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The Internet of Things Research in Agriculture: A Bibliometric Analysis

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ABSTRACT

An in-depth analysis of Internet of Things (IoT) applications expertise for agriculture. This article's primary purpose is to provide a comprehensive and organized review of IoT research in agriculture themes. Although recent research has offered some pertinent information regarding the analysis of IoT applications in agriculture, further information is needed. Bibliometric analysis is utilized to objectively investigate, and develop information knowledge of IoT applications in agriculture. The papers investigated and examined the themes of IoT-agriculture by analyzing the co-occurrence keywords. The analysis began by picking 550 papers from the Scopus database that were published from 2003 to May 2023. The results show that IoT agriculture papers have grown rapidly since 2015 until now. The three journals that published the most IoT agricultural publications are Sensors (Switzerland), Computers and Electronics in Agriculture, and IEEE Access. Based on the co-occurrence keywords, the focus of IoT paper in agriculture is wireless sensors network (WSN) and radio frequency identification (RFID) for agricultural monitoring, smart agriculture with IoT blockchain and machine learning, IoT greenhouses with cloud computing and artificial intelligence (AI), components of IoT agriculture, precision agriculture with low power low range (LoRa) communication network and IoT cloud platform, smart farming with sensor networks and automation. The study provided an understanding of themes of the IoT agriculture that has been carried out and its future growth. The future of IoT application will elaborate a system efficient, consumes less energy, and emits less carbon dioxide. It has begun by combining IoT-agriculture with the technology edge-fog-cloud layer.

Keywords:
Agriculture; bibliometric analysis; co-occurrence keywords; internet of things; IOT agriculture research.

1. Introduction

An outline of agriculture today and in the future to address the issues of meeting the demands for food globally. Cost constraints in traditional agriculture make it more expensive and less competitive. Internet of Things (IoT) technology has the potential to expand new markets and boost agricultural competitiveness. IoT is the idea of tying up physical object equipment with sensing, actuating, and computing capacity also protocol network connection that is incorporated in a microcontroller and has the capability to function in collaboration with internet-connected work (Lakhwani and Gianey, 2019). IoT has the potential to facilitate the development of informational and physical monitoring facilities in agriculture. Due of automation's capacity to make agricultural processes more precise, intelligent, and efficient. Using sensors, IoT can automate the data collection procedure in agriculture (Farooq et al., 2020). Sensors utilized most frequently in agriculture, such as soil sensors (pH sensors, moisture sensors), gas sensors (O_2 sensors, CO_2 sensors), light sensors (light dependent resistor sensors, ultra violet sensors), motion sensors [passive infrared receiver (PIR) sensors], temperature-humidity sensors [detection humidity temperature (DHT): DHT11 sensors, DHT22 sensors] and air pressure sensors (barometric pressure sensors). In addition to sensors, automation control and completion also utilizes actuator (Lara et al., 2021; Singh et al., 2020). Moreover, network connection protocol supports the fulfillment of automation data acquisition. The five most prevalent wireless IoT protocols in agriculture are Wireless Sensors Networks (WSN), Wireless Fidelity (WiFi), Zona Intercommunication Global-Standard (ZigBee), Radio Frequency Identification (RFID), and Low-Power Long-Range (LoRa) (Farooq et al., 2020). In conventional agriculture, however, the automation method is inapplicable. Such as requiring direct human engagement, more expenses and energy usage, and greater resource consumption (Venkatesan and Tamilvanan, 2017; Islam et al., 2020). Moreover, according to Lakhwani and Gianey (2019), the application of IoT in agriculture has demonstrated numerous benefits, including greater input efficiency with relation to water, fertilizer, soil, and pesticides, reduced production costs, increased profit and sustainability, food security maintenance, and environmental protection.

Solutions for agriculture problems are important and urgent. Due to the rising demand for both quantity and quality of food. Planning, implementing, and controlling the movement of information, goods, and money from upstream to downstream agriculture rely heavily on IoT technology. According to Farooq et al. (2020), the internet of things has three applications in agriculture: monitoring, controlling, and tracking. Many parameters can be measured in monitoring applications, such as irrigation, soil, temperature, relative humidity, air, disease, water, and fertility.

