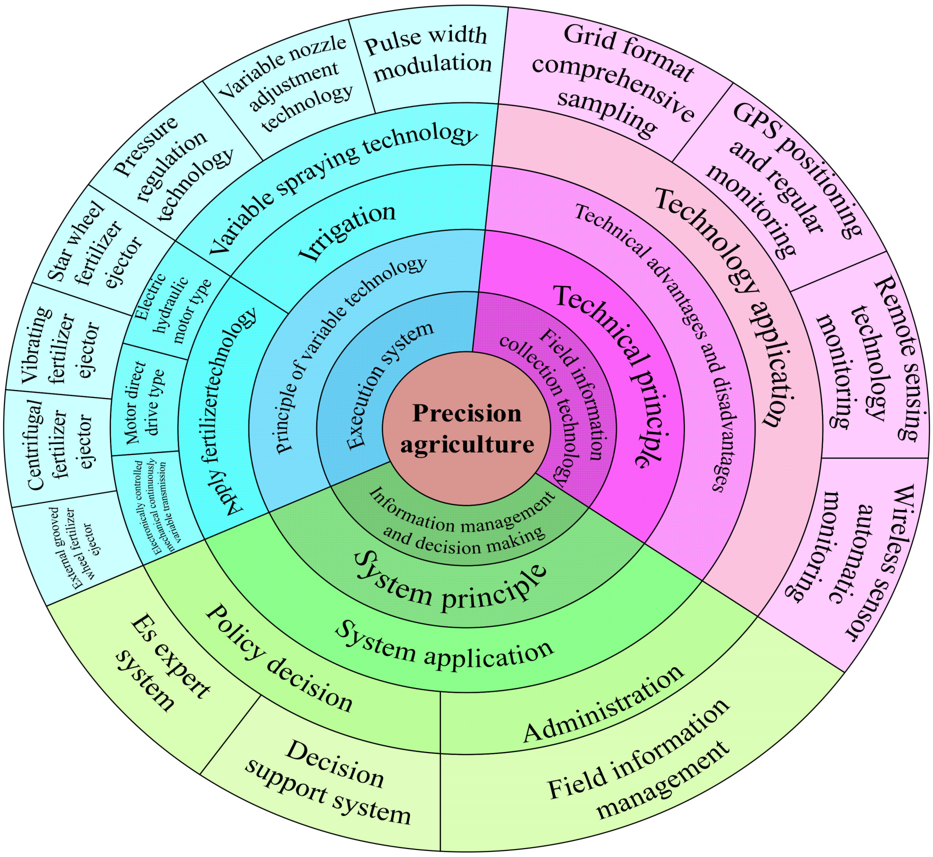


Figure 1. Article structure chart.

2. Field Information Collection

The field information acquisition system is the fundamental premise of implementing precision fertilization and irrigation. The sensing and acquisition of biological characteristic parameters and growth environment information of agroforestry plants are an important basis for precision fertilization and irrigation [11,12]. Basic farmland information has a decisive influence on crop growth and final yield. A high-density, high-resolution, fast, and low-cost information acquisition technology scheme is of great importance for the application and promotion of precision fertilization and irrigation [13,14]. Farmland information acquisition technologies mainly focus on farmland soils, crops, micrometeorology, pests and diseases, and extreme disasters. The mainstream acquisition methods include conventional field surveys, regular monitoring based on GPS positioning, remote sensing and unmanned aerial vehicle (UAV) multisource image monitoring, and wireless sensor automatic monitoring [15–17]. Field information can be roughly divided into soil attribute, location, crop growth, farmland surrounding environment, and crop yield information [18–20]. It has the characteristics of large quantity, multidimensional, dynamic, uncertain, incomplete, sparse, and strong temporal and spatial variability. At present, research on rapid field information acquisition technology is still relatively undeveloped and has become an important topic in many international units [21,22].

2.1. Principles

(1) Conventional field investigation usually adopts the network format (arranging and creating relationships between elements in a vertical and horizontal distribution) for comprehensive sampling investigation, focusing on laboratory tests and analyses of soil information. A sampling grid is set in accordance with the requirements of precision fertilization and irrigation. This method costs considerable manpower and material resources and is usually used as the basic evaluation of a certain plot [15].

(2) GPS positioning is monitored regularly. The sampling points are located through the GPS and introduced in the geographic information system (GIS), which can realize the spatial vectorization, interpolation, and visualization of the whole farmland plot and provide an important reference for the scientific management of farmland information and the formulation of farming plan. At present, relatively mature technologies are found in this regard [15,23]. Farmland location information mainly includes the longitude and latitude of the sampling point, and the shape and area of the field, which is mainly obtained by global positioning technology. GPS is used to collect information in the field, so as to form a fertilization and irrigation prescription map. If multiple known points are found, then the method of resection can be used to obtain the coordinates of an unknown point. GPS collects some farmland information and provides real-time location information for agricultural machines and tools to guide accurate property management [18,24]. The traditional work of surveying and collecting information on agricultural land is usually stored on paper, which is unconducive to finding and reading information and to keeping and storing information, and cannot be analyzed and tabulated. Agricultural production information and geographic information can be organically combined by using GIS technology to provide unprecedented spatial and temporal characteristics for all types of agricultural information [25]. Existing soil and crop information data are sorted and analyzed by the GIS as attribute data; an efficient and operational field management system can be created by combining them with the vectorized basemap data [18].

(3) High-precision, real-time remote sensing imaging technologies, such as UAV and 3D laser scanning, are introduced to provide more accurate and powerful technical support for precision fertilization and irrigation decision-making services [26–30]. Remote sensing technology refers to detecting and identifying electromagnetic energy and accurately obtaining various field information without direct contact between the sensor and the object [31]. Sensors installed on satellites, aircraft, or ground equipment [32] can be adopted in the application of remote sensing in precision fertilization and irrigation. Collecting and analyzing information on crop and soil characteristics, obtaining information on spatial and temporal changes in agricultural land, predicting crop yields, and accurately reporting the agricultural situation are all essential operations [33]. The remote sensing system obtains the data for each period of the whole process of agricultural production for monitoring soil and crop moisture, crop nutrition, crop diseases, and pests [34,35]. Precision fertilization and precision irrigation use remote sensing and telemetry technologies to accurately grasp the spatiotemporal differences in soil, water, fertilizer, diseases and insect pests, and crop yields, which maximize the economic and ecological benefits with minimum production input [36]. The popularization of laser measurement technology has greatly improved the efficiency of the measurement and collection of basic farmland information. The use of laser measurement technology can realize the real-time measurement of relevant data, such as the length, area, and regional elevation of agricultural production areas. The miniaturization trend of measurement equipment enables it to be applied to more measurement carrier platforms, such as UAVs, unmanned ships, and mapping vehicles, which further improves the speed and accuracy of surveying and mapping [37]. However, the information obtained from remote sensing, such as soil moisture and crop canopy biochemical parameters, is not directly used for precision fertilization and irrigation. The relationship between remote sensing information and parameters related to soil and crop growth states needs to be established through analysis, which is the "bottleneck" restricting the application of remote sensing information in agricultural information acquisition [38]. Remote sensing technology is an important source of field data in the future precision agriculture technology system. It can provide a large amount of field temporal and spatial change information. The application of remote sensing technology in precision fertilization and irrigation mainly includes: (i) Monitoring of crop growth and its background:

high-resolution (meter resolution) sensors are used to implement comprehensive monitoring in different crop growth periods, and spatial qualitative and positioning analyses are conducted in accordance with spectral information to provide a basis for positioning agriculture. (ii) Crop canopy multispectral monitoring: the information obtained by ground object spectrometer and multispectral camera is used to monitor the change in chlorophyll density and analyze the relationship between its change and nutrients. (iii) Multispectral remote sensing information (infrared band) is used to monitor soil moisture under crop conditions [39,40]. Spectral images can be used to determine the field leaf area index and ground cover plants, which is helpful to yield prediction. In the field of agriculture, the most commonly used remote sensing technologies include optical remote sensing and thermal remote sensing [41]. Optical remote sensing uses visible light to create an image of the Earth's surface by detecting the energy reflected from the surface of the target area [42]. It has been successfully applied to estimate various plant parameters, such as leaf area, plant cover, biomass, and chlorophyll content. The largest disadvantage of optical remote sensing is the slow response of these variables, which are usually adjusted only when plants have obvious stress damage [43]. Thermal remote sensing is a process of measuring the radiation emitted from the surface of an object and converting it into temperature without establishing direct contact with the object. Crop canopy surface temperature is a function of transpiration rate and a function of atmospheric evaporation and crop available soil water status. Pressure in crops (water, weeds, and nutrients) will affect their canopy temperature, which can be measured at key stages for managing and optimizing agricultural production and inputs [44].

(4) Automatic monitoring by wireless sensor. A remote automatic monitoring method integrating sensors, microprocessors, and wireless communication can greatly reduce the consumption of human and material resources in the implementation of precision fertilization and irrigation and has become one of the hot spots in the field of agricultural informatization and intelligence [45,46]. The real-time sensor technology has been widely used in variable spraying due to its high precision and strong real-time performance. The spray target profile, location, density, and other information are acquired in real time by using a variety of sensors (such as vision, ultrasonic, infrared, and laser sensors) through the analysis and processing of the control system to determine the spray water and form the spray decision. However, this technology is still affected by some factors and still has a high misjudgment rate in recognition, especially in complex environments where the recognition ability is unsatisfactory and the recognition accuracy can still be improved [47,48].

Table 1 shows a comparison of the advantages and disadvantages of various field information collection.

Table 1. Comparison of advantages and disadvantages.

