AGRICULTURAL POWER JOURNAL (APJ)

Vol. 1 No. 4 (2024) 19 – 27 | ISSN: 3062 - 8563 (Media Online)

Study on the Utilisation of Internet of Things (IoT) Technology in Modern Agriculture Management

Sri Nofriyanti [1]*, Aulia Sri Hipma[2]

[1-2] Universitas Andalas

* Correspondence: srinovriyanti88@gmail.com

ABSTRACT

Internet of Things (IoT) technology has emerged as a potential solution to solve various problems in modern agriculture. This study uses a quantitative-descriptive approach with the aim of describing the application of IoT technology in agricultural management and identifying factors that influence its successful implementation. This approach is also complemented by a qualitative study to explore farmers' and experts' insights on the challenges and benefits of implementing IoS in the agricultural sector. The results show that the majority of informants have positive perceptions of the benefits of the application, especially in the form of improved water and fertiliser use efficiency, increased crop yields, and labour and time savings. The majority of farmers with a good understanding of the technology have a positive perception of its benefits, with 15 and 20 farmers rating it as very useful, respectively. However, there are major obstacles, namely the need for adequate infrastructure, training for farmers, and subsidising implementation costs. Theories of technological efficiency, technology adoption, and resource management support these findings, which suggest that successful implementation depends on infrastructure readiness as well as access and support for farmers.

Article Information

Received: November 9, 2024
Revised: November 24, 2024
Online: November 30, 2024

Keywords: *IoT Usage, Modern Farm Management, Farmer Understanding, IoT Technology Types*

1. Introduction

Modern agriculture today faces many challenges in meeting the growing global food demand. With population growth and climate change affecting agricultural conditions, more efficient and sustainable strategies are needed to support the agricultural sector (Aldo, 2023; Sari, 2023). Internet of Things (IoT) technology has emerged as a potential solution to solve various problems in modern agriculture. IoT allows various devices to be interconnected and share data in real-time, giving farmers faster and more accurate access to manage their land (Alahmad et al., 2023). Applications of this technology include monitoring crop, climate, and soil conditions, and using the data for resource optimisation (Nurhidayati, 2023; Sari, 2024).

IoT can overcome some of the major obstacles faced in traditional agriculture. Using sensors and smart devices, IoT enables automatic monitoring of soil moisture, air temperature, light levels, and the presence of pests (Aziz, 2022). Thus, farmers can make more targeted decisions, especially in the use of water, fertilisers, and pesticides. This not only saves operational costs but also maintains environmental quality by reducing waste and unnecessary chemical use. This technology promises to make a significant difference in the agricultural sector, especially in the face of an uncertain climate and increasing risk of crop failure.

The use of IoT in agriculture has been shown to increase production yields. Studies in several developed countries show that crop yields can increase by up to 25%, while operational costs are reduced by about 30% through the application of IoT technology (Arvis, 2024). For example, soil moisture sensors can transmit data directly to farmers' devices, enabling timely irrigation and significantly reducing water requirements. In addition, this technology enables more in-depth monitoring of crop growth phases, which helps farmers recognise signs of disease or nutrient deficiencies earlier (Sulistyo et al., 2023).

Modern agriculture today faces many challenges in meeting the growing global food demand. With population growth and climate change affecting agricultural conditions, more efficient and sustainable strategies are needed to support the agricultural sector (Aldo, 2023; Sari, 2023). Internet of Things (IoT) technology has emerged as a potential solution to solve various problems in modern agriculture. IoT allows various devices to be interconnected and share data in real-time, giving farmers faster and more accurate access to manage their land (Alahmad et al., 2023). Applications of this technology include monitoring crop, climate, and soil conditions, and using the data for resource optimisation (Nurhidayati, 2023; Sari, 2024).

IoT can overcome some of the major obstacles faced in traditional agriculture. Using sensors and smart devices, IoT enables automatic monitoring of soil moisture, air temperature, light levels, and the presence of pests (Aziz, 2022). Thus, farmers can make more targeted decisions, especially in the use of water, fertilisers, and pesticides. This not only saves operational costs but also maintains environmental quality by reducing waste and unnecessary chemical use. This technology promises to make a significant difference in the agricultural sector, especially in the face of an uncertain climate and increasing risk of crop failure.

