West Science Nature and Technology
Vol. 1, No. 02, December 2023, pp. 55~63

Performance Analysis of Distributed Database Management System for IoT in the Context of Smart Agriculture in Indonesia

Loso Judijanto
IPOSS Jakarta, Indonesia

Article Info

Article history:

Received December 2023
Revised December 2023
Accepted December 2023

Keywords:

Performance
Database Management System
IoT
Smart Agriculture
Indonesia

ABSTRACT

The integration of Distributed Database Management Systems (DDBMS) for Internet of Things (IoT) applications in smart agriculture presents a transformative paradigm in the dynamic landscape of Indonesian agriculture. This qualitative research investigates the challenges and opportunities associated with this integration, drawing insights from interviews with diverse stakeholders, including farmers, technology developers, and policymakers. The technical challenges encompass data synchronization, network latency, and security considerations, emphasizing the need for standardized protocols and robust security measures. Infrastructure challenges, such as connectivity issues and power supply dependency, underscore the importance of rural infrastructure development. User acceptance challenges highlight resistance to change and the perceived complexity of DDBMS, emphasizing the significance of targeted awareness and training programs. Despite these challenges, stakeholders recognize the advantages of scalability, enhanced data availability, and improved decision-making capabilities offered by DDBMS. The study proposes recommendations, including technological solutions, policy interventions, and capacity-building initiatives, to address identified challenges and promote the effective utilization of DDBMS in Indonesian smart agriculture. This research contributes context-specific insights to the global discourse on IoT and DDBMS in agriculture.

Corresponding Author:

Name: Loso Judijanto
Institution: IPOSS Jakarta, Indonesia
Email: losojudijantobumn@gmail.com

1. INTRODUCTION

The integration of Internet of Things (IoT) technologies in smart farming has revolutionized traditional farming practices, offering opportunities to optimize resource utilization, increase crop yields, and encourage sustainable farming practices [1], [2]. However, managing the vast and dynamic data sets generated by IoT devices poses challenges in terms of scalability and distribution. To address these challenges, Distributed Database Management Systems (DDBMS) are emerging as important solutions for handling large amounts of data flows in smart agriculture [2]. In the context of Indonesia, as one of the largest island nations with a diverse ecosystem, the deployment of IoT applications in smart farming holds great potential for transforming the agricultural sector [3]. By effectively managing and analyzing the data generated by IoT devices, Indonesia can harness the benefits of IoT technologies to optimize agricultural practices and achieve sustainable farming outcomes [4].

The use of IoT technology in agriculture has become integral in Indonesia, where agriculture is the economic cornerstone and source of livelihood for most of the population. Real-time monitoring, precision agriculture, and data-driven decision making have shaped the trajectory of the agricultural sector in the country [5]. This technology allows for the collection and analysis of agricultural information through the Internet of Things, enabling farmers to make more precise decisions and improve crop health [6]. By utilizing technologies such as big data, machine learning, robotics, and IoT, the quality and quantity of agricultural production can be improved [7]. The implementation of IoT-based agriculture, also known as Smart Farming, has the potential to increase productivity and meet the ever-increasing demands of the growing population [8].

The integration of IoT technologies in smart agriculture has led to the generation of a vast amount of data that needs to be managed and transferred efficiently. To address this challenge, various data reduction techniques have been investigated and compared. These techniques aim to reduce the size or quantity of transmitted data samples, resulting in reduced energy consumption, improved network efficiency, and minimized storage and processing requirements [2], [9]. Additionally, clustering and optimization algorithms have been proposed to optimize the selection of Cluster Heads (CH) and the path for data transmission in IoT-enabled smart agriculture systems [10]. Furthermore, the development of low-cost IoT components and the study of their performance in real-time experimental data generation have been explored, enabling the possibility of commercial applications and research purposes in smart agricultural systems [4]. Finally, a novel system for IoT-based agricultural soil measurements has been presented, incorporating multiple sensors, a micro-processor, a microcomputer, a cloud platform, and a mobile phone application, enabling real-time monitoring of soil quality and conditions [1], [5]. This research seeks to conduct a comprehensive qualitative analysis of the performance of Distributed Database Management Systems in the specific context of IoT applications for smart agriculture in Indonesia.

