

Smart Agriculture with Machine Learning and Internet of Things Techniques: Literature Review and Bibliometric Analysis

Karima El Majdouby¹ , Mohamed El Mohadab^{2,3} , Karim Abouelmehdi¹ 

¹ ELITES laboratory, Faculty of Sciences, University of Chouaib Doukkali, El Jadida, Morocco

² Laboratory of Information Processing and Decision Support, Higher School of Technology Beni Mellal, Sultan Moulay Slimane University, Beni Mellal, Morocco

³ Laboratory of Information Processing and Decision Support, Faculty of Sciences and Technology, Sultan Moulay Slimane University, Morocco

Abstract

A booming field known as "smart agriculture" has emerged because of the rapid revolution and transformation of agriculture. It makes use of cutting-edge agricultural technologies, like the internet of things and machine learning (ML) algorithms, to enhance farm management tasks, boost agricultural productivity, and lessen environmental impact by empowering farmers to react swiftly and efficiently to climate change. A key component of the shift to smart farming is the Internet of Things (IoT), which makes it easier for sensors and devices to connect and share data. It also gives farmers access to actionable information and knowledge, enabling them to make well-informed decisions using machine learning algorithms to enhance crop management and boost yields. Numerous tasks, including weed identification, fertilization requirement analysis, irrigation adjustment, and pest and soil management, are made possible by the automation made possible by these technologies. They allow farmers to make targeted interventions by continuously monitoring crop health, which lowers labor costs and the environmental impact. The effects of technological advancements, such as machine learning and the Internet of Things, on the agriculture industry are thoroughly examined in this paper. It draws attention to the useful applications of these instruments, which help farmers better, more automatically, and more precisely manage their resources and output..

Keywords

Smart agriculture, machine learning, internet of things, bibliometric.

El Majdouby, K., El Mohadab, M. and Abouelmehdi, K. (2026) "Smart Agriculture with Machine Learning and Internet of Things Techniques: Literature Review and Bibliometric Analysis", *AGRIS on-line Papers in Economics and Informatics*, Vol. 18, No. 3, pp. 3-16. ISSN 1804-1930. DOI 10.7160/aol.2026.180301.

Introduction

A major revolution has recently taken place in agriculture. Farmers have begun to implement some advanced agricultural techniques and technologies to optimize the efficiency of their daily tasks. They suggest innovative ways of integrating artificial intelligence (AI) and Internet of Things (IoT) into farming activities to stimulate growth and increase production yields (Kasera and Acharjee, 2024). The advent of digital technologies such as the Internet of Things (IoT) and Machine Learning (ML) is radically transforming human food production techniques, giving rise to what is known as smart farming.

The Internet of Things (IoT) is an important technology that offers efficient and reliable

solutions in a variety of agricultural practices, (IoT) plays a central role in smart farming by giving farmers the ability to effectively monitor and regulate their products in real-time and with remote management such as irrigation and crop and livestock health diagnostics using several sensors that can detect parameters such as soil NPK, humidity, nitrate, pH, electrical conductivity, temperature, CO₂, light, humidity, water level, weather station (Morchid et al., 2024). Intelligent agriculture uses technological advances that combine the Internet of Things (IoT) and machine learning (ML) to increase production, reduce waste and costs, and reduce the environmental footprint (Ribeiro Junior et al., 2022). Machine learning enables farmers to solve problems such as pests, optimize irrigation, and facilitate informed decisions

on crop selection and predictive modeling of future challenges.

Intelligent agriculture using the Internet of Things (IoT) and artificial intelligence techniques in the agricultural sector responds to many challenges, providing a better understanding of soil, crops, and climatic variations. System sensors help monitor and manage resources, while machine learning approaches based on this collected data facilitate crop prediction. This enables sustainable agriculture by guiding farmers towards the right crop for each season, guaranteeing a significant increase in production, while offering low-cost remote monitoring.

This paper proposes a systematic review and bibliometric analysis focusing on the use of artificial intelligence and the Internet of Things in the smart agriculture sector to deepen current knowledge. The rest of the document is structured into sections as follows: Section 2 discusses the definition of smart agriculture, Section 3 describes modern technologies integrated into the agricultural domain, such as the Internet of Things and machine learning, and then Section 4 presents preferred Internet of Things and machine learning applications in agricultural operations. Section 5 presents the methodology followed to select and analyze articles collected in various databases, then the sixth part deals with bibliometrics. Related work on agriculture is presented in Section 6, and a conclusion is offered in the final section. The structure of our paper, including all of the contributions, is shown in Figure 1.

Materials and methods

Machine learning

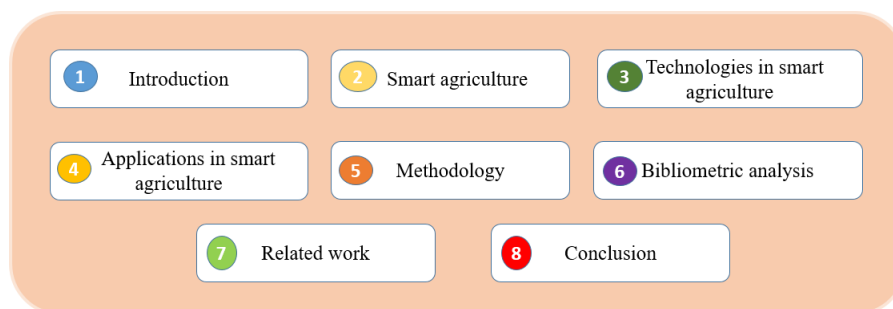
Artificial intelligence can be found in virtually every sector, from agriculture to healthcare. Machine learning is a branch of artificial

intelligence that involves training machines to a degree of autonomy that enables them to predict outcomes independently. In agriculture, a range of applications based on artificial intelligence are feasible, such as agricultural robots that surpass human performance in managing crop and soil monitoring, as well as climate change forecasting (Liakos et al., 2018). The fundamental principle of artificial intelligence in agriculture is flexibility, rapid efficiency, accuracy and cost-effectiveness. Artificial intelligence in the agricultural sector not only supports farmers in improving their farming skills, it also involves increasing their yield and ensuring quality while reducing costs. The application of artificial intelligence to wireless sensors boosts efficiency in a variety of sectors, while offering methods for the challenges faced by many branches of agriculture, such as harvesting, irrigation and soil sensitivity.

