THE AGBIZ TODAY *E-Magazine*, Vol. -2 Issue-2, April 2025: 032 -041
ISSN: 3049-2491 (Online)
Pathania1et al.
https://sabm.scholics.in/

A Review of IoT and Machine Learning in Precision Agriculture: Towards Sustainable Smart Farming

Nutan Pathania[1], Sanjeev Khan[2] and Pawan Kumar[3]*

[1*,3-]Department of Computer Science, Himachal Pradesh University, Shimla

[2-]Department of Data Science and Artificial Intelligence, Himachal Pradesh University, Shimla

***Correspondence Author Email :** pathaniatanu3@gmail.com

ABSTRACT

Precision agriculture represents the modern farming methodology that seeks to enhance productivity, efficiently use resources, and ensure sustainability. The tandem working of IoT with machine learning further revolutionizes the entire field of precision agriculture, enabling real-time monitoring, data-based decision-making, and predictive analytics. This review investigates IoT and ML applications in precision agriculture with specific changes in technology, applications, benefits, and challenges. The IoT integrates smart farming by deploying networked sensing nodes, drones, and automated machinery to collect and dispatch agricultural data. In contrast, machine learning software sifts through copious amounts of those data to provide insights, forecasts, diagnoses diseases, and recommends optimization of irrigation and fertilization. By lowering waste, increasing efficiency, and eventually lessening their impact on the environment, these technologies support sustainable farming practices. Despite the enormous progress, issues with data privacy, implementation costs, and the requirement for a robust ICT infrastructure in rural areas remain. Additionally, this study highlights current research trends, real-world applications, and potential future directions for IoT and ML integration in precision agriculture. Improving smart farming involves overcoming existing inefficiencies and implementing new technologies like edge computing, blockchain, and 5G connectivity. In light of the most recent developments and challenges, this paper seeks to provide useful insights to the policymaker, the farmer, and to researchers in furtherance of the cause of sustainable precision agriculture.

Keywords: *Precision Agriculture, IoT, Machine Learning, Smart Farming, Sustainable*

1. Introduction

1.1 Background and Significance

The agricultural sector is undergoing a technological revolution. Traditional methods of farming, mostly labour-intensive and experience-based, are no longer sufficient to address the challenges of climate change, resource limitation, and food security. The advent of digital technology modes, such as the Internet of Things (IoT) and Machine Learning (ML), made it conducive for precision agriculture to come into play. In general, digital technology provides real-time monitoring, decisions based on data analytics for intervention, and automation that enhances productivity and sustainability (Navarro et al., 2020). Precision agriculture rises to increase productivity through optimizing agricultural practice while reducing resource wastage, diminishing the impact of agriculture on the environment, and providing higher agricultural yields. IoT aids in smart farming, thus allowing soil conditions, the weather forecast, and crop health to be monitored and reported in real-time through sensor networks connected to UAVs. This huge chain of data is mined with machine learning algorithms to drive prediction, automate irrigation and fertilization purposes, and help manage disease attack in its initial phases. These advances improve efficiency and sustain agriculture as the market grows (Almalki et al., 2021) (Soussi et al., 2024). Rapid population growth and the impacts of climate change push traditional agricultural techniques towards efficient and sustainable practices. Smart farming exploits IoT sensors, volunteer devices, and mobile applications for real-time monitoring and decision-making in crop management, soil management, irrigation, disease detection, and yield prediction(Navarro et al., 2020). This paper examines the cutting-edge developments of IoT and ML for precision agriculture and their role in sustainable farming.

1.2 Importance of the Integration between Agriculture, IoT, and ML

Advanced practices might be incorporated with IoT, ML, and agriculture for the solution of challenges such as climate change, optimization of natural resources, and food security(Ayoub Shaikh et al., 2022a). Traditional modes of agricultural practices heavily depend on farm labor along with the subjective agricultural management practices leading to incorrect input allocation and yield estimation(Ronaghi & Forouharfar, 2020).With this alignment of IoT and ML, precision agriculture aggregates real-time data, predictive analytics, and thus automates decision-making:

