A Review of Precision Agriculture Solutions Powered by Internet of Things

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***Abstract*— The focal point of discussion within the Internet industry currently revolves around the Internet of Things (IoT). The term "Internet of Things" or "IoT" denotes the conceptual framework that empowers physical entities with sensing, actuating, and processing capabilities to interconnect and collaborate while remaining connected online. The integration of actuators, sensors, and embedded microcontrollers is instrumental in materializing the concept of a smart object. In this context, these intelligent devices collect data from their surroundings, process it, and subsequently initiate appropriate actions. Consequently, the Internet of Things presents unprecedented advantages, contributing to enhanced, intelligent lifestyles. Given the myriad potential applications of the Internet of Things, it has become a prominent subject of scientific inquiry. Although discussions and research on the applications and significance of these technologies abound, their prevalence in the realms of forestry and agriculture has been comparatively limited. Consequently, this paper delves into the exploration and analysis of IoT applications specifically in the fields of forestry and agriculture. The paper offers a concise introduction to IoT technology, focusing on agriculture IoT, delineates potential application domains, outlines the benefits of employing IoT in agriculture, and presents a comprehensive review of pertinent literature.**

Keywords*— *IoT, Agricultural IoT, smart agriculture, and ITU

I. INTRODUCTION

The Internet of Things (IoT) emerges as a transformative technological paradigm, fostering connections among individuals, objects, and systems, as delineated by the International Telecommunication Union (ITU) [1]. This groundbreaking technology heralds a future characterized by the seamless exchange of information and computational capabilities [1]. Its foundation rests on the interaction between diverse components, including infrared sensors, mobile communication, RFID (radio-frequency identification), GPS (global positioning systems), remote sensing, and other communication networks [2].

This concept embodies a network primarily centered around objects, typically of a wireless nature, which can be dynamically reconfigured [1]. The primary objective of the Internet of Things is to establish an extensive network by integrating various sensor devices like RFID, GPS, RS, and laser scanners with networks, facilitating the global exchange of information among interconnected entities. The IoT comprises millions of networked embedded smart devices, commonly referred to as smart things, capable of collecting data about themselves, their environment, and other connected smart devices through the ubiquitous connectivity of the Internet [3].

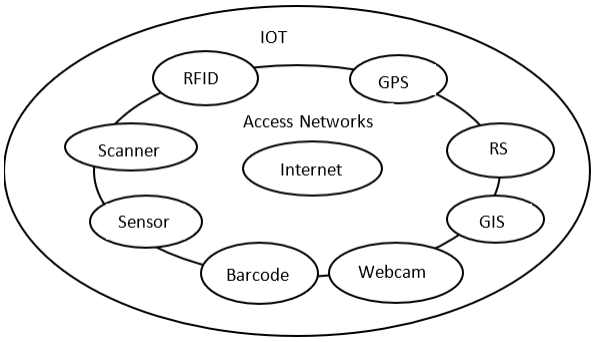

Fig. 1. Internet of things

The applications of IoT are diverse, spanning domains such as supply chain management, marketing, smart agriculture, transportation, environmental monitoring, healthcare, and infrastructure surveillance [1]. Within this framework, all physical entities can autonomously interconnect and communicate in adherence to established protocols, ensuring comprehensive perception, intelligent processing, and reliable transmission between information-sensing equipment and systems, tailored to the needs of diverse applications [2].

A. Probmem Statement

This paper focuses on agriculture, a foundational industry crucial for the prosperity of any nation and the sustenance of its citizens [4]. The continuous contraction of the agriculture sector in India poses a threat to the ecosystem's production capacity. To restore vitality and redirect the region towards a more favorable trajectory, addressing this issue is imperative. The reappearance of the global recession has generated consequences for both developed and developing economies [1]. Enhancing efficiency and resilience in the agriculture sector is vital to ensure global food security. Indian farmers face undue challenges arising from technological advancements, farm scale, trade dynamics, and governmental policies. The integration of Internet of Things (IoT) technology holds promise in mitigating several of these challenges, providing an avenue for transformative change [1].

