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Research Article

Precision farming through the use of Internet of Things (IoT) innovations in agriculture

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ABSTRACT

Using state-of-the-art technology, precision agriculture boosts agricultural output while minimizing negative environmental effects. Precision agriculture is a farming method that maximizes crop yields, reduces waste, and boosts production by using cutting-edge technology and data analysis. It is a viable tactic for addressing some of the main problems facing modern agriculture, such as feeding a growing global population while lessening its negative effects on the environment. This study looks at some recent developments in big data utilization and Internet of Things (IoT) based precision agriculture. The objective of this article is to present a summary of the latest advancements and potential applications of smart farming and precision agriculture. It provides a review of precision agriculture's current situation, taking into account the newest technological advancements such as machine learning, sensors, and drones.

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1. Introduction

The Internet of Things (IoT) has become increasingly important in various aspects of life, making it challenging for researchers to identify its optimal usage potential. IoT refers to things connected through the Internet via various technologies such as Wireless Sensor Networks (WSN), RFID, Bluetooth, Near-field communication (NFC), Long Term Evolution (LTE), and other smart communication technologies. These technologies facilitate the transfer of information from various devices to destined places over the Internet. Despite being the most reliable term in the technological world, IoT still lacks potential compliance(Karunathilake et al., 2023).

Precision agriculture (PA) is a management strategy that uses data and contemporary technologies to address geographical and temporal variabilities in agricultural fields. With a forecasted human population of between 9 and 10 billion by 2050, precision agriculture is crucial for maximizing output using fewer inputs, reducing adverse environmental impacts, and ensuring sustainability. The Third Industrial Revolution, known as Industry 3.0, led precision agriculture to digitalization by integrating information technologies and improved automation capabilities.

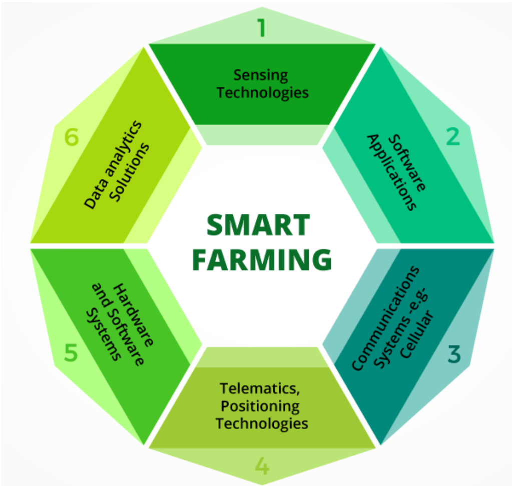

Fig. 1. Smart agriculture technique.

Precision agriculture mainly consists of variable rate technologies (VRTs), electronic maps, yield monitors, and guidance farming systems. GPS services were opened for general use in U.S. farms in 1983, and GPS technology facilitated farmers to precisely locate and map their fields. In the second millennium, yield monitors were developed, enabling farmers to monitor crop yield in real-time via best matching. Advancements in remote-sensing technology, such as satellites, drones, ground-based sensors, and crews, authorized farmers to collect high-resolution data on their fields, allowing them to make informed decisions about crop management(Salam & Salam, 2020).

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However, precision agriculture faces several issues, such as unsustainable resource utilization, long-term monoculture, intensive animal farming, environmental compromises, uneven distribution of digitization, food safety issues, inefficient agri-food supply chain, and lack of awareness of novel changes. The fourth industrial revolution, Industry 4.0, occurred in 2011 with the Internet of Things (IoT), big data, artificial intelligence (AI), robotics, and blockchain technology.

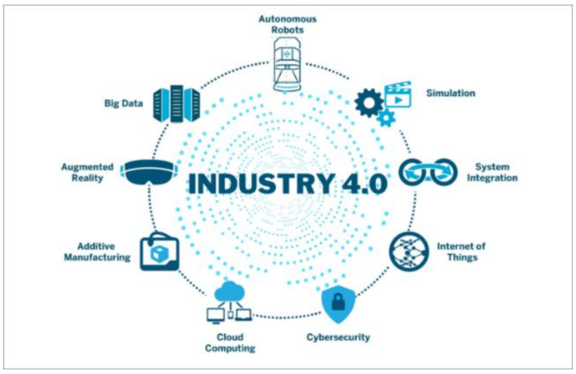

Fig. 2. Industry 4.0 for precision agriculture.