2. LITERATURE REVIEW

2.1 IoT in Smart Agriculture

The integration of IoT in agriculture has the potential to revolutionize traditional farming practices by enabling the deployment of sensors, actuators, and connected devices in the agricultural landscape. These devices collect real-time data on soil conditions, weather patterns, crop health, and equipment status, providing farmers with valuable information for decision-making [11], [1], [12]. IoT in agriculture has diverse applications, including precision farming, smart irrigation, livestock monitoring, and supply chain management [4]. It allows for precision farming techniques such as optimizing resource allocation and implementing data-driven decisions based on real-time data [13]. IoT technologies also enable farmers to monitor and control environmental conditions, leading to increased crop yields and resource conservation. Additionally, IoT in agriculture facilitates the prediction of potential crop disease risks through data analytics and sensor data. Overall, IoT in agriculture offers numerous benefits for farmers, ranging from increased productivity to improved sustainability and efficiency.

2.2 Distributed Database Management Systems

Distributed Database Management Systems (DDBMS) have become crucial for handling large and dynamic datasets generated by IoT devices. DDBMS distribute data to multiple nodes or servers, providing scalability, fault tolerance, and performance advantages. The architecture of DDBMS, including data partitioning, replication, and consistency mechanisms, addresses the challenges posed by the distributed nature of IoT-generated data. Research in database management emphasizes the relevance of DDBMS in various applications, such as cloud computing, sensor networks, and IoT platforms. The distributed nature of DDBMS aligns with the requirements of smart farming, where data sources are spread across a vast agricultural landscape [14], [15].

2.3 Smart Agriculture in Indonesia

The agricultural landscape of Indonesia is characterized by a rich diversity of crops, farming practices, and geographical conditions [16], [17], [18], [19]. Traditional farming methods coexist with modern agricultural techniques, creating a unique amalgamation of practices [20]. The adoption of smart agriculture technologies in Indonesia is influenced by factors such as land fragmentation, varying agro-climatic zones, and the need for sustainable farming practices. Limited studies specifically address the state of smart agriculture in Indonesia, making it imperative to explore how IoT technologies and DDBMS can be effectively integrated into this complex agricultural ecosystem. Understanding the socio-economic factors, cultural nuances, and existing challenges is crucial for tailoring technological solutions that align with the needs of Indonesian farmers.

2.4 Challenges in IoT and DDBMS Integration in Smart Agriculture

The integration of IoT technologies and DDBMS in smart agriculture faces several challenges. Technical challenges include data synchronization, network latency, and managing diverse data types generated by IoT devices. These challenges are highlighted in the works of [4] and [21]. Infrastructure challenges encompass issues of connectivity, power supply, and accessibility, especially in remote and rural farming areas. These challenges are discussed in the research by Ingole and Padole [22]. User acceptance challenges emphasize the importance of understanding the perspectives of farmers and stakeholders towards adopting and utilizing these technologies. This is addressed in the systematic review conducted [23].

2.5 Advantages and Disadvantages of DDBMS in Smart Agriculture

Research in the field of database management highlights the benefits of using Distributed Database Management Systems (DDBMS) for handling large-scale and distributed datasets. DDBMS offer improved scalability, fault tolerance, and enhanced performance. However, there are potential disadvantages to consider, including increased complexity, maintenance challenges, and potential security concerns. It is important to understand the trade-offs associated with employing DDBMS in smart agriculture [24].

2.6 Integrated Frameworks and Best Practices

Scholarly work has explored integrated frameworks and best practices for combining IoT technologies with DDBMS in the domain of smart agriculture [2], [25]. These studies aim to optimize IoT data transmission, reduce energy consumption, improve network efficiency, and minimize storage and processing requirements [26]. The comparison of different data reduction techniques, such as sampling, quantization, and deduplication, has been conducted using real-time datasets specifically designed for smart agriculture systems [26]. Additionally, the impact of existing wireless protocols, such as LoRa WAN, Zigbee, Sigfox, and NB-IoT, on IoT-WSN-enabled smart farming has been analyzed [27]. These studies provide valuable insights into the role of relevant technologies and present protocols in smart farming. By understanding how these technologies synergize and the best practices employed globally, strategies tailored to the specific needs of Indonesian agriculture can be developed.