Given the global trend of industrializing agriculture, the establishment of an "agricultural information network" is crucial. This network represents a pivotal aspect of global

agricultural expansion [5]. In the context of Indian agricultural development, promoting agricultural development and transformation hinges on the strategic implementation of "agricultural information networks". The existing agricultural information system in India grapples with numerous challenges. Notably, there is a prioritization of hardware over software, leading to the inability to furnish high-quality information necessary for meeting farmers' production needs. Additionally, the effective utilization of information by Indian farmers is limited, and its impact on rural areas, agriculture, and farmers remains relatively inconspicuous. The management of agricultural product supply and demand faces challenges, as factors such as changes in farmland, crop diseases, insect damage, and weather variations cannot be accurately predicted [5]. To address this situation and facilitate the rapid growth of agricultural information networks, the utilization of the Internet of Things is crucial for ushering in smart agriculture and improving the predictability of various agricultural factors [5].

B. Internet of Things Applications in Agriculture

Digital agriculture is revolutionized by IoT: supply chain monitoring, precision farming technique optimization, irrigation needs testing, crop growth observation, soil and plant health analysis, and greenhouse environment control. These applications boost productivity, raise yields, save resources, and advance the sustainability of agriculture as a whole.[1]. The following well-known technologies are used in agricultural IoT applications:

Agriculture with Sensor Technology: Agriculture relies heavily on sensor technology, which comes in many forms: soil moisture sensors, water-level sensors, biosensors for analyte detection, gas sensors for gas detection, heavy metal detection sensors, and atmospheric sampling equipment. These sensors help to ensure environmental sustainability, increase productivity, and monitor and optimise agricultural processes.

RFID Methods: RFID technology is widely used in tracking and identifying animals. It allows for intelligent animal monitoring, tracking, and traceability in addition to supporting effective management techniques.

In the agricultural domain, the deployment of ZigBee wireless sensor networks has become commonplace for facilitating data transmission in extensive farming operations. This technology is favoured for its ability to offer wireless data transfer coupled with self-organizing characteristics.

Technology for intelligent irrigation: By combining satellite positioning networks and underground cable technology [4] with automated irrigation systems, it becomes feasible to automate farmland irrigation by collecting data on water levels, irrigation schedules, electricity usage, and timing. Furthermore, the irrigation process can be monitored and analysed comprehensively through information technology software.

Technical Quality and Safety of Farm Products: Production, circulation, and sales make up the agricultural industrial chain [4]. By recording and monitoring this chain, one may comprehend the complete regulatory process.

Techniques for Efficient Seeding and Spraying: An analogous strategy to spraying, planting, and maximising the use of pesticides, seeds, and other materials is made possible by integrating GPS navigation technology with seeding, fertilisation, and seeding at customisable rates, leading to accurate and efficient agricultural methods.[4].

C. Internet of Things Applications in Agriculture

The usage of IoT in the agriculture sector has many advantages, some of which are listed below:

- Effectiveness of the input: The effectiveness of agricultural inputs such as soil, water, fertilisers, pesticides, etc. will all be improved.
- Diminution of costs: It will lower the manufacturing costs.
- Earnings capacity: Farmers' profitability will rise as a result.
- Durability: Enhances the sustainability.
- Nutritional stability: It will assist in achieving the mission of food safety.
- Safeguarding the environment: It is crucial for protecting the environment

II. LITRATURE SURVEY

This work extensively explores the myriad applications of cloud computing and the Internet of Things (IoT) within the realms of forestry and agriculture [6]. The text underscores the substantial benefits that smart agriculture accrues through the integration of IoT technologies. Leveraging foundational IoT components such as RFID, photoacoustic electromagnetic sensors, laser scanners, and others, agricultural innovations can experience substantial enhancement. Notably, precision irrigation, intelligent cultivation control, agricultural product safety, and the seamless transmission of agricultural information emerge as key areas of improvement. Furthermore, the article sheds light on various IoT applications within the forest industry, demonstrating the technology's notable impact on forest management, tracking, and identification. The research discerns a discernible trend towards the convergence of cloud computing and IoT, signifying a growing synergy between these two technological domains [6].

