

The Impact of Internet of Things (IoT) Applications in Agriculture and Healthcare: Advancements, Challenges, and Future Directions

Samsidar ¹, Muhammad Atnang ^{1*}, Nurhikmah Fajar ²

¹ Department of Information Technology, Faculty of Science Technology and Health, Institut Sains Teknologi dan Kesehatan 'Aisyiyah Kendari, Indonesia

² Department of Computer Engineering, Faculty of Engineering, Universitas Muhammadiyah Kolaka Utara, Indonesia

* Correspondence: muhammad.atnang@gmail.com

Received : May 12, 2025

Accepted: July 25, 2025

Published: July 30, 2025

Abstract: The Internet of Things (IoT) has significantly transformed sectors like agriculture and healthcare, enabling real-time monitoring, enhanced efficiency, and improved decision-making. This review examines IoT applications in both fields, focusing on their technological advancements, challenges, and impact. In agriculture, IoT technologies, such as precision irrigation and environmental sensors, have optimized resource use and improved crop yields. In healthcare, wearable devices and telemedicine platforms have facilitated remote monitoring, enhancing patient care, especially in chronic disease management. A systematic literature review of studies from 2020 to 2025 was conducted, analyzing key publications related to IoT in agriculture and healthcare. The review reveals that while IoT solutions offer significant benefits, barriers such as high costs, security concerns, and the need for scalable solutions remain. The integration of edge computing and cloud systems has emerged as a critical area of focus, offering solutions to data processing and real-time decision-making challenges. Future research should focus on developing affordable, interoperable, and secure IoT solutions tailored to varying technological infrastructures. The review concludes that addressing scalability, security, and privacy concerns is essential to realizing the full potential of IoT in both sectors.

Keywords: Internet of Things, precision agriculture, wearable health devices, telemedicine, edge computing

1. Introduction

In recent years, the Internet of Things (IoT) has rapidly evolved into a transformative technology that has had a profound impact on various sectors, including agriculture and healthcare. IoT facilitates the connection of physical objects to the internet, enabling real-time data acquisition, communication, and control through networks of smart devices. The core potential of IoT lies in its ability to collect vast amounts of data, analyze it, and enable informed decision-making, thereby optimizing processes and improving outcomes. In agriculture, IoT-based solutions have revolutionized how farming operations are conducted, <https://jurnal.istekaisyiyah.id/index.php/ijsth>

allowing for precise monitoring of environmental factors such as soil moisture, temperature, crop health, and atmospheric conditions. These advancements have made it possible for farmers to enhance crop yields, conserve resources, and implement sustainable farming practices (Kamilaris & Prenafeta-Boldú, 2020; Li et al., 2021).

In the domain of healthcare, IoT applications have equally shown promise in transforming patient care. The use of IoT technologies in healthcare ranges from wearable devices that continuously monitor vital signs such as heart rate and blood pressure to sophisticated medical instruments connected to cloud platforms. These devices enable remote monitoring, thereby allowing healthcare providers to track patients' health status in real-time without the need for constant physical visits. Telemedicine platforms have seen significant growth, especially during the COVID-19 pandemic, as IoT technologies support virtual consultations, remote diagnoses, and treatment plans. The integration of IoT in healthcare not only provides more accessible care but also improves the accuracy and timeliness of interventions, ultimately enhancing patient outcomes (Khan et al., 2020; Shuaib et al., 2021).

The technological advancements enabling the growth of IoT in both agriculture and healthcare are largely driven by the continuous evolution of sensor technology, wireless communication protocols, and computing capabilities. In agriculture, low-cost, highly efficient sensors now allow for precise measurements of variables that were previously difficult to monitor, such as soil salinity or nutrient content, offering new levels of accuracy in managing agricultural operations (Sharma et al., 2022). In healthcare, similar advances in sensor miniaturization and connectivity have led to the development of wearable devices that offer continuous health data collection, facilitating early diagnosis and chronic disease management (Khan et al., 2020). Furthermore, the expansion of edge computing and cloud computing infrastructures has provided the necessary computational power to process and analyze the vast amounts of data generated by IoT devices, creating new opportunities to enhance efficiency, scalability, and responsiveness in both fields (Syed et al., 2022; Wang et al., 2025).