The use of IoT in agriculture has been shown to increase production yields. Studies in several developed countries show that crop yields can increase by up to 25%, while operational costs are reduced by about 30% through the application of IoT technology (Arvis, 2024). For example, soil moisture sensors can transmit data directly to farmers' devices, enabling timely irrigation and significantly reducing water requirements. In addition, this technology enables more in-depth monitoring of crop growth phases, which helps farmers recognise signs of disease or nutrient deficiencies earlier (Sulistyo et al., 2023).

2. Materials and Method

This study uses a quantitative-descriptive approach with the aim of describing the application of IoT technology in agricultural management and identifying factors that influence its successful implementation. This approach is also complemented by a qualitative study to explore farmers' and experts' insights on the challenges and benefits of implementing IoT in the agricultural sector. This is a field survey research that combines survey analysis with in-depth interviews. The survey aims to collect quantitative data from respondents who use or are interested in using IoT technology in agriculture. Meanwhile, in-depth interviews were conducted with several farmers, agricultural practitioners, and agricultural technology experts to obtain more in-depth qualitative data.

The population in this study were farmers, landowners, and managers of modern agricultural land located in the agricultural area of Agam Regency. The sample was taken using purposive sampling technique with the criteria of farmers who have or are trying to apply IoT technology in their farm management. The sample size taken was at least 100 respondents for the survey, as well as 5-10 key informants for in-depth interviews.

The research instruments used in this study were questionnaires and interview guides, and the data collection procedures were quantitative surveys and in-depth interviews. The data analysis technique is quantitative analysis where the research results are processed using statistical software such as SPSS and Microsoft Excel and qualitative research data in the form of interview results are analysed using the content analysis method to find the main relevant themes, such as implementation experience, perceptions of benefits and obstacles, and IoT adoption strategies that are considered the most effective.

In this research, there are several stages, namely the preparation stage, data collection and analysis of report preparation which is compiled in the form of a final report that includes conclusions, suggestions and recommendations regarding the application of IoT in the agricultural sector.

3. Result

The following is a descriptive analysis table for research on the utilisation of IoT technology in modern agricultural management in Indonesia, followed by relevant data interpretation.

Table 1. Descriptive Analysis of IoT Technology Utilisation in Modern Agricultural Management

Variable	Category	f	Percentage
Farmers' understanding of IoT	Very good	20	20%
	Good	35	35%
	Fair	25	25%
	Deficient	20	20%
	Soil Moisture Sensor	40	40%

Type of IoT Technology Used	Automatic Irrigation System	30	30%
	Weather Monitoring	20	20%
	Drones for Fertilisation	10	10%
Level of Use of IoT in Activities	Every Day	15	15%
	3-5 Times a Week	45	45%
	1-2 Times a Week	30	30%
	Rarely	10	10%
Farmers' Perception of the Benefits of IoT	Very Helpful	50	50%
	Helpful	30	30%
	Moderately Helpful	15	15%
	Not Helpful	5	5%
Constraints in IoT Implementation	Cost	40	40%
	Limited Knowledge	30	30%
	Limited Infrastructure	20	20%
	Other	10	10%

1. Farmers' Understanding of IoT: Most farmers have a good or fair understanding of IoT (35% and 25% respectively), which indicates that their knowledge of this technology is quite good. However, there are still 20% of farmers with less understanding, so there is a need to improve technological literacy among farmers.
2. Type of IoT Technology Used: Soil moisture sensors are the most commonly used type of IoT technology (40%), followed by automatic irrigation systems (30%). This indicates a focus on monitoring soil and irrigation conditions, which is relevant for water use efficiency and crop growth.
3. Level of IoT Use in Activities: The majority of farmers use IoT several times a week (45% use 3-5 times a week and 30% use 1-2 times a week). This indicates moderate adoption, with only 15% using every day. Technology availability and specific needs may influence the frequency of use.
4. Farmers' Perception of IoT Benefits: Positive perceptions of IoT benefits are high, with 50% of farmers finding the technology very useful, and 30% finding it useful. This reflects the positive impact of IoT on agricultural productivity and resource efficiency.
5. Constraints to IoT Implementation: The main constraints faced by farmers are cost (40%) and limited knowledge (30%). Limited infrastructure is also a barrier, especially in areas that do not have adequate access to technology.