The research study highlighted in this work has identified potential applications of the Internet of Things (IoT) in agriculture, focusing on fostering sustainable rural development [2]. The accompanying book explores various commercial opportunities within the agriculture sector and underscores the advantages attainable through the integration of IoT. The primary objective of this literature is to furnish ideas aimed at promoting the widespread use of IoT in rural and agricultural development initiatives. The literature asserts that developers possess the capability to devise agriculturally-oriented, nation-specific technologies by harnessing the potential of IoT technologies. It is posited that technological advancements, facilitated by IoT, will not only enhance people's quality of life but also contribute significantly to the ongoing efforts in the fight against poverty.

The research study conducted in reference [7] delves into various issues within the agricultural sector and introduces an architectural framework designed to address these challenges. The paper advocates for advising farmers on optimal crop planting times at different growth stages, thus contributing to a comprehensive knowledge base. This knowledge repository encompasses various crop specifics, covering aspects such as knowledge gathering, market accessibility, geographic data flow, and data utilized for weather forecasting. The monitoring module outlined in this research project encompasses crucial functionalities such as crop profit computation, irrigation planning, catastrophe checks, and the tracking of different plant growth stages. The evapotranspiration method is employed to calculate a plant's daily water requirements, relying on a developed algorithm. The paper concludes with a comparative analysis of several applications existing within the system, each distinguished by its unique features, including reliability, efficiency, and monitoring modules.

This study, presented in reference [8], elucidates the significance of both cloud computing and the Internet of Things (IoT) within the Agricultural System, emphasizing the pivotal role played by cloud computing in enhancing IoT capabilities. The research delves into the intricate relationship between IoT and cloud computing, elucidating how the latter provides substantial computing power to IoT systems. A focal point of the study involves the creation of an information cloud specifically tailored for agriculture. In this research project, RFID technology and the Internet of Things are synergistically integrated to establish a smart agriculture system within the agricultural information cloud. The purpose of the agricultural information cloud is to efficiently manage the vast volumes of data generated by IoT components, including RFID, sensors, wireless communication, and other relevant technologies. The study concludes that the integration of hardware resources into the resource pool within the agricultural information network enables dynamic resource distribution, load balancing, and increased efficiency in resource utilization.

This research, detailed in reference [9], introduces an application prototype designed for precision farming that integrates a wireless sensor network and an Internet of Things (IoT) cloud. The paper specifically focuses on a warning system utilizing IoT technologies to regulate plant water stress. The initial section of the paper delineates the procedures involved in developing a decision support system tailored for an agricultural community, enabling the prediction of required water amounts. The application facilitates real-time monitoring of soil conditions by farmers through a dashboard software presented graphically. As a preventative measure against water stress, an SMS notification system is integrated into the application, which activates when critical soil moisture levels are detected. As the application evolves, there is potential for sophisticated enhancements, such as integrating the evapotranspiration method to determine a plant's daily water demand within the overarching decision support system.

A "Greenhouse monitoring system" that combines wireless and Internet connectivity is suggested in the paper [10]. The "greenhouse monitor system," which was created using the Internet of Things, is extremely easy to use, has a user-friendly interface, and provides real-time monitoring of the greenhouse's environmental factors. It also has definitive precision in control and monitoring. Other features of this system include its high performance, dependability, and ease of improvement.

The content presented in paper [11] delineates the architectural components of the Internet of Things (IoT), showcasing various application areas where its implementation can be advantageous. The paper also delves into the challenges associated with IoT, emphasizing the critical consideration of security issues. These challenges encompass widespread deployment, standardization, interoperability, data security, efficient spectrum utilization, unique identification, safety, security of collected objects, and energy consumption. The momentum gained by the Internet of Things is attributed to advancements in Radio-Frequency Identification (RFID), sensor technology, and actuator technology. This technology aims to facilitate a seamless transition between the virtual and physical realms, bridging the gap between these two domains.

The study detailed in reference [12] utilizes an open-source platform named OpenIoT to create the Phenonet platform, essentially constituting a semantically enhanced digital agriculture use case. Various applications and the efficacy of Phenonet were showcased through multiple use cases, elucidating how an OpenIoT platform can effectively address the challenges encountered by the Phenonet application. At the core of the Phenonet project is the concept of gathering, validating, processing, annotating, and storing data acquired from smart sensors deployed in the field. The study further presents semantic queries, reasoning processes, and experimental results corresponding to the Phenonet project.