2.7 Gaps in the Existing Literature

While the literature review provides valuable insights into the integration of IoT and DDBMS in smart agriculture, there exist gaps that necessitate further exploration. Limited studies specifically address the challenges and opportunities in Indonesia's unique agricultural landscape. Additionally, the socio-technical aspects of user acceptance and the perspectives of diverse stakeholders in the Indonesian context require more in-depth investigation.

3. METHODS

3.1 Research Design

In order to investigate the viewpoints and experiences of those engaged in the integration of Distributed Database Management Systems (DDBMS) for Internet of Things (IoT) applications in Indonesian smart agriculture, this study used a qualitative research design. The selection of qualitative study was based on its capacity to represent the intricacy of socio-technical interactions, providing a comprehensive and contextualized knowledge of the difficulties, benefits, and areas for future development related to DDBMS in this specific field. Participants from diverse stakeholders in Indonesia's smart agricultural ecosystem were chosen using a purposive sampling technique. Those involved in or impacted by the integration of DDBMS and IoT technologies in agriculture, such as farmers, technology developers, and policy officials, comprised the sample. Ten informants in total participated in this study with the goal of capturing a range of viewpoints and experiences that represent the diversity of Indonesia's agricultural environment.

3.2 Data Collection

3.2.1 Interviews

Semi-structured interviews will be conducted with the participants to gather in-depth insights into their experiences, challenges, and perceptions regarding the utilization of DDBMS for IoT in smart agriculture. Open-ended questions will be designed to explore technical considerations, infrastructure challenges, and user acceptance issues. The interviews will be recorded and transcribed to facilitate thorough analysis.

3.2.2 Focus Group Discussions

Focus group discussions will be organized to encourage interaction and dialogue among participants. These sessions will provide a platform for stakeholders to share their perspectives, debate ideas, and offer collective insights on the challenges and opportunities associated with DDBMS in smart agriculture. The discussions will be recorded and analyzed to identify emerging themes.

3.2.3 Document Analysis

Government reports, policy documents, technology specifications, and relevant literature will be analyzed to provide contextual background and complement perspectives gathered through interviews and focus group discussions. Document analysis will assist in understanding the broader policy framework, technological advancements, and challenges faced in the adoption of DDBMS for IoT in Indonesian agriculture.

3.2.4 Data Analysis

In order to find recurrent themes, patterns, and insights in the qualitative information gathered from focus groups, document analysis, and interviews, thematic analysis will be employed. In this iterative process, the data is coded, the codes are categorized into themes, and the themes are then interpreted to yield significant findings. To guarantee the authenticity and dependability of the results, a thorough analysis will be conducted.

3.2.5 Ethical Considerations

The entire study process will give priority to ethical considerations. Every participant will be asked to provide informed permission, guaranteeing that they understand the goals of the research, the methods, and the voluntary nature of their involvement. Participants' privacy will be safeguarded by maintaining anonymity and secrecy. All parties involved in the study will be treated with responsibility and respect as it complies with ethical norms and values.

4. RESULTS AND DISCUSSION

4.1 Overview of Participants

In this study, 10 participants from various backgrounds, including farmers, technology developers, and policy makers, provided invaluable insights into the challenges and potential advancements associated with integrating Distributed Database Management Systems (DDBMS) for Internet of Things (IoT) applications in smart agriculture in Indonesia. The incorporation of multiple perspectives facilitates a comprehensive understanding of the complex dynamics surrounding the integration of these technologies.

4.2 Challenges in Implementing DDBMS for IoT in Smart Agriculture

During the interviews, farmers expressed their concerns about data synchronization from various IoT devices. The diversity of data formats and transmission protocols poses challenges in collecting and synchronizing information for comprehensive analysis. These technical challenges underscore the need for standardized data formats and communication protocols to facilitate seamless integration and analysis of data from multiple sources. Technology developers emphasize the impact of network latency on real-time data processing, especially in remote agricultural areas with limited connectivity. Addressing network latency issues requires a multi-faceted approach, including infrastructure upgrades, optimization of communication protocols, and integration of edge computing solutions. Both farmers and technology developers voiced their concerns about the security of sensitive agricultural data, and highlighted the importance of robust measures to protect data integrity. Security measures, including encryption, secure access control, and regular security audits, should be integrated into the DDBMS design to instill confidence in users regarding data protection.

