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Internet of Things in Agriculture: A Systematic Review of Applications, Benefits, and Challenges

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Abstract. Internet of Things (IoT) technologies are transforming modern agriculture through applications like precision farming, smart water management, and livestock monitoring. This paper presents a systematic literature review analyzing the impact and potential benefits of IoT adoption in the agricultural sector. This study analyzed data from multiple databases, including Scopus, IEEE Xplore, Science Direct, and Emerald. Following PRISMA guidelines, 15 relevant studies published between 2018-2023 were selected from scientific databases. Key findings indicate that IoT can enhance agricultural efficiency, sustainability, and productivity through improved real-time monitoring, data-driven decision making, and automated control of farming operations. However, challenges remain regarding technology integration, security, data utilization, and costs. Further research is needed to develop a framework encompassing technological, economic, and social perspectives on IoT in agriculture. This review contributes by synthesizing the current knowledge on IoT in the agricultural domain and highlighting critical areas for future investigation

Keywords: one Smart Farming, Agriculture, Internet of Things

1. Introduction

Journal Modern advancements in technology have the capacity to yield advantages for a wide demographic. In recent times, the Internet of Things (IoT) has progressively assumed a pivotal function in the routines of everyday life. It facilitates an expanded cognitive scope and the capability to exert influence over our surroundings. Industries such as agro-industry and environmental management have notably harnessed the potential of IoTs for purposes encompassing diagnostics and regulatory measures. Moreover, IoT implementation can provide end users and consumers with comprehensive insights about product provenance and attributes (Abdullahi et al., 2021; Talavera et al., 2017).

The IoT refers to the technology employed in embedded systems, where devices are connected to the internet. This technology includes actuators, network connectivity, transducers, as well as sensors that enable these devices to collect and exchange information with each other (Singh et al., 2014), as shown in Figure 1. Kevin Ashton, who led the Auto-ID Center located at the Massachusetts Institute of Technology (MIT), introduced the term "IoT" in 1999. In his foresight, he anticipated the eventual integration of IoT into commonplace items by utilizing Radio Frequency Identification (RFID) and sensors. This concept envisions a technological landscape where objects are made with sensors that may interact over the internet, enabling real-time data exchange.

Globally, IoT technologies have disrupted various industries, much like powerful waves. The devices within the IoT framework can detect, collect, preserve, and transmit information to various applications, as seen in the field of smart agriculture.

Smart agriculture involves integrating and deploying advanced technologies, including IoT, in the agricultural sector. The primary objective is to improve both yield and quality of crop production (Muntjir et al., 2017; Srilakshmi et al., 2018).

In addition to that, internet-connected devices have relied on human intervention for transmitting and receiving data. Nonetheless, the IoT facilitates the sharing of information among objects autonomously, utilizing technologies like Near-Field Communication (NFC), Bluetooth, sensor-generated data. This connectivity occurs through network connections, all achieved without the need for human involvement (Wan et al., 2019).

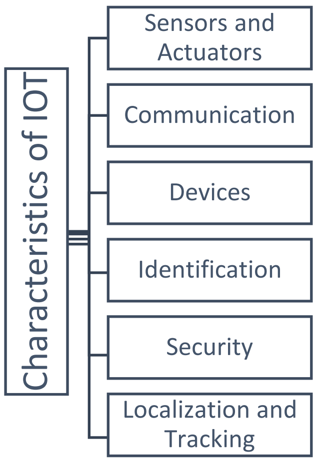

Fig.1: Characteristics of IoT

Agriculture will continue to serve as a fundamental economic pillar for numerous nations, and in the foreseeable future, smart agriculture is poised to transform the agricultural scene within countries. IoT technologies will provide farmers with the ability to remotely oversee as well as control their agricultural operations. Simultaneously, this technological advancement will facilitate the seamless establishment and meticulous oversight of large-scale agricultural operations (Jaiganesh et al., 2017).