The paper discussed in reference [13] introduces a tailored agricultural architecture leveraging the Internet of Things (IoT) as an application for precision agriculture. The proposed IoT architecture is cloud-based, offering potential benefits for numerous precision agriculture applications. The research proposes a three-tiered architecture for implementation. In the first layer, environmental data is gathered, and necessary actions are initiated. The second layer, functioning as a gateway, processes and stores the collected data, establishing a connection between the front and back ends of the system over the Internet. Researchers validated this architecture by constructing a prototype, and the performance evaluation results substantiate the efficiency of the proposed design.

In contrast to traditional manual agricultural methods, the paper [14] introduces an automated Smart Agriculture system employing Internet of Things (IoT) technology to enhance efficiency and resource utilization. It incorporates features such as water level monitoring and soil moisture assessment, showcasing its potential to provide insightful information for farmers. The emphasis on IoT underscores the technological foundation, reflecting a shift towards sophisticated and environmentally friendly farming practices.

Technology is positioned as a critical means to address the global challenge of feeding an estimated 9.6 billion people by 2050.The study focuses on the accessibility and ease for farmers to remotely monitor field conditions, particularly through IoT applications in smart farming with real-time sensor data. The use of soil moisture sensors is emphasized for monitoring volumetric water content, while water level sensors underscore the significance of water sources in agriculture. It concludes by summarizing the Smart Agriculture system's design accomplishments, notably in reducing labor and material costs associated with manual processes. While recognizing the need for further development, particularly in suboptimal conditions, the system operates effectively under ideal circumstances. The closing remarks present a hopeful outlook on the system's role in promoting sustainable farming practices. In essence, the paper provides a comprehensive overview of IoT-driven Smart Agriculture, highlighting practical applications and potential enhancements. The integration of technological solutions into agriculture emerges as a promising approach to address contemporary challenges and enhance productivity in farming practices.

The paper [15] emphasizes financial savings and energy efficiency, presenting a comprehensive solution for real-time water management in smart agriculture. The system architecture focuses on the transmitting module, addressing energy dissipation in sensor nodes. Components, including low-cost sensors and ATmega series microcontrollers, are selected for energy efficiency, complexity, and cost-effectiveness. Integrated LoRa technology enables data transmission over great distances with reduced power consumption, making it suitable for remote agricultural areas. Operational testing in Vietnam confirms the system's efficacy in monitoring temperature, humidity, and soil moisture. Accuracy in data collection and transmission is demonstrated in both farm conditions and research lab settings. Rural farm settings evaluate the dependability and range of LoRa-based data transmission, showcasing successful connections between nodes and the gateway over considerable distances. The system offers benefits such as independent operation of multiple farms via a single mobile application, energy-saving attributes of LoRa technology, and real-time updates for enhanced efficiency. Acknowledging limitations, such as reliance on the ESP8266 module's stability and potential internet access issues, the paper suggests areas for further development[15]. The proposed methodology provides a scalable, dependable, and cost-effective approach to smart agriculture. Its success in practical applications suggests suitability for real-world implementation, enabling quick decision-making and administration through real-time data availability. Advancements in data processing efficiency and stability may enhance its robustness, fostering more effective and sustainable farming techniques in various agricultural contexts.

