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Cloud-Assisted IoT-Based Monitoring and Evaluation In Agriculture

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ABSTRACT

Agriculture is the primary economic activity in many rural areas and emerging nations, and it serves as the economic backbone for many nations. The agricultural industry has come a long way since its humble beginnings, and it is now significantly more complicated and multi-faceted. The problem that challenges agriculture in the modern day is how to provide food for the entire world's population in a fair and equitable manner while also preventing irreversible damage to the natural environment. Farmers' traditional techniques are insufficient to meet the rising demand of food. The agriculture sector faces various challenges such as producing more and better products while enhancing the sustainability through the smart use of natural resources, minimizing environmental harm, and adapting to the climate change. The purpose of introducing information technology into agriculture is to save production costs, improve production efficiency, and accelerate the development of productivity. Geographic information system technology is widely used in agriculture, such as precision agriculture, land resource management, crop yield estimation and monitoring, and soil and water conservation. The characteristic of expert decision-making system is the logical reasoning of knowledge, and the advantage of network is the acquisition of knowledge. In this paper, the agricultural data obtained from the expert database are displayed in the form of a tree list and are used in the process of system design. The geospatial data can be uploaded through the map loading function, find the map path, and easily uploaded by modifying the expert database. Efficient agricultural policies are essential to meeting increasing demand for safe and nutritious food in a sustainable way. While growing demand for food, feed, fuel and fibre presents significant opportunities for agriculture, government policies must address challenges such as increasing productivity growth, enhancing environmental sustainability, including reducing greenhouse gas emissions, and improving adaptation and resilience in the face of climate change and other unforeseen shocks.

Keywords: Agricultural informatization, Geographic spatial data, Internet of Things, Greenhouse

I. INTRODUCTION

Agriculture is the process of cultivating particular plants and rearing domesticated animals to provide food, nutrition, fiber, and a variety of other desirable items. According to the United Nations Food and Agriculture Organization (FAO) report, the world population is increasing with each passing day and will be more than 8 billion by the year 2025 and will exceed 10 billion by the year 2050 [1]. Keeping the significant increase in population worldwide, the global food production must grow by 70–72% by the year 2050. The rapid growth of the world's population, as well as the increasing demand for high-quality goods and products, leads to a need for the modernization and development of smart agricultural methods. Also, there is a need for a system that can efficiently use the water and other resources and contribute to the production of the agriculture sector [2].

Precision agriculture (PA) is one of the most auspicious concepts, which is anticipated to provide a significant contribution to the increasing demand for food production in a sustainable manner [3]. The primary objective of PA is to increase the agricultural output and quality while lowering the operational costs and emissions. PA has transformed the agricultural processes, as it was established on the basis of agricultural mechanization by integrating remote sensing technologies, global information system (GIS), and global position system (GPS) [4].

The main goal of PA is to optimize and enhance the agricultural operations and to ensure maximum productivity [5]. Further, it necessitates fast, trustworthy, and distributed measurements in order to provide the farmers a more detailed picture of the current situation of the cultivation land and to coordinate the automated machinery in a manner that reduces the energy consumption, water, and pesticide usage.

Agricultural productions and administration can be digitally and geographically connected using digital technologies. The connection will provide the control to the administration to keep track of the agriculture sector, so the agriculture will develop in accordance with the goals and directions of human needs. The development of digital agriculture and related technologies, the construction of digital agricultural technology standards and systems, and the promotion of agricultural high-tech development are important for enhancing the international competitiveness of agriculture [6].

It is of great significance to adjust and improve comprehensive agricultural production capacity, sustainable development capacity, coordination of economic and social growth in urban and rural areas, as well as the establishment of a prosperous society in rural areas. The construction of digital agriculture is inseparable from the support of various agricultural data. Moreover, the majority of agricultural data are based on geographical dispersion. Agricultural resources are dispersed across large geographical regions, and agricultural products are also dispersed across a large geographical area [7].

Nowadays, spatial information technology is widely used in the agriculture sector. This field is getting more and more attention from agricultural experts and has various applications in the desired domain. GIS and GPS technologies are working as the frontiers of IT and are involved in the construction of farmland, dynamic collection of farmland information, farmland management and decision-making, construction of intelligent agricultural machinery, ecological environment protection of farmland, and the monitoring of natural disasters, etc. It provides technical support and solutions for crop yield estimation and monitoring and can also play a huge role in agricultural informatization and digital agriculture [8].