Artificial intelligence can identify plant diseases, pest invasions, and nutrient shortages on farms. In addition, AI-enabled sensors can monitor and manage agricultural indicators (Murugamani et al., 2022). ML applications are used in many fields, such as land management, crop health monitoring, disease detection, and weed infestation control (Abbasi et al., 2022).

ML is a data-driven method that develops a model capable of generalizing by learning rules and knowledge from large datasets. Thanks to their ability to analyze large volumes of data collected by IoT sensors, machine learning algorithms facilitate the optimization of agricultural processes, resulting in increased productivity while minimizing resource consumption. Machine learning techniques outperform all traditional methods, offering a cost-effective and efficient solution for agricultural activities (Aldossary et al., 2024).

Machine learning is used in a variety of fields, from image detection and linguistic analysis to forecasting and autonomous systems



Source: Authors

Figure 1: Organization of the paper.

(Wang et al., 2025). Machine learning aims to create algorithms and models that enable machines to learn, predict or decide without the need for precise programming. Machine learning models analyze the information provided, detect consequences and use statistical analysis to make predictions or classifications (Choudhary et al., 2025). This field includes a variety of algorithms, classified into three main categories: 1) supervised learning (SL), where models are trained on labeled data; 2) unsupervised learning (USL), which operates on unlabeled data; and finally, 3) reinforcement learning (RL), which focuses on sequential decision making (El Majdouby et al., 2024).

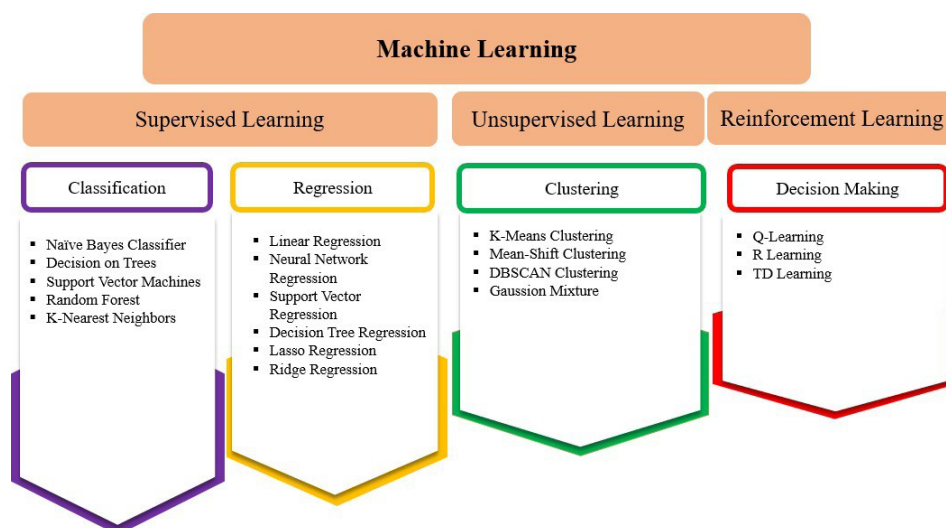
- Supervised learning is a technique that utilizes models trained on a set of labeled data to predict an outcome based on an input. This method is used to design machine learning models for regression (when the results are numerical) and classification (when the results are categorical) (Staff, 2025).
- Semi-supervised learning is a machine learning approach that combines labeled and unlabeled data to train algorithms, aiming to enhance the efficiency of predictive models. Indeed, algorithms start training with a limited amount of labeled data to initiate their learning, and are then progressively fed with a much larger volume of unlabeled data to improve the model (Fu et al., 2025).
- Reinforcement learning consists of training artificial intelligence models to perform

a sequence of choices in which an autonomous agent learns to decide by interacting with its environment through trial and error based on its experiences and actions. This genre is often used in fields such as robotics, interactive video games, or autonomous cars, where the agent must adapt to constantly changing situations (Saad Alotaibi et al., 2024).

Machine learning (ML) is an innovative method that enables machines to simulate the learning activities of humans, continuously improving performance and achieving set goals. Machine learning (ML) techniques are applied on agricultural farms for disease detection, weather forecasting, irrigation scheduling, weed detection, crop quality, and soil conditions to reduce crop costs and maximize yields (Maduranga and Abeysekera, 2020). Major ML algorithms applied in IoT-based agriculture major ML algorithms can be applied such as support vector machine (SVM), naive Bayes, fuzzy clustering, discriminant analysis, K-means clustering, K-nearest neighbor (K-NN), Gaussian mixture models, artificial neural networks (ANN), decision making, and deep learning. Figure 2 illustrates the structure of ML classification, specifying the different divisions of machine learning.

Machine learning (ML) has several uses in agriculture, such as:

- Disease detection: Conventional approaches to identifying the type and severity of leaf diseases frequently rely on human observation and expert



Source: Authors

Figure 2: Categories of machine learning.

judgment. However, thanks to the evolution of deep learning methods, it is possible to improve the accuracy and efficiency of detecting complex pathologies by processing leaf images (Wang et al., 2025).

- Crop management: The inclusion of machine learning algorithms in the agricultural sector to anticipate future harvests has produced positive results in helping to better understand the influence of climate and agricultural conduct on future yield, while facilitating the management of problems that lead to poor agricultural performance and food shortages linked to low yields (Zhang et al., 2025).
- Irrigation planning: Machine learning-based irrigation programs can autonomously calculate the ideal volume of water, using current weather data to guide the irrigation of agricultural fields (Gao et al., 2023).
- Weed detection: In agriculture, machine learning is crucial in identifying weeds, their position in each row, and their spacing, thus promoting optimum productivity. Machine learning models are based on images of cultivated fields, soils, and weeds (Kumar Nagothu et al., 2023).
- Crop quality assessment: Abiotic stresses, which threaten food security worldwide, are among the reasons for crop failure. However, thanks to deep learning (DL) methods, rapid identification and accurate prediction of indicators of these abiotic stresses are now possible (Subeesh and Chauhan, 2025).
- Weather forecasting: Machine learning models are an effective way of predicting future weather conditions, such as wind speed, temperature, humidity, and pressure, to optimize the productivity of agricultural crops (Kumari and Muthulakshmi, 2024).
- Water management: Machine learning (ML) techniques facilitate real-time monitoring of water quality and prediction of parameters such as microbial indicators, heavy metals, and chlorine (Li et al., 2024).