A microcontroller and RFID sensor system is utilized for monitoring animal by tracking. Next, for communication protocol like WSN, LoRa, Zigbee. It is supporting the communication of data acquisition that sensed by the RFID and sensors. It can be linked with the android webserver application framework for real-time user monitoring. Control and decision making are based on the results of monitoring, which is followed by an analysis of the data acquired. RFID application enables objects to be tracked using radio frequencies. Domain tracking is utilized in the same manner as animal tracking. RFID tags connected to the animal are used for tracking function. Then using WSN as a communication network protocol to acquire animal position data. By applying alerts and sending mobile messaging to farmers, agriculture can be monitored in more detail. When there is unwelcome movement in an agricultural region.

With the implementation of IoT, smart and precision agriculture becomes feasible. Because it has a system for smart objects in agriculture. Utilizing embedded sensors and actuators in a microcontroller that are connected to the internet. Smart objects are capable of collecting agricultural data, analyzing it, and taking the required action (Lakhwani and Gianey, 2019; Jaiswal et al., 2019; Deepa et al., 2021). Several research findings have produced smart and precision conclusions. Such as Smart management fresh water by Annapoorani et al. (2020) and Zeng et al. (2021). This system is smart in monitoring and controlling the water that plants need. Moreover, Amalraj et al. (2019) created irrigation systems with IoT to be efficient because the process is automatic. Effendi et al. (2020) designed an IoT prototype for monitoring, controlling and atomizing systems for agricultural parameter analysis. Such as rainfall, temperature, humidity, light level, soil PH, and soil moisture. Similar results related to real-time monitoring and analysis of agricultural weather parameters using IoT (Suciu et al., 2019).

Additional study from other authors (Atmaja et al., 2021; Al-Qurabat, 2022) employs WSN as one of the IoT backbones for communication protocols in agricultural data collecting. According to studies done by Alharbi and Aldossary (2021) and Haseeb et al. (2020) the application of IoT in agriculture makes it more sustainable and energy-efficient. Smart and precision agricultural systems continue to be developed. Examples include research that blends IoT with the cloud, android mobile phones for tracking mobility, and agricultural control (Helmy et al., 2022; Bouali et al., 2022). The IoT has also been used in rural regions and is capable of fostering precision agriculture, and the detection of agricultural diseases and pests (Chandana et al., 2020; Kaushik and Prakash, 2021).

This article employs bibliometric analysis to investigate knowledge regarding the agricultural application of IoT. Some of the prior research that employs bibliometric analysis, as an example done by Rejeb et al. (2022) analyzing IoT research on SCM and Logistics to investigate IoT applications in the SCM and Logistics industry. Consequently, IoT has become an interesting technology utilized in SCM and Logistics at now. Singh et al. (2020) use bibliometric analysis to describe exhaustively the interaction between IoT and agriculture. The results indicate that agricultural IoT literature is developing rapidly. In addition, bibliometric analysis will be used to investigate the publishing trend of precision agriculture and IoT papers (Lara et al., 2021).