- **Productivity:** IoT monitoring systems provide real-time data on soil conditions, temperature, and humidity that help farmers optimize irrigation, fertilization, and crop management (Alwis et al., 2022).
- **Maximum Resource Efficiency:** Millisecond algorithms handle a vast data set and give advice on water and fertilizer application in a way that prevents wastage and encourages sustainable resource utilization(Akhter & Sofi, 2022).
- **Pre-emptive Pest and Disease Detection:** Sensor-based crop monitoring utilizing AI image recognition-based techniques pre-emptively detects plant diseases and pest infestations prior to loss of yield(Kok et al., 2021).
- **Climate Adaptability:** AI technology handles climate data in such a way that farmers can take the best decisions possible regarding planting and harvesting periods with reduced risks of uncertain weather(Ayoub Shaikh et al., 2022a).
- **Farm Automation:** Planting, harvesting, and spraying pesticides are being done with the help of robotics and drones powered by AI that leads to massive reduction of human labor and immediate efficiency(Torky & Hassanein, 2020)
- **Transparency in the Supply Chain:** Blockchain and IoT will ensure traceability in food safety and reduce cases of fraud in the chain (Torky & Hassanein, 2020).

It warns that farmers' transition to IoT and ML will bring an age of data-based decision-making as far as nourishing the world with guaranteed yields, costless agriculture, and environmental conservation(Zhang et al., 2021).

2. Literature Review

In recent years, studies on the integration of IoT and ML in precision agriculture have been highly in consideration because of the potential to enable efficiency, sustainability, and productivity. The following section discusses the brief description of relevant progress for local areas.

2.1 Precision Agriculture through IoT

Operational, data-driven decision-making and real-time monitoring IoT-based systems were at the core of precision agriculture adoption. Edge computing, wireless sensor networks (WSNs), and unmanned aerial vehicles (UAVs) are the primary elements of smart farming (Almalki et al., 2021; Navarro et al., 2020)

Examples of applications of IoT are:

- Irrigation systems that use less water and react to soil moisture (Soussi et al., 2024).
- Real-time monitoring of climatic and soil conditions through remote sensing technology (Wang et al., 2024).
- Detection of productivity and animal well-being(Demestichas et al., 2020).

2.2 Machine Learning in Precision Agriculture

Machine learning algorithms serve to inform decisions in agriculture by predictive modeling and the automation of sophisticated datasets. In recent studies, some of the machine learning applications were demonstrated such as:

- Crop yield prediction with the use of Support Vector Machines (SVM) and Random Forest models(Condran et al., 2022).

- Disease and pest detection using Convolutional Neural Networks (CNNs) and deep learning(Sharma et al., 2021).

- Resource allocation optimization, for instance, Reinforcement Learning techniques(Demestichas et al., 2020).

Other than these applications, ML models are also being applied to an ever-growing extent for soil condition monitoring, detection of weeds, and precision fertilizing. Predictive analytics models driven by AI enable decision-making on planting at the right time, crop rotation, and sustainable soil practices (Gupta et al., 2020).

2.3 Overview of IoT and ML integration in Precision Agriculture

A smart agriculture method uses ML and IoT for creating decision support systems that include data gathering and smart analysis in real-time too. The key developments are

- Autonomous drones with the support of ML have been developed for monitoring crop health, nutrient deficiency, and intervention areas(Soussi et al., 2024).
- IoT sensors and AI in smart greenhouses for self-management of climate and irrigation and pest control(Soussi et al., 2024).
- Blockchain precision agriculture systems offer data security and traceability in the agricultural supply chain(Alwis et al., 2022).

3. Research Objectives

The overall research goals are:

• To examine the application of IoT and ML for precision agriculture and their contribution towards contemporary farming.

• To critically discuss new developments in IoT and ML technologies to promote agricultural productivity, sustainability, and efficiency of resources.

• To consider actual case studies showing practical application of IoT and ML to agriculture.

• To understand the principal challenges and potential opportunities of IoT and ML in precision agriculture.

3.2 Scope of Work

This work covers:

- Infra-depth explanations of IoT technologies such as smart sensors, UAVs, and edge computing, and why they are suitable for precision agriculture.
- •ML methodologies for use in agricultural decision support, including but not limited to deep learning, reinforcement learning, and predictive modelling.
- Case studies to elucidate the pros and cons of real-time IoT and ML deployments in practice.
- An overview of constraints and possibilities for future research toward addressing security, cost, and access challenges in smart agriculture.

4. IoT and ML in Precision Agriculture

4.1 Comparison between Conventional and Present Technology

A major increase in efficiency and productivity in agriculture is attributed to the transition from conventional practices to precision agriculture through IoT and ML. The following comparison shows some of the main features of the conventional and the current technologies in agriculture.