A systematic approach that efficiently utilizes the resources, realizes the rational allocation of agricultural resources, and ensures the smooth realization of "green agriculture." In modern agricultural production, high input and high output have brought serious environmental problems. The use of a large number of pesticides, fertilizers, and agricultural machinery has continuously brought about an increase in agricultural production, and at the same time, it has brought about the deterioration of soil texture and the pollution of surrounding water bodies [9]. The increase in harmful residues of agricultural products has seriously affected the sustainable development of agriculture. Therefore, protecting the ecological environment, adhering to the sustainable development of agriculture, and realization of ecological agriculture are some of the important issues in the current agricultural development. Further, we should reduce the gaps with the developed countries of the world, thus greatly improving the country's comprehensive competitiveness.

The main contributions of this paper are given as follows:

- This paper studies the historical data of agricultural economic indicators; we repeatedly tested the effect of system and to predict the future value of agricultural indicators.
- This paper determines the model parameters and analyzes the current situation of agricultural informatization in our country's villages and towns, combined with the existing problems of the current agricultural economic spatial analysis.
- This study suggests developing a system for township agriculture economic information spatial analysis and auxiliary decision-making.

The rest of the paper structure is organized as follows: Section 2 represents the related work, Section 3 demonstrates the proposed methodology, and Section 4 illustrates the experimental results and analysis. Finally, the research work is concluded in Section 5.

II. METHODS AND MATERIAL

Precision agriculture is defined by exact measurements at local sites and data-intensive techniques, which are aided by advances in crop growth modelling, advancements in the use of technologies to monitor and gather information from farms in a less labour-congested way [10]. Crop yield forecast is a critical challenge for decision makers at all levels, including national and regional decision-making. An accurate crop yield forecasting model can assist the farmers to make a decision that what to grow and how to grow. Different approaches have been used in the past for the crop yield prediction, and some are currently used by the researchers [11].

Research on integrated technologies for digital agriculture is vigorously developing in Europe and the USA, and many developing countries are also planning to implement this plan in order to increase their economy. Using IT as the link, integrating computer networks, "3S" technology, and other advanced technologies, and applying them to agricultural resources, environmental monitoring, macro decision-making management, building, and developing [12]. Besides, we developed a satellite remote sensing information extraction technology, combined with agricultural climate and meteorological analysis, model's agricultural situation forecasting, crop yield estimation service system, and Web GIS-based agricultural meteorological information service application system [13]. Further, we developed a series of software and related supporting equipment, such as PA, geographic information management (GIM), combine harvester output data processing, variable fertilization prescription map generation, and farmland information collection.

Through the incorporation of "3S" technology into agricultural research and practice, diverse agricultural resource information with spatial qualities may be managed successfully, analyze and test agricultural management and practice models, facilitate decision-making, and evaluate scientific and policy standards. In addition, this can effectively monitor, analyze, and compare changes in agricultural resources and production activities over multiple periods [14]. At present, agricultural GIS research supported by "3S" technology has been used in agricultural resource monitoring and evaluation, agricultural zoning, land resources and land use research, crop growth monitoring and yield estimation, agricultural disaster early warning, and emergency response. Further, it is also used for the agricultural environmental monitoring, agricultural basic production materials management and reasonable utilization, agricultural water resources management, soil quality monitoring and management, and agricultural climate resource management [15].

From the late 1980s to the early 1990s, foreign countries began to produce the idea of combining expert decision making systems (EDMS) and artificial neural networks (ANNs) and produced a number of representative neural network expert decision-making systems. The launch of the integrated EDMS for disease diagnosis has created a precedent for the combination of neural networks and EDMS. The direct result of the synthesis was the first ANN-based EDMS. Its essence was to use ANN to construct various components of traditional education system [16]. The crop nutrition diagnosis EDMS based on neural network designed by He Yong of Zhejiang University showed through field experiments that the system fully imitates the function of expert decision-making, on-site diagnosis, and greatly improves the diagnosis efficiency.

This paper studies the prediction model and realizes it through coding. With the aid of historical data of agricultural economic indicators, we repeatedly tested the effect of using grey system and neural network model to predict the future value of agricultural indicators. Finally, we determined the model parameters, analyzed the current situation of agricultural informatization in our country and towns, and combined with the existing problems of the current agricultural economic spatial analysis. Thus, it is suggested to develop a system for the agricultural economic information spatial analysis and auxiliary decision-making which is easily transplantable and expandable.