The IoT has been implemented in many extent, for instance, smart farming (Ahmed et al., 2018), smart home (Song et al., 2017), wearables (Ometov et al., 2016), smart city (Mohammadi et al., 2017), connected health (Al-Hamadi & Chen, 2017), connected car (Lu et al., 2014), connected drones (Chen & Wang, 2018), as well as others. The IoT enables physical objects to interact, exchange data, as well as make collaborative decisions. It converts conventional objects into smart entities by harnessing key technologies like communication protocols, internet connectivity, applications, as well as sensor networks (Al-Fuqaha et al., 2015; Elijah et al., 2018).

Conversely, the trend of urbanization is expected to intensify, with approximately 70% with regard to the global population forecasted to reside in urban areas by the year 2050, compared to the current figure of 49%. Moreover, income levels are anticipated to increase substantially, leading to a heightened demand for food, particularly in developing nations. Consequently, these countries will pay greater attention to their dietary choices and food quality, potentially shifting consumer preferences from wheat as well as grains to legumes and, eventually, to meat. To meet the needs of this larger, more urbanized, as well as wealthier population, food production must double by the year 2050 (Assembly, 2009; Zhang & Davidson, 2018).

Agriculture serves a critical role in the global economy, while in India, more than 70% of the population builds on agriculture for their livelihoods (Arunlal & Rajkiran, 2018). Numerous farmers have traditionally employed farming methods that yield limited crop output and plant growth, creating an opportunity for automation in agriculture, particularly in areas like plowing, irrigation, harvesting, sowing, as well as pesticide spraying. IoT can significantly contribute to agriculture, including precision pesticide application, soil management, crop monitoring, and water management, as shown in Figure 2.

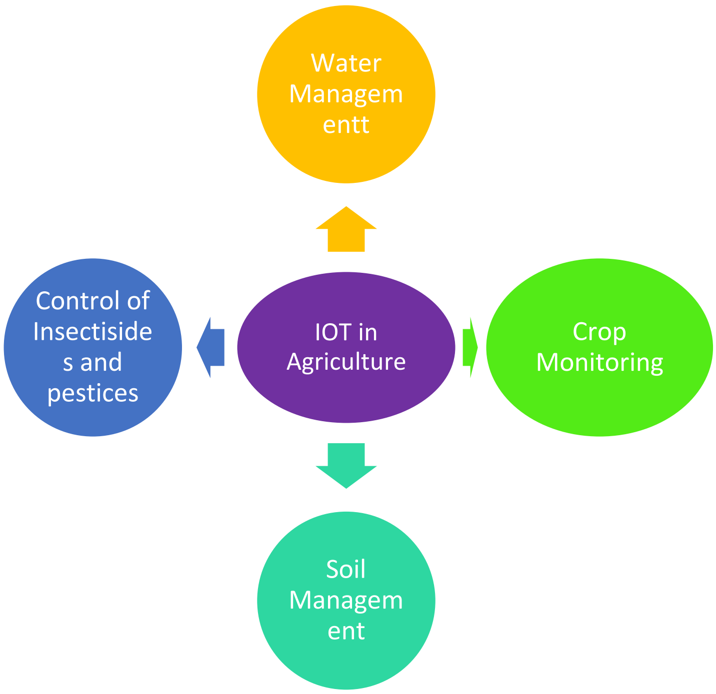

Fig.2: IoT in Agriculture

Smart agriculture utilizes IoT applications to improve operational efficiency, profitability, and environmental sustainability. However, the agricultural sector faces many challenges, such as the limited availability of resources and the effects of climate change.

Due to these challenges and an ever-growing population, the agricultural industry is urged to transform. IoT has the potential to transform agriculture, but its impact remains uncertain.

A comprehensive literature review is necessary to obtain a clear knowledge of the benefits of this technology in agricultural industries.

In this systematic study, the primary objective is to gather relevant research regarding IoT applications in agriculture, including network types, communication protocols, and sensors. The study also identifies and classifies IoT applications that are relevant to agricultural settings, and aims to measure the benefits and enhancements that result from integrating IoT into agricultural practices.