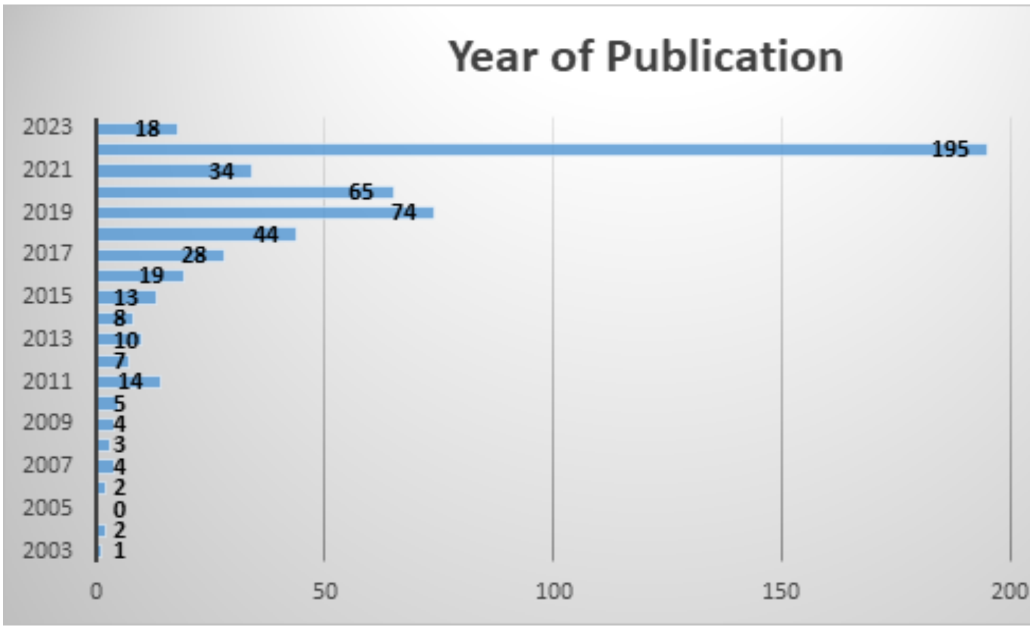
We expect that by analyzing IoTin agricultural research articles with bibliometric analysis, more organized information will be generated. In order to identify research gaps that can be explored for future studies. On this basis, this essay seeks to address numerous topics, including trends in the IoT agriculture over the past two decades, journal publishers have made contributions, the most research subjects within the IoT agriculture, based on the keywords co-occurrence grouping of the IoT agriculture literature used to investigate the structure of knowledge of past and future study.

2. Materials and Methods

This article's primary objective is to investigate the knowledge structure behind the research of IoT-Agriculture. Bibliometric analysis was used in this study. This is a systematic analysis that measures publication indicators such as scholars, affiliation, keyword, linkage between articles, and collaboration between scholars, institutions, and countries (Nandiyanto et al., 2020; Rejeb et al., 2022). The bibliometric technique permits research to present a transparent, static, and systematic image (Ardito et al., 2019). The type of bibliometric analysis is based on statistical approaches to find bibliometric indicators. Bibliometric analysis is performed in this article to proceed articles with the IoT agriculture theme.

The article sample data material is sourced from the Scopus database. Scopus is the most popular and most trusted scientific database for its contents. The Scopus database contains international journal publishers such as IEEE, Elsevier, ScienceDirect, Francis & Taylor and Springer. Articles from Scopus database was obtained using the Publish or Perish application search tool. Keywords used in conjunction with the format: ("internet of things" OR IoT OR RFID OR WSN OR "wireless sensor network*" OR GPS OR actuator* OR sensor*) AND (agriculture* OR "smart agriculture" OR "precision agriculture"). Searches for articles are conducted using Title Words and Keywords. The top 200 search results each receive 200 data articles. To add document data, conduct a second search with a new keyword format, such that the document results are distinct from those of the initial search. The second formatted term, "Internet of Things for Agriculture," is inserted in The Title. In the Keywords section is the phrase "smart agriculture, Internet of Things, IoT." The second result of the search is 158 data articles. Furthermore, to update the article sample data. A third data collection was carried out from 2022 to May 2023. The third sample data was obtained 200 articles. Where previously the data collection stages 1 and 2 were carried out in mid-2022. Thus, 558 articles comprise the initial sample size. The next step is to export the document data in RIS format from the application Publish or Perish. Then, for the sake of bibliometric analysis, the document information is verified for completeness using the Mendeley desktop tool. Although the publication appears on the Mendeley desktop in the first data, abstracts and keywords have not yet been added. Thus, manually complete it initially. Following the completion of the document screening and data collection procedure. The document data is reduced by eight, resulting in a final sample of 550 articles. The final data are exported from Mendeley desktop as RIS files for analysis with the VOSviewer application. VOSViewer is an open-source application designed for the visualization, generalization, and network analysis of co-occurrence keywords in the form of visual maps (Rejeb et al., 2022), (Hendy et al., 2023). The Scopus database source contains 550 articles. Figure 1, shows a sample of the distribution of the quantity of articles by year of publication.