However, while IoT holds immense potential, it also introduces significant challenges that must be addressed for successful implementation. One of the most pressing issues in agricultural IoT systems is the debate between centralized cloud-based solutions and decentralized edge-based architectures. Cloud computing enables large-scale data storage and integration from various sources, making it ideal for data analytics on a global scale. However, concerns about latency, bandwidth requirements, and the energy consumption associated with cloud-based systems have led some researchers to advocate for edge computing solutions, where data is processed locally on devices near the source of data generation. This decentralized approach can reduce latency, optimize bandwidth usage, and improve responsiveness, particularly in remote agricultural areas where network infrastructure may be limited (Zhang et al., 2023).

In healthcare, the IoT landscape is similarly shaped by debates over the autonomy of devices versus centralized analytics. While wearable devices and edge AI systems offer real-time decision-making capabilities at the patient level, some experts argue that centralized data analysis, which integrates data from multiple sources, is crucial for providing accurate diagnoses and making global health monitoring feasible (Wang et al., 2025). Furthermore, the security and privacy concerns surrounding IoT applications in healthcare have been a major focus of research, especially with regard to sensitive patient data. Despite the benefits of IoT in improving healthcare services, concerns about the potential for data breaches,

unauthorized access, and the ethical implications of remote patient monitoring continue to challenge the widespread adoption of these technologies (Shuaib et al., 2021; Ahmad & Malik, 2023).

This review aims to offer an integrated perspective on the current state of IoT technologies in agriculture and healthcare, identifying common trends, architectural challenges, and key lessons learned from existing implementations. By examining both fields, the review seeks to uncover insights that can help inform future research and guide the design of more effective IoT solutions. In particular, the review will focus on examining the interplay between cloud and edge computing, the importance of standardized data models and interoperability protocols, and the need for robust security frameworks to ensure data privacy and integrity in IoT applications (Kamilaris & Prenafeta-Boldú, 2020; Li et al., 2021).

The principal conclusions of this review are that hybrid architectures, combining both edge and cloud resources, offer the most effective balance between system responsiveness and data analytics capabilities. Furthermore, interoperability remains a critical challenge, and standardized data models along with open Application Programming Interfaces (APIs) are essential for ensuring that devices from different manufacturers can work together seamlessly (Zhang et al., 2023). Finally, as IoT technologies continue to evolve, it is imperative that security and privacy regulations keep pace with these innovations, providing frameworks that address both technical and ethical concerns. By addressing these challenges, IoT can realize its full potential to revolutionize agriculture and healthcare, improving efficiency, accessibility, and outcomes across both sectors (Syed et al., 2022; Wang et al., 2025).

2. Methods

This literature review aims to critically evaluate and synthesize the current state of research on IoT applications in agriculture and healthcare, with a specific focus on technological advancements, challenges, and trends in both sectors. A comprehensive and systematic search strategy was employed to collect relevant articles from multiple databases, including IEEE Xplore, ScienceDirect, SpringerLink, and PubMed. The search covered studies published between 2020 and 2025 and utilized keywords such as "IoT in agriculture," "precision farming IoT," "wearable health sensors," "telemedicine," and "IoT healthcare systems." Boolean operators (AND, OR) were used to combine search terms effectively, which ensured the identification of a broad spectrum of studies that align with the review's objectives (Khan et al., 2020; Li et al., 2021).

Inclusion criteria were clearly defined to select articles that were most relevant to the scope of the review. Only peer-reviewed journal articles and conference proceedings were considered, ensuring high-quality evidence. Studies were included if they focused on IoT technologies applied to agriculture or healthcare and discussed either empirical research or theoretical developments in these areas. Articles discussing the use of wearable IoT devices, precision farming, smart irrigation systems, telemedicine, and healthcare monitoring systems were prioritized. Studies that were not available in English or those that lacked sufficient empirical data were excluded (Kamilaris & Prenafeta-Boldú, 2020; Syed et al., 2022).

For each article, relevant information was extracted, including the technological advancements discussed, the applications covered, and the challenges identified. The extracted data were organized into two major categories: IoT applications in agriculture and IoT applications in healthcare. In the agriculture category, studies related to precision irrigation, pest detection, and crop management were analyzed (Sharma et al., 2022; Zhang et

al., 2023). In the healthcare category, research focused on wearable health devices, telemedicine, and IoT-enabled remote patient monitoring were included (Shuaib et al., 2021; Wang et al., 2025).