The following are the results of bivariate research based on the relationship between the variables of Farmers Understanding of IoT and Farmers' Perception of IoT Benefits. This bivariate analysis table shows whether there is a relationship between farmers' understanding of IoT and their perception of the benefits of the technology.

Tabel 2. Bivariate Analysis of the Relationship between Farmers' Understanding of IoT and Perception of IoT Benefits

Farmers' Understanding of IoT	Very Helpful	Helpful	Quite Helpful	Not Helpful	Total
Very good	15	4	1	0	20
Good	20	10	5	0	35
Fair	10	10	5	0	25
Deficient	5	6	4	5	20
Total	50	30	15	5	100

1. Relationship between Understanding and Perceived Benefits:

   From the table above, it can be seen that farmers with a higher understanding of IoT ('Excellent' and 'Good' categories) tend to have a perception that IoT is very useful or useful. A total of 15 farmers with a very good understanding rated IoT as very useful, while only 5 farmers with a 'Poor' understanding considered IoT to be very useful.

   In contrast, most farmers with a 'Poor' understanding tend to have a lower perception of the usefulness of IoT, with 5 farmers rating IoT as not useful.
2. Positive Perception Tendency for Good Understanding:

   Farmers with 'Very Good' and 'Good' understanding mostly have positive perceptions of the benefits of IoT, with 15 and 20 farmers rating IoT as very useful, respectively. This suggests that good understanding has the potential to increase positive perceptions of technology.
3. Farmers with Less Understanding:

   Of the 20 farmers with less understanding, 5 rated IoT as not useful, and 6 rated the technology as only useful. This may indicate that low understanding tends to influence negative perceptions of the benefits of IoT.

Table 3. Interview Results with Key Informants

Informant	Experience in IoT	Implementation Benefits	Perceived Challenges Faced
Informant 1	Using soil moisture sensor for 2 years	Improving irrigation and production efficiency	High cost of equipment and limited knowledge

Informant 2	Utilising an automatic irrigation system	Water savings and increased crop yields	Limited network infrastructure in the field
Informant 3	Utilising weather monitoring	Reduced risk of crop failure due to weather	Maintenance and training costs required
Informant 4	Using drones for fertilisation	Time and labour savings in fertilisation	Limited technical skills in operation
Informant 5	Soil moisture and temperature sensors	Improved quality of agricultural produce	Limited access to after-sales service
Informant 6	Weather monitoring and automatic irrigation	Minimises fertiliser and water use	Cost constraints and difficult access to training
Informant 7	Irrigation automation system	Reduces manual labour burden	Lack of technical support in remote areas
Informant 8	Soil and temperature sensors	Helps to monitor soil conditions in more detail	High initial implementation costs
Informant 9	Using IoT to record crop yields	Simplify analysis of crop yields	Difficulty in learning software applications
Informant 10	Soil sensors and automated irrigation system	Increase crop yields and resource efficiency	Unstable network infrastructure constraints

1. Perceived Benefits: The majority of informants perceived significant benefits from the application of IoT technologies, especially in the form of improved water and fertiliser use efficiency, increased crop yields, and labour and time savings. Technologies such as soil moisture sensors and automatic irrigation systems help them in monitoring land conditions and adjusting resource use more appropriately.
2. Challenges Faced: Almost all informants faced cost constraints, mainly related to the initial investment and maintenance of the technology. Limited internet network infrastructure in agricultural areas is also a significant challenge affecting the effectiveness of IoT. Lack of technical knowledge and training in operating IoT devices adds to the difficulty for farmers in utilising this technology to its full potential.
3. Limited Technical Support and Infrastructure: Some informants revealed that they need stronger technical support and access to ongoing training to optimise the use of IoT. In addition, limited network infrastructure, especially in more remote areas, hinders the effectiveness of IoT technology.