Technology	Benefits	Limitations
GPS	GPS provides location information for real-time accurate data collection of intelligent agriculture.	1. It provides poor signal due to obstacles such as trees, buildings, and storms. 2. Due to limited power supply, this is not a cost-effective solution for small farms.
RS	It has a visual representation of field conditions and monitors crop and field health.	1. It uses expensive and precise instruments. 2. Experts are required to analyze the results. 3. It requires stable image and data analysis methods. 4. Its resolution and accuracy are low. 5. It has small coverage area and high cost. 6. Trees, buildings, weather conditions, and natural disasters easily cause signal interruption, resulting in data acquisition errors.

Table 1. *Cont.*

Technology	Benefits	Limitations
SENSOR	It can continuously monitor field and weather conditions in real time and provide precise rate control.	1. In the process of data transmission by different sensors at the same time, the possibility of data variability is greater. 2. Maintaining integrity and security of data transmission is a challenging task. 3. Sensor battery life is limited.
GIS	It can provide accurate geospatial information, topological structure of the site, and prescription map with hierarchical structure for resource allocation.	1. GIS packages such as ArcView, ArcGIS, and IDRISI are expensive. 2. Generating hierarchical maps requires a lot of geographic data. Such a large amount of data incurs costs in storage space and processing time. 3. Analysis of prescription charts requires specialized technical knowledge.

2.2. Examples of Concrete Implementations

Examples of soil information management, crop growth information, pest and weed information, and farmland environmental information acquisition are listed in Table 2 [49–66]. The methods and techniques used are analyzed, and the data obtained and the development of precision fertilization and irrigation are briefly summarized. The field information collection method improves the yield and economic efficiency of crops, and the farming environment.

Table 2. Field information collection method.

Reference	Application	Involved Technologies	Main Objective/Function
[49]	Soil information management	Soil electrical conductivity sensor	Measure soil solute concentration in assessing soil salinity hazards
[50]		Electrodes for frequency domain (FDR) or time domain reflectometry (TDR)	Measures soil water content
[51]		Tensiometer	Test the water absorption of the root
[52]		Photodiode	Determination of clay, organic matter, and water content in soil
[53]		Ion-selective electrodes (ISEs) and ion-selective field effect transistor sensors (ISFETs)	Used for detection of major plant nutrients in soil (NO_3, NH_4, K, and PO_4)
[54]		Ground penetrating radar (GPR) and gamma ray spectrometry (GRS)	GPR is related to soil hydrological parameters, while GRS data are related to certain soil nutrients and soil texture characteristics
[55]		GNSS reflectometry	A high-resolution soil moisture map is made by using a low-altitude UAV
[56]	Crop growth information	Wavelet energy entropy, wavelet singular entropy, and wavelet variance entropy of plant electrical signals are extracted by wavelet transform, and combined features are constructed.	To identify plant electrical signals

Table 2. *Cont.*

Reference	Application	Involved Technologies	Main Objective/Function
[57]		Based on the morphological characteristics of row crop canopy and spectral monitoring mechanism, an active light source device for crop growth monitoring and diagnosis was developed.	Crop canopy vegetation index—normalized difference vegetation index (NDVI), and ratio vegetation index (RVI)—crop growth parameters—leaf area index (LAI), leaf dry weight (LDW), leaf nitrogen accumulation (LNA), and leaf nitrogen content (LNC) were obtained in real time.
[58]		Digital image of winter wheat canopy based on unmanned aerial vehicle (UAV) (i.e., high-frequency IWD (information)). Variables obtained by continuous wavelet transform	The crop above-ground biomass (AGB)
[59]		Image processing techniques	Calculate the leaf number and leaf area of the plant
[60]	Pest information	Farmland microclimate data preprocessing method based on Wireless Sensor Network.	Analyze and deal with the farmland microclimate at each monitoring point.
[61]		Developed an automatic system based on the network GIS platform, which effectively realized the automatic monitoring of pests and diseases nationwide.	Disease dynamic habitat monitoring and early forecasting.
[62]		Investigation, diagnosis, and decision support system of cotton diseases and pests based on Android system (client) and Windows system (server).	Build a rich knowledge base and realize the application functions of knowledge-based browsing and query, intelligent diagnosis, expert consultation, and information reporting for all app users.
[63]	Farmland environmental information	Based on database technology, Web GIS and model theory, a farmland environmental quality evaluation and prediction system is developed	Direct information about the farmland environmental pollution status and pollution trends can be provided for scientific decision making of soil quality monitoring
[64]		Using the technology of combining GPS positioning information and farmland environmental information, a farmland information acquisition and processing system is studied and developed.	The system can be easily combined with the external processing system to provide data support for agricultural decision making.
[65]		Based on embedded chip, a farmland information acquisition system is designed.	Collect, analyze, and store farmland meteorological, soil, and crop information.
[66]		A rapid information acquisition system based on GPRS + RTU technology is studied and developed.	Quickly and accurately monitor farmland environmental information.

(1) GPS technology. In 2021, Huang designed a rice soil nutrient detection system based on GPS technology. The system data acquisition module is mainly composed of a single-chip microcomputer system board, various measurement modules, and external interfaces. The structure is shown in Figure 2. The system can complete the detection of various nutrient data of rice soil and can access the monitoring data online. It has strong operability, high reliability, and certain popularization value [67,68]. Wu designed a high-precision positioning system of agricultural plant protection UAV based on GPS and satellite navigation system and comprehensively analyzed the specific software and hardware implementation. The system was tested. The test

results show that the designed system can effectively meet the requirements of UAV for accurate positioning [69].

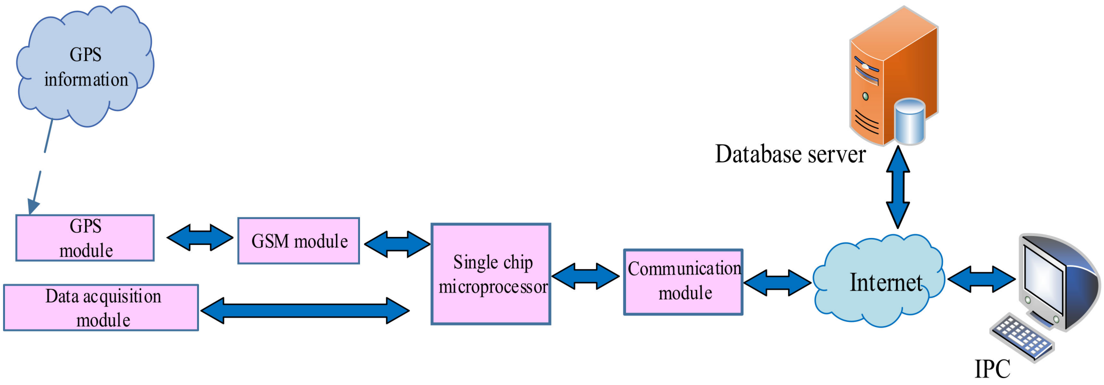


Figure 2. Overall structure diagram of a detection system.

(2) Remote sensing technology. Ma et al. evaluated the vegetation index, surface temperature, and reflectance characteristics of each band in the image through remote sensing and constructed a prediction model of powdery mildew during the wheat filling period by using the remote sensing meteorological characteristics. The overall accuracy of the model prediction reached 84.2% [45]. Ma et al. performed spectral determination of the diseases and pests of fruit trees and *Lycium barbarum* by using remote sensing near-earth hyperspectral technology [70]. Li et al. realized the collection of dead wood position information through small UAV remote sensing technology [71]. Yuan et al. used remote sensing and GIS to analyze the highly complex information environment under the current mode [72]. Liu et al. used hyperspectral remote sensing technology to find the best density of grain maturer [73].

(3) Wireless sensor technology. Wang investigated the detection of lateral cypress moth damage based on gas-sensitive sensor technology, selected the characteristic components of the volatiles of the pest-affected lateral cypress, and realized the detection of lateral cypress damaged by different pest types using a homemade gas-sensitive sensor, thereby providing a reference for the application of gas-sensitive sensors in moth damage detection [74]. Rui presented a new method called magnetic resonance measurement technology that can quickly and quantitatively measure soil moisture. Free water and bound water in soil have different attenuation laws of transverse relaxation time. A method of analyzing the magnetic resonance echo signal is proposed; it can distinguish the components of free water and bound water in soil. Experiments show that the magnetic resonance sensor has a sufficient signal-to-noise ratio and resolution to accomplish the sensor tasks [75]. For the acquisition and reconstruction of plant 3D information, Liu et al. used Kinect sensor technology to achieve greenhouse hanging basket plant measurements and 3D reconstruction and depth and area information measurements. This method can be further extended and applied to the 3D reconstruction and measurements of other irregular plants, so as to realize the collection and processing of plant information in the process of real-time monitoring of agricultural plant growth states based on a Kinect sensor and serve as a reference for Kinect 3D sensors. The precise application of fertilizers and a timely control of diseases and insect pests can be achieved [76].

3. Information Management and Decision-Making System

3.1. Principle

Accurate decision-making technology refers to appropriate processing and processing (data analysis technology) after collecting the overall situation of relevant farmland (using data acquisition technology). These data must be analyzed to obtain the best crop management decision-making scheme (accurate decision-making technology). The key to success is timely access to information and careful decision making. Precision fertilization and precision irrigation are directly related to farmers' decision making. In agriculture, these can make correct decisions for farmers in terms of farm management, so it can be described as the brain that converts data into decision making [41]. The decision support system (DSS) is widely used in agriculture and is a system based on a computer to support agricultural decision making [77,78]. Expert systems are computer systems that apply computer technology to simulate the idea of experts in dealing with the problems that experts can solve. They have a dominant role in dealing with qualitative knowledge [79].