III.PROPOSED METHODOLOGY

This section represents the methodologies followed in carrying out this research study. The GIS technology, grey decision-making system-based prediction, and a prediction model in the agriculture sector, and at last we have presented the overall structure design of the proposed system. The following subsections describe the methods and technologies followed in carrying out this study in more detail.

A. Geographic information system (GIS) technology

The use of GIS technology began in the era of 1960s, when the computer and earlier concepts of computational and quantitative geography were emerged. The composition of this system includes personnel, data, hardware, software, and processes. Based on functionality, it is divided into thematic GIS, regional GIS, and GIS tools, which include two data formats of vector and raster. It is a professional data management system and is often used in scientific investigations, development planning, resource evaluation, environmental monitoring, and route planning [17]. Due to the rapid development of computer technology and its application in cartography, it has become possible for people to collect, query, and analyze various attributes of data and map the data related to spatial location and geographic distribution through computers, and try to use computers to analyze data.

Further, it provides management and decision-making services for various departments. After entering into the twenty-first century, Chinese GIS technology has grown up and has made various achievements in many fields. In terms of product development technology, the original sporadic development mode of independent basic functions or single technology has been transformed into the development stage of comprehensive and multi-technology integration [18]. At the same time, a number of hightech companies with GIS software development and system integration are emerged, occupying a great part of the domestic market in terms of smart agriculture and information management. With the continuous improvement in GIS technology, people started relying on GIS technology and are using GIS-related methods to study the other traditional fields. At present, this technology has shown very broad application prospects and has become the "third generation language" of geography[19].

The main difference between GIS and traditional systems based on IT is that it takes spatial data as a processing object and has strong spatial analysis capabilities such as overlay analysis, buffer analysis, and path analysis. These technologies provide great advantages for the application of GIS in various industries. Keeping these advantages in consideration, GIS has become one of the technologies that attract more and more attention from people of different sectors of life. Figure 1 shows a basic and generic application diagram of GIS system in different fields such as street data, building data, and vegetation data

Figure 1 Architecture of Internet of Things for Smart Agriculture

In recent years, a series of IoT applications for agriculture have been introduced. According to survey results, we divided these applications into categories based on their purpose, including monitoring, tracking and traceability, and greenhouse production. The detailed results are presented in the following subsection.

Monitoring

In the agriculture sector, factors affecting the farming and production process can be monitored and collected, such as soil moisture, air humidity, temperature, pH level, etc. In the agriculture sector, factors affecting the farming and production process can be monitored and collected, such as soil moisture, air humidity, temperature, pH level, etc. These factors depend on the considered agricultural sector [20]. Some smart agricultural sectors are applying the following monitoring solutions.

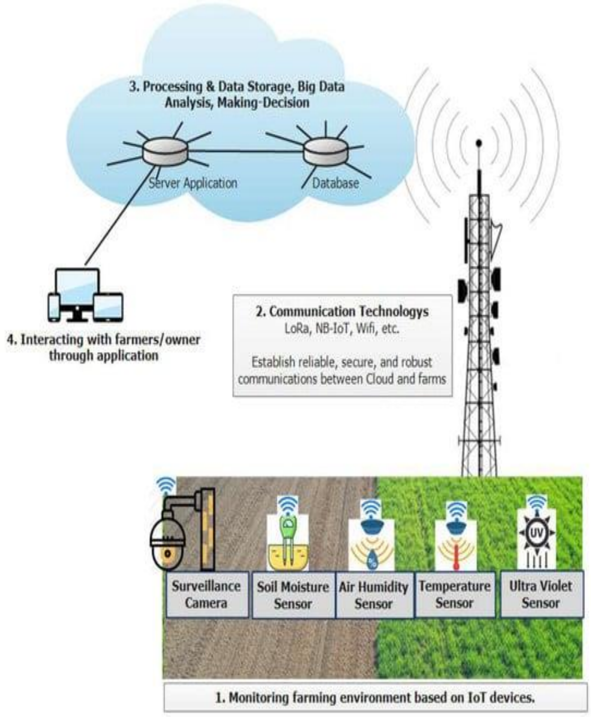

Figure 2 Monitoring based on IoT devices and applications

Crop Farming

In this sector, some vital factors that affect the farming process and production efficiency include air temperature, precipitation, air humidity, soil moisture, salinity, solar radiation, pest status, soil nutrient ingredients, etc. This device allows real-time collection and analysis of the composition of the farming soil and transmits the information to farmers/owners via the Internet [21]. The results demonstrate the health of the soil is monitored in real time to provide timely recommendations to farmers aiming to increase productivity and farming efficiency.