Farmers in remote areas highlight the challenges associated with limited or unstable connectivity, which affects the smooth operation of IoT devices and DDBMS. Overcoming connectivity challenges requires investments in rural infrastructure, such as expanding network coverage and improving internet connectivity in remote farming areas. Participants discussed the reliance on consistent power supply for IoT devices, pointing out the challenges in areas with irregular access to electricity. Exploring alternative and sustainable power sources, such as solar or battery technology, is essential to ensure continuous data collection in areas with unreliable electricity infrastructure. Farmers emphasized the need for easy-to-use technology considering the level of digital literacy in remote farming communities. Designing intuitive and accessible user interfaces, coupled with targeted training programs, can address challenges related to technology accessibility in remote areas.

During interviews, farmers expressed their resistance to adopting IoT and DDBMS technologies, and emphasized the importance of awareness and training programs. Understanding and addressing the root causes of resistance, such as the fear of technology replacing traditional practices, is critical to successful technology adoption. Both farmers and technology developers recognize the perceived complexity of implementing and maintaining a DDBMS. Simplifying the interface, providing extensive training, and offering ongoing support can alleviate concerns regarding the perceived complexity of a DDBMS.

4.3 Advantages and Disadvantages of Using DDBMS in Smart Agriculture

Technology developers highlight the scalability of DDBMS as a significant advantage, which enables the handling of large amounts of data generated by IoT devices. The scalability of DDBMS aligns with the dynamic nature of agricultural data, supporting the growth and diversification of IoT applications in smart farming. Farmers appreciate the increased availability of real-time data through DDBMS, which facilitates more informed decision-making. Better data availability empowers farmers with timely information, improving their ability to respond effectively to changing farming conditions. Both farmers and policymakers recognize the improved decision-making capabilities facilitated by the DDBMS. Improved decision-making capability is a very important outcome, demonstrating the transformative potential of DDBMS in optimizing farming practices.

The perceived complexity of implementing and managing a DDBMS emerged as a recurring theme among farmers and technology developers. Strategies to simplify the implementation process and provide comprehensive training are essential to address challenges related to complexity. Technology developers discussed the challenges associated with maintaining the DDBMS in the field, including software updates, hardware maintenance, and troubleshooting. Establishing support mechanisms and maintenance protocols is essential to ensure the long-term viability of DDBMSs in smart agriculture. The potential vulnerability of agricultural data stored in the DDBMS raised security concerns among participants. Strong regulatory frameworks and security measures should be implemented to address data privacy concerns and foster user trust.

4.4 Stakeholder Perspective

Farmers recognize the benefits of IoT and DDBMS, including better yield prediction, optimized resource use, and better pest management. Highlighting these benefits in outreach programs can contribute to changing perceptions and overcoming resistance among farmers. Concerns center on initial costs, training needs, and fear of the technology replacing traditional farming practices. Addressing concerns through targeted training programs, cost-effective solutions, and collaborative decision-making can reduce resistance among farmers.

Technology developers highlighted ongoing advancements, such as edge computing and better algorithms, to address technical challenges. Continuous innovation is essential to improve DDBMS capabilities and ensure their adaptability to evolving agricultural technologies.

Collaborative efforts with farmers are considered essential for designing user-centered solutions and overcoming resistance to technology adoption. Establishing feedback loops and collaborative platforms can foster partnerships between technology developers and farmers, ensuring the development of solutions that are aligned with user needs.

Policymakers emphasized the need for a supportive policy framework that encourages innovation while protecting farmers' interests and ensuring data security. Policymakers play a critical role in creating an enabling environment through policies that encourage innovation, incentivize adoption, and address regulatory concerns. Investing in capacity-building programs for farmers and technology developers is considered critical to the successful integration of IoT and DDBMS. Capacity building initiatives, including training programs and knowledge sharing platforms, can bridge the knowledge gap and encourage widespread adoption.