The information management and decision-making system uses computers to manage and analyze huge amounts of crop production data, which saves considerable manpower, avoids unnecessary human errors, and facilitates the query and application of data. The use of the simulation function of computer software for simulation prediction can guide production more accurately and quickly, improve the accuracy and efficiency of prediction, and enhance the predictability of production [80,81]. Precision fertilization and precision irrigation are the inevitable results of the development of modern agriculture. It is a new advanced agricultural technology and is an important part of information agriculture and the concretization of the integration of multidisciplinary technology systems. Research on various integrated systems (GIS and RS, GIS and GPS, and GIS and DSS, etc.) must be strengthened, and their depth and breadth must be continuously developed in some original application directions to improve their practicability and develop China's applicable precision fertilization and irrigation technology and application systems [82,83]. Figure 3 shows the ecosystem of information management and decision-making system.

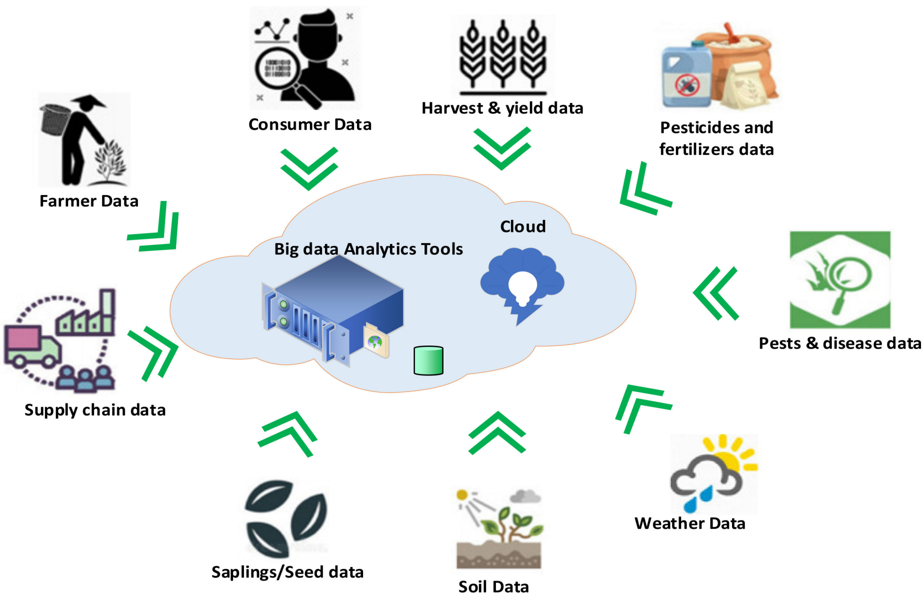


Figure 3. Information management and decision-making system.

3.2. System Application

Table 3 [79,84–86] shows the application of precise decision-making system.

Feng et al. constructed a cotton digital information management decision-making system with farmers as the basic unit based on WebService technology by comprehensively using the Chinese cotton production prosperity index model (CCPPI) and Chinese cotton growth index model (CCGI). The system can dynamically release cotton growth information, spatial change information, and management decision-making plan so as to realize rapid monitoring and evaluation and efficient management of face-to-face production [80]. Using knowledge engineering and system modeling methods, Liu et al. established quantitative dynamic knowledge models for planting system evaluation, agricultural product ecological zoning, agricultural production potential analysis, and accurate agricultural management. Using software component technology, a networked and digital agricultural spatial information management and auxiliary decision-making system was established. The system realizes the functions of basic map operation, agricultural spatial information query and analysis, planting system evaluation, agricultural product ecological zoning, agricultural production potential analysis, accurate agricultural management, and visual output and system maintenance. The experimental results show that the system can effectively manage regional agricultural spatial information and has good adaptability and guidance in agricultural production management decision making based on spatial information [87]. Cao et al. established a fertilization model, case base, expert knowledge base, and fertilization decision scheme based on regional soil fertility differences, fertilizer supply performance, and fertilizer utilization rate, etc. and constructed a fertilization management decision system for Fan tobacco production. It realizes the integration of farmland and crop production information management and intelligent fertilization decisions, as well as fast and efficient online access. The results show that the system can provide users with a scientific and reasonable fertilization program, and the amount of fertilization can be more accurately controlled. Moreover, RIA/REST development frameworks are characterized by flexible deployment, easy development, strong scalability, and more advantages in user experience and interaction [88].

Table 3. Application of decision systems.

Reference	Technology	Application
Yongcheng L. et al. [79]	Es expert system	The establishment of soil automatic classification expert system (SCE) based on ES and GIS can make full use of the soil survey data accumulated over many years and improve the utilization rate of data.
Guoqiang Q. et al. [84]		A computer simulation and optimization decision-making consultation system for high-quality and high-yield cultivation of soybean based on expert system (ES) and geographic information system (GIS) is proposed, which has passed the test and experimental verification and achieved good results.
Haijiang W. et al. [85]		The application of integrated geographic information system (GIS) technology to Xinjiang cotton fertilization expert system (ES) is studied and discussed. By accessing the interface of the expert system through the Internet, users can obtain the geographic information of farmland plots and recommend fertilization in cotton fields. At the same time, it can make comprehensive query of farmland fertility and thematic map.
Liping et al. [86]	Decision support system (DSS)	Based on Internet/Intranet technology, the system studies and integrates the key technologies in precision agriculture—geographic information system (GIS) and expert system (ES), which can provide decision support for precision agriculture practice. By accessing the system, users can not only obtain the geographic information based on farmland plots, but also analyze farmland fertility; At the same time, it can make expert intelligent decisions on varieties, fertilization, irrigation, pest control, and so on.

4. Execution System

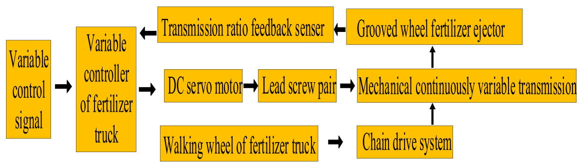
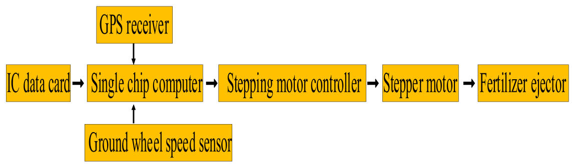
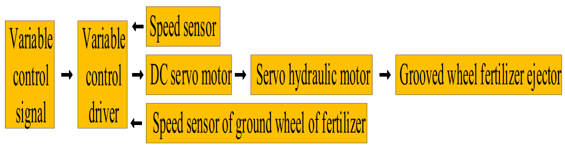
4.1. Variable Rate Fertilization Technology

4.1.1. Principle

Variable control technology is the most important research direction, and the development of equipment to control variables is the key to realize precision agricultural machinery [89]. Variable rate fertilization equipment is an important research content of controlling fertilization variables. Precision fertilization and precision irrigation are a fertilization technology based on the comprehensive analysis of the yield data of different spatial units and multilayer data, such as soil physical and chemical properties, diseases, pests, and climate. This technology is supported by the crop growth model and crop nutrition expert system and intended for high yield, high quality, and environmental protection. The nutrient balance of an agricultural platform system must be investigated [90–95].

The core performance of variable rate fertilization equipment is to achieve high fertilization accuracy. At present, China has developed suitable variable rate fertilization mechanisms based on foreign advanced automatic control. Variable rate fertilization mechanisms can be divided into three types: electronic mechanical stepless transmission type, electronic–hydraulic motor type, and motor direct-drive type, as shown in Table 4. Many types of fertilizer ejectors are used in variable rate fertilization devices, including the outer grooved wheel type, centrifugal type, vibrating type, and star wheel type, as shown in Table 4 [96–103].

Table 4. Variable rate fertilization mechanisms with different driving types.

Type	Principle Block Diagram of Device Composition	Characteristics
Electronically controlled mechanical continuously variable transmission		It has the advantages of low technical level, simple structure, stable operation, and low cost. It is suitable for medium-sized variable devices.
Motor direct-drive type		The control is difficult, and the output torque is small. It is suitable for small and medium variable devices.
Electronic–hydraulic motor type		With high technical level, complex structure, and high cost, it is suitable for large variable devices.

(1) The outer grooved wheel fertilizer metering device, which is based on the outer grooved wheel seed metering device, increases the diameter of the grooved wheel, reduces the number of teeth, and increases the volume of the inter groove (Figure 4). It is characterized by a simple structure and good fertilization uniformity. This metering device is applicable to loose chemical and compound granular fertilizers with good fluidity. However, it is susceptible to hollowing and breaking when powdered or wet fertilizers are applied. The amount of fertilizer discharged is shown in Figure 4 [97,104–106].

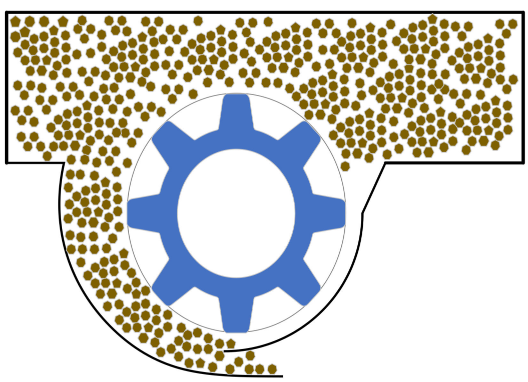


Figure 4. External grooved wheel fertilizer ejector.

(2) The centrifugal fertilizer ejector uses the rotating disk at the bottom to scatter fertilizer particles under the action of centrifugal force. It is mainly applicable to granular and powdery fertilizers with good fluidity. The rotating disk at the bottom of the fertilizer ejector has a high speed. The working width of the fertilizer ejector will be determined when its speed is fixed (Figure 5). At this time, the amount of fertilizer discharged per hectare is mainly related to the travel speed of machines and tools. The faster the travel speed of machines and tools, the greater the amount of fertilizer discharged [98,99].

