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IoT for Smart Agriculture and Crop Monitoring

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Abstract: The growth of the global population coupled with a decline in natural resources, farmland, and the increase in unpredictable environmental conditions leads to food security is becoming a major concern for all nations worldwide. These problems are motivators that are driving the agricultural industry to transition to smart agriculture with the application of the Internet of Things (IoT) and big data solutions to improve operational efficiency and productivity. The IoT integrates a series of existing state-of-the-art solutions and technologies, such as wireless sensor networks, cognitive radio ad hoc networks, cloud computing, big data, and end-user applications. This study presents a survey of IoT solutions and demonstrates how IoT can be integrated into the smart agriculture sector.

Keywords: IoT in agriculture, Smart agriculture, Precision agriculture, Smart farming, IoT crop monitoring.

I. INTRODUCTION

In recent times, the incorporation of the Internet of Things (IoT) into farming practices has ushered in a transformative phase for the sector, especially concerning smart agriculture and crop monitoring. This technological advancement is characterized by the use of connected devices that enable real-time data gathering and analysis, empowering farmers to make informed choices that improve productivity and sustainability. By utilizing IoT technologies, agricultural professionals can track environmental factors such as soil moisture, temperature, and crop health with extraordinary accuracy. This approach not only enhances the efficiency of resource usage, like water and fertilizers, but also reduces the environmental impact of farming operations. Additionally, as global food needs grow, adopting smart agriculture solutions becomes increasingly crucial for ensuring food security.

Significance:

A major technological advancement, the Internet of Things (IoT) links disparate systems and devices to enable seamless data sharing and real-time monitoring. IoT technology is essential for increasing productivity and maximising resource utilisation in the agriculture industry. Precision agriculture, in which actions are tailored to each crop's unique needs rather than according to general guidelines, is supported by this data-centric approach.

Additionally, IoT makes it easier to automate nutrient supply, pest management, and irrigation systems, which drastically lowers water and chemical input costs while boosting production. Beyond productivity, IoT is important in agriculture since it minimises environmental effects and promotes sustainable practices. IoT technology is becoming increasingly important in creating resilient and sustainable food systems as the agriculture sector deals with the strains of population expansion and climate change.

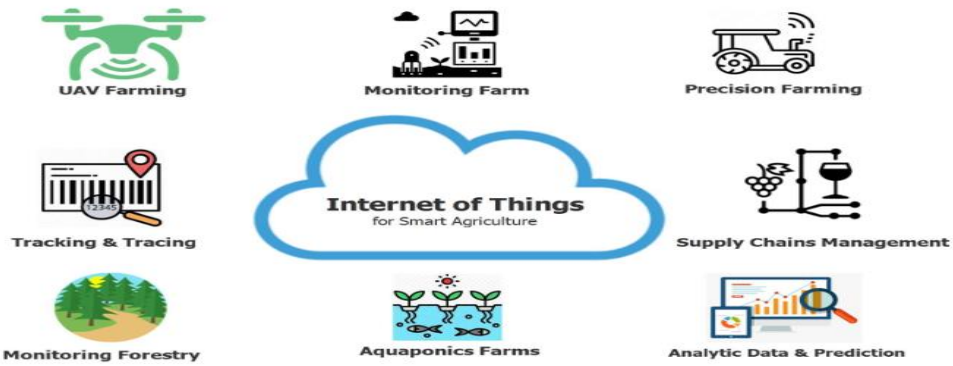

Fig. 1. An illustration of IoT applications for smart agriculture. (source: *Applied Sciences* (Appl. Sci.) in 2022)

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The IoT applications in agriculture, including (1) monitoring, (2) tracking and traceability, (3) precision agriculture, and (4) greenhouses. introduces some open issues and future research challenges of IoT for smart agriculture. Issues are discussed for two main directions: business and technology. we present the main conclusions of this work.

IoT Ecosystem Architecture for Smart Agriculture
we present a common framework of an IoT ecosystem for smart agriculture based on three main components, including (1) IoT devices, (2) communication technologies, and (3) data process and storage solutions. An illustration of the IoT ecosystem for smart agriculture is presented in Figure 2.