In 2017, advanced technologies were integrated into agriculture to transform precision agriculture to Agriculture 4.0 or smart farming. This transition has led to a growing focus on sustainability in agriculture, with many farmers adopting precision agricultural technologies to reduce environmental impacts and promote long-term sustainability. The integration of cutting-edge technologies, such as machine vision technology, the Internet of Things (IoT), and artificial intelligence (AI), can lead to enhanced precision and efficiency in agricultural processes, benefiting both farmers and the environment(Dhanaraju et al., 2022).

This article aims to provide an easy and comprehensive approach to understanding the concept and contribute to its channelization for optimal service. It presents research articles related to Precision Agriculture research using IoT, focusing on the most valuable content and distinct research over the years. The most relevant topics are addressed and discussed in detail.

2. Related works

A recent study shows that Precision agriculture is revolutionizing the agriculture industry by leveraging IoT technology for remote monitoring and control. This paper proposes a scalable wireless sensor network architecture for efficient water resource irrigation management. The WSN structure, analyzed for throughput maximization, latency minimization, and high signal-to-noise ratio, improves farmers' productivity. The proposed methodology outperforms conventional IoT-based agriculture and farming, enhancing water resource utilization and productivity(Sanjeevi et al., 2020). Another research states that The Internet of Things (IoT) has transformed the real world into smarter devices, allowing humans to control and update objects via the Internet. IoT has become a benchmark for communication among objects. This article reviews the current standings of IoT in Precision Agriculture, evaluating contributions from researchers and academicians. It also discusses challenges faced in agricultural activities and future research directions to improve IoT's standing and inspire innovative ideas(Khanna & Kaur, 2019).

The paper, an innovative Internet of Things (IoT) based system for precision farming, presents a system designed to monitor real-time agricultural parameters like soil moisture, temperature, air humidity, and temperature at the agro-field level using open-source platforms. The system consists of an Arduino-based IoT device, a smartphone application, and a web server. The data is then transferred to a cloud server for analysis. An adjustable steel probe is also included for field use. The system is evaluated through a case study and comparison to existing systems(Gaikwad et al., 2021).

3. Precision Agriculture Approaches

Precision agriculture uses data-driven management to improve resource use efficiency, reduce costs, and reduce environmental impacts. It involves data collection systems, decision support tools, and data-driven equipment adjustments. Before smart technologies, ICT was used to capture real data, such as remote sensing, automated hardware, and robotics. John Deere introduced GPSs for tractors.

3.1. Data Collection and Acquisition:

Precision agriculture relies on data collection and decision support tools to identify and diagnose various aspects of the agricultural sector. This involves observing, measuring, and sensing data on fields and crops using various sensors, yield, soil monitors, and remote-sensing tools like drones, crews, aircraft, or satellites. Sensing is a fundamental management tool in precision agriculture, providing detailed information on climate conditions, soil conditions, fertilizer requirements, water availability, pest and disease stresses, and other field parameters. Remote-sensing technologies, such as drones, crews, aircraft, satellites, and ground-based sensors, are used to collect data on crops and soil conditions. These technologies help identify spatial patterns of plant signatures coincidental with soil characteristics, pest or disease stresses, and ground truthing. Geocoded sampling is a crucial component of precision agriculture, enabling continuous and automatic recoding of real-time images of crops and soil with GIS reference. Sensor data and geospatial coordinates from GNSS provide information to create maps, yield maps, and soil maps for site-specific management decisions. Soil maps offer valuable insights into the spatial distribution of physical and chemical properties within a given field, and weather and climate trends can be predicted using sensor data.

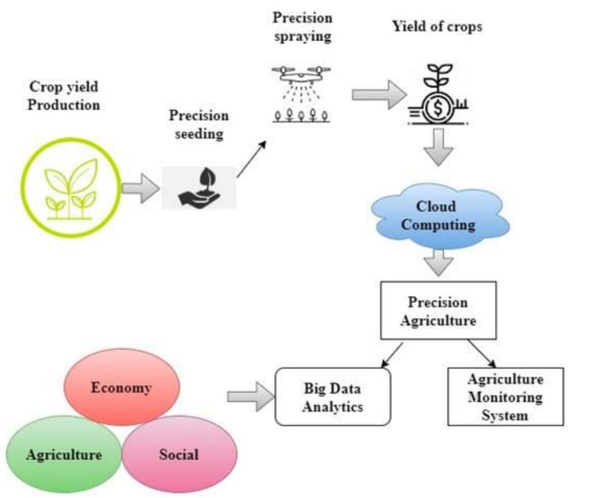

Fig. 3. precision agriculture processing and approaches(Song et al., 2022).