4.2 Key Precision Agriculture Technologies

Some of the most important technologies that help provide IoT and ML deployment in precision agriculture are:

- **Wireless Sensors Network:** The network can be deployed over fields, which will gather data such as soil moisture, temperature, humidity, and nutrients, allowing real-time monitoring and management of irrigation systems. The networks prevent water loss and enhance crop production by providing farmers with precise, data-driven information (Akhter & Sofi, 2022).
- **Unmanned Aerial Vehicles (UAVs):** Equipped with remote sensing technology, UAVs collect high-resolution images for crop health monitoring, disease detection, and yield estimation. Multispectral and hyperspectral imaging add strength to the potential for vegetation health analysis and the early detection of stress factors (Ayoub Shaikh et al., 2022a).
- **Edge and Cloud Computing:** This allows real-time data analysis, storage, and processing by farmers so they can make decisions instantaneously based on real-time scenarios. The Edge reduces time blockage on information transit and enables farmers to respond in time with respect to any variation in climate and crop conditions, while the Cloud supplies data security and scaling abilities (Akhter & Sofi, 2022).
- **Artificial Intelligence (AI) and Machine Learning (ML):** AI and ML are employed for predictive analytics, anomaly detection, and machine-driven decision-making that help farmers maximize yield and resource utilization. ML models improve the prediction so that farmers can anticipate disease outbreaks, weather, and optimum harvesting times (Ayoub Shaikh et al., 2022a).
- **Blockchain Technology:** Ensures secure and transparent transactions in agricultural supply chains by providing an immutable record of farming data, improving traceability and reducing fraud. It also enhances food safety by tracking produce from farm to consumer, ensuring authenticity and quality (Torky & Hassanein, 2020)

Table 1 below gives a brief comparison between Conventional and Present Technology.

Table 1: Comparison between the Traditional and Current Technology

Aspect	Traditional Technology	Current Technology	References
Data Collection	Manual record-keeping and observations	Sensors of Internet of Things for direct surveillance	(Alwis et al., 2022; Gaikwad et al., 2021)
Decision Making	Historical trends and farmer experience	Predictive analytics with use of Artificial Intelligence and Machine Learning technique	(Ayoub Shaikh et al., 2022a; Akhter & Sofi, 2022)
Resource Management	Generalized application of fertilizers, water, and pesticides	Precision agriculture utilising Internet of Things and big data analysis	(Torky & Hassanein, 2020; Kok et al., 2021)
Livestock Farming	Manual monitoring of livestock feeding and health	Health and activity monitoring with Internet of Things wearable devices	(Zhang et al., 2021)
Supply Chain	Paper-based tracking of farm products	Immutable and transparent tracking powered by blockchain	(Torky & Hassanein, 2020)
Irrigation Systems	Fixed irrigation times	Smart irrigation systems	(Gamal et al., 2023; Ragab et al., 2022)
Pest and Disease Control	Reactive strategy with general pesticides	AI detection and treatment of diseases	(Ayoub Shaikh et al., 2022b)
Sustainability & Environmental Impact	High wastage of resources and environmental footprint	Resource optimization and low environmental footprint.	(Ronaghi & Forouharfar, 2020; Akhter & Sofi, 2022)

- **Automated Irrigation Systems:** Uses IoT sensors to optimize water usage, reduce wastage, and enhance efficiency by adjusting irrigation schedules based on real-time soil conditions. Smart irrigation reduces dependency on manual interventions and ensures plants receive adequate hydration without overuse of resources (Akhter & Sofi, 2022).
- **Robotic Farming:** AI-powered robots perform planting, weeding, harvesting, and sorting tasks, reducing human labour dependency and increasing precision in agricultural operations. Robotics also contribute to efficiency by operating 24/7 and performing repetitive tasks with high accuracy(Ayoub Shaikh et al., 2022a).
- **Geographic Information Systems (GIS):** Utilized for spatial analysis and mapping of farmlands, assisting in precision farming by integrating multiple data sources for better land use planning. GIS helps in soil fertility assessment, pest infestation tracking, and optimizing land resources (Ragab et al., 2022)
- **Hyperspectral Imaging and Remote Sensing:** Helps in detecting nutrient deficiencies, soil properties, and plant stress factors, allowing timely intervention for crop management. These imaging techniques enable precision agriculture by providing insights into soil conditions and plant health beyond what is visible to the naked eye (Ayoub Shaikh et al., 2022a)
- **Internet of Things (IoT) Platforms:** Integrated with various agricultural tools and machinery, enabling seamless connectivity between sensors, drones, robots, and farm management systems for automated decision-making. IoT-based predictive maintenance systems also help in monitoring the condition of farm equipment and reducing downtime (Akhter & Sofi, 2022).
- **Smart Greenhouse Systems:** Automated greenhouse systems leverage IoT and AI to regulate temperature, humidity, and lighting conditions to optimize plant growth. These systems enhance year-round crop production by maintaining optimal growth conditions regardless of external weather conditions (Gamal et al., 2023)
- **Autonomous Vehicles and Tractors:** AI-driven tractors and farm vehicles equipped with GPS and sensor technology improve efficiency in planting, ploughing, and harvesting operations. Autonomous tractors reduce human labour costs and improve accuracy in field operations (Ronaghi & Forouharfar, 2020).