Internet of things

The concept of the Internet of Things refers to the interconnection of physical devices through sensors, networks, and data analytics that facilitate the collection and analysis of data from sensors placed on the farm site, monitoring various criteria

such as soil moisture, nutrient concentrations, temperature, humidity levels, and even plant well-being. This information guides farmers in improving techniques such as fertilization, pest control, and irrigation, leading to increased production while making more efficient use of available resources (Choudhary et al., 2025). IoT integration in agriculture aims to provide farmers with the tools they need to adopt automation strategies and improve their decision-making. These technologies increase crop quality, productivity, and profitability by effectively integrating data, expertise, and a variety of services. Intelligent algorithms and sensors can be utilized to precisely recommend methods for preserving field quality and ensuring high-quality harvests (Venkatesh et al., 2022).

The Internet of Things (IoT) refers to a network of digital devices, sensors, machines, and equipment interconnected over the web, each with its own identity and the ability to observe and control remotely (Javaid et al., 2025). The IoT is based on a five-level structure: the perception layer (hardware devices), the network layer (information transmission), the middleware layer (device management and interoperability capability), and the service layer (cloud computing) and the application layer (information integration and analysis). Finally, we reach the end-user layer, which provides the user interface (Razaque et al., 2025).

- Sensor layer: This physical layer is mostly made up of hardware components, such as actuators and sensors. These devices are used to gather environmental data, including brightness, wind direction, wind speed, soil moisture, pH, temperature, air pressure, and humidity (Lefoane et al., 2025).
- Network layer: Through communication protocols like Bluetooth, WiFi, 3G, GSM, and others, sensors transmit the data they have collected. Sending data to the cloud for remote control or analysis at a later time is made simple by this layer (El Majdouby et al., 2024).
- Data processing layer: a layer where gathered data is processed and stored, typically situated between the application and the network. It provides the ability to analyze data more thoroughly and make decisions automatically (Sarohe et al., 2025).

- Service layer: Data processed and stored in the previous layer can be sent to a cloud environment. This layer makes it possible to centralize data and offer scalable services, which is essential for managing the large quantities of data generated by connected objects. The cloud can also host artificial intelligence services for advanced analysis (Huo et al., 2024).
- Application layer: Applications and user interfaces are developed to enable interaction with the end-user. It shows end-users information about the data collected from the previous layer to help them make decisions. The application layer deals with the creation of efficient and useful applications for services, and the user can control IoT devices via a smartphone application, PC, tablet, etc. (El Majdouby et al., 2024). Figure 3 shows the four layers of Internet of Things technology.

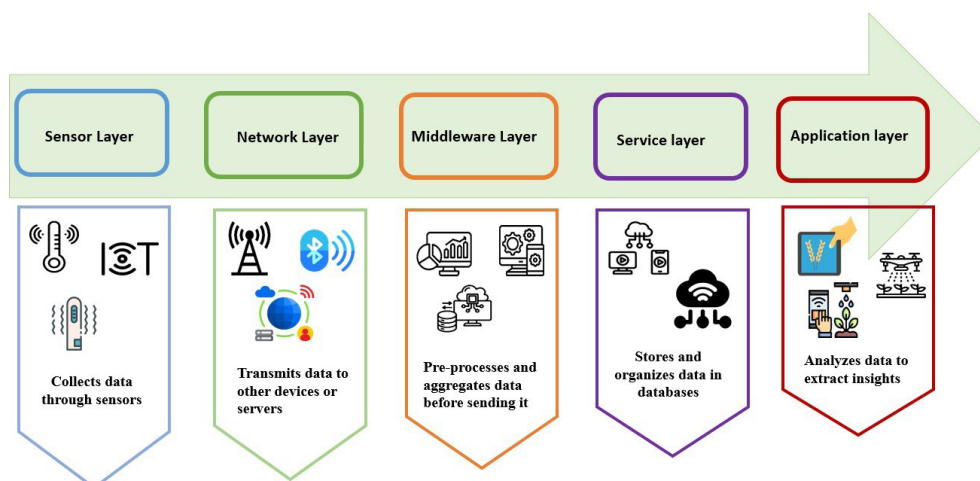
In smart farming, various IoT sensors have been employed to gather information on various agricultural aspects, including soil, crop, environment, and more. For substrate monitoring, electronic sensors were used to collect substrate data such as soil and water temperature, humidity, and nitrogen levels. Also, pH sensors were used to assess the level of acidity or alkalinity of the water in hydroponic cultures. In addition, for environmental monitoring, electronic sensors are integrated into IoT solutions to gather environmental information such as temperature, luminosity, and humidity. For crop monitoring, multispectral sensors and cameras have been used

to gather images of crops. These devices can be mounted on a drone to obtain aerial photos of vast crops or integrated into robots to achieve precise capture of a plant's leaves (Navarro et al., 2020).

Applications in smart agriculture

In recent years, new solutions and technologies have been introduced in the agricultural sector to increase crop production. A variety of IoT applications for smart farming help farmers make good decisions about their crops and automate farm management to reduce labor costs (Quy et al., 2022). Intelligent agriculture consists of a range of services that could be provided, for example, irrigation management, disease management, input management (pesticides, fungicides, and herbicides), yield prediction, remote monitoring, farm machinery control, product traceability, vehicle guidance, animal tracking...