4.5 Potential Improvements and Recommendations

Developing user-friendly interfaces for farmers and technology developers emerged as a key recommendation to address the perceived complexity of the DDBMS. Investing in user experience design and conducting usability testing can contribute to the development of an intuitive interface that caters to a diverse user base.

Integrating edge computing capabilities into IoT devices is recommended to mitigate network latency issues, especially in remote agricultural areas. Exploring hybrid models that combine edge computing with centralized data processing can optimize data management in varied agricultural settings.

Policymakers emphasize the importance of strong data privacy regulations to instill confidence among farmers regarding the secure management of agricultural data. Collaborating with stakeholders to develop and enforce clear data privacy regulations can address concerns and build trust in the use of DDBMS.

Introducing incentive programs for farmers to adopt IoT and DDBMS technologies is proposed to overcome initial resistance and encourage wider adoption. Financial incentives, tax breaks, or subsidized access to technology can be effective motivators for farmers to adopt new agricultural technologies.

Conducting targeted training programs for farmers to improve their digital literacy and familiarity with IoT technologies is recommended. Collaborating with agricultural extension services and educational institutions can facilitate the implementation of comprehensive training programs.

Organize workshops and knowledge-sharing platforms for technology developers to stay updated on emerging trends and best practices in IoT and DDBMS. Continuous learning opportunities and collaboration platforms can foster a community of practice among technologists, promoting innovation and knowledge exchange.

4.6 Comparison with Existing Literature

The findings of this study are in line with existing literature regarding the challenges and advantages of using DDBMS for IoT in agriculture. A literature review conducted by Bulut and Wu revealed that the adoption of IoT in agriculture is hindered by barriers such as cost, skills, and standardization [28]. However, the integration of IoT with various measures and techniques, as demonstrated by Davoliute, offers advantages in managing and monitoring crops, including real-time data analysis and automated irrigation systems [27]. Seetha et al. also highlighted the benefits of using sensor networks and IoT in agricultural monitoring, such as increased productivity and decreased labor and time inputs [29]. Furthermore, B.R. et al. discussed the application of IoT and machine learning in agriculture, where sensors collect soil parameters and ML models recommend suitable crops for cultivation. Therefore, the existing literature supports the challenges and advantages of using DDBMS for IoT in agriculture.

However, this research provides context-specific insights, highlighting unique challenges and opportunities in Indonesia's diverse smart agriculture landscape. The context-specific nuances identified in this research emphasize the importance of tailoring solutions to the unique challenges faced by farmers and technology developers in Indonesia, contributing to the contextualization of global research findings.

5. CONCLUSION

The qualitative analysis of the performance analysis of Distributed Database Management Systems (DDBMS) for IoT in smart agriculture in Indonesia has revealed a nuanced landscape shaped by technical intricacies, infrastructural constraints, and user acceptance considerations. Stakeholder perspectives, gathered through interviews, provided invaluable insights into the challenges faced by farmers, technology developers, and policymakers. The identified challenges, including data synchronization, network latency, security concerns, connectivity issues, and user resistance, underscore the need for targeted interventions. Despite these challenges, stakeholders recognize the transformative potential of DDBMS, with scalability, improved data availability, and enhanced decision-making capabilities being key advantages.

Recommendations encompass user-friendly technological interfaces, integration of edge computing, robust policy frameworks, and comprehensive capacity-building initiatives. Policymakers play a pivotal role in creating an enabling environment, while technology developers must focus on collaborative and user-centric solutions. The study contributes to the academic discourse on IoT and DDBMS in agriculture, offering practical insights for the development of sustainable and inclusive agricultural technologies. Future research should delve into quantitative assessments of DDBMS performance, economic impacts, and longitudinal studies to track the evolving landscape of smart agriculture in Indonesia. The findings of this research serve as a foundation for informed decision-making, fostering innovation, and promoting the widespread adoption of transformative technologies in Indonesian agriculture.