5. Ethical Considerations

This study has adhered to ethical research by making use of publicly available data and proper citation of sources. No personal or sensitive data were used in this research. With the gradual establishment of PA within the spheres of IoT and ML, essential ethical considerations such as data privacy and protection, along with responsible AI usefulness, arise. Most ought to guarantee data integrity, secure sensitive information from farmers, and guarantee transparency of decision-making guided by algorithms (Akhter & Sofi, 2022). In another dimension, ethical AI usage in PA can address biased ML models, recommending pragmatically to ensure justice or fairness while hindering unintended discrimination against gambled farming communities (Ayoub Shaikh et al., 2022a). Data security is still a concern since cyber-attacks targeting IoT devices in smart farming could impact critical Agri-activities. Researchers state that further insistence is provided for processing data encryption advantages and blockchain solutions as aids to enhancing data security and tracking (Torky & Hassanein, 2020), accountability in automated decision-making is mammoth. The farmer should be able to see comprehensible insights from AI models, not black-box solutions. Explain ability mechanisms must be a part of any ethical AI frameworks so that decisions made by predictive models can be interpreted and acted upon by farmers (Ronaghi & Forouharfar, 2020).This review surveys the recent research conducted into IoT and ML's applications in PA, conducting case studies on diversified methodologies and implementations. Studies were chosen with a criterion irrelevant of win location, novelty, or contribution to smart farming (Sharma et al., 2021; Wang et al., 2024). Future research must put emphasis on framing guidelines for ethical AI-aided agriculture focused on fairness and sustainability in farming.

6. Challenges

The IoT and ML for Precision Agriculture Encounter Many Valuable Challenges. Although the mixture of IoT and ML gathers some considerable interest via adoption in precision agriculture, many aspects hold it back from permeating into all possible fields. Firstly, one of the most considerable barriers appears to be that the IoT and ML technologies are expensive to deploy. The massively capital-intensive expense to deploy IoT sensors, AI-propelled machinery, and predictive models is enormous, in which could be exceedingly difficult for a small- or medium-scale farmer to adopt. Also, this kind of(Javaid et al., 2022) technological operation is generally complex, requiring some specialized knowledge and technical expertise that traditional farmers do not always possess (Boursianis et al., 2022). With dependence on connected smart farming systems growing, the biggest threat is posed to data security and privacy. Agricultural operations and supply chain data are under threat from cyber incidents, unauthorized access, and even misuse. Therefore, cybersecurity measures such as data encryption and secure cloud storage for maintaining the integrity of their farming operations are crucial (Gupta et al., 2020). Many cyber incidents work to disrupt certain IoT-based infrastructures in agriculture, other than which are food security at the same risk (Demestichas et al., 2020). When IoT and ML converge into agriculture, scalability becomes another problem in question. The efficiency of the technologies would vary with the geographical, climatic, and soil conditions. What works for a farm in some region might not yield any good in another, and thus should be intense solutions of custom and adaptive nature(Terence & Purushothaman, 2020). The custom nature and brainless, concealability poses a baffling task for both developers and farmers. Furthermore, typically the models based on ML are very often black-box, rendering it very hard for farmers to understand the recommendations based on them. Hence, boosting XAI is very important in establishing trust so that farmers know how such decisions were arrived at based on AI (Condran et al., 2022). The other big issue has been the poor internet connection in remote agricultural zones. A bunch of farm activities have been conducted in such places with very poor digital