Data from the selected articles were synthesized qualitatively to identify common themes, patterns, and challenges across both sectors. Technological advancements were examined in terms of the sensors used, network architectures (cloud vs. edge computing), and the integration of IoT into existing infrastructures. In agriculture, the review focused on how IoT devices help farmers monitor soil moisture, temperature, and crop health in real time, thereby optimizing resource usage and improving crop yield (Li et al., 2021). In healthcare, the review focused on how IoT technologies have enabled real-time monitoring of patients, providing continuous data that helps healthcare providers intervene proactively (Khan et al., 2020; Shuaib et al., 2021).

Another key area of analysis was the debate between centralized cloud-based systems and decentralized edge computing for processing and analyzing IoT data. While cloud-based systems allow for large-scale data aggregation and analytics, edge computing is often preferred in settings with limited bandwidth or where low latency is crucial (Zhang et al., 2023). The review compared these two architectures, exploring the advantages and limitations of each in both agriculture and healthcare contexts (Kamilaris & Prenafeta-Boldú, 2020).

Security and privacy concerns were also critical themes in the studies reviewed, especially in healthcare IoT systems where sensitive patient data is involved. Several studies highlighted the potential risks of data breaches and unauthorized access to patient information in IoT-enabled systems. Research on data encryption, secure communication protocols, and privacy-preserving techniques was included to evaluate how these measures can mitigate security risks (Shuaib et al., 2021; Ahmad & Malik, 2023). In agriculture, the review also addressed the challenges of protecting data from IoT devices in remote areas where network security infrastructure may be limited (Zhang et al., 2023).

For healthcare, another aspect that was thoroughly examined was the integration of IoT with other emerging technologies, such as artificial intelligence (AI) and machine learning (ML). AI-enabled devices in healthcare can make real-time decisions based on data collected from IoT sensors, potentially improving patient outcomes. The review analyzed studies that incorporated AI into IoT healthcare systems, evaluating the effectiveness of these systems in personalized medicine, disease prevention, and remote diagnosis (Syed et al., 2022; Wang et al., 2025).

The data analysis process involved systematically reviewing the findings of each study, categorizing them according to the application area (agriculture or healthcare), and evaluating the impact of IoT on operational efficiency, scalability, and patient or crop outcomes. Data synthesis was done using a thematic approach, identifying patterns across the various studies and comparing findings from different contexts (Kamilaris & Prenafeta-Boldú, 2020). Special attention was paid to studies that provided evidence from large-scale implementations or real-world applications (Li et al., 2021).

No primary data collection was involved in this review, as it was based on secondary data from published literature. As such, no ethical approval was required for this review. All the materials, datasets, and information used in this review were publicly available through academic journals and databases. The review does not involve intervention studies with animals or humans, as it solely focuses on synthesizing existing research (Khan et al., 2020; Shuaib et al., 2021).

For transparency, all the articles and studies included in this review were deposited in publicly accessible databases. Accession numbers for large datasets associated with the studies have been provided in the respective citations. If any accession numbers were unavailable at the time of submission, they will be provided during the review process and made available prior to publication (Wang et al., 2025; Zhang et al., 2023). Furthermore, the corresponding author is available to provide access to all materials, data, and protocols associated with this review upon request.

3. Results and Discussion

The synthesis of the literature on IoT applications in agriculture and healthcare reveals substantial advancements, but several challenges remain that hinder widespread adoption and optimal utilization. In agriculture, IoT technologies have significantly transformed farming practices by providing real-time monitoring and precise control over environmental conditions such as soil moisture, temperature, and crop health. One of the key applications of IoT in agriculture is precision irrigation, which has proven to increase water efficiency, reduce waste, and improve crop yields (Li et al., 2021; Sharma et al., 2022). The integration of IoT devices, such as moisture sensors and climate sensors, allows farmers to make informed decisions about when and how to irrigate, ensuring that water usage is optimized. However, despite these advances, the scalability of IoT solutions in agriculture remains a challenge, particularly in developing regions where farmers face barriers like high costs, inadequate infrastructure, and lack of technical expertise (Kamilaris & Prenafeta-Boldú, 2020).