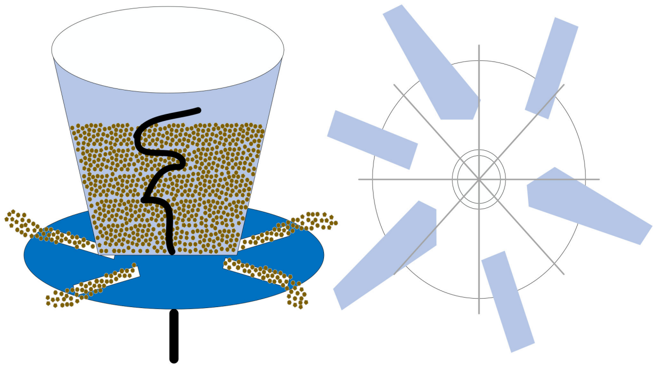


Figure 5. Centrifugal fertilizer ejector.

(3) When the vibrating fertilizer ejector operates, the rotating fertilizer discharging cam causes the fertilizer discharging vibrating plate to vibrate continuously (Figure 6). Under the dual action of vibration and its own gravity, the fertilizer in the fertilizer box slides along the slope of the vibrating plate and is discharged through the fertilizer discharging port. The vibrating fertilizer ejector is suitable for granular and highly hygroscopic powdery fertilizers. It has a wide application range and simple structure. This fertilizer ejector is mostly used on the mid-tillage fertilizer chaser [101].

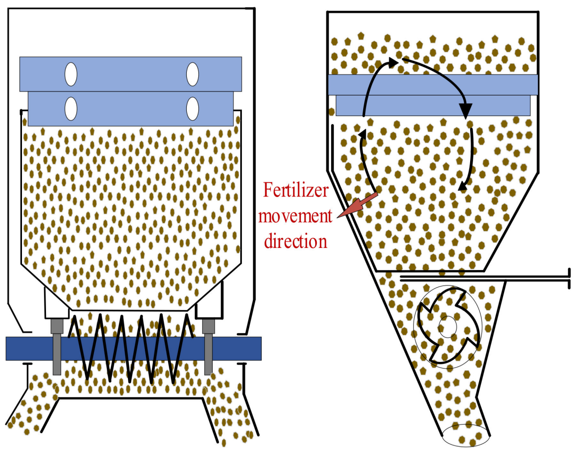


Figure 6. Centrifugal fertilizer ejector.

(4) The star wheel-type fertilizer extractor is used to apply crystalline and dry powder fertilizers (Figure 7). During the fertilization operation, the rotating star wheel continuously directs fertilizer from the fertilizer tank into the fertilizer pipe. The adjustment of the discharge quantity of the star wheel-type fertilizer exhauster can be realized by adjusting the opening of the discharge valve or changing the speed of the star wheel. Under normal circumstances, the bottom of the fertilizer tank is movable to facilitate the cleaning of excess fertilizer. The star wheel fertilizer exhauster is easy to disassemble and has low troubleshooting difficulty [107].

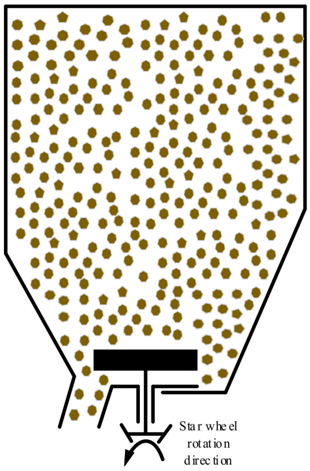


Figure 7. Star wheel fertilizer ejector.

4.1.2. Variable Rate Fertilization Technology Device

(1) Double-variable fertilization device. Univariate fertilization is realized by regulating the rotation speed of the main shaft of the fertilization machine. However, some problems, such as small adjustable range, low fertilization accuracy, and poor uniformity, are encountered when the rotation speed is low. Zhang's team at Shihezi University proposed a set of double-variable fertilization device and a supporting principle based on the external trough wheel fertilizer ejector. The double-variable fertilization mechanism is shown in Figure 8. Double-variable fertilization is mainly realized by the main shaft hydraulic motor installed at two ends of the main shaft of the fertilizer ejector and the hydraulic motor with opening (the effective working length of the outer groove wheel and the groove wheel of the fertilizer ejector). The double-variable fertilizer applicator with a double adjustment of the spindle speed and fertilizer ejector opening can effectively avoid low fertilization accuracy and poor uniformity of fertilizer applicator operation at a small fertilizer discharge and low spindle speed through a high speed and low opening. At the same time, it can also better avoid the significant effect of the motor pulsation on the fertilization accuracy when the fertilizer with hydraulic motor discharges fertilizer. The double-adjustment structure of the speed opening is shown in Figure 9 [108].

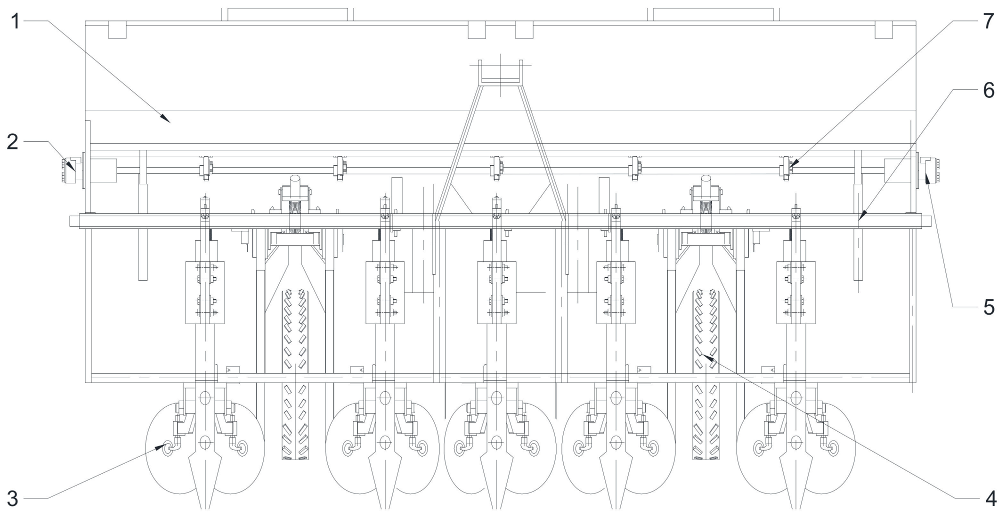


Figure 8. Structure of variable rate fertilization mechanism. 1: Fertilizer bin; 2: Opening motor; 3: Trenching and earth covering device; 4: Profiling wheel structure; 5: Speed motor; 6: Rack; 7: Fertilizer discharging device.

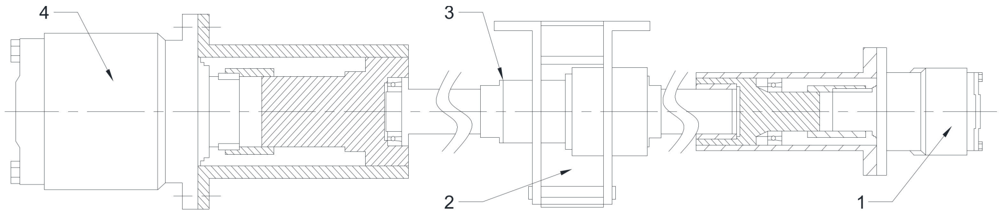


Figure 9. Double regulating mechanism structure of speed and opening. 1: Speed hydraulic motor; 2: Fertilizer discharge box; 3: Fertilizer discharge stop shaft; 4: Opening hydraulic motor.

(2) Spiral vertebral body centrifugal fertilizer ejector. The smoothness of fertilizer discharge depends on the arching principle of bulk materials above the rectangular discharge port. However, the discharge port easily forms a spherical cavity, which prevents the granular fertilizer from moving down smoothly. Applying external force to the granular fertilizer with spiral blades can effectively prevent its arching and the formation of a cavity. At the same time, the agglomerated fertilizer is disturbed and broken to ensure the smooth downward movement and discharge of the granular fertilizer. To ensure that the granular fertilizer is evenly distributed around the vertebrae, and at the same time, according to the principle of centrifugal seed discharge, the centrifugal fertilizer discharging mode is adopted to ensure the uniformity of the fertilizer entering the fertilizer chamber. A centrifugal push plate at a certain angle with the radial longitudinal section of the fertilizer discharge device is designed to improve the stability of fertilizer discharge capacity and prevent the granular fertilizer from continuously and stably moving to the outer edge under the action of centrifugal force due to insufficient friction. Considering the influence of the traditional fertilizer ejector on the fertilizer discharge performance due to the overhead arching and blockage of fertilizer, Professor Liu of Huazhong Agricultural University analyzed the movement model of granular fertilizer in the fertilizer discharge process of a spiral cone centrifugal fertilizer ejector and the mechanism of disturbance arch breaking and antiblocking. The centrifugal fertilizer ejector with spiral disturbance vertebral body was then designed, as shown in Figure 10, which is mainly composed of an upper shell, a spiral disturbance vertebral disk, and a lower shell [98,99].

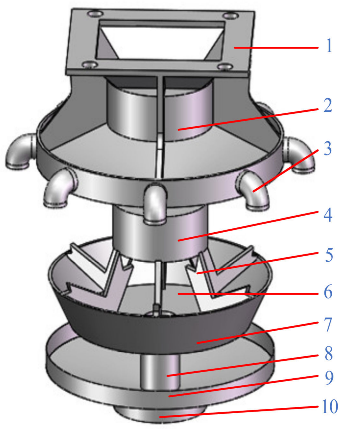


Figure 10. Spirally disturbed vertebral centrifugal fertilizer extractor. 1: Connecting base of fertilizer box; 2: Upper shell; 3: Fertilizer discharge pipe; 4: Spiral disturbance cup; 5: Centrifugal push plate; 6: Fertilizer room; 7: Vertebral disk; 8: Drive shaft; 9: Lower shell; 10: Bearing pedestal.