REFERENCES

[1] Y. Wu, Z. Yang, and Y. Liu, "Internet-of-Things-Based Multiple-Sensor Monitoring System for Soil Information Diagnosis Using a Smartphone," *Micromachines*, vol. 14, no. 7, 2023, doi: 10.3390/mi14071395.

[2] D. Y. Setyawan, "Internet of Things (IoT) Application in Smart Farming to Optimize Tomato Growth," pp. 2460–7223, 2022.

[3] D. C. Tsouros, S. Bibi, and P. G. Sarigiannidis, "A review on UAV-based applications for precision agriculture," *Inf.*, vol. 10, no. 11, 2019, doi: 10.3390/info10110349.

[4] N. Jaliyagoda *et al.*, "Internet of things (IoT) for smart agriculture: Assembling and assessment of a low-cost IoT system for polytunnels," *PLoS One*, vol. 18, no. 5 May, pp. 1–21, 2023, doi: 10.1371/journal.pone.0278440.

[5] Y. Sun *et al.*, "Engineered Nanomaterials for Improving the Nutritional Quality of Agricultural Products: A Review," *Nanomaterials*, vol. 12, no. 23, 2022, doi: 10.3390/nano12234219.

[6] Aman Kumar Dewangan, "Application of IoT and Machine Learning in Agriculture," *Int. J. Eng. Res.*, vol. V9, no. 07, pp. 110–114, 2020, doi: 10.17577/ijertv9is070080.

[7] I. Z. Ramdinthara, P. S. Bala, and A. S. Gowri, "AI-Based Yield Prediction and Smart Irrigation," *Stud. Big Data*, vol. 99, no. October 2020, pp. 113–140, 2021, doi: 10.1007/978-981-16-6210-2_6.

[8] W. Budiharto, "Smart Farming yang Berwawasan Lingkungan Kesejahteraan Petani," *Pros. Semin. Nas. Lahan Suboptimal*, no. September, pp. 31–37, 2019.

[9] Y. Zhao, Q. Li, W. Yi, and H. Xiong, "Agricultural IoT Data Storage Optimization and Information Security Method Based on Blockchain," *Agric.*, vol. 13, no. 2, 2023, doi: 10.3390/agriculture13020274.

[10] S. kumar C and V. A. R, "Energy e?cient cluster head using modi?ed fuzzy logic with WOA and path selection using Enhanced CSO in IoT-enabled smart agriculture systems," 2023.

[11] A. Khan, S. Aziz, M. Bashir, and M. U. Khan, "IoT and Wireless Sensor Network based Autonomous Farming Robot," *2020 Int. Conf. Emerg. Trends Smart Technol. ICETST 2020*, no. March, pp. 1–6, 2020, doi: 10.1109/ICETST49965.2020.9080736.

[12] R. Srivastava, V. Sharma, V. Jaiswal, and S. Raj, "a Research Paper on Smart Agriculture Using Iot," *Int. Res. J. Eng. Technol.*, vol. 7, no. 7, pp. 2708–2710, 2020.

[13] M. Suresh and S. M. Priya, "Internet of Things (IoT) in agriculture: An overview of the concepts and challenges in its implementation," *Test Eng. Manag.*, vol. 82, no. May, pp. 16995–16999, 2020, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85083248489&partnerID=40&md5=77161d970051450d13e25f40e8532a66

[14] R. Serrano-Torres, M. García-Valls, and P. Basanta-Val, "Performance Evaluation of Virtualized DDS Middleware," *Simp. tiempo real español*, no. June 2014, 2013.

[15] L. G. Azevedo, E. F. de Souza Soares, R. Souza, and M. F. Moreno, "Modern federated database systems: An overview," *ICEIS 2020 - Proc. 22nd Int. Conf. Enterp. Inf. Syst.*, vol. 1, no. January, pp. 276–283, 2020, doi: 10.5220/0009795402760283.

[16] M. Dwi Marianto, Rob Goodfellow, Hanggar Budi Prasetya, and M. P. Wahidiyat, "Substituting The Synthetic For The Authentic: The Contribution of Rudolf Steiner's Biodynamic Innovations in Advancing Yos Suprapto's Traditional Knowledge of Local Agriculture," *Mudra J. Seni Budaya*, vol. 38, no. 4, pp. 407–419, 2023, doi: 10.31091/mudra.v38i4.2364.