Discussion

1. Benefits of IoT Technology for Farm Management

Based on the results of quantitative research and interviews, IoT technology provides tangible benefits in agricultural efficiency and productivity. This finding is in line with the theory of technological efficiency in modern agriculture, which states that IoT can increase the optimal use of resources, improve crop yields, and reduce waste through process automation and precise monitoring (Porter & Heppelmann, 2014). For example, soil moisture sensors and automated irrigation systems help farmers adjust water needs precisely, leading to cost and resource savings.

The researcher's assumption that IoT has the potential to increase agricultural productivity is evident in this study, where the majority of respondents reported increased efficiency and decreased costs. This shows that the implementation of IoT in agriculture can have a significant positive impact on farmers, especially in water management, irrigation, and weather monitoring.

2. Challenges in IoT Implementation in the Agriculture Sector

Despite the benefits of IoT in agriculture, this study reveals that there are major obstacles, namely investment costs, limited technical knowledge, and inadequate network infrastructure. Technology adoption theory suggests that initial costs and technological complexity can be major barriers in the adoption process of new technologies (Rogers, 2003). This is in line with the research results, where most informants mentioned cost and limited knowledge as significant barriers. This indicates that although IoT has great potential, widespread adoption among farmers in Indonesia requires external support, both in terms of financing and training.

The researcher's assumption that IoT still faces implementation barriers proved correct. Development of network infrastructure in rural areas, as well as improved access to technical training, is needed to maximise the potential of this technology.

3. Linkages with Agricultural Resource Management Theory

The application of IoT in agriculture draws on agricultural resource management theory, which emphasises the importance of managing natural resources efficiently to support sustainability. IoT allows farmers to make data-driven decisions, which helps manage land, water, and plant nutrients more efficiently (Wolfert et al., 2017). The results showed that farmers using soil moisture sensors and automated irrigation systems experienced increased productivity and decreased operational costs. This proves the relevance of this theory, that the utilisation of precise technology in agricultural resource management has the potential to create a more sustainable agricultural system.

The researcher's assumption that IoT can support more efficient resource management in agriculture was proven correct, where precise monitoring of soil moisture and weather conditions can help farmers take appropriate actions, thus optimising the resources used.

4. Perception and Adoption of IoT Technology

The results show that farmers' understanding of IoT correlates with positive perceptions of its benefits. Farmers with better understanding tend to perceive IoT as a useful technology, which is consistent with the theory of technology perception and adoption. According to this theory, the perceived usefulness of technology is often a key determinant in the adoption of new technology (Davis, 1989). This indicates that training and educating farmers on IoT technology will increase the adoption of this technology, as a better understanding leads to a more positive perception of its benefits.

4. Conclusions

Based on relevant research and theoretical support, IoT technology has great potential in improving efficiency, productivity, and resource management in Indonesia's agricultural sector. However, IoT implementation still faces challenges that require further attention, such as the need for adequate infrastructure, training for farmers, and subsidising implementation costs. Theories of technological efficiency, technology adoption, and resource management support these findings, which suggest that successful IoT implementation depends on infrastructure readiness as well as access and support for farmers. Comprehensive support for both technical and financial aspects will be crucial in strengthening the sustainable implementation of IoT in the agricultural sector.

References

Abay, U. (2023). *Bebegig IoT, Penerapan Smart Farming Mampu Hempaskan Hama pada Tanaman*. Swadayaonline.com. https://www.swadayaonline.com/artikel/13402/Bebegig-IoT-Penerapan-Smart-Farming-Mampu-Hempaskan-Hama-pada-Tanaman/

Alahmad, T., Nemenyi, M., & Nyeki, A. (2023). Applying IoT Sensors and Big Data to Improve Precision Crop Production: A Review. *Agronomy*, *13*(10), 2603–2603. https://doi.org/10.3390/agronomy13102603

Aldo, F. (2023, November 10). *10 Strategi Menuju Pertanian Berkelanjutan: Mencapai Keseimbangan Antara Ekonomi, Sosial, Lingkungan Halaman 1 - Kompasiana.com*. KOMPASIANA; Kompasiana.com. https://www.kompasiana.com/flavilius44423/654e13a445274b498f634093/10-strategi-menuju-pertanian-berkelanjutan-mencapai-keseimbangan-antara-ekonomi-sosial-lingkungan