- Monitoring of climate conditions: IoT facilitates the real-time collection and analysis of agricultural soil composition and the transmission of information to farmers or landowners via the Internet (soil condition, temperature, and humidity, as well as forecasts of natural factors such as precipitation and weather). The data collected was also used to automate farm management to reduce labor costs.
- Precision farming: In smart precision farming, we find the use of drones in monitoring and farming activities. Some common agricultural tasks using drones include pesticide spraying, seed sowing, fertilization, crop evaluation and mapping, and crop growth monitoring (Zhou



Source: Authors

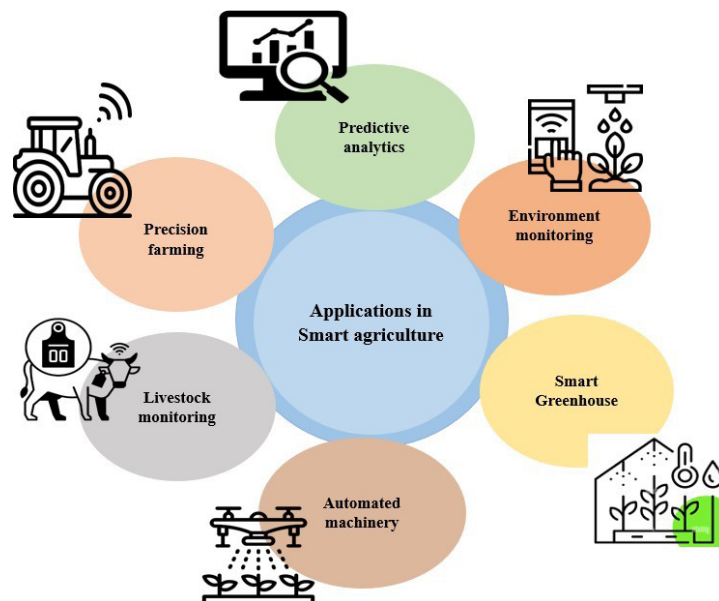
Figure 3: The architecture of the Internet of Things.

and Zhou, 2020). Precision farming relies on technologies such as irrigation systems, UAVs (unmanned aerial vehicles), and intelligent farm machinery, which can be programmed to operate autonomously according to various criteria or controlled remotely by the farmer via the Internet. To achieve healthier, more productive crops while minimizing costs, farmers can consult various parameters such as light levels, temperature, soil conditions, humidity, and pest infestations to determine the ideal quantities of water, fertilizers, and pesticides needed for their plantations.

- Livestock monitoring: There are IoT sensors specifically designed for agriculture, which can be attached to farm animals to monitor their health and record their performance. These devices can monitor and collect information relating to the health, well-being, and geographical position of animals. The use of intelligent agricultural sensors (collar tags) provides detailed information on the health, temperature, activity, and nutrition of each animal, as well as collective information on the herd (Shalimov, 2023).
- Smart greenhouse management: Greenhouse agriculture is considered the oldest method of smart farming, but it involves precise monitoring of environmental parameters to manage and maintain the local climate.

Using an IoT-based prototype, this method monitors greenhouses to measure internal parameters and obtain detailed, real-time information on greenhouse conditions, including illuminance, soil condition, temperature, humidity, and pressure (Ayaz et al., 2019).

- Agricultural drones: The use of drones (unmanned aerial vehicles) is particularly well suited to agricultural data collection, thanks to their high surveillance capacity. Drones can also perform a multitude of activities that previously required human intervention: plant cultivation, pest and infection control, spraying of agricultural products, crop monitoring.
- Predictive analysis: IoT is a technology based on intelligent sensors that provide crucial data in real time. Exploiting the analysis of this data enables farmers to better understand it and make significant forecasts: crop harvesting time, production quantity, risks of disease and infestation, etc. Farmers can anticipate the volume and quality of their crops, as well as their vulnerability to adverse weather conditions, such as flooding and drought. It also gives growers the ability to optimize the supply of water and nutrients for each plant, while allowing them to select yield characteristics to improve quality.



Source: Authors

Figure 4: Applications in smart agriculture.

- Smart irrigation and water management: Farmers can maintain proper humidity levels while maximizing the effectiveness of the resources used by using smart irrigation systems and Internet of Things (IoT) technology to monitor water. Drip irrigation systems can be automatically managed based on region, crop cycle, and growth phases thanks to the use of soil sensors and weather data. One of the best digital agriculture solutions provided by the Internet of Things is intelligent irrigation. Real-time soil property monitoring is made possible by the placement of sensors in fields (Razaque et al., 2025). In order to ensure more effective water management, this provides farmers with the chance to enhance and optimize their irrigation systems while accounting for the crops, local weather patterns, and soil types. While guaranteeing that every plant receives the precise moisture needed for maximum production, this resource-saving technology reduces water waste.

This study's primary goal is to systematically compile recent research on smart agriculture that integrates Internet of Things (IoT) and artificial intelligence (AI) technologies, such as machine learning (ML). This study aims to investigate the ways in which these advanced technologies have been used in the agricultural industry, particularly for managing livestock, administering land, identifying weeds, controlling plant diseases, and optimizing irrigation.

Our research methodology used in this systematic

review was inspired by the SLR process suggested by Kitchenham and Charters (Kitchenham, no date). It consists of the following sequential steps (Figure 5).

Research questions

This in-depth literature review aims to outline the major issues and trends in smart agriculture, focusing on the associated technologies, applications, and consequences. Seven research questions are presented in Table 1 to address the objectives of this study.

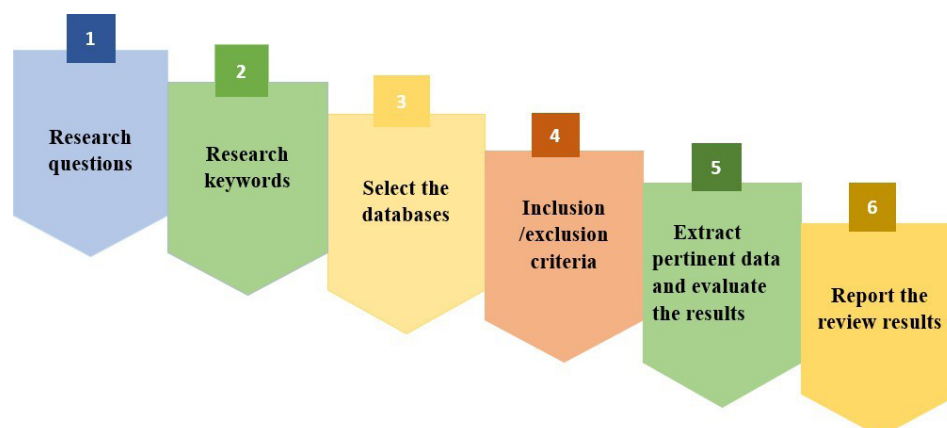
No	Research Question (RQ)
RQ1	Which ML techniques have been used in smart agriculture?
RQ2	Which Internet of Things and machine learning applications are most favored in intelligent agriculture?
RQ3	Which machine Learning/IoT techniques are well-suited to smart agriculture?
RQ4	What is the overall performance of ML techniques for intelligent agriculture?
RQ5	What is the benefit of combining IoT and Machine Learning in environmental applications?
RQ6	Which countries are the most influential in the field of smart agriculture?
RQ7	What trends and advancements may we expect in intelligent agriculture in the future?