4.2. Variable Spraying Technology

Variable spraying technology is a type of equipment that can be developed to irrigate different amounts of water at different locations in accordance with the shape of crops or plots. The sprinkler irrigation machine can be equipped with GPS and GIS. It is the main technical means to realize variable sprinkler irrigation and rational utilization of water resources [109,110].

4.2.1. Principle of Variable Spraying Technology

Variable spraying technology collects detailed crop growth in cultivated land requiring plant protection through visual equipment, sensors, artificial data sampling, and other methods combined with GIS and GPS. A regional grid map with the characteristics of crop disease, insect, and grass is formed by information technology. During operation, plant protection machinery combined with GPS technology performs variable spray operation on crops at different coordinate positions [111–115].

Variable spraying technology can be divided into pressure regulation, variable nozzle regulation, and pulse width modulation (PWM) regulation.

(1) The pressure regulation technology mainly adjusts the servo valve opening size through the control instruction and changes the pressure of each pipeline in the spraying system. The pressure sensor obtains pressure feedback information by adjusting the pressure to change the flow and variable spray results [116,117]. The spray flow rate is proportional to the square root of the pressure difference, which is a nonlinear relationship. Excessive pressure variation affects the nozzle flow rate and has a significant effect on the droplet particle size and droplet distribution. This condition leads to poor spraying results. Therefore, the range of pressure and flow variation in the variable application control process should not be extremely large, usually limited to 25% of the flow variation in engineering applications. Although an inherent nonlinearity is found in pressure-regulated flow, the cost of pressure sensors is lower than that of flow sensors under the same accuracy conditions. Therefore, pressure-regulating flow has potential advantages from an economic standpoint. The regulation characteristics of pressure regulation can be expressed as follows:

$$Q = \frac{1}{\rho R}(p_1 - p_2)^{\frac{1}{\alpha}} \tag{1}$$

where Q is the fluid flow; ρ is the fluid density; p_1 and p_2 are the fluid pressures at the inlet and outlet of the regulating valve; α is the throttling type; R is the flow resistance.

(2) Variable nozzle adjustment technology allows you to change the flow rate of the spray nozzle. The control of variable nozzle spraying area is mainly realized by adjusting the nozzle range. When the range of the nozzle changes, the area sprayed by each unit angle of rotation of the nozzle also changes. The rotation speed or flow of the nozzle should be adjusted with the change in range to make the spraying water received on the same area of land the same [118–120].

$$Q = \frac{1}{2}KkR^2 \tag{2}$$

For a given sprinkler and sprinkler system, K is a constant; k is the rotational speed of variable nozzle at time t; R is the range of variable nozzle at time t; Q is the instantaneous flow at time t.

(3) PWM is the process where the liquid is mixed in the box in advance; the pipeline pressure is kept constant within a certain flow regulation range, and the nozzle flow is adjusted by controlling the on–off frequency and duty cycle of the nozzle solenoid valve, so as to achieve the effect of variable application. As shown in Figure 11, PWM requires a high response frequency of solenoid valve and needs to respond quickly to the pulse signal. Therefore, a high-frequency solenoid valve is usually used [121–123].

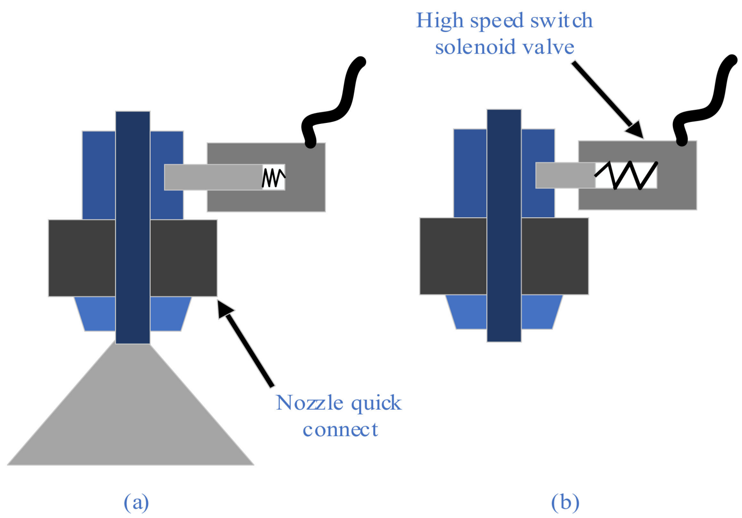


Figure 11. PWM variable nozzle. Solenoid valve on (**a**); Solenoid valve closed (**b**).

4.2.2. Variable Rate Spraying Technology Device

(1) Pressure regulation technology. Gonzalez et al. designed a nonlinear variable spray system based on pressure regulation, as shown in Figure 12. This system measures the pressure in real time by the pressure sensor and controls the injection volume through the electric proportional valve and electric on–off valve. With the opening of the electric proportional valve as the input and the spray pressure measured by the pressure sensor as the output, Gonzalez et al. concluded that the open-loop system can be described by a first-order system and gave the specific formula of the system transfer function as:

$$G(s,p) = \frac{k(p)}{T(p)s+1} \quad (3)$$

where the static gain parameter k and time parameter T of the system are written in the form associated with the system pressure ρ, which reflects the idea of Gonzalez and others to deal with nonlinearity by using the parametric method [124].

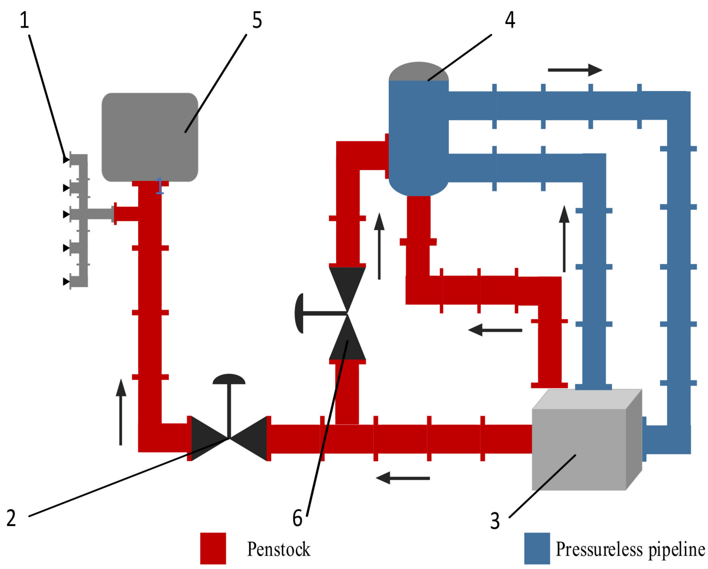


Figure 12. Nonlinear variable spray system. 1: Nozzle; 2: Electric on–off valve; 3: Pump; 4. Medicine box; 5: Pressure sensor; 6: Electric proportional valve. (The black arrow in the figure shows the flow direction of the aqueous solution.)

(2) Variable nozzle adjustment technology. Variable nozzle is relative to the traditional fixed nozzle. "Fixed" denotes that the internal structure of the nozzle is fixed during the working process. To realize variable spraying in crop protection areas, Huang et al. designed an agricultural variable sprinkler based on magnetorheological fluid (Figure 13). The inlet opening of the atomization chamber is controlled without changing the pump pressure to achieve the effect of flow regulation. Magnetorheological fluid is added and controlled at the inlet of the atomization chamber to change its physical state, affect the space of atomization chamber, and realize the required functions [125].

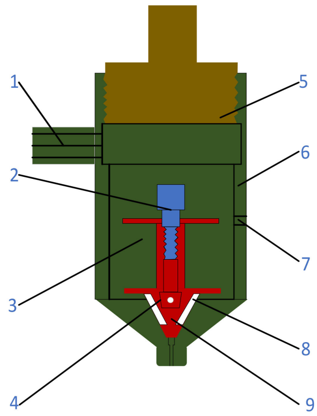


Figure 13. Three-dimensional cutting view of nozzle. 1: Water inlet; 2: Magnetorheological fluid cavity plug; 3: Coil winding shaft; 4: Magnetorheological fluid chamber; 5: Nozzle end cover; 6: Shell body; 7: Conductor hole; 8: Elastic cavity; 9: Swirl chamber.

(3) PWM. This technology mainly controls electronic actuators by using fast on and off (pulse mode) conversion equipment. The speed of conversion equipment driven by pulse is frequency. Although the PWM intermittent spray flow regulating system has a fast response speed and large flow regulating range, and the use of conventional nozzles can achieve an excellent spraying effect, the requirements for the control system are relatively high. Wang studied the low-altitude variable spraying measurement and control technology of multirotor plant protection UAV and designed a dual nozzle PWM variable spraying measurement and control system. Its spray actuator is shown in Figure 14. The system uses a PWM controller to wirelessly receive the pulse width, operation state, and centrifugal nozzle control signals with adjustable duty ratio. The PWM controller is used to control the working state of the system after data acquisition and drive amplification. The speed of the diaphragm pump and centrifugal nozzle motor can adjust the instantaneous spraying amount of the system [126].