Furthermore, authors proposed an IoT device to allow intelligent control of temperature and humidity factors, called weather radar. This device will automatically turn on the warning mode using the light signal and send messages to the farmer when the temperature or humidity exceeds a pre-installed threshold. In, the authors introduced an IoT system based on Web GIS to monitor pest status and provide early warnings. In addition, this study also proposes a predictive model based on monitoring the habitat of pests and diseases [22].

Monitoring information, such as soil condition, moisture, and temperature, and the prediction of natural factors, such as rainfall and weather, support the control of growing conditions of crops, helping farmers plan and make irrigation decisions to optimize production and reduce labour costs. In addition, the collected data, combined with big data processing technology, can provide recommendations for implementing preventive and remedial solutions against pests and diseases in farming [23].

Aquaponics

It is an integration of aquaculture and hydroponics. Aquaponics is a farming technique where fish waste becomes a source of nutrients needed by plants. One of the most important issues in such farms is constantly monitoring water quality, water level, temperature, salinity, pH, sunlight, etc. According to this research direction, in, the authors designed an IoT system to monitor the temperature and pH value of water for aquaponics farms. Moreover, this system is also equipped with a control system of water metrics to keep the fish habitat stable and an automatic fish feeding function to increase the productivity of the fish. The results show that the IoT system had stable operation and provided real-time monitoring parameters. The authors of designed an aquaponics farm for households/urban areas based on IoT. This system recommends the proper ratio of fish and plants [24].

Consequently, the system decreases feed consumption as well as reduces carbon emissions into the environment. The primary purpose of this proposal aims to balance the self-sustaining ability of the aquaponics system. The experimental results demonstrate the number of fish decreases from 30 to 15, and the number of plants increases from 20 to 30, but the crop production will increase by more than

50%. A detailed and diverse survey of the IoT systems and devices for control and monitoring of aquaponics farms is introduced. Based on the obtained data, monitoring can improve the production of fish and plants through the control, supplementation, and regulation of nutritional ingredients in the water [25]. The collected data were also used to automate the management of aquaponics farms to reduce labour costs.

Forestry

Humans depend on forests for survival. Moreover, forests play a vital role in the carbon cycle and provide a habitat for more than two-thirds of animal species in the world. Forests also have the effect of protecting watersheds, limiting floods, and mitigating climate change [26]. The main factors that need to be monitored in a forest include soil ingredients, air temperature, humidity, and concentration of several different gases, such as oxygen, methane, ammonia, and hydrogen sulphide.

An IoT system to monitor environmental conditions, such as temperature, humidity, wind direction, barometric pressure, and manage possible disasters. For the purpose of enhancing feasibility, IoT devices use the solar-powered system and communicate with the monitoring centre based on the network. Survey results indicate that monitoring in forestry focuses on providing early warning systems against forest fires, pest control, or deforestation.

Livestock Farming

It is defined as the process of raising domesticated animals, such as cows, pigs, sheep, and goats, chickens, etc., in an agricultural environment to obtain traction, serve production, and obtain products such as meat, eggs, milk, fur, leather, etc. In this area, the factors to be monitored depend on the type and number of farming animals. A support system for the diagnosis, prevention, and treatment of diseases for livestock called VetLink. This system can provide recommendations for animal health for farmers in rural areas where it is difficult to access veterinary doctors immediately. This system can be used for remote monitoring of animal health and timely anomaly detection. In [28], the authors introduced a monitoring system for large-scale pig farms based on IoT. The specific solution is to attach an IC tag on each pig to monitor the behaviour of each pig, such as their period of feeding and resting and exercise.

The monitoring data of water, feed, and animal health for livestock in the farming process helps farmers set up livestock plans, reduce labour costs, and enhance production efficiency. While a series of solutions has been provided for monitoring large-scale farms, their application in small and medium-sized farms is very limited, especially in developing countries. This can be attributed to the high cost and the lack of knowledge needed to set up, manage, and operate IoT systems. Therefore, effective and low-cost solutions for agricultural IoT have much potential [29].