Source: Authors

Table 1: Research questions of the study.

Data sources

This systematic review relies on an in-depth search to gather significant articles by exploiting scientific databases and indexing services such as Scopus and Web of Science, to identify conference



Source: Authors

Figure 5: Systematic review process.

and journal articles related to agricultural technologies and innovations.

Keyword selection strategy

This study used several keyword combinations to locate relevant literature related to smart agriculture, including terms such as “smart farming”, “precision agriculture”, “smart farming”, “machine learning”, “artificial intelligence”, and “internet of things”. These combined terms were employed in different configurations, using logical operators (AND, OR, NOT) to refine results and optimize the relevance of selected searches. This method favored the inclusion of various technical, theoretical, and practical studies, while excluding works that lacked relevance or were too far removed from the subject.

Inclusion criteria

- To ensure the relevance and quality of the studies included, several elements must be specified:
- Only studies that integrate ML and IoT in the context of smart agriculture.
- The study is published in a peer-reviewed journal. The study is written in English.
- The studies focus on the use of IoT sensors to collect agricultural data and the use of machine learning algorithms to analyze and make decisions.
- Only research carried out between 2020 and 2024 will be considered to incorporate recent work in the agricultural field.

Exclusion criteria

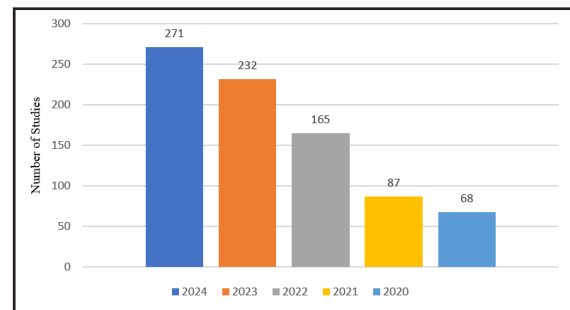
Studies were excluded based on the following criteria:

- The study does not focus on ML and IoT integration.
- Studies not written in English are excluded.
- The study is a conference abstract, editorial, letter, or opinion piece with no original research data.

Results and discussion

Bibliometric analysis

Scopus database

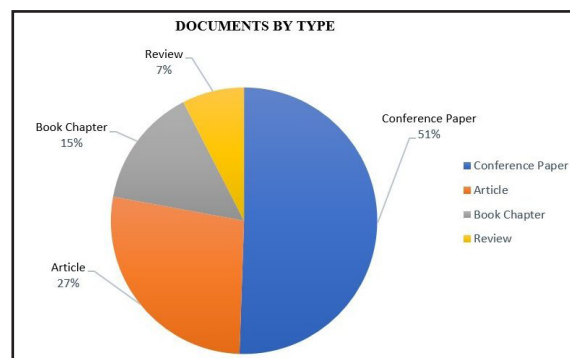


Source: Authors

Figure 6: Documents published in Scopus.

The Scopus database contains a total of 823 research articles focusing on the use of relevant keywords. The following figure 6 illustrates the annual progression of publications from 2020 to 2024, indicating a growth in the number of works related to the integration of IoT and ML in the smart agriculture sector. The surge in recently published articles reflects the growing debate and relevance of the smart agriculture theme.

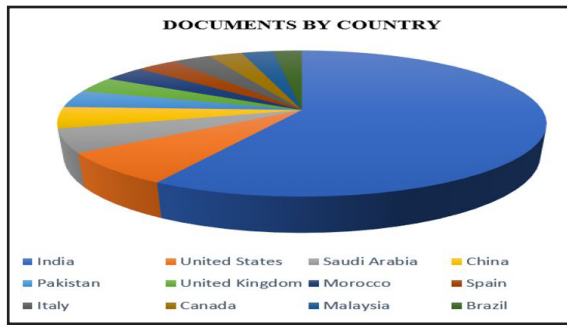
The publications found on smart agriculture were divided into various documents: Conference paper (51%, n = 416), Article (27%, n = 225), Review (7%, n = 62), and Book chapter (15%, n = 120) as shown in Figure 7.



Source: Authors

Figure 7: Type of documents published in Scopus.

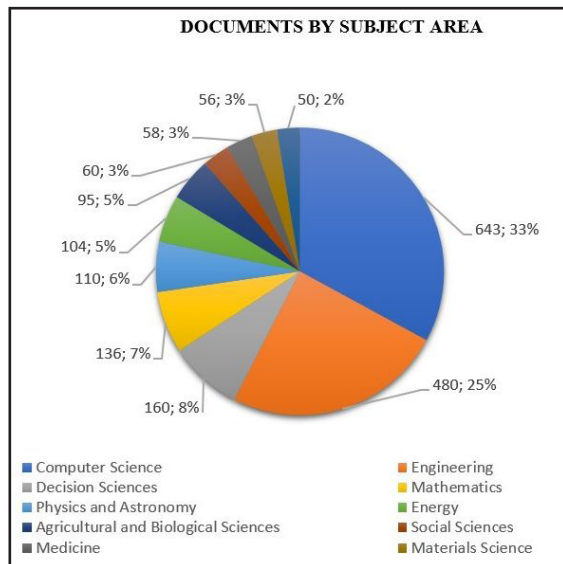
The graph below (Figure 8) shows that India leads the way in the production of documents relating to technological agriculture, followed by other countries such as the United States, Saudi Arabia, China, Pakistan, the United Kingdom, Morocco, and various other countries focused on agricultural research.



Source: Authors

Figure 8: Documents contributed by country.