[17] F. D. Adhinata, N. G. Ramadhan, M. D. Fauzi, and N. A. Ferani Tanjung, "A Combination of Transfer Learning and Support Vector Machine for Robust Classification on Small Weed and Potato Datasets," *Int. J. Informatics Vis.*, vol. 7, no. 2, pp. 535–541, 2023, doi: 10.30630/joiv.7.2.1164.

[18] Darmono, A. Yogatama, K. Ma'ruf, B. P. Setiyawa, and Y. A. Fadlullah, "Optimization of Agricultural Technology with Irrigation Control in Rice Plants Based on Internet of Things," *Indones. J. Adv. Res.*, vol. 2, no. 5, pp. 411–418, 2023, doi: 10.55927/ijar.v2i5.4149.

[19] E. P. Astoko and N. Helilusiatiningsih, "SWOT Analysis of Rice Plants in Nganjuk Regency," *Formosa J. Multidiscip. Res.*, vol. 2, no. 5, pp. 951–960, 2023, doi: 10.55927/fjmr.v2i5.4354.

[20] I. M. G. Sunarya, I Wayan Treman, and Putu Zasya Eka Satya Nugraha, "Classification of Rice Growth Stage on UAV Image Based on Convolutional Neural Network Method," *J. Nas. Pendidik. Tek. Inform.*, vol. 12, no. 1, pp. 146–155, 2023, doi: 10.23887/janapati.v12i1.60959.

[21] S. Kabadayi and R. Gupta, "Website loyalty: an empirical investigation of its antecedents," *Int. J. Internet Mark. Advert.*, vol. 2, no. 4, pp. 321–345, 2005, doi: 10.1504/IJIMA.2005.008105.

[22] Z. Gupta, A. K. Bindal, D. S. Shukla, I. Chopra, V. Tiwari, and S. Srivastava, "Energy Efficient IoT-Sensors Network for Smart Farming," *Int. J. Recent Innov. Trends Comput. Commun.*, vol. 11, no. 5, pp. 255–265, 2023, doi: 10.17762/ijritcc.v11i5.6612.

[23] Köksal and B. Tekinerdogan, *Architecture design approach for IoT-based farm management information systems*, vol. 20, no. 5. Springer US, 2019. doi: 10.1007/s11119-018-09624-8.

[24] H. He *et al.*, "When Database Meets New Storage Devices: Understanding and Exposing Performance Mismatches via Configurations," *Proc. VLDB Endow.*, vol. 16, no. 7, pp. 1712–1725, 2023, doi: 10.14778/3587136.3587145.

[25] V. K. Quy *et al.*, "IoT-Enabled Smart Agriculture: Architecture, Applications, and Challenges," *Appl. Sci.*, vol. 12, no. 7, 2022, doi: 10.3390/app12073396.

[26] S. Islam, S. Jamwal, M. H. Mir, and Q. R. Khan, "IoT-Smart Agriculture: Comparative Study on Farming Applications and Disease Prediction of Apple Crop using Machine Learning," *Iraqi J. Sci.*, vol. 63, no. 12, pp. 5520–5533, 2022, doi: 10.24996/ijs.2022.63.12.37.

[27] M. Dhanaraju, P. Chenniappan, K. Ramalingam, S. Pazhanivelan, and R. Kaliaperumal, "Smart Farming: Internet of

Things (IoT)-Based Sustainable Agriculture," *Agric.*, vol. 12, no. 10, pp. 1–26, 2022, doi: 10.3390/agriculture12101745.
[28] C. Bulut and P. F. Wu, "More than two decades of research on IoT in agriculture: a systematic literature review," *Internet Res.*, no. June, 2023, doi: 10.1108/INTR-07-2022-0559.
[29] T. Satish, T. Bhavani, and S. Begum, "Agriculture Productivity Enhancement System using IOT," *Int. J. Theor. Appl. Mech.*, vol. 12, no. 3, pp. 543–554, 2017, [Online]. Available: http://www.ripublication.com