This article follows a methodical structure that emphasizes the impact of IoT in agriculture. It examines the study's literature review, methodology, and framework in detail. Moreover, the paper presents and evaluates results derived from a systematic review, shedding light on the topic. In conclusion, the article concisely summarizes the main findings and implications discussed throughout the paper.

2. Research Methodology

Following the recommendations made by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), we conducted a systematic review. The review focused on IoT applications in agriculture, covering articles published from 2018 to 2023. The aim was to comprehensively explore the advancements in this field over the past five years. A checklist adapted from PRISMA's figure was used to ensure a structured and transparent review process(Moher et al., 2009). The review's search strategy was likely conducted using a platform referred to as "Sphere." This systematic review approach aims to provide insights into the latest trends and developments in IoT applications within the agricultural sector.

A search was conducted on Scopus, IEEE Xplore, ScienceDirect, and Emerald for journal articles and conference proceedings regarding IoT applications in agriculture. The following search terms were used to identify relevant articles after a meticulous assessment of relevant keywords: (IoT application OR agriculture) AND (IoT platform OR agricultural operations) AND (smart farming OR precision agriculture OR IoT sensors OR crop monitoring). In the initial search result of 2035 articles, we reviewed the titles and abstracts and then reviewed the full texts (Figure 3). PRISMA approach, which involves four distinct stages of search and outcome analysis: the initial screening process, screening of studies, identification of eligible studies, and inclusion of selected studies. The initial screening stage commences with formulating search queries and identifying pertinent articles across diverse databases. Likewise, the screening study phases eliminate duplicate and irrelevant papers, while eligible studies further narrow down articles based on the subject matter criteria of this research. Finally, the included study phase assembles a compilation of articles chosen for the review process. The intricacies of this procedure are elucidated in Figure 3.

The inclusion criteria for the study encompassed articles published in journals, conference proceedings, and review articles written in English from 2018 to 2023. The focus was on studies related to IoT in agriculture, including reviews, empirical studies, and case studies. Full papers specifically addressing IoT in agriculture were sought. However, inaccessible full papers and articles in book chapters or books, as well as those not in the English language, were excluded as illustrated in Table 1.

Table 1: Criteria for Inclusion and Exclusion

Inclusion Criteria	**Exclusion Criteria**
• Journal, Conference proceedings, review articles, • English language articles • Publication from 2018 to 2023 • Review, empirical and case study articles • Full papers related to IOT in agriculture	• None related articles. • Full papers were not accessible. • book chapters and books • Non-English language articles

The authors conducted a manual evaluation of all 2035 articles by examining their titles, abstracts, and full content. Of these, 1040 articles were excluded due to duplication, and 590 abstracts were discarded during the screening process. Furthermore, 312 articles did not meet the criteria after a complete text screening, and 78 articles were rejected based on full-text eligibility screening. Consequently, 15 documents were considered appropriate for further analysis. Figure 3 provides a visual representation of the comprehensive search processes.