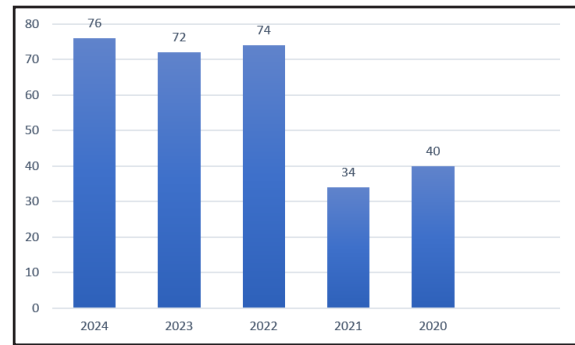
More than 25% of the works listed in the Scopus database focus on computer science and engineering, reflecting a predominant preference for technological dimensions.



Source: Authors

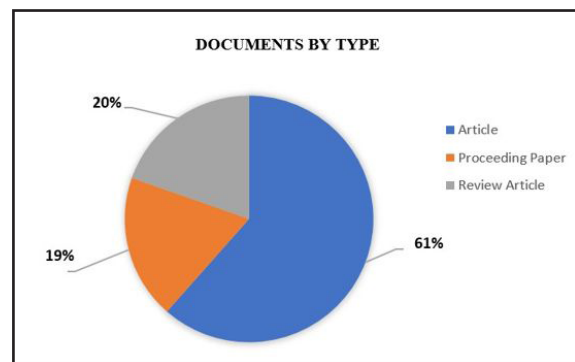
Figure 9: Documents contributed by subject.

The data used in this analysis comes from the Web of Science (WOS) database, and the same filter was applied to the Scopus database. We found 296 academic publications: 61% articles, 19% proceedings papers, and 20% review articles (Figure 11) on the concept of smart agriculture. The integration of ML-based algorithms into IoT systems for various applications has grown exponentially in recent years. This is reflected in the annual scientific output shown in Figure 10. This is a clear sign that researchers are considering the joint use of ML/ AI and IoT to solve farmers' problems.



Source: Authors

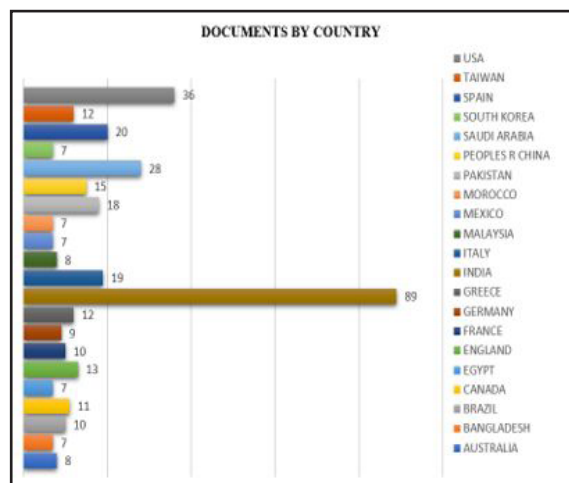
Figure 10: Number of articles by years of publication in WOS.



Source: Authors

Figure 11: Document type published in WOS.

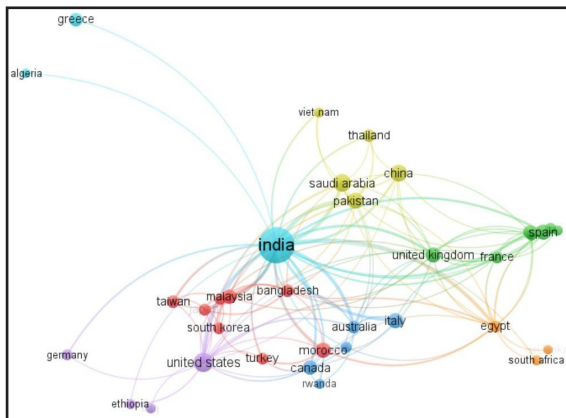
The graphs below show, the main countries involved in in-depth agricultural research are India, the USA, and Saudi Arabia, followed by a number of other countries. However, researchers are showing a particular interest in the fields of computing, engineering, and telecommunications, indicating that the world's attention is increasingly focused on new technologies and the it sector.



Source: Authors

Figure 12: Document published by the country in WOS.

and to analyze the geographical distribution of scientific contributions and the impact of publications worldwide. The graphical representation in Figure 16 provides an overview of publication trends, international collaborations, and the geographical areas where research is most influential. Countries that rank among the leaders in terms of scientific citations. Seven clusters are distributed as follows: Eight pieces make up Cluster 1, seven pieces make up Cluster 2, four pieces make up Cluster 3, four pieces make up Cluster 5, and seven pieces make up Cluster 6.



Source: Authors

Figure 16: Citation visualization by countries in Scopus.

Conclusion

In conclusion, this study demonstrates that the integration of innovative agricultural management techniques based on the Internet of Things (IoT) and artificial intelligence

represents a modern, effective, predictive, and automated approach that has helped refine agricultural practices to optimize crop production and, consequently, increase yields. These innovations are transforming the agricultural sector, paving the way for smarter and more sustainable farming in various areas such as disease and weed detection, crop and livestock monitoring, crop productivity assessment, improved irrigation, soil and water conservation, crop yield estimation, as well as robotics and automation. This bibliometric study highlights the considerable potential of these innovations: IoT sensors automatically collect agricultural data such as humidity, soil moisture, and temperature in real time, and facilitate connectivity and information exchange between various devices, while ML algorithms analyze this data to predict ideal environmental conditions and optimize farmers' decision-making processes. Although this literature review emphasizes the importance of these technologies in smart agriculture and provides an overview of machine learning and IoT technologies applied to smart agriculture, as well as their application in the agricultural sector to make it more efficient and environmentally friendly. This study examines the dynamic evolution of global publications on smart agriculture over the past few years, from 2020 to 2024. During this period, the topic of smart agriculture has gained increasing prominence, as evidenced by the number of scientific publications in the Scopus and Web of Science databases. A bibliometric analysis provides insight into the evolution of this research field.