3.2. Tracking and Tracing

In order to meet the needs of consumers and increase profit value, in the future, farms need to demonstrate that products offered to the market are clean products and can be tracked and traced conveniently, thereby enhancing the trust of consumers in product safety and health-related issues. In order to solve this problem, a series of tracking- and tracing-based problems for the smart agricultural sector has been proposed, specifically as follows:

An information system designed that allows tracking and tracing of agricultural products and foods such as dairy and vegetables, called SISTABENE. This system helps suppliers track the production process and errors arising in the supply chain, and helps end-users trace the origin of food [30]. A food supply chain traceability system based on blockchain technology. It helps to track and trace agrifood supply chains' production process and trace the origin of agricultural products. Although there are still limitations, the results demonstrate that this solution has successfully supported the tracing of food and agricultural products through QR codes, improving product quality and ensuring the clear traceability of products. Smart agricultural solutions are used for tracking and tracing agricultural products, thereby allowing consumers to know the product's entire history. These solutions enable tracking and tracing some of the data collected along the supply chain, ensuring that consumers and other stakeholders can identify products' origin, location, and history [31].

3.3. Smart Precision Farming

The advent of the GPS (global positioning system) has created breakthrough advances in many fields of science and technology [32]. The GPS provides the most important parameters for locating a device, such as location and time. GPS systems have been successfully deployed in many fields, such as smartphones, vehicles, and IoT ecosystems. However, GPS is only good support for outdoor systems and the sky. Meanwhile, the demand for the locating and navigating systems in the home and on the streets of smart cities is growing rapidly. Aiming to solve this problem, an advanced global navigation satellite system (GNSS) is being deployed. Based on GPS and GNSS systems, suitable farming maps have been established for fields and farms. As a result, agricultural machinery and equipment can be operated autonomously [34]. Figure 3 presents an illustration of the typical cloud-assisted, IoT-based precision agriculture platform.

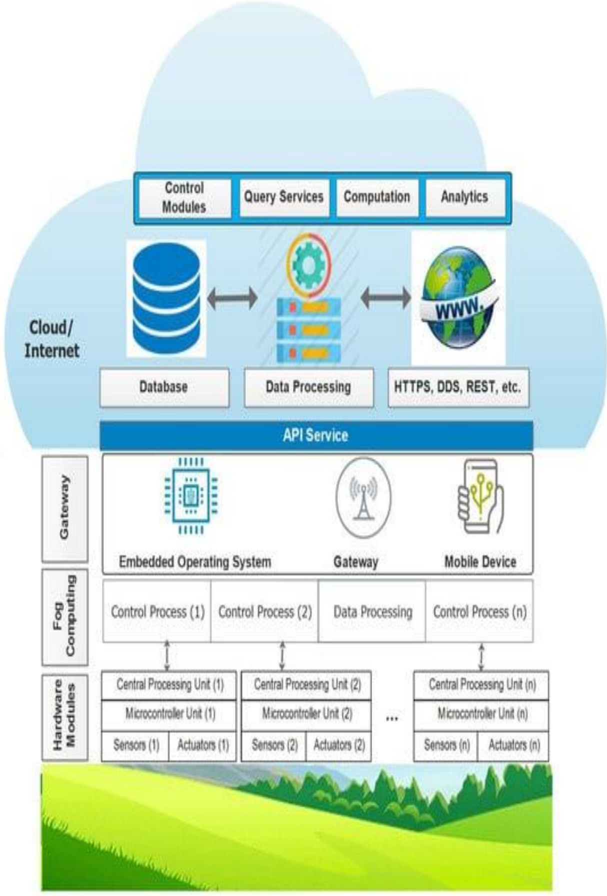

Figure 3. Cloud-assisted IoT-based precision agriculture platform.