7. Future Directions

Advancing technology in IoT and ML in the agricultural sector towards the future will aim to eliminate these problems while enhancing efficiency, sustainability, and accessibility. One important focus will be to create tailored, cost-effective, and scalable solutions for all types of farming environments, enabling small-to-medium-scale farmers to also benefit from these innovations (Terence & Purushothaman, 2020)More attention should be devoted to improving cybersecurity that could stand between agricultural sensitive data and the risks posed by increasing cyber nuisances. Enhanced internet connectivity, particularly rural areas, via satelliteinternet and long-range wireless networks (LoRaWAN), will enable real-time monitoring and decision-making even in remote locations (Gupta et al., 2020)As XAI develops, ML models will be even more transparent, which will boost trust and therefore farmer uptake (Condran et al., 2022)This, when combined with blockchain technology, will therefore enhance the value chain of precision agriculture with traceability and security attributes to guarantee food safeties while averting fraudulent activities(Torky & Hassanein, 2020). Machined IoT and advanced robotics and automated systems will collaborate to streamline farm operations while reducing labour costs and increasing productivity. Implementing AI-powered drones and automated harvesting systems will thus allocate resources more optimally while acting to minimize human inputs (Boursianis et al., 2022). Finally, the cooperation brought about between researchers, policymakers, and any other related agricultural stakeholders will be paramount to put in place good frameworks for both the ethical and practical deployment of these technologies (Ayoub Shaikh et al., 2022a). By addressing these focus areas, the IoT and ML would contribute tremendously in granting modern agriculture a sneak look into that safer, protective future.

8. Conclusion

Through integrating IoT and machine learning with precision farming, productivity, efficiency, and sustainability in agriculture have been greatly improved. Through real-time data collection, AI-driven analytics, and automization, farmers have enough capacity to base their decisions on data, which will elevate the batch of resource utilization along with yield quality (Condran et al., 2022)Since the technology of Agriculture 4.0, which covers IoT, AI, and smart agriculture systems, is there in the field, most challenges such as but not limited to high-cost issues, selling or compromising of data security issues and further still non-scalable aspects are obsolete (Ragab et al., 2022)

Overcoming these challenges with affordable solutions, enhanced connectivity, and accessible AI models will be key to mass adoption. Future advancements must also address cybersecurity, incorporating blockchain for supply chain visibility, and using robotics for automation(Demestichas et al., 2020).

The future of precision agriculture is in leveraging these innovations to achieve higher levels of food security, environmental stewardship, and farm productivity on a global basis. By developing interdisciplinary partnerships between researchers, policymakers, and business executives, precision agriculture has the capacity to convert conventional farming into a smarter, more efficient, and more resilient system (Ayoub Shaikh et al., 2022a)

9. References

- Akhter, R., & Sofi, S. A. (2022). Precision agriculture using IoT data analytics and machine learning. *Journal of King Saud University - Computer and Information Sciences*, *34*(8), 5602–5618. https://doi.org/10.1016/j.jksuci.2021.05.013
- Almalki, F. A., Soufiene, B. O., Alsamhi, S. H., & Sakli, H. (2021). A Low-Cost Platform for Environmental Smart Farming Monitoring System Based on IoT and UAVs. *Sustainability*, *13*(11), 5908. https://doi.org/10.3390/su13115908
- Alwis, S. D., Hou, Z., Zhang, Y., Na, M. H., Ofoghi, B., & Sajjanhar, A. (2022). A survey on smart farming data, applications and techniques. *Computers in Industry*, *138*, 103624.

https://doi.org/10.1016/j.compind.2022.103624

- Ayoub Shaikh, T., Rasool, T., & Rasheed Lone, F. (2022a). Towards leveraging the role of machine learning and artificial intelligence in precision agriculture and smart farming. *Computers and Electronics in Agriculture*, *198*, 107119. https://doi.org/10.1016/j.compag.2022.107119

- Ayoub Shaikh, T., Rasool, T., & Rasheed Lone, F. (2022b). Towards leveraging the role of machine learning and artificial intelligence in precision agriculture and smart farming. *Computers and Electronics in Agriculture*, *198*, 107119. https://doi.org/10.1016/j.compag.2022.107119

- Boursianis, A. D., Papadopoulou, M. S., Diamantoulakis, P., Liopa-Tsakalidi, A., Barouchas, P., Salahas, G., Karagiannidis, G., Wan, S., & Goudos, S. K. (2022). Internet of Things (IoT) and Agricultural Unmanned Aerial Vehicles (UAVs) in smart farming: A comprehensive review. *Internet of Things*, *18*, 100187. https://doi.org/10.1016/j.iot.2020.100187