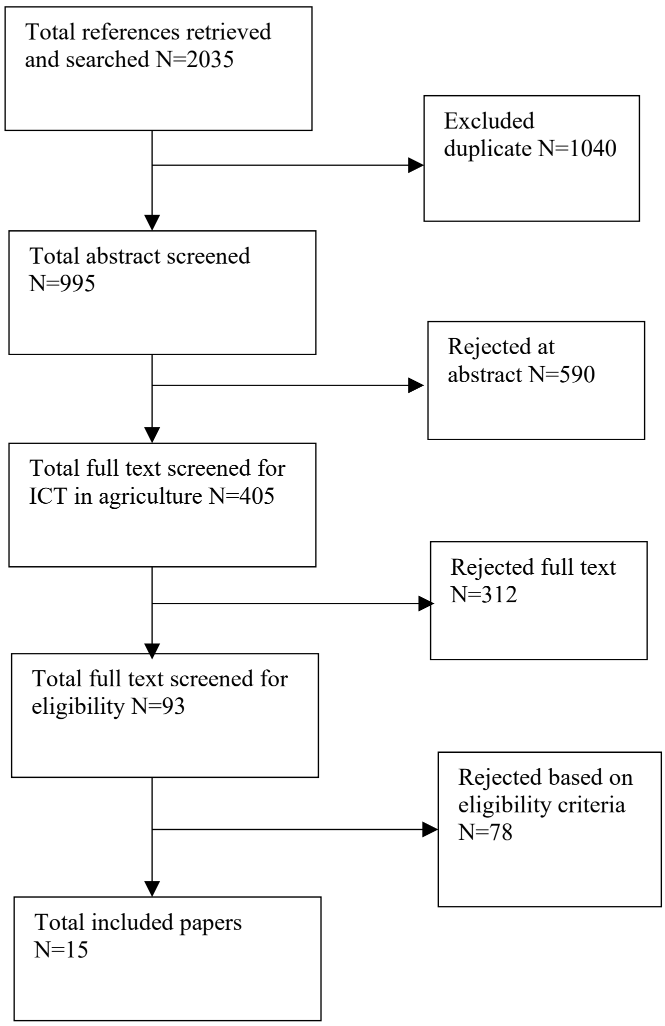

Fig.3: Study selection process overview

3. Results and Discussion

Despite obtaining 2035 unique papers through our search terms, only 15 met our inclusion criteria (Table 2). The articles covered a wide range of perspectives, including experts' opinions, case studies, original research, and literature reviews. All of the articles selected were written and published in English. It is clear that most of these papers were published between 2018 and 2023, indicating that the subject has recently been of interest. The following table illustrates:

Table 2. A review of the content within the selected articles

Author	**Title**	**Type**	**Purpose**	**Contribution**	**Limitation**
(Alhasnawi et al., 2020)	Internet of Things (IoT) regarding Smart Precision Agriculture	Journal	The paper aim to explore IoT-based smart irrigation systems for efficient water use in precision farming.	The paper propose an open-source technology-based smart system for predicting irrigation requirements in precision farming employing IoT solutions and sensor data acquisition. They also mention the use of the Message Queue Telemetry Transportation (MQTT) protocol .	Limitations of this paper: The paper does not mention any limitations of the proposed architecture and protocols. The paper does not provide any information about the limitations of the proposed control system for farming as well as agriculture.
(Khanna & Kaur, 2019)	Evolution of the Internet of Things (IoT) and its substantial impact in the field of Precision Agriculture	Research paper	The objective is to save time, lower human effort, enhance yield, as well as profits in agriculture by connecting actuators and agriculture sensors, including devices over the internet for interaction, controlling, and decision making.	It highlights the primary use cases within the realm of precision, agriculture in IoT as well as provides an in-depth analysis of each. The most relevant research articles in the Precision Agriculture field using IoT are addressed and discussed in the paper.	IoT has evolved significantly in recent years, but resource limitations and unresolved issues raise questions about its future scalability. This article emphasizes key concerns within the expanding IoT landscape and emphasizes the need to address these issues for the post-IoT era's improvement.
(Farooq et al., 2019)	A Survey on the Role of IoT regarding Agriculture for the Implementation of Smart Farming	Research paper	Assess the efficiency gains in agricultural data processing through the integration of IoT technologies, big data storage, cloud computing, and analytics.	IoT in agriculture aims to modernize and automate farm management processes with minimal human involvement. Also, contributed IoT-based smart farming comprises protocols, topologies, layers, architecture, as well as network technologies.	IoT-based smart farming security vulnerabilities explored in limited detail. There is a lack of depth in the discussion of confidentiality, access control, and authentication. The challenges of addressing information leaks and protecting devices in open fields are briefly mentioned but not thoroughly discussed.
(Goap et al., 2018)	An IoT-based smart irrigation management system using Machine learning and open-source technologies	Research Paper	The focus of this study is to develop an open-source technology-based smart system for predicting irrigation requirements with regard to a field employing sensor data as well as weather forecast information.	The work offers an open-source IoT-based precision farming system with autonomous water supply. The system offers real-time soil moisture prediction and irrigation control based on sensor data and weather forecasts after three weeks of data analysis.	The paper does not emphases and discussed depth the potential limitations and challenges regarding the usage of Zigbee technology for implementing a Wireless Sensor Network (WSN)
(Ahmed et al., 2018)	Internet of Things (IoT) regarding Smart Precision Farming and Agriculture in Rural Areas	Research Paper	The objective of the study is to recommend a scalable network architecture with regard to monitoring as well as controlling agriculture, including farms in rural areas,	The study introduces WiLD network along with fog computing into WSN solutions to extend coverage as well as reduce latency. It aims to enhance rural connectivity, creating a scalable	In this study, there is a lack of potential security as well as privacy concerns connected with the IoT implementation in agriculture and farming. The study does not explore the potential environmental impacts or sustainability considerations of