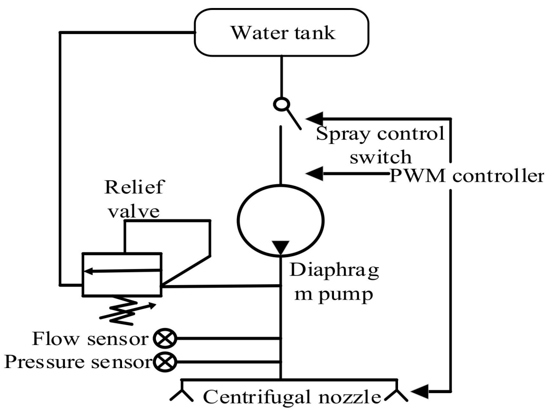


Figure 14. Composition of spray actuator.

5. Contribution and Recommendation

5.1. Contribution

Figure 15 shows the key timetable for the development of precision agriculture in relevant countries and the core research objects. After the introduction of precision agriculture technology in 1960, many modern scientific and technological elements were derived. These elements can be divided into three key stages. The first stage is agricultural information collection technology; the second is information processing and decision-making technology, and the third is information execution technology. Each of them is proposed to ensure the quality and quantity of crops [127–131]. A large number of documents have been published and widely studied with the proposal of precision agriculture technology. However, bibliometric analysis is an effective tool for the quantitative analysis of scientific publications, research trends, hotspots, and cooperation relationships to comprehensively understand the current situation and future trend of precision agriculture. The published articles were searched by SCI-E on 10 April 2022 and analyzed by CiteSpace and bibliometrics. The search method was a keyword search, and the content was "precision agriculture". Figure 16 shows the annual number and trend of documents issued in precision agriculture from 2008 to 2021. The attention in this field has increased since 2008. In particular, the annual number of documents issued in this field has increased significantly since 2016 and exceeded 100 in 2017. China, Brazil, and the United States are the main contributors to the number of documents published in this field. As the world's most advanced scientific and technological power, the United States has always been in the forefront of research on advanced technology. In recent years, the number of documents issued by China and Brazil has increased, and they have been the main contributors in this field. In particular, the number of documents issued by China in this field has shown a straight-line upward trend since 2018, which reflects China's attention to agricultural green, environmental protection, and low-carbon transformation.

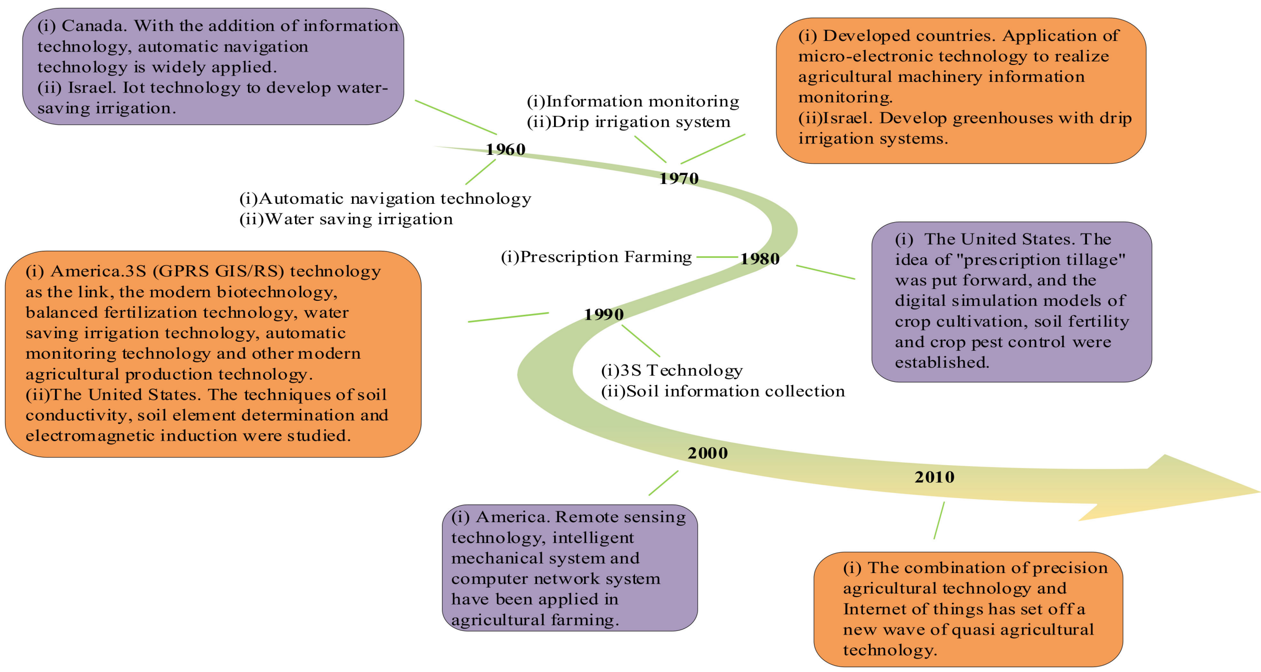


Figure 15. Time and derivation of precision agriculture development.

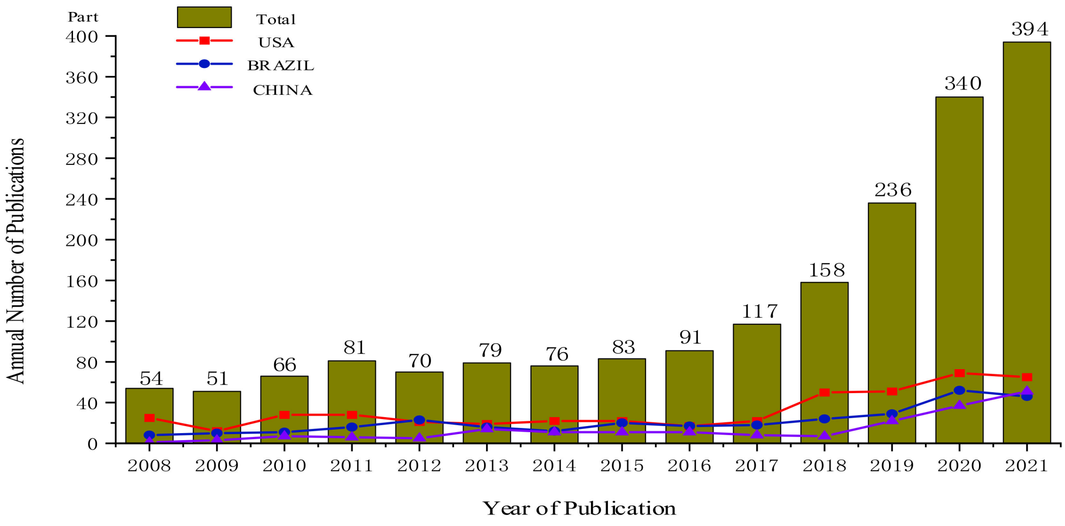


Figure 16. Annual number of documents issued and the trend of documents issued in accordance with the search formula: "precision agriculture".

5.1.1. Contribution of Leading Countries

Researchers from 99 countries and regions have conducted detailed and extensive research in this field from 2008 to 2022 through the quantitative analysis of the academic literature published in the field of precision agriculture. Figure 17 shows the top 10 most productive countries/regions. Among them, the literature published by the United States ranks first in the world (about 25.5%), followed by Brazil (about 17.3%), and China ranks third (about 11.3%), and Spain (about 11%) and Italy (about 8.8%) rank fourth and fifth, respectively. Figure 18 shows the cooperation relationship of the top 20 most productive countries/regions. The larger the circle, the more cited; the thicker the connecting line, the more cooperation, and the darker the color, the older the year. The number of citations in American literature is the highest.

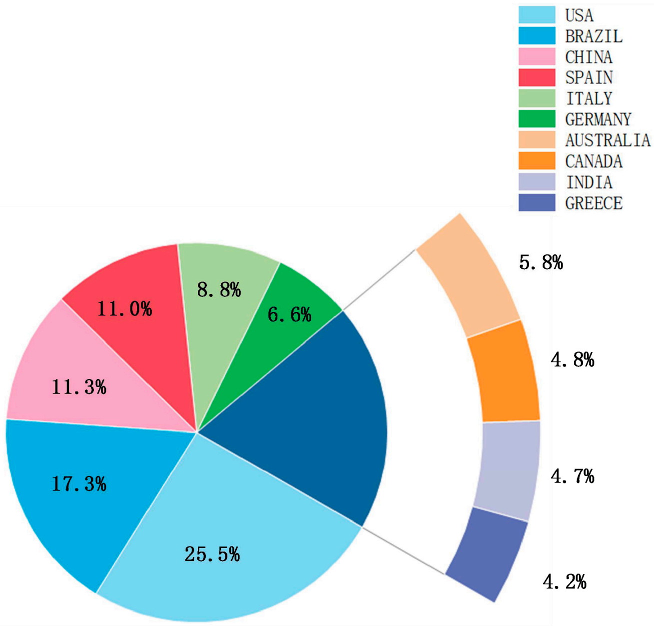


Figure 17. Contribution and influence of top 10 countries/regions in the field of precision agriculture.

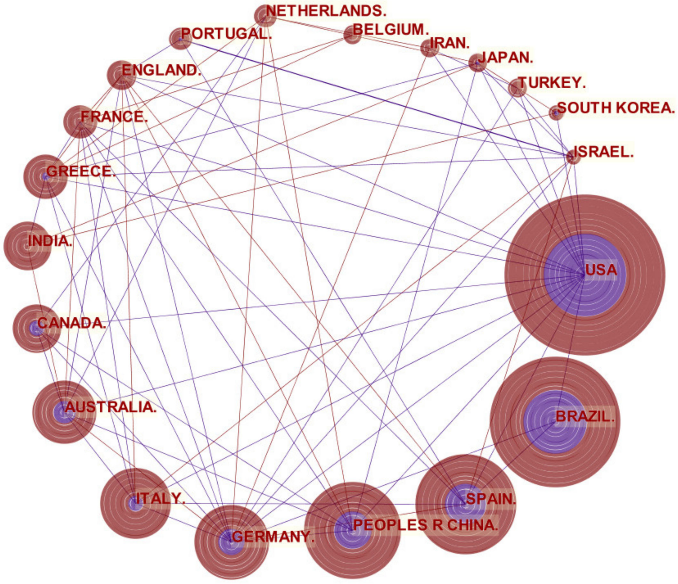


Figure 18. Cooperation matrix of the top 20 countries/regions with the highest productivity (circle size represents the number of citations).