In the contemporary landscape of Indian agriculture, marked by diverse challenges from impoverished villages to advanced farms, the integration of modern technologies is essential for overcoming limitations in ecosystem control. The paper under consideration presents a pioneering approach to address these challenges through an intelligent monitoring platform grounded in the Internet of Things (IoT)[16]. With Indian agriculture contributing significantly to the nation's Gross Domestic Product (GDP) and serving as a livelihood source for a substantial population, the transition from traditional to modern farming practices becomes imperative.The proposed IoT-based system focuses on creating an ecosystem that seamlessly connects various sensing devices, including RFID, sensors, and GPS, to enable intelligent recognition, data acquisition, and control. The primary objective is to bridge information gaps, improve communication, and mitigate production losses attributed to factors such as lack of precise information and communication breakdowns. The system introduces a novel project targeting the regulation of water levels in agricultural activities, addressing the unpredictability of weather conditions and water availability.Key components of the proposed system include a hybrid solar cell as the primary power source, VRS-20 SDI-12 Radar Level Sensor, hard suction hose, soil hygrometer, and GSM modem. These components are strategically integrated into a belt conveyor, forming an interconnected and easily maintainable platform. The IoT-driven methodology involves real-time monitoring and automated actions based on data from sensors, enhancing the efficiency of agricultural operations.The significance of this research lies in its potential to revolutionize Indian agriculture by leveraging IoT technologies for continuous monitoring, automated responses, and efficient water management. The intelligent use of renewable energy sources, coupled with sophisticated sensors, underscores the sustainability and innovation embedded in the proposed system. As India has made substantial progress in food productivity over the past 50 years, this paper[16] contributes to the ongoing efforts to further enhance agricultural productivity, reduce manual labor, and address key challenges faced by farmers in the evolving landscape of modern agriculture.

The paper[17] introduces a comprehensive solution to address security challenges in the agricultural sector by leveraging Internet of Things (IoT) technology. Identifying the need for enhanced security beyond resource protection, the authors integrate traditional methodologies with IoT and Wireless Sensor Networks to create a sophisticated security system. Implemented using a Raspberry Pi and various sensors, the proposed system aims to modernize agriculture by providing real-time notifications and remote monitoring capabilities. The literature review effectively underscores the scarcity of IoT-based security devices in agriculture, especially in regions experiencing significant crop losses. The authors highlight the limitations of existing solutions, primarily focused on insects and pests. The research methodology details the architecture, design, and testing phase, demonstrating an 84.8% success rate in test cases. The paper discusses the potential implications of the findings, emphasizing improved food preservation and productivity in grain stores[17]. The future scope outlines valuable directions for device enhancement, including sensor grids, pattern recognition, and expanded data collection for machine learning. While the paper makes commendable advancements in agricultural security, particularly in integrating IoT, it would benefit from addressing potential drawbacks and limitations, offering a more comprehensive

evaluation of the proposed system's performance and practical challenges in real-world applications.

III. CONCLUSION

The persistent challenges surrounding agriculture, rural areas, and the livelihoods of farmers have consistently hindered India's progress. A viable remedy for these issues lies in the modernization of agriculture. However, the current state of India's agriculture is considerably distant from achieving this goal. The integration of Internet of Things (IoT) technology in agricultural practices holds the potential to address these challenges effectively. IoT, coupled with cloud computing, cloud services, Service-Oriented Architecture (SOA), and visualization technologies, can generate substantial data pertaining to agricultural production. The amalgamation of Radio-Frequency Identification (RFID) with IoT can facilitate the development of plant factories, allowing for automated control of agricultural production. A strategic utilization of modern technology and IoT can catalyze rapid advancements in the modernization of the agricultural system, offering practical solutions to issues faced by farmers, agriculture, and rural areas. In light of the aforementioned analysis, it is imperative to encourage collaboration between information technology professionals and agricultural scientists. Particularly, individuals possessing a dual understanding of both planting practices and IT can innovate and drive the modernization of farming. The adoption of modernized farming practices not only enhances agricultural production and management but also aligns with the goals of environmental protection and energy conservation. The incorporation of smart IoT in agriculture can effectively address various concerns faced by farmers. It enables farmers to make informed decisions about the selection of agricultural soil, identifies suitable crops for the current stage of farming, and provides essential environmental information about farmland. Intelligent analysis and improved management practices become possible through the integration of IoT, offering farmers insights into optimal agricultural practices. A transformative scenario emerges, where farmers can replace labor-intensive fieldwork in arduous conditions with computerized manipulation. Accessible through computers, mobile phones, or intelligent tools, farmers can efficiently manage watering, cultivating, seeding, and reaping processes. The ongoing and rapid progress in microelectronic technology and network technology presents an opportune moment for professionals to actively explore the technological advancements in modern agriculture. The vital role played by the Internet of Things in fostering the development of global modern and smart agriculture establishes a solid foundation for industrial growth.

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