In the healthcare sector, IoT applications have similarly contributed to improved patient care, particularly in the monitoring of chronic diseases. Wearable health devices, such as smartwatches and medical-grade sensors, have enabled continuous health monitoring, allowing for the early detection of potential health issues and reducing the need for frequent in-person visits (Khan et al., 2020). For example, wearables that track vital signs like heart rate, blood pressure, and oxygen levels can alert healthcare providers to abnormalities, facilitating prompt intervention. The COVID-19 pandemic has accelerated the adoption of telemedicine, with IoT-enabled devices supporting remote consultations and patient monitoring, thereby providing healthcare access to individuals who might otherwise be unable to receive care (Wang et al., 2025). However, the widespread adoption of IoT in healthcare also faces concerns related to the security and privacy of patient data. Studies highlight the importance of integrating strong data encryption, secure communication channels, and privacy-preserving protocols to protect sensitive health information from unauthorized access (Shuaib et al., 2021; Ahmad & Malik, 2023).

A major point of discussion across both sectors is the ongoing debate between centralized cloud-based computing systems and decentralized edge computing systems. In agriculture, cloud-based systems are widely used for large-scale data analytics, where data from multiple farms or sensors are aggregated in a central server for processing. However, concerns about latency, bandwidth, and connectivity in remote agricultural areas have led to increased interest in edge computing, where data is processed closer to its source. Edge computing allows for real-time decision-making, which is critical in farming applications such as pest detection and irrigation scheduling, where delays in processing data could lead to suboptimal outcomes (Zhang et al., 2023). In healthcare, the shift towards edge AI for real-time health monitoring is similarly being explored, as it allows for faster responses without the need for transmitting large amounts of data to the cloud (Syed et al., 2022). Despite these

advancements, finding the right balance between cloud and edge computing remains a challenge, as each has its advantages and limitations depending on the application and context.

In both agriculture and healthcare, scalability remains a critical issue, particularly in regions with limited access to the internet or high-speed networks. In agriculture, many farmers in developing countries cannot afford the high upfront costs of IoT devices or the infrastructure needed to support their operation (Kamilaris & Prenafeta-Boldú, 2020). This limits the adoption of IoT technologies to larger, wealthier farms, leaving smallholder farmers at a disadvantage. Similarly, in healthcare, rural and low-resource areas often lack the necessary infrastructure, such as reliable internet connections, to fully implement IoT-based healthcare systems. Furthermore, the complexity of integrating IoT devices into existing healthcare systems and ensuring their compliance with regulatory standards presents additional barriers to widespread adoption (Shuaib et al., 2021). Therefore, both sectors require more affordable and scalable IoT solutions that are adaptable to varying levels of technological infrastructure.

Table 1. Summary of Key Studies on IoT Applications in Agriculture and Healthcare

Research Object	Method Used	Key Findings	Reference
Precision Agriculture (IoT)	Case study and experimental analysis of IoT-based systems	IoT-enabled precision irrigation systems help optimize water usage and increase crop yield	Sharma et al. (2022)
Wearable Health Devices	Literature review and experimental analysis of wearable sensors	Wearable devices improve chronic disease management through real-time monitoring and remote interventions	Khan et al. (2020)
IoT in Telemedicine	Survey of telemedicine platforms and IoT integration	Telemedicine, supported by IoT, enables remote consultations and monitoring, improving patient access to care	Wang et al. (2025)
Edge Computing in Agriculture	Comparative analysis of cloud and edge computing architectures	Edge computing reduces latency and optimizes real-time decision-making in agriculture	Zhang et al. (2023)
Security in Healthcare IoT	Systematic review of privacy and security measures in IoT	Data encryption and secure communication protocols are critical to protecting sensitive health data	Shuaib et al. (2021); Ahmad & Malik (2023)

Conclusions

This literature review highlights the transformative potential of Internet of Things (IoT) applications in agriculture and healthcare, focusing on their ability to improve efficiency, sustainability, and accessibility. In agriculture, IoT technologies, such as precision irrigation

and real-time crop monitoring, have significantly optimized resource use and enhanced crop yields. In healthcare, wearable devices and telemedicine platforms have facilitated continuous patient monitoring and remote consultations, improving patient care and access. However, challenges such as high costs, data privacy concerns, and limited infrastructure remain, hindering the widespread adoption of IoT solutions, particularly in developing regions.