5.1.2. Contribution of Leading Institutions

Figure 19 shows that more detailed and specific information can be achieved by scholars through the statistical analysis of research institutions. Among the top 40 most productive research institutions, most of them are from the top 10 countries. The University of Florida ranks first with 19 articles, followed by the agricultural organization of the U.S. Department of Research and the University of Sao Paulo in Brazil. In terms of TC (total citations), the University of Florida ranked first (19), followed by the agricultural organization of the United States Department of Research (17) and the University of Sao Paulo in Brazil (15). The cooperative relationship among organizations can send a message of cooperation intention to researchers, so as to help scholars cooperate more. Figure 19 shows the cooperation relationship among the institutions with 5 or more papers among the top 100 highly cited papers from 2008 to 2022, where the larger circle size represents the more cited papers, and the thicker connecting line represents the more cooperation between the two. From the figure, cooperation has become the choice of various institutions, and most institutions have more or less cooperative relations.

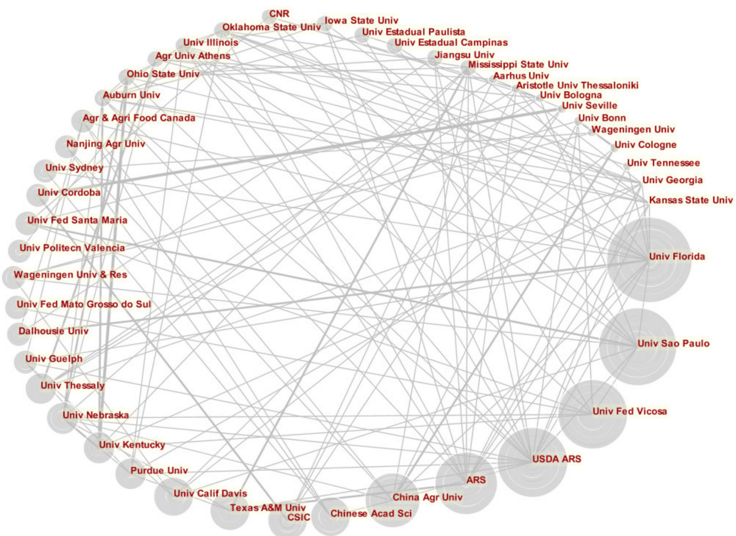


Figure 19. Figure cooperation relationship of institutions with five or more documents.

5.1.3. Contribution of Leading Corresponding Authors

As shown in Figure 20, the academic contribution of precision agriculture comes from different research teams, and that the research team is scattered by analyzing the relationship between the author and cocitation. The size of the text in the figure represents the influence of the work. Molin JP, Teodoro PE, and Osco LP are the extremely active representative researchers in this field. These active teams and authors also focus on greater contributions. Molin JP and others are mainly interested in GPS and sensor technology of information acquisition technology in precision agriculture. Teodoro PE and Osco LP are mainly interested in UAV and remote sensing vegetation spectrum prediction.

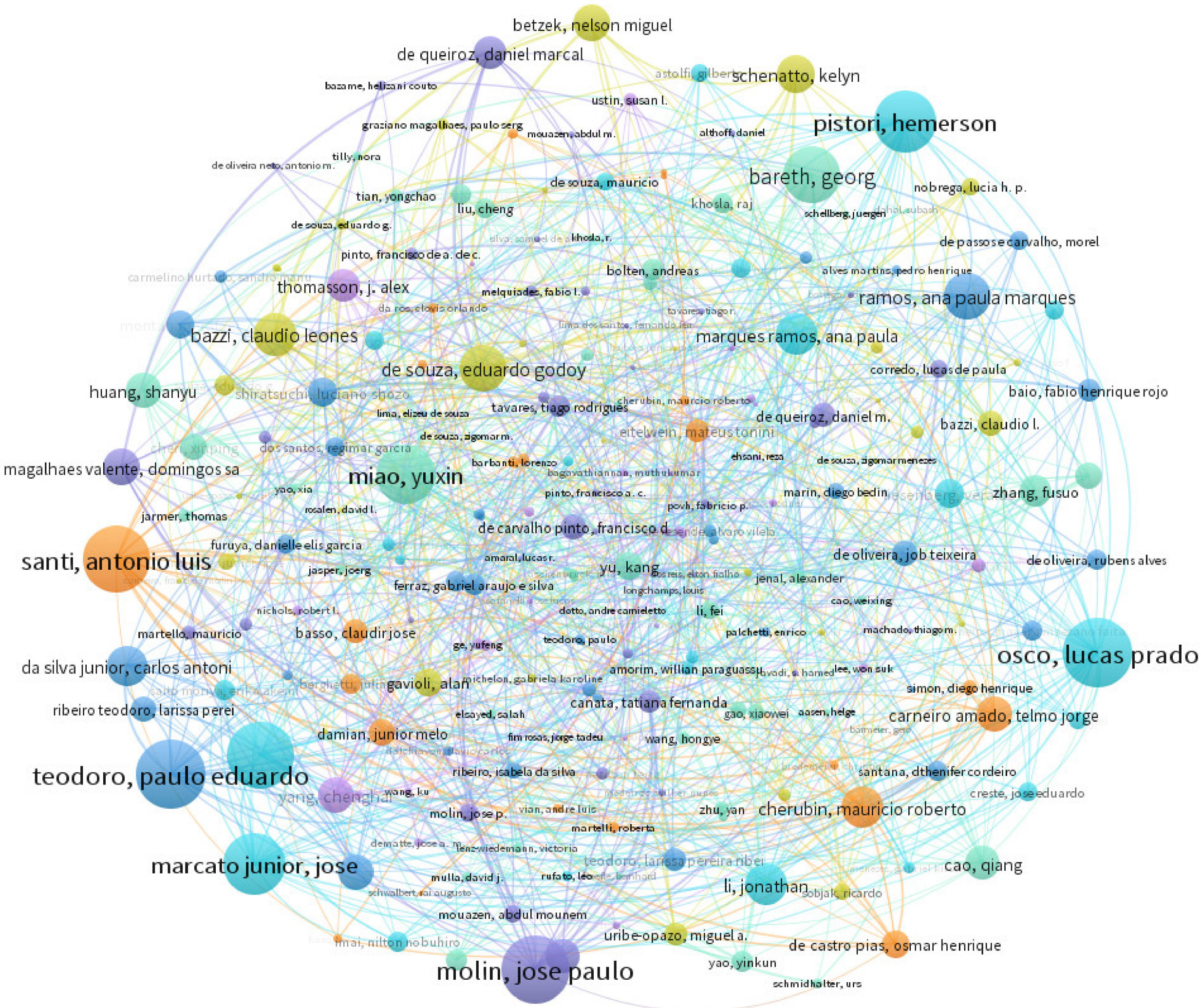


Figure 20. Author influence analysis.

5.1.4. Leading Journals in Terms of the Number of Publications

In accordance with statistics, 219 publishers published 2001 articles related to this field, where the top 10 journals are shown in Table 5. The top 10 journals published 873 articles, accounting for 43.6% of the total number, where *Computers and Electronics in Agriculture* published the most, with a total of 246 articles, and *Remote Sensing* (132) and *Sensors* (124) ranked second and third, respectively, and *Agriculture Basel* (77) ranked fourth. In terms of acpp, *IEEE* access ranked first with an average of 23.47 citations per article, and *Precision Agriculture* (8.68) and *Transactions of the ASABE* (8.27) ranked second and third, respectively.

Table 5. Journal impact analysis.

Rank	Journal	TC	TA	ACPP	IF
1	*Computers and Electronics in Agriculture*	1843	246	7.49	5.565
2	*Remote Sensing*	880	132	6.67	4.848
3	*Sensors*	798	124	6.44	3.576
4	*Agronomy* (*Basel*)	391	77	5.08	3.417
5	*Precision Agriculture*	634	73	8.68	5.385
6	*Transactions of the Asabe*	488	59	8.27	1.188
7	*Agriculture* (*Basel*)	183	45	4.07	2.925
8	*Applied Engineering in Agriculture*	256	42	6.10	0.985
9	*Engenharia Agricola*	224	41	5.46	0.716
10	*IEEE Access*	798	34	23.47	3.367

Abbreviations: TA = total articles; TC = total citations; ACPP = average citations per publication; IF = impact factor.

5.1.5. Leading Institutions in Terms of the Number of Publications

In accordance with statistics, 196 publishers published articles related to this field, where the top 20 are shown in Table 6. The top 20 journals published 887 articles, accounting for 44.3% of the total, where the United States Department of Agriculture published the most, with a total of 104 articles. Universidade de Sao Paulo (72) and Consejo Superior de Investigaciones Cientificas (64) ranked second and third, respectively, and the State University System of Florida (56) ranked fourth. In terms of acpp, the University of California System ranked first with an average of 38.82 citations per article, and China Agricultural University (38.78) and Wageningen University Research (33.90) ranked second and third, respectively. The top 20 institutions from the USA account for 45%.

Table 6. Mechanism impact analysis.