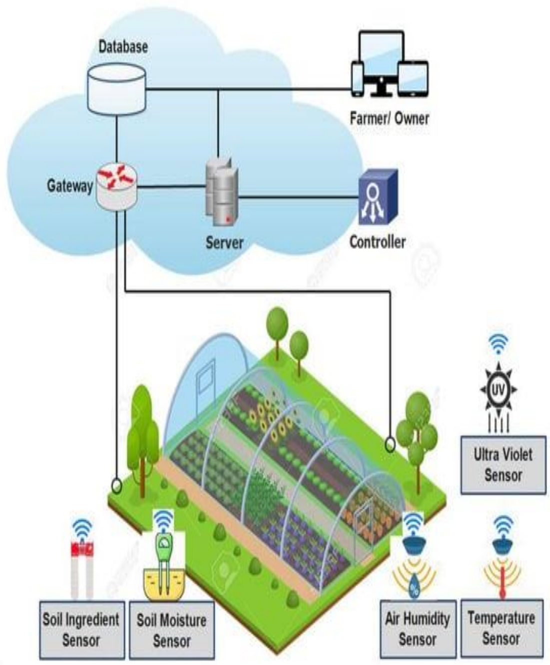

Figure 4. IoT application for monitoring farming conditions in a greenhouse.

IV. RESULTS AND DISCUSSION

The following subsections explain the designing, development, and experimental results attained via different experiments in more detail. Prediction refers to a discipline that analyzes the internal laws of things based on past occurrences, so as to preestimate and speculate about what has not happened and then discuss and study the results that will happen.

Deploying a huge number of IoT devices for smart agriculture can cause interference to different network systems, especially some IoT networks. Interference can degrade system performance as well as reduce the reliability of IoT ecosystems. IoT networks that use cognitive technology to reuse unlicensed spectra increase the cost of the device.

Security and Privacy: One of the most important problems of applying IoT in smart agriculture is the security problem, including the protection of data and systems from attacks on the Internet. In regard to system security, IoT devices' limited capacity and ability led to complex encryption algorithms that are impossible to implement on IoT devices. In addition, cloud servers can be attacked by data spoofing to perform unauthorized tasks that affect the autonomous farming processes of farms. Cloud infrastructures can also be controlled by attackers. Regarding data security, the obtained information from IoT systems in farms is collected, processed, and commercially exploited by service providers to varying degrees.

Therefore, one of the most important problems of policies regards the validity and legal status of farm data. In reality, these data are of great value when aggregated and analysed for large-scale agricultural activities. Consequently, without policies, the data privacy and security of farms can affect the competitive advantage of farmers/farm owners. In our opinion, using cryptography coupled with access keys is a possible solution to solve this problem. In our opinion, the security problems of IoT systems will be an exciting research topic and garner attention for both academia and industry research. An in-depth survey of threats and solutions to improve robustness, trust, and privacy for future IoT systems is presented.

Most IoT devices are expected to be deployed outdoors (in fields and farms). Harsh work environments lead to the rapid degradation of IoT devices' quality and can lead to unexpected manufacturer failures. The mechanical safety of IoT devices and systems must be ensured so they can withstand extremes of weather, such as temperature, humidity, rainstorms, and floods. In our opinion, new materials and technologies need to continue to be studied to improve the durability of devices.

The open problems and challenges discussed in this section indicate that for IoT to be widely deployed in the smart agriculture sector. Service providers need to reduce the service costs, more effectively exploiting the information collected from the farm. On the other hand, farmers need to improve their skills to be able to apply IoT solutions on their farm to enhance productivity and farming efficiency. Researchers need to continually study and propose optimal solutions and technologies to ensure IoT systems privacy and security and improve the durability of IoT devices. These are really major challenges and exciting research topics in the future so IoT can be widely applied in the smart agriculture sector.

V. CONCLUSION

The town-based agricultural economic information spatial analysis and auxiliary decision-making system is based on the Agricultural Economic Electronic Map of the Academy of Agricultural Sciences. In addition, it uses GIS, GPS, and a series of other core technologies such as agricultural economic forecasting to develop and design an intelligent agricultural system based on neural network. Further, it uses the GIS technology to mine the information service of rural agricultural economic index data. The purpose of introducing information technology into agriculture is to save production costs, improve production efficiency, and accelerate the development of productivity. Geographic information system technology is widely used in agriculture, such as precision agriculture, land resource management, crop yield estimation and monitoring, and soil and water conservation. The geospatial data can be uploaded through the map loading function, find the map path, and easily uploaded by modifying the expert database. Efficient agricultural policies are essential to meeting increasing demand for safe and nutritious food in a sustainable way. While growing demand for food, feed, fuel and fibre presents significant opportunities for agriculture, government policies must address challenges such as increasing productivity growth, enhancing environmental sustainability, including reducing greenhouse gas emissions, and improving adaptation and resilience in the face of climate change and other unforeseen shocks.

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