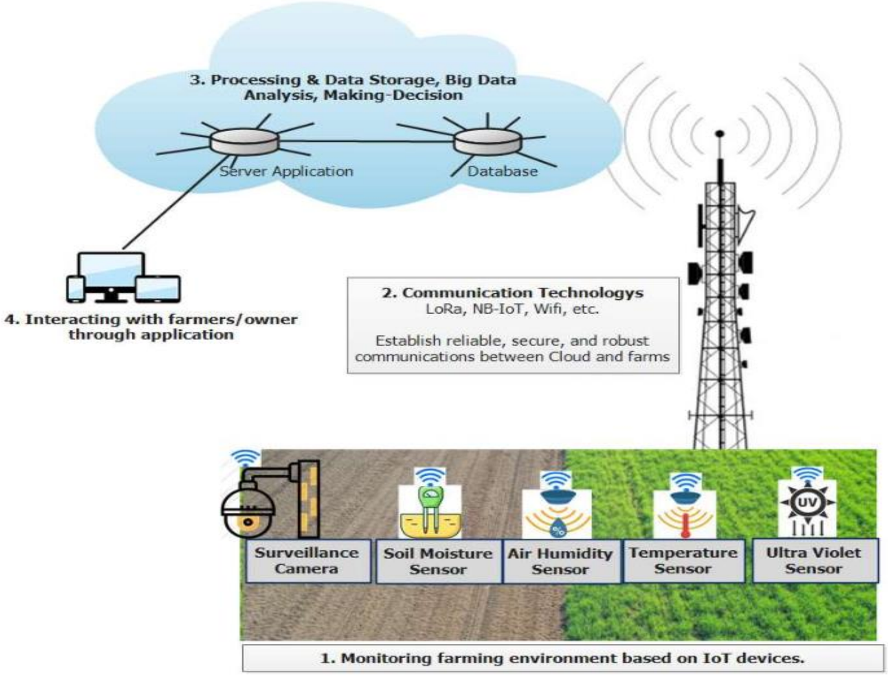

Fig. 2. An illustration of IoT ecosystems' architecture for smart agriculture. (source: *Applied Sciences* Appl. Sci.) in 2022)

IoT Devices
The common architecture of an IoT device consists of sensors to collect information from the environment, actuators based on wired or wireless connections, and an embedded system that has a processor, memory, communication modules, input–output interfaces, faces, and battery power. The common architecture of a typical IoT device for smart agriculture is shown in Fig. 3.

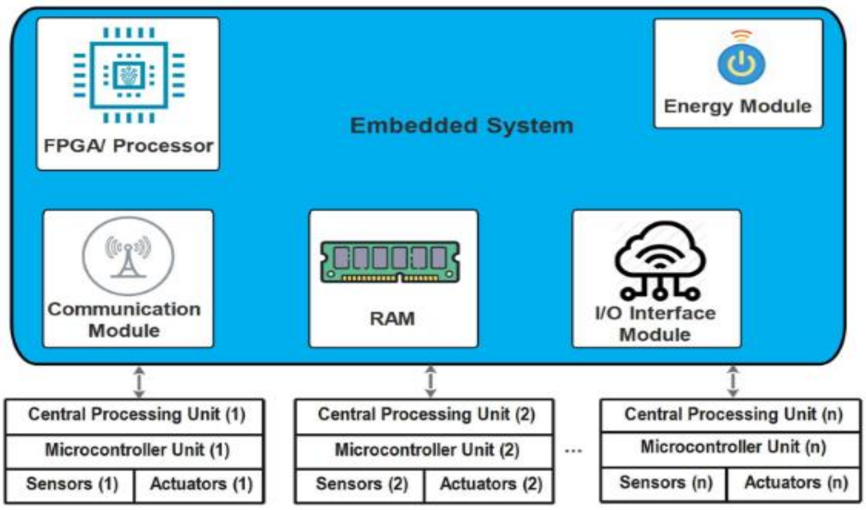

Fig. 3. An illustration of the common architecture of an IoT device. (source: *Applied Sciences* Appl. Sci.) in 2022)

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Embedded systems are programmable interactive modules, namely FPGAs (field programmable gate arrays). Sensor devices are specially designed to operate in open environments, in nature, in soil, water, and air to measure and collect environmental parameters that affect production, such as soil nutrients, humidity, temperature, etc. Smart farming solutions are agricultural operations that are often deployed on large farmlands, outdoors, so the devices that support solutions need some unique characteristics, such as the ability to withstand the effects of weather, humidity, and temperature instability throughout their service lifecycle. Some of their main features, as shown in Fig. 4, make IoT devices suitable for smart agriculture solutions.