Rank	Institutions	TA	TC	ACPP	Country/Region
1	United States Department of Agriculture Usda	1233	104	11.86	USA
2	Universidade De Sao Paulo	519	72	7.21	Brazil
3	Consejo Superior De Investigaciones Cientificas Csic	1461	64	22.83	Spain
4	State University System of Florida	1322	56	23.61	USA
5	University of Florida	1325	55	24.09	USA
6	Universidade Estadual Paulista	353	50	7.06	Brazil
7	Universidade Federal De Vicosa	263	46	5.72	Brazil
8	League of European Research Universities Leru	980	40	24.50	Europe
9	University of California System	1514	39	38.82	USA
10	China Agricultural University	1435	37	38.78	China
11	Universidade Federal De Mato Grosso Do Sul	252	36	7.00	Brazil
12	Consiglio Nazionale Delle Ricerche Cnr	548	35	15.66	Italy
13	Texas A&M University System	836	35	23.89	USA
14	Chinese Academy of Sciences	541	34	15.91	China
15	University of California Davis	1136	34	33.41	USA
16	Texas A&M University College Station	556	32	17.38	USA
17	Universidad Politecnica De Madrid	953	30	31.77	Spain
18	Wageningen University Research	1017	30	33.90	Netherlands
19	University of Nebraska Lincoln	507	29	17.48	USA
20	University of Nebraska System	507	29	17.48	USA

5.1.6. Patent Status for Precision Agriculture

The number of patent applications can reflect the application prospect of this technology to a certain extent. A total of 531 invention patent applications are found worldwide, and the number of applications in recent years is relatively large after searching the number of invention patent applications related to precision agriculture around the world, as shown in Figure 21. However, the recent decline in the number of patent applications for invention related to precision agriculture may be related to the current application of the technology, which indicates that the existing technical scheme is transitioning to a mature stage. The relevant patents are listed in Figure 22. The relevant invention patent applications are concentrated in China.

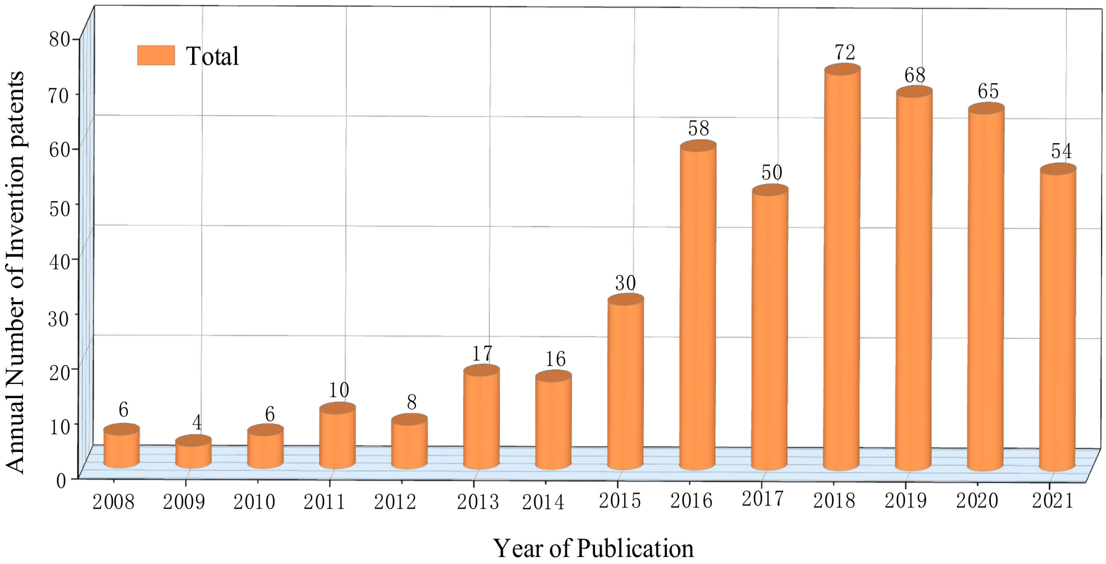


Figure 21. Number of patent applications for inventions related to precision agriculture in the last 14 years.

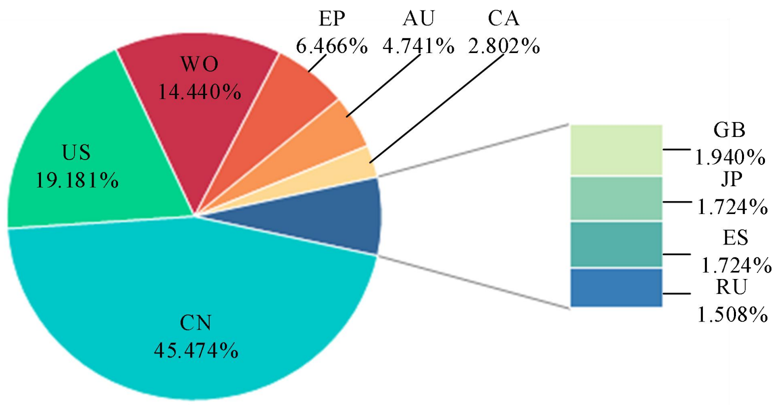


Figure 22. Contribution and influence of top 10 countries/regions in the number of patents in precision agriculture. CN: China; US: United States; WO: World Intellectual Property Organization; EP: Europe; AU: Australia; CA: Canada; GB: Great Britain; JP: Japan; ES: Spain; RU: Russia.

5.2. Recommendation—Intelligent Agriculture

Data collection and sorting are essential in precision agriculture and require the intervention of big data. Therefore, this study arranges the first five highly cited papers [132–136] by searching the keywords of Web of Science database for readers (Table 7). The retrieval formula is: "intelligent agriculture."

Table 7. Impact analysis of relevant literature.

Rank	Author, (PY)	Title	Journal	TC
[132]	Maddikunta et al. (2021)	Unmanned aerial vehicles in smart agriculture: Applications, requirements, and challenges	*IEEE Sensors Journal*	40
[133]	Popescu et al. (2020)	Advanced UAV–WSN system for intelligent monitoring in precision agriculture	*Sensors*	39
[134]	Jiang et al. (2020)	A multifunctional TENG yarn integrated into agrotextile for building intelligent agriculture	*Nano Energy*	27
[135]	Rovira-Más et al. (2011)	Sensor architecture and task classification for agricultural vehicles and environments	*Sensors*	22
[136]	SepúLveda et al. (2012)	Fernández R., Navas E., et al. Robotic aubergine harvesting using dual-arm manipulation	*IEEE Access*	19

6. Conclusions and Prospects

6.1. Conclusions

The three basic steps of realizing precision fertilization and irrigation are analyzed, and the conclusions can be summarized as follows: (1) GPS, remote sensing, and wireless sensor technologies are used in the information collection system to realize crop information collection, which can effectively realize field information collection. (2) The information management and decision-making system can manage and summarize the information in crop growth. At the same time, it organically combines the knowledge of various disciplines and expert knowledge and applies it to specific crops. (3) The execution system can accurately realize the fertilizer and water required by crops. With variable rate fertilization, the accuracy of fertilizer use is the key factor, and the stability of variable rate equipment is the primary factor. In variable rate spraying, pressure-regulating technology and variable rate nozzle in variable rate spray technology still occupy the mainstream of the market due to their relatively low cost. The development of new technologies is extremely important to improve the performance of low-cost devices. The feedback speed of the sensor and the response speed of the controller are insufficient at this stage. The response time is extremely long, which prevents the flow to be accurately adjusted for target pests and weeds. Therefore, sensitivity is an important factor restricting the development of variable spray technology. Improving the sensitivity of parts and reducing the response time are imperative. New algorithms and new software must be developed to accelerate the speed of information processing.

6.2. Prospects

Research on precision fertilization and irrigation should be strengthened in several aspects to improve its development level: (1) Agriculture is developing from the traditional extensive type to the refined type. How to combine the actual characteristics of farmland, utilization of network technology, and the development of a real-time monitoring system of farm machinery based on GPS and sensor technology are the key factors to improve traditional agriculture. The analysis of geographic information data can effectively handle all farming types, improve the efficiency of mechanical operation, and provide technical support for the further realization of variable farming and is a track for further improvements. (2) On the basis of introducing and processing foreign advanced technology, the development of a professional precision fertilization and irrigation monitoring system with independent intellectual property rights should be prioritized. Low-cost technological achievements and supporting key technology and equipment of precision fertilization and irrigation are urgent problems to be solved in China's implementation of precision fertilization and irrigation. (3) A national unified agricultural data center and information platform should be created. The government, enterprises, and research parties should work together to integrate multiple fragmented agricultural information platforms and databases and build a national agricultural cloud platform with all data in one and a corresponding data sharing and coconstruction mechanism with the help of cloud, network security, and data-intensive computing technologies. Farmers will have access to all basic services (subsidies, credit, insurance, government services, market, and farming information) under one roof. The platform will address the needs of smallholder farmers throughout the agricultural cycle—from farm preparation, farm inputs, harvest, and postharvest activities—by integrating agricultural stakeholders at the national level. (4) Research of technology integration should be strengthened, and the compatibility, standardization, and common interface among various technologies should be explored, and the effective connection between diversified technologies should be realized. Deep integration and integration of agricultural equipment with remote sensing technology, positioning system, intelligent decision making, wireless sensor network technology, electronic control, and other technologies are regarded as the fundamental elements of the future of precision fertilization and irrigation.

Author Contributions: Y.L. was the main author of the review and completed the collection and analysis of relevant literature and the writing of the first draft of the paper. M.L., X.L. (Xiaochu Liu), C.C., X.L. (Xinping Li), and Z.K. participated in the analysis and collation of literature materials. C.L. is the author and principal of the project and supervised the writing of the thesis. All authors have read and agreed to the published version of the manuscript.

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