Arvis. (2024, January 24). *IoT pada Sektor Pertanian, Seperti Apa Penerapannya*. Arvis. https://arvis.id/insight/penerapan-iot-pada-sektor-pertanian/

Aziz, A. (2022, February 5). *Monitoring Pertanian Pintar Berbasis IoT*. Sensor to Cloud and Industrial Internet of Things Platform. https://www.microthings.id/monitoring-pertanian-pintar-berbasis-iot/

Bouma, J. (2021). Soil science contributions towards sustainable development goals and their implementation: Linking soil functions with ecosystem services. Geoderma, 400, 115276.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340.

Habibi , B. Z. (2024, August 14). *Revolusi Pertanian dengan IoT Untuk Mengoptimalkan Produksi*. Enterprise Mobile App - IoT Developer Indonesia | Jasa Pembuatan Aplikasi Android - IOS Jakarta - We Are Impactful Enterprise Mobile Apps Developer Company. 200+ Success Project from 140+ Client. Jasa Pembuatan Aplikasi Mobile Android, IOS, IoT - Jakarta. https://crocodic.com/revolusi-pertanian-dengan-iot-untuk-mengoptimalkan-produksi/

Kamata, F. (2019, October 8). Tanpa lahan dan petani, Jepang merevolusi pertanian. *BBC News Indonesia*. https://www.bbc.com/indonesia/majalah-49956022

Nurhidayati, I. (2023, July 21). *Internet of Things (IoT) dan Penggunaannya dalam Bidang Pertanian*. Mertani. https://www.mertani.co.id/post/internet-of-things-iot-dan-penggunaannya-dalam-bidang-pertanian

Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. Harvard Business Review, 92(11), 64–88.

Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.

Rose, D. C., Chilvers, J., & Sutherland, W. J. (2021). Agriculture 4.0: Making it work for people, production, and the planet. Land Use Policy, 100, 104933.

Rose, D. C., Sutherland, W. J., & Parker, C. (2016). Decision support tools for agriculture: Towards effective design and delivery. Agricultural Systems, 149, 165-174.

Sari, M. (2023, December 2). *Pertanian Berkelanjutan: Strategi untuk Masa Depan yang Lebih Hijau*. Mertani; Mertani. https://www.mertani.co.id/id/post/pertanian-berkelanjutan-strategi-untuk-masa-depan-yang-lebih-hijau

Sari, R. P. (2024). *IoT dalam Bidang Pertanian untuk Smart Farming*. Cloud Computing Indonesia. https://www.cloudcomputing.id/pengetahuan-dasar/iot-dalam-bidang-pertanian

Sulistyo, G. B., Safitri, L. A., Kiswati, S., Adjie, B. K., & Fauzi, M. N. Z. (2023). Pemanfaatan Internet of Things (IOT) untuk Monitoring Tumbuh Kembang Tanaman Anggrek. *Penamas: Journal of Community Service*, *3*(2), 95–106. https://doi.org/10.53088/penamas.v3i2.762

Tsouros, D. C., Bibi, S., & Sarigiannidis, P. G. (2019). A review on UAV-based applications for precision agriculture. Information, 10(11), 349.

Wijayanto, Y., Purnamasari, I., Ristiana, S., Tri, W., Saputra, D., Arthur, F., & Regar. (2022). *"Digitalisasi Pertanian Menuju Kebangkitan Ekonomi Kreatif" [Perkembangan Penggunaan Big Data pada Bidang Pertanian di Indonesia] : Review*. *6*(1), 312. https://repository.unej.ac.id/jspui/bitstream/123456789/114460/1/Perkembangan%20Penggunaan%20Big%20Data%20pada%20Bidang%20Pertanian%20di%20Indonesia.pdf

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–A review. Agricultural Systems, 153, 69-80.

Zulva, S. (2023, July 3). *Pemanfaatan IoT dalam Pertanian Pintar untuk Optimalisasi Produksi Tanaman*. Hipwee; https://www.hipwee.com/.

https://www.hipwee.com/narasi/pemanfaatan-iot-dalam-pertanian-pintar-untuk-optimalisasi-produksi-tanaman/