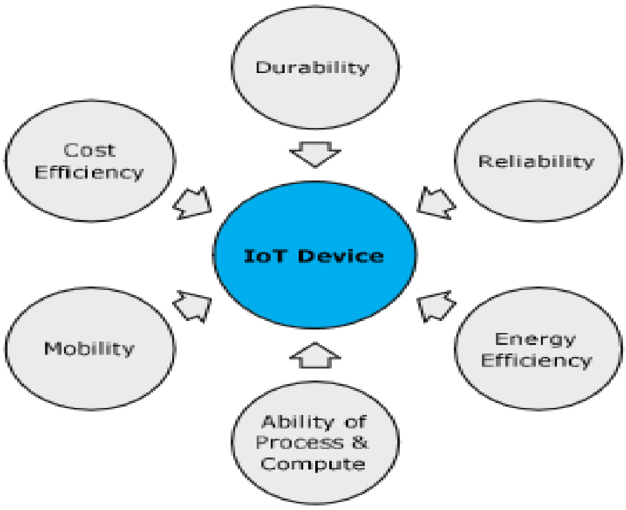

Figure 4. The main characteristics of IoT devices. (source: *Applied Sciences* Appl. Sci.) in 2022)

Typical Applications of IoT in 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.

1. 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. These factors depend on the considered agricultural sector. Some smart agricultural sectors are applying the following monitoring solutions:

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.

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.

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.

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.

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.

3. Smart Precision Farming

The advent of the GPS (global positioning system) has created breakthrough advances in many fields of science and technology. 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,

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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

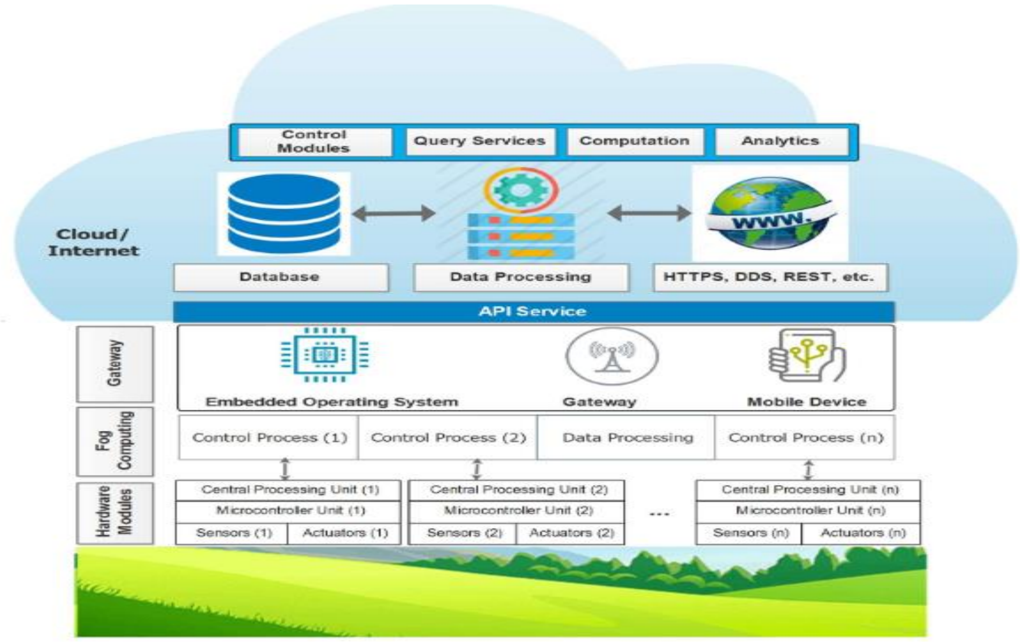

Fig. 5. Cloud-assisted IoT-based precision agriculture platform. (Source: **"Network Architecture of a Fog–Cloud-Based Smart Farming System"** published in the journal *Future Internet* by MDPI

4. Greenhouse Production

A greenhouse consists of walls and a roof, which are usually made from transparent materials, such as plastic or glass. In a greenhouse, plants are grown in a controlled environment, including controlling for moisture, nutrient ingredients of the soil, light, temperature, etc. Consequently, greenhouse technology makes it possible for humans to grow any plant, at any time, by providing suitable environmental conditions. Figure 6 illustrates a smart agriculture IoT system for monitoring greenhouse farming factors based on IoT ecosystems.