			utilizing IoT along with fog computing technologies.	architecture for efficient agriculture as well as farm monitoring with reduced network delays.	implementing IoT in agriculture and farming practices.
(Gaikwad et al., 2021)	An innovative IoT-based system for precision farming	Research paper	The research aims to establish a real-time IoT-based precision farming system for monitoring agricultural parameters.	The research introduces the design and development of an innovative IoT-based system with regard to precision farming in the agriculture sector.	The paper does not explicitly mention limitations in its IoT-based precision farming system. Possible constraints may involve reliance on stable internet connections, open-source platform limitations regarding scalability, as well as customization. Additionally, sensor accuracy as well as reliability details are not provided, posing a potential limitation.
(Ojha et al., 2021)	Internet of Things (IoT) for Agricultural Applications: The State-of-the-art	Research paper	The paper aims to examine the particular challenges as well as issues connected with IoT in agriculture as well as review a variety of IoT architectures, middleware, communication, along information processing technologies.	The paper investigates the challenges as well as issues connected with IoT in agriculture and reviews a variety of IoT architectures, middleware, communication, along information processing technologies.	The author only focused on reviewing a variety of IoT architectures, middleware, communication, along with information processing technologies, presented case studies, and discussed design and implementation parameters.
(Almadani & Mostafa, 2021)	IIoT-Based Multimodal Communication Model regarding Agriculture and Agro-industries	Research paper	The review aims to study technology integration in agriculture, address supply chain gaps, and propose a communication model for multi-vendor systems.	The author suggests a multimodal communication framework concerning the agricultural industry, aiming to combine diverse vendor production systems within a real-time, heterogeneous environment.	The proposed multimodal communication model lacks versatility and does not address the implementation of Industrial Internet of Things (IIoT) technologies challenges in the agricultural domain. The study does not discuss the scalability issues that may arise from the use of a gateway in the proposed model.
(Wójcicki et al., 2022)	Internet of Things (IoT) in Industry: Research Profiling, Application, Challenges and Opportunities—A Review	Research paper	This study's primary goal is to describe the idea of the IoT as well as its implementation in numerous sectors of the modern economy, including quality control, healthcare, energy, logistics, agriculture, as well as production.	The study provides an overview of Industrial Internet of Things (IIoT), Internet of things (IoT), as well as Industry 4.0 concepts, highlighting their implementation in numerous modern economy sectors, such as quality control, healthcare, energy, logistics, agriculture, as well as production.	The study provides a general overview and review of IIoT, IoT, as well as Industry 4.0 rather than presenting original research findings or conducting a comprehensive analysis of specific challenges and limitations.
(Dhanaraju et al., 2022)	Smart Farming: Internet of Things (IoT)-Based Sustainable Agriculture	Research paper	This research intends to utilize information and communication technology, for instance, the IoT, artificial intelligence, along cloud computing, to enhance sustainability as well as efficiency in agriculture.	The study examines wireless sensor applications in IoT agriculture, offering technical insights useful to growers throughout the crop cycle, including planting, harvesting, packing, transportation, as well as digital connections with farmers.	The author does not comprehensively analyze innovative farming technologies' potential environmental impacts on soil health, biodiversity, and ecosystem services, such as using robots and artificial intelligence.
(Farooq et al., 2020)	Role of Internet of Things (IoT) Technology in Agriculture: A Systematic Literature Review	Journal	To comprehensively examine IoT's role in agriculture through literature review, taxonomy development, smart	This research significantly contributes by systematically reviewing the role of IoT technology in agriculture,	In the paper, the IoT's role in agriculture is not fully explored, the smart farming framework is expected to overlook specific methods, and it is possible that