Corresponding author:

Karima El majdouby

Computer Science department, ELITES laboratory, Faculty of Sciences

University of Chouaib Doukkali, Avenue Jabran Khalil Jabran, El Jadida, Morocco

Phone: +212 6 46 453022, Email: elmajdouby.karima@ucd.ac.ma

References

- [1] Abbasi, R., Martinez, P. and Ahmad, R. (2022) "The Digitization of Agricultural Industry - A Systematic Literature Review on Agriculture 4.0", *Smart Agricultural Technology*, Vol. 2, p. 100042. ISSN 2772-3752. DOI 10.1016/j.atech.2022.100042.
- [2] Aldossary, M., Alharbi, H. A. and Anwar Ul Hassan, C. (2024) "Internet of Things (IoT)-Enabled Machine Learning Models for Efficient Monitoring of Smart Agriculture", *IEEE Access*, Vol. 12, pp. 75718-75734. ISSN 2169-3536. DOI 10.1109/ACCESS.2024.3404651.
- [3] Ayaz, M., Uddin, A., Sharif, Z., Mansour, A. and Aggoune, E.-H. M. (2019) "Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk", *IEEE Access*, Vol. 7, pp. 129551-129583. ISSN 2169-3536. DOI 10.1109/ACCESS.2019.2932609.

- [4] Chen, X., Tian, W. and Fang, H. (2025) "Bibliometric Analysis of Natural Language Processing Using CiteSpace and VOSviewer", *Natural Language Processing Journal*, Vol. 10, p. 100123. ISSN 2949-7132. DOI 10.1016/j.nlp.2024.100123.
- [5] Choudhary, V., Guha, P., Pau, G. and Mishra, S. (2025) "An Overview of Smart Agriculture Using Internet of Things (IoT) and Web Services", *Environmental and Sustainability Indicators*, Vol. 26, p. 100607. ISSN 2665-9727. DOI 10.1016/j.indic.2025.100607.
- [6] El Majdouby, K., El Mohadab, M., Ait Daoud, R. and Abouelmehdi, K. (2024) "Exploring the Use of Machine Learning and the Internet of Things in Intelligent Agriculture: Short Survey", *2024 10th International Conference on Optimization and Applications (ICOA)*, pp. 1-6. DOI 10.1109/ICOA62581.2024.10754078.
- [7] Fu, R., Chen, Z., Tian, H., Hu, J., Bu, F., Zheng, P., Chi, L., Xue, L., Jiang, Q., Li, L. and Zhu, L. (2025) "A Review on the Applications of Machine Learning in Biomaterials, Biomechanics, and Biomanufacturing for Tissue Engineering", *Smart Materials in Medicine*, Vol. 6, No. 2, pp. 171-204. ISSN 2590-1835. DOI 10.1016/j.smaim.2025.06.003.
- [8] Gao, H. et al. (2023) "How Can Agricultural Water Production Be Promoted? A Review on Machine Learning for Irrigation", *Journal of Cleaner Production*, Vol. 414, p. 137687. ISSN 0959-6526. DOI 10.1016/j.jclepro.2023.137687.
- [9] Huo, D., Zhangzhong, L., Zheng, W., Chen, G. (2024) "Mapping Smart Farming: Addressing Agricultural Challenges in Data-Driven Era", *Renewable and Sustainable Energy Reviews*, Vol. 189, p. 113858. ISSN 1364-0321. DOI 10.1016/j.rser.2023.113858.
- [10] Javaid, M., Haleem, A., Sing, R. P., Suman, R., Khan, S. and Rab, S. (2025) "Adoption of Internet of Things for Smart City-Enabled Smart Hospitals", *Intelligent Hospital*, p. 100011. ISSN 2949-8716. DOI 10.1016/j.inhs.2025.100011.
- [11] Kasera, R. K. and Acharjee, T. (2024) "A Comprehensive IoT Edge Based Smart Irrigation System for Tomato Cultivation", *Internet of Things*, Vol. 28, pp. 101356. E-ISSN 2542-6605, ISSN 2543-1536. DOI 10.1016/j.iot.2024.101356.
- [12] Kitchenham, B. (2004) "*Procedures for Performing Systematic Reviews*", Corpus ID: 54019416. [Online]. Available: <https://www.semanticscholar.org/paper/Procedures-for-Performing-Systematic-Reviews-Kitchenham/29890a936639862f45cb9a987dd599dce9759bf5> [Accessed: Feb. 15, 2026].
- [13] Kumar Nagothu, S., Anitha, G., Siranthini, B., Anandi, V. and Prasad, P. S. (2023) "Weed Detection in Agriculture Crop Using Unmanned Aerial Vehicle and Machine Learning", *Materials Today: Proceedings*. ISSN 2214-7853. DOI 10.1016/j.matpr.2023.03.350.
- [14] Kumari, S. and Muthulakshmi, P. (2024) "SARIMA Model: An Efficient Machine Learning Technique for Weather Forecasting", *Procedia Computer Science*, Vol. 235, pp. 656-670. ISSN 1877-0509. DOI 10.1016/j.procs.2024.04.064.
- [15] Lefoane, M., Ghafir, I., Kabir, S. and Awan, I.-U. (2025) "Internet of Things Botnets: A Survey on Artificial Intelligence Based Detection Techniques", *Journal of Network and Computer Applications*, Vol. 236, p. 104110. ISSN 1084-8045. DOI 10.1016/j.jnca.2025.104110.
- [16] Li, Z., Ma, W., Zhong, D., Ma, J., Zhankg, Q., Yuan, Y., Liu, X., Wang, X. and Zou, K. (2024) "Applications of Machine Learning in Drinking Water Quality Management: A Critical Review on Water Distribution System", *Journal of Cleaner Production*, Vol. 481, p. 144171. ISSN 0959-6526. DOI 10.1016/j.jclepro.2024.144171.
- [17] Liakos, K. G., Busato, P., Moshou, D., Pearson, S. and Bochtis, D. (2018) "Machine Learning in Agriculture: A Review", *Sensors*, Vol. 18, No. 8, p. 2674. ISSN 1424-8220. DOI 10.3390/s18082674.
- [18] Maduranga, M. W. P. and Abeysekera, R. (2020) "Machine Learning Applications in IoT Based Agriculture and Smart Farming: A Review", *International Journal of Engineering Applied Sciences and Technology*, Vol. 4, No. 12, pp. 24-27. ISSN 2455-2143. DOI 10.33564/IJEAST.2020.v04i12.004.v04i12.004.