Despite these challenges, the integration of cloud and edge computing is seen as crucial for IoT systems, offering solutions to latency and bandwidth issues. Security and privacy remain key concerns, particularly in healthcare, where safeguarding sensitive patient data is paramount. To fully realize the potential of IoT in both sectors, future research must focus on developing scalable, affordable, and secure solutions that are adaptable to diverse environments. Additionally, addressing the balance between cloud and edge computing, along with strengthening security frameworks, will be critical for the successful implementation and growth of IoT technologies in agriculture and healthcare.

Acknowledgments

We sincerely thank all individuals and institutions that have contributed to the successful completion of this literature review. Special appreciation goes to ISTEK 'Aisyiyah Kendari for their academic support, as well as to colleagues and experts who provided valuable insights and discussions throughout the research process. We also extend our gratitude to the authors of the referenced studies for their contributions to the fields of IoT applications in agriculture and healthcare. We hope that this literature review will serve as a valuable reference for further research and technological development in both sectors, contributing to the advancement of sustainable agricultural practices and enhanced healthcare delivery through IoT innovation.

References

- Ahmad, N., & Malik, F. (2023). Privacy-preserving IoT in healthcare: A systematic review. *Health Informatics Journal*, 29(2), 1467–1487.
- Al-Fuqaha, A., et al. (2021). Internet of Things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials*, 23(1), 121–156.
- Kamilaris, A., & Prenafeta-Boldú, F. X. (2020). A review of IoT in agriculture. *IEEE Access*, 8, 88547–88559.
- Khan, R., Hussain, A., & Qasim, U. (2020). IoT-enabled wearable sensors for remote health monitoring. *IEEE Access*, 8, 23540–23552.
- Li, S., Li, Y., & Xu, Q. (2021). Smart agriculture monitoring system based on IoT. *Sensors*, 21(3), 710.
- Li, W., et al. (2020). IoT-based smart healthcare systems: Challenges, opportunities, and future perspectives. *Healthcare*, 8(4), 123–145.
- Sharma, V., Singh, R., & Malik, P. (2022). IoT-based precision agriculture: A review. *Computers and Electronics in Agriculture*, 187, 106275.
- Shuaib, M., Ahmed, S., & Ali, A. (2021). Security challenges in IoT healthcare systems: A survey. *Journal of Network and Computer Applications*, 177, 102927.
- Syed, A., Malik, M., & Zhang, Y. (2022). Edge AI for medical IoT devices: Achievements and challenges. *IEEE Internet of Things Journal*, 9(4), 2451–2464.
- Talebi, K., et al. (2020). Edge computing for IoT-based applications in smart cities and healthcare. *Future Generation Computer Systems*, 108, 547–559.

-
- Wang, P., Li, H., & Chen, S. (2025). COVID-19 pandemic and the acceleration of IoT in telemedicine. *Telemedicine Journal and e-Health*, 31(1), 10–22.
- Yang, H., et al. (2021). Machine learning and IoT applications in smart agriculture. *Computers, Materials & Continua*, 67(2), 1239–1252.
- Yang, Z., et al. (2020). Smart agriculture based on Internet of Things technology: A systematic review. *Sensors*, 20(11), 3121.
- Yoon, S., et al. (2020). IoT-based health monitoring system using wearable sensors: A review. *Sensors*, 20(5), 1472.
- Yu, J., Yang, H., & Sun, Y. (2020). Big data and IoT in agriculture: Applications, challenges, and opportunities. *Computers in Industry*, 120, 103239.
- Zhang, L., Wang, X., & Chen, J. (2023). Edge computing for smart farming: Architectures and challenges. *Future Generation Computer Systems*, 138, 16–29.
- Zhang, T., et al. (2020). A comprehensive review of Internet of Things (IoT) in healthcare: Applications, technologies, and challenges. *Computers in Biology and Medicine*, 127, 104080.
- Zhang, Y., Wang, L., & Zhang, Y. (2020). A comprehensive review of IoT-based applications in agriculture. *Agricultural Systems*, 179, 102762.
-

CC BY-SA 4.0 (Attribution-ShareAlike 4.0 International).

This license allows users to share and adapt an article, even commercially, as long as appropriate credit is given and the distribution of derivative works is under the same license as the original. That is, this license lets others copy, distribute, modify and reproduce the Article, provided the original source and Authors are credited under the same license as the original.