			farming framework proposal, and identification of research gaps.	categorizing relevant research, highlighting current challenges, introducing an IoT agriculture framework, discussing government policies, and identifying future research directions.	the research gaps do not include all possible challenges.
(Sinha & Dhanalakshmi, 2022)	Recent advancements and challenges of Internet of Things (IoT) in smart agriculture: A survey	Journal	The aim is to investigate recent IoT advancements in smart agriculture and assess related challenges for informed future implementations.	The contributions of the paper include a comprehensive exploration of IoT frameworks for automated agriculture, analysis of key components and challenges, highlighting recent advancements and trends, assisting researchers in problem identification and technology selection.	The study does not provide specific details about the limitations of IoT-based smart agriculture connectivity.
(Misra et al., 2020)	IoT, Big Data, as well as Artificial Intelligence (AI) in the Agriculture and Food Industry	Journal	The paper's objective is to explore the transformative impact of IoT, big data, and AI on agri-food systems, covering agriculture, supply chains, social media, food quality, and safety, providing insights into their evolving landscape and trends.	The study examines IoT, big data, and AI in agri-food systems—agriculture, supply chains, and social media. It explores monitoring, supply chains, sentiment analysis, quality, gene sequencing, and safety via blockchain, emphasizing commercial and research aspects.	In this study, there is a lack of quantitative data regarding IoT's benefits in the food supply chain, necessitating further research.
(Jayashankar et al., 2018)	Internet of Things (IoT) adoption in agriculture: the role of trust, perceived value and risk	Journal	The study aims to investigate IoT adoption drivers among farmers, exploring trust's impact via perceived value and risk	The study integrates adoption models to analyze IoT's impact through perceived value, risk, and trust. It uncovers key IoT adoption drivers among farmers, emphasizing trust's role and addressing data concerns for B2B marketers and stakeholders.	The study has several limitations, including its focus on Iowa, USA farmers, potential survey bias, and omission of key factors like cost and expertise. In addition, farmers' network roles are not adequately considered, and little research has been done on risks associated with B2B ag data handling.
(Hussein, 2019)	Internet of things (IoT): Research challenges and future applications	Journal	The primary objective is to enable seamless connections between objects, individuals, and networks, regardless of time, location, or communication path.	The study contributes by examining recent IoT advances, envisioning applications, and addressing challenges in domains, for instance, agriculture, healthcare, smart cities, as well as logistics. it suggests Information-Centric Networking (ICN) for managing data in smart cities.	The research's limitations include an incomplete list of IoT research challenges, insufficient feasibility analysis for applications, neglect of technology limitations, shallow analysis of adoption implications, no exploration of ethical and privacy concerns, as well as a lack of examination of data management limitations.

IoT technology has been applied in various domains, including connected industries, logistics (Li, 2011), smart cities (Sanchez et al., 2014; Zanella et al., 2014) , health care (Islam et al., 2015), smart energy(Husni et al., 2016), smart homes(Park et al., 2017), smart agriculture (Brewster et al., 2017), connected buildings (Sastra & Wiharta, 2016), among other domains. The goal of IoT is to connect the physical realm with the digital realm, achieved through internet-based communication as well as information exchange (Vermesan, 2010). IoT refers to a network of interconnected computing devices, machinery, digital devices, living beings, or individuals equipped with distinctive identifiers as well as capable of transferring data over a network without the need for human-to-computer interaction or human-to-human. Numerous advantages arise from implementing IoT in agriculture, such as:

- Community Farming: IoT utilization can promote communal farming, particularly in rural regions. IoT technology may be harnessed to enhance services that enable communities to access shared data storage, exchange data and information, as well as enhance communication between farmers, including agricultural experts (Bo & Wang, 2011).
- Safety Control and Fraud Prevention: Here, the agriculture sector faces a challenge that extends beyond mere production; it involves ensuring a secure environment along with a healthy food supply. Incidents of food fraud, encompassing issues like adulteration and counterfeiting, including artificial enhancement, have been reported (Marvin et al., 2016).
- Cost Reduction and Wastage: Among the commonly recognized IoT benefits is its capability to remotely monitor devices as well as equipment (Asplund & Nadjm-Tehrani, 2016). Employing IoT in agriculture may lead to cost and time savings in the inspection of vast fields, as opposed to relying on manual field inspections through vehicles or on foot. IoT's capacity to determine when, as well as where to use insecticides or pesticides, can result in cost reduction along with reduced wastage.
- Wealth Creation and Distributions: The IoT implementation may establish fresh business models, enabling individual farmers to bypass intermediaries and establish direct connections with consumers, ultimately leading to increased profits (Dlodlo & Kalezhi, 2015).

The study Stated that the IoT-based smart irrigation management systems with regard to efficient water resource usage in precision farming. The research also focused on using sensors to collect data on ground parameters, for instance, soil temperature and moisture, as well as weather forecast data, including environmental conditions, to predict irrigation requirements and automate the irrigation process(Alhasnawi et al., 2020).

Furthermore, another study also highlighted that IoT technology integration into agriculture for developing smart farming systems to increase sustainability, resource efficiency, and overall productivity in modern agriculture. add one more statement(Dhanaraju et al., 2022)

According to Farooq et al. (2019), this study examines the challenges of implementing IoT in agriculture, with an emphasis on enhancing security for smart farming. There is a thorough discussion of critical topics such as the latest technological advancements, industry trends, and government regulations. Additionally, governments support IoT integration in agriculture, and significant companies are investing in cutting-edge farm management systems. The study emphasizes the challenges and opportunities associated with IoT in smart agriculture, focusing on use of wireless sensors and applications in soil preparation, crop monitoring, irrigation, pest detection, and supervision (Ayaz et al., 2019). IoT has the potential to increase crop yield, optimize farming, and improve food security, according to the discussion. The study also deliberates autonomous machines, drones, and sensors for real-time data in agriculture, emphasizing the importance of sustainable sensor technology and the impact of IoT on agriculture.

Additionally, another study offers an in-depth exploration of IoT-enabled smart farming. This research uses a literature review methodology to discuss relevant research on smart farming, precision agriculture, and IoT integration in smart agriculture. In the context of smart farming with IoT, it provides valuable insights into research methodologies, classification networks, and citation bursts(Huo et al., 2024).

The study has several limitations that need to be addressed. The study relies only on a few databases including Scopus, IEEE Xplore, Science Direct, and Emerald, which may lead to missing some important research from other databases like web science, Springer Link, and others. Furthermore, the study's scope may not include all aspects of IOT applications in agriculture due to the dynamic nature of the field, which might mean excluding new developments. In this study, the study period runs from 2018 to 2023, and geographical bias and language limitations are potential factors. Despite these limitations, the study offers valuable insights within its defined scope.

4. Conclusion

In conclusion, this systematic review of literature published over the past five years provides insights into the applications and implications of adopting IoT technologies in agricultural systems. The integration of IoT-based monitoring, control, and decision automation has the potential to significantly enhance agricultural productivity, efficiency, and environmental sustainability. However, substantial challenges remain concerning data security, interoperability, integration costs, and development of comprehensive frameworks considering technological, economic, and social factors. Key knowledge gaps also persist regarding the real-world economic and environmental impact of IoT in agriculture. Further research through collaborative efforts between stakeholders is critical to address these limitations and facilitate evidence-based implementations of agricultural IoT. This review contributes to the literature by synthesizing findings across multiple studies, identifying limitations in current knowledge, and outlining recommendations to guide future investigation. The insights from this analysis can inform technological developments, policies, and practices to successfully leverage IoT innovations in moving towards the next generation of smart, sustainable agriculture worldwide.

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