- [19] Morchid, A., El Alami, R., Raezah, A. A. and Sabbar, Y. (2024) "Applications of Internet of Things (IoT) and Sensors Technology to Increase Food Security and Agricultural Sustainability: Benefits and Challenges", *Ain Shams Engineering Journal*, Vol. 15, No. 3, p. 102509. ISSN 2090-4479. DOI 10.1016/j.asej.2023.102509.
- [20] Murugamani, C., Shithart, S., Hemalatha, S., Ksirsagar, P. R., Riyazuddin, K., Naveed, Q. N., Islam, S., Mazher Ali, S. P. and Batu, A. (2022) "Machine Learning Technique for Precision Agriculture Applications in 5G-Based Internet of Things", *Wireless Communications and Mobile Computing*, Vol. 2022, No. 1, p. 6534238. ISSN 1530-8677. DOI 10.1155/2022/6534238.
- [21] Navarro, E., Costa, N. and Pereira, A. (2020) "A Systematic Review of IoT Solutions for Smart Farming", *Sensors (Basel, Switzerland)*, Vol. 20, No. 15, p. 4231. ISSN 1424-8220. DOI 10.3390/s20154231.
- [22] Quy, V. K., Hau, N. V., Anh, D. V., Quy, N. M., Ban, N. T., Lanza, S., Randazzo, G. and Muzirafuti, A. (2022) "IoT-Enabled Smart Agriculture: Architecture, Applications, and Challenges", *Applied Sciences*, Vol. 12, No. 7, p. 3396. ISSN 2076-3417. DOI 10.3390/app12073396.
- [23] Razaque, A., Hariri, S., Alajlan, A. M. and Yoo, J. (2025) "A comprehensive review of cybersecurity vulnerabilities, threats, and solutions for the Internet of Things at the network-cum-application layer", *Computer Science Review*, Vol. 58, p. 100789. ISSN 1574-0137. DOI 10.1016/j.cosrev.2025.100789.
- [24] Ribeiro Junior, F. M., Bianchi, R. A. C., Prati, R. C., Koleihmainen, K., Soinen, J.-P. and Kamienski, C. A. (2022) "Data reduction based on machine learning algorithms for fog computing in IoT smart agriculture", *Biosystems Engineering*, Vol. 223, pp. 142-158. ISSN 1537-5110. DOI 10.1016/j.biosystemseng.2021.12.021.
- [25] Saad Alotaibi, B., Sherma, A. I., Ibrahim, A. U., Abuhussain, M. A., Abdulmalik, H., Dodo, Y. A. and Atakara, C. (2024) "Assimilation of 3D printing, Artificial Intelligence (AI) and Internet of Things (IoT) for the construction of eco-friendly intelligent homes: An explorative review", *Heliyon*, Vol. 10, No. 17, p. e36846. ISSN 2405-8440. DOI 10.1016/j.heliyon.2024.e36846.
- [26] Sarohe, S., Harit, S. and Kumar, M. (2025) "A systematic and comprehensive survey of load balancing techniques in Software Defined Network based Internet of Things", *Computer Networks*, Vol. 269, p. 111412. ISSN 1389-1286. DOI 10.1016/j.comnet.2025.111412.
- [27] Shalimov, A. (2023) "IoT in Agriculture: 9 Technology Use Cases for Smart Farming (and Challenges to Consider)", Eastern Peak - Technology Consulting & Development Company. [Online]. Available: <https://easternpeak.com/blog/iot-in-agriculture-technology-use-cases-for-smart-farming-and-challenges-to-consider/> [Accessed: Feb. 6, 2025].
- [28] Staff, C. (2025) "Qu'est-ce que l'apprentissage automatique? Définition, types et exemples", Coursera. [Online]. Available: <https://www.coursera.org/fr-FR/articles/what-is-machine-learning> [Accessed: 23 Sept. 23, 2025]. (In French).
- [29] Subeesh, A. and Chauhan, N. (2025) "Deep learning based abiotic crop stress assessment for precision agriculture: A comprehensive review", *Journal of Environmental Management*, Vol. 381, p. 125158. ISSN 0301-4797. DOI 10.1016/j.jenvman.2025.125158.
- [30] Venkatesh, V., Raj, P. and Anushia Devi, R. (2022) "Chapter Ten - A smart framework through the Internet of Things and machine learning for precision agriculture", In Raj, P., Saini, K. and Surianarayanan, C. (eds.) "Advances in Computers", Elsevier (Edge/Fog Computing Paradigm: The Concept Platforms and Applications), pp. 279-306. ISSN 0065-2458. DOI 10.1016/bs.adcom.2022.02.007.
- [31] Wang, J., Liu, Z., Yang, X. Li, M. and Lyu, Z. (2025) "The Internet of Things under Federated Learning: A Review of the Latest Advances and Applications", *Computers, Materials & Continua*, Vol. 82, No. 1, pp. 1-39. ISSN 1546-2218. DOI 10.32604/cmc.2024.058926.

- [32] Wang, X., Tang, S. H., Mohd Ariffin, M K. A. B, Ismail, M. I. S. B. and Zhao, R. (2025) "LeafMamba: A novel IoT-integrated network for accurate and efficient plant leaf disease detection", *Alexandria Engineering Journal*, Vol. 123, pp. 415-424. ISSN 1110-0168. DOI 10.1016/j.aej.2025.03.033.
- [33] Zhang, E., Liu, Y., Tan, Q., Chen, J. and Pan, T. (2025) "Projected changes in future wheat yield across China under CMIP6 climate simulations and agricultural management scenarios", *Journal of Cleaner Production*, Vol. 508, p. 145570. ISSN 0959-6526. DOI 10.1016/j.jclepro.2025.145570.
- [34] Zhou, X. and Zhou, J. (2020) "Data-Driven Driving State Control for Unmanned Agricultural Logistics Vehicle", *IEEE Access*, Vol. 8, pp. 65530-65543. ISSN 2169-3536. DOI 10.1109/ACCESS.2020.2983424.