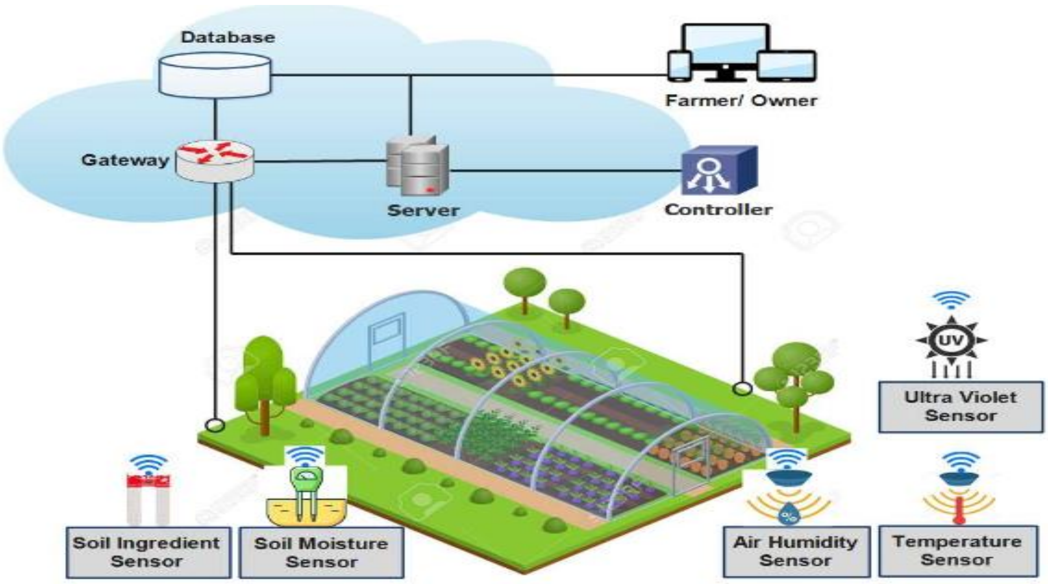

Fig. 6. An illustration of IoT application for monitoring farming conditions in greenhouse.

(Source: Greenhouse Automation Using Wireless Sensors and IoT Instruments Integrated with Artificial Intelligence by Redmond R. Shamshiri, Ibrahim A. Hameed, Kelly Thorp, Saba Samiei, et al., published in 2021)

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II. LITERATURE REVIEW

The application of emerging technologies such as the Internet of Things (IoT), machine learning (ML), and wireless sensor networks (WSNs) has significantly transformed traditional agriculture practices into more data-driven and efficient systems. The following studies highlight various approaches and innovations in this domain.

Patil and Kale (2016) present a foundational model for smart agriculture leveraging IoT technologies. Their proposed architecture incorporates multiple sensors to monitor environmental parameters such as temperature, humidity, and soil moisture. This model facilitates real-time decision-making for farmers, aiming to improve yield and resource utilization. The study emphasizes the role of microcontrollers and wireless communication in building scalable and low-cost smart farming systems.

Expanding on this, Bhargava et al. (2019) implement IoT sensors in smart farming to enable automated monitoring and control of agricultural environments. Their work includes data acquisition from fields, followed by remote access to these data streams via mobile and web interfaces. They argue that IoT-based automation enhances productivity and reduces manual labour, laying the groundwork for precision agriculture.

Chlingaryan, Sukkarieh, and Whelan (2018) explore machine learning approaches for crop yield prediction and nitrogen status estimation. Their comprehensive review categorizes various supervised and unsupervised learning algorithms applied in precision agriculture. These methods utilize multispectral and hyperspectral imaging, alongside in-situ data, to predict outcomes and optimize input use. The authors highlight the potential of ML in reducing environmental impact while maintaining or improving productivity.

Jawad et al. (2017) provide a detailed review of energy-efficient wireless sensor networks (WSNs) tailored for agricultural applications. The study identifies key design considerations such as network topology, data routing, and power consumption. The authors propose solutions to extend the lifespan of sensor nodes, which is crucial for remote and large-scale farming environments. Their findings suggest that optimizing WSNs is fundamental for reliable and sustainable smart agriculture systems.

Zhang et al. (2020) present a deep learning-based approach to smart irrigation. Their system integrates convolutional neural networks (CNNs) to analyse environmental and crop data, predicting optimal irrigation schedules. The model demonstrates significant water savings without compromising crop health, showcasing how deep learning can enhance decision-making in water resource management.

These studies collectively highlight the interdisciplinary nature of smart and precision agriculture, driven by IoT infrastructure, sensor networks, and AI techniques. While IoT enables real-time monitoring and automation, machine learning enhances predictive capabilities for better decision-making. Future research should focus on integrating these technologies into cohesive, scalable platforms while addressing challenges such as energy efficiency, data security, and farmer accessibility.