- Condran, S., Bewong, M., Islam, M. Z., Maphosa, L., & Zheng, L. (2022). Machine Learning in Precision Agriculture: A Survey on Trends, Applications and Evaluations Over Two Decades. *IEEE Access*, *10*, 73786–73803. https://doi.org/10.1109/ACCESS.2022.3188649

- Demestichas, K., Peppes, N., & Alexakis, T. (2020). Survey on Security Threats in Agricultural IoT and Smart Farming. *Sensors*, *20*(22), 6458. https://doi.org/10.3390/s20226458

- Gaikwad, S. V., Vibhute, A. D., Kale, K. V., & Mehrotra, S. C. (2021). An innovative IoT based system for precision farming. *Computers and Electronics in Agriculture*, *187*, 106291. https://doi.org/10.1016/j.compag.2021.106291

- Gamal, Y., Soltan, A., Said, L. A., Madian, A. H., & Radwan, A. G. (2023). Smart Irrigation Systems: Overview. *IEEE Access*, 1–1. IEEE Access. https://doi.org/10.1109/ACCESS.2023.3251655

- Gupta, M., Abdelsalam, M., Khorsandroo, S., & Mittal, S. (2020). Security and Privacy in Smart Farming: Challenges and Opportunities. *IEEE Access*, *8*, 34564–34584. https://doi.org/10.1109/ACCESS.2020.2975142

- Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2022). Enhancing smart farming through the applications of Agriculture 4.0 technologies. *International Journal of Intelligent Networks*, *3*, 150–164. https://doi.org/10.1016/j.ijin.2022.09.004

- Kok, Z. H., Mohamed Shariff, A. R., Alfatni, M. S. M., & Khairunniza-Bejo, S. (2021). Support Vector Machine in Precision Agriculture: A review. *Computers and Electronics in Agriculture*, *191*, 106546. https://doi.org/10.1016/j.compag.2021.106546

- Navarro, E., Costa, N., & Pereira, A. (2020). A Systematic Review of IoT Solutions for Smart Farming. *Sensors*, *20*(15), 4231. https://doi.org/10.3390/s20154231

- Ragab, M. A., Badreldeen, M. M., Sedhom, A., & Mamdouh, W. M. (2022). IOT based Smart Irrigation System. *International Journal of Industry and*

Sustainable Development, *3*(1), 76–86. https://doi.org/10.21608/ijisd.2022.148007.1021

- Ronaghi, M. H., & Forouharfar, A. (2020). A contextualized study of the usage of the Internet of things (IoTs) in smart farming in a typical Middle Eastern country within the context of Unified Theory of Acceptance and Use of Technology model (UTAUT). *Technology in Society*, *63*, 101415. https://doi.org/10.1016/j.techsoc.2020.101415
- Sharma, A., Jain, A., Gupta, P., & Chowdary, V. (2021). Machine Learning Applications for Precision Agriculture: A Comprehensive Review. *IEEE Access*, *9*, 4843–4873. https://doi.org/10.1109/ACCESS.2020.3048415
- Soussi, A., Zero, E., Sacile, R., Trinchero, D., & Fossa, M. (2024). Smart Sensors and Smart Data for Precision Agriculture: A Review. *Sensors*, *24*(8), 2647. https://doi.org/10.3390/s24082647
- Terence, S., & Purushothaman, G. (2020). Systematic review of Internet of Things in smart farming. *Transactions on Emerging Telecommunications Technologies*, *31*(6), e3958. https://doi.org/10.1002/ett.3958
- Torky, M., & Hassanein, A. E. (2020). Integrating blockchain and the internet of things in precision agriculture: Analysis, opportunities, and challenges. *Computers and Electronics in Agriculture*, *178*, 105476. https://doi.org/10.1016/j.compag.2020.105476
- Wang, J., Wang, Y., Li, G., & Qi, Z. (2024). Integration of Remote Sensing and Machine Learning for Precision Agriculture: A Comprehensive Perspective on Applications. *Agronomy*, *14*(9), 1975. https://doi.org/10.3390/agronomy14091975
- Zhang, M., Wang, X., Feng, H., Huang, Q., Xiao, X., & Zhang, X. (2021). Wearable Internet of Things enabled precision livestock farming in smart farms: A review of technical solutions for precise perception, biocompatibility, and sustainability monitoring. *Journal of Cleaner Production*, *312*, 127712. https://doi.org/10.1016/j.jclepro.2021.127712