3.2. Planning, Decision Making, and Execution:

Precision agriculture has revolutionized agricultural practices by utilizing technologies to manage spatial and temporal variabilities in fields. Variable rate technologies, such as applying inputs like fertilizers, water, seeds, and crop protection chemicals at varying rates, can reduce residual issues of chemicals and wastage of input resources. This approach can improve performance and environmental quality, leading to increased crop yield and reduced input costs. Technology-driven smart irrigation systems can determine and apply water amounts based on the identified heterogeneity of a field. These systems can be automated, increasing irrigation water use efficiency (IWUE). Precision seeding can control sowing depth, densities, and distances effectively, saving seeds, time, and labor costs.

Site-specific management increases the number of correct decisions per unit area per unit of time, supporting the conservation of agricultural inputs and reducing costs while reducing environmental impacts. Grid sampling and computer-aided farming can provide representative information of the entire variation within a field, allowing for site-specific management and optimization of management practices.

Industry 4.0 and digital technologies have allowed for gradual automation of diagnosis and decision-making steps, focusing on optimal farming and variability management to enhance production. However, fulfilling food demand should also consider less wastage of both inputs and outputs of agricultural production.

4. Internet of Things (IoT) for Agriculture innovations

The Internet of Things (IoT) is a significant technological advancement in precision agriculture, enabling the collection and analysis of data for various applications such as livestock monitoring, smart greenhouses, fishery management, and weather tracking. IoT sensors, such as agricultural sensors with ICT and UAVs, collect and receive data for real-time monitoring, which are then uploaded to cloud information support systems for management. These sensors can directly combine with agricultural robots, autonomous platforms, machines, and weather stations for real-time monitoring.

IoT sensors in precision agriculture are typically in wireless frameworks or low-power wide-area networks, allowing for on-site analysis and mass data transfer without interruptions. However, implementing IoT in agricultural operations presents challenges such as cost, operational, technical, and data management difficulties. The development of an IoT framework can solve these issues by integrating different IoT devices as networks for high-speed data exchange.

Edge computing enables affordable real-time data transmission in IoT precision agriculture, reducing data package size and alleviating strain on centralized cloud resources. Pioneers like Cisco and Huawei have developed comprehensive frameworks and lightweight computing systems, while research explores aerial edge-IoT systems for improved convergence speed and task completion rates. Overall, IoT sensors and IoT frameworks are revolutionizing precision agriculture and enhancing the efficiency and effectiveness of agricultural operations.

Fig. 4. IoT in agriculture(Kim et al., 2020).

5. Future required developments

Precision agriculture, a growing trend in the agricultural sector, offers potential benefits such as improved efficiency, sustainability, and productivity. However, the adoption of these technologies faces challenges such as bridging the gap between expertise personnel and farmers, providing better education and vocational training, and establishing infrastructure that supports the establishment of precision agriculture. Governments can play a significant role by investing in energy infrastructure, communication infrastructure, internet connectivity, service markets, consultancy services, and credit markets.

Addressing the lack of professional agricultural sensors is crucial, with the design of high-quality, high-resolution, and reliable IoT-powered sensors tailored for the agricultural production environment. Wireless power transfer options can eliminate the need for frequent battery replacements, while on-site energy generation with renewable solar power or biogas can be more profitable than grid power. Cross-technology communication, such as machine vision for animal monitoring and smartphone applications, can generate valuable data and inform decisions.

Future advancements in precision agriculture technologies hold great promise for the agricultural sector, but overcoming existing roadblocks and uncertainties is essential to unlock their full potential. By focusing on education, infrastructure development, sensor technology, communication systems, and novel agricultural approaches, we can pave the way for a more efficient, sustainable, and productive future in agriculture.

6. Conclusion

Precision agriculture, a key aspect of Agriculture 4.0, utilizes digital technologies like drones, GPS technology, and artificial intelligence to enhance farming practices. These technologies enable informed decision-making and are essential for sustainable and intelligent agriculture. However, widespread adoption faces challenges such as initial investment, data privacy concerns, and compatibility issues with existing farming systems. Education and training programs are necessary to equip farmers with the necessary skills to effectively leverage these technologies. This review paper provides insights into IoT devices, automation systems, data analytics, and precision farming techniques, promoting awareness and understanding of the opportunities and challenges in smart farming. By embracing Industry 4.0 technologies, farmers and companies can enhance their agricultural operations, optimize resource utilization, and contribute to the future of smart farming.

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