Challenges and Concerns in Implementing IoT in Agriculture

The adoption of IoT technologies in agriculture faces several significant challenges that can impact their effectiveness and sustainability. One major concern is data security and privacy. Agricultural IoT systems gather vast amounts of sensitive information, including soil conditions, crop health, water usage, and weather data. Without strong cybersecurity measures and standardized protocols, this data remains vulnerable to unauthorized access, cyber-attacks, and misuse, which could disrupt farm operations or lead to breaches of confidential information.

Another critical challenge is system reliability and maintenance. IoT devices often operate in harsh and remote environments, exposing them to dust, moisture, extreme temperatures, and physical damage. Such conditions can cause device malfunctions or inaccurate sensor readings, potentially leading to poor decision-making that adversely affects crop yields. Maintaining and repairing these devices, especially over large or rural areas, can be costly and logistically difficult.

Connectivity issues also pose a significant barrier, particularly in rural or underdeveloped regions where internet access may be weak, intermittent, or unavailable. Reliable, real-time data transmission is essential for automated actions like irrigation or pest control, and poor connectivity can limit the efficiency and responsiveness of IoT systems.

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High initial costs and ongoing expenses further restrict widespread adoption. Purchasing IoT hardware, cloud services, and data analytics tools requires substantial investment, which may be prohibitive for small and medium-sized farms. Moreover, the long-term return on investment is often uncertain, making farmers hesitant to adopt these technologies. Alongside financial challenges, many farmers face technological literacy gaps; without proper training, they may struggle to interpret data or effectively utilize IoT tools, limiting the benefits of smart agriculture.

The management and analysis of large volumes of data generated by IoT devices require advanced cloud infrastructure and analytics capabilities. This complexity, combined with limited expertise among many farmers, can hinder the effective use of data-driven insights.

Furthermore, interoperability remains a challenge due to the wide variety of devices, platforms, and data standards in use. The absence of universal communication protocols complicates seamless integration across the smart agriculture ecosystem, reducing system efficiency.

Another practical limitation is power supply and energy efficiency. Many IoT sensors deployed outdoors depend on battery power or solar energy, which can be unreliable in regions with inconsistent sunlight or lacking infrastructure.
Scalability and customization of IoT solutions also require attention. Agricultural practices vary widely by farm size, crop type, climate, and regional conditions, meaning one-size-fits-all solutions often fail to meet specific needs.

Additionally, overdependence on automated systems can lead to a loss of traditional farming knowledge and reduced human oversight. In cases of system failure or cyber-attacks, farmers without manual alternatives may face significant difficulties managing their crops effectively.

Finally, there are ethical and environmental concerns related to the deployment of large numbers of electronic devices in agricultural fields. Issues such as e-waste disposal, battery pollution, and long-term sustainability must be addressed. Ethical questions also arise around data ownership and the risk of marginalizing farmers who cannot afford advanced IoT technologies.

III. CONCLUSION

In this study, we presented an overview of IoT and big data for the smart agriculture sector. Several issues related to promoting IoT deployment in the agriculture sector have been discussed in detail. Survey results indicate that many studies have been performed to apply IoT for smart agriculture, aiming to enhance productivity, reduce human labour, and improve production efficiency. The benefits of applying IoT and big data in agriculture were discussed. In addition, we also pointed out the challenges we need to overcome to be able to accelerate the deployment of IoT in smart agriculture. However, there are still some challenges that need to be addressed for IoT solutions to be affordable for the majority of farmers, including small- and medium-scale farm owners. In addition, security technologies need to be continuously improved, but in our opinion, the application of IoT solutions for smart agriculture is inevitable and will enhance productivity, provide clean and green foods, support food traceability, reduce human labour, and improve production efficiency. On the other hand, this survey also points out some interesting research directions for security and communication technologies for IoT. We think that these will be very exciting research directions in the future.

REFERENCES

[1]. Patil, K. A., & Kale, N. R. (2016). A model for smart agriculture using IoT. *International Conference on Global Trends in Signal Processing, Information Computing and Communication*.
[2]. Bhargava, K., et al. (2019). Smart Farming Using IoT Sensors. *IEEE International Conference on Communication and Signal Processing*.
[3]. Chlingaryan, A., Sukkarieh, S., & Whelan, B. (2018). Machine learning approaches for crop yield prediction and nitrogen status estimation in precision agriculture. *Computers and Electronics in Agriculture*.
[4]. Jawad, H. M., et al. (2017). Energy-Efficient Wireless Sensor Networks for Precision Agriculture: A Review. *Sensors*.
[5]. Zhang, C., et al. (2020). A Deep Learning-based Approach for Smart Irrigation System. *Agricultural Water Management*.