Figure 1. Distribution of the number of IoT agriculture articles by year of publication.



3. Results and Discussion

3.1 Descriptive of The IoT Agricultural Research

Since 2003, the frequency distribution of articles demonstrates an upward tendency, as shown in Figure 1. This indicates that during the past two decades, research on the deployment of IoT in agriculture has grown. From 2011 through may-2023, the final decade of the 21st century. Specifically, its growth is anticipated to be substantial between 2015 and 2022. Despite the fact that 2021 is not as high as 2018-2020. But in 2022, the number of IoT agriculture articles is seen to increase by a significant amount. So, if it is predicted for 2023 and in the future, the number of IoT agricultural articles will still tend to be high (Singh et al., 2020; Lara et al., 2021; Rejeb et al., 2022). This is due to that IoT agriculture is backed by technologies such as cloud computing, which enables high-speed networks and quick remote access to control data. The combination of IoT agriculture with various technologies, such as edge-fox-cloud layer, further improves automation, smartness, and efficacy (Alharbi and Aldossary, 2021).

In Table 1 are listed the contributions of journal publishers with a topic on IoT-agriculture. With a total of 71 articles, the top three journal publishers account for 13% of the 550 samples. Among the top three journal publishers is Sensors (Switzerland), which has published 26 articles. Computers and Electronics in Agriculture ranks second with 24 publications, followed by IEEE Access with 21 items.

Table 1. Top three journal publishers with IoT-Agriculture theme

No	Journals	Number Articles
1	Sensors (Switzerland)	26
2	Computers and Electronics in Agriculture	24
3	IEEE Access	21

Table 2 shows the most prolific IoT agriculture paper authors based on a Scopus database sample. The top three authors are M.S. Farooq, E. Symeonaki, and S. Li. Next, the top thre IoT agricultural articles with the most citations are presented in table 3. Where the overall sample consists of 550 articles with a total of 20,766 citations. While the top three articles have a total of 1,853 citations (9%). This indicates that the three articles are the most influential within the IoT agricultural literature. That themes focus using IoT, WSN, RFID, automation, sensors based smart and precision agriculture.

Table 2. Most productive scholars with IoT agriculture theme

No	Authors	Number Articles
1	M.S. Farooq	5
2	E. Symeonaki	4
3	S. Li	3

Table 3. Top three most cites articles with IoT agriculture theme

No	Cites	Authors	Title
1	830	N. Wang	Wireless sensors in agriculture and food industry - Recent development and future perspective.
2	517	T. Ojha	Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges
3	506	L. Ruiz-Garcia	A review of wireless sensor technologies and applications in agriculture and food industry: State of the art and current trends

In Table 4, the seven most frequent keywords with an aggregate frequency of 85%. Internet of things and agriculture became the most used keywords. The internet of things is considered a breakthrough in agriculture due to its ability to combine agricultural processes and improve automation (Puranik et al., 2019; Bogdanoff and Tayeb, 2020), productivity dan visibility

(Martinez et al., 2020; Bhat et al., 2022). Wireless sensor networks (WSN) are the third most popular search term. WSN is one of network communication technology that is utilized extensively in IoT agriculture. The fourth and fifth most popular search terms are precision agriculture and smart agriculture. Precision and smart agriculture are advantages of utilizing IoT to produce agriculture with precise procedures and outcomes and smart procedures and outcomes (Muangprathub et al., 2019; Ayaz et al., 2019). The sixth most popular keyword is sensors. Sensors are components of sensing and have become an integral feature of IoT agriculture applications (Khoa et al., 2019; García et al., 2020; Sengupta et al., 2021). The seventh most popular keyword, cloud computing, is a technology-based cloud technology that has a significant impact on data and video remote sensing operations in agriculture (Namani and Gonen, 2020; Thalluri et al., 2020).

Table 4. Top Co-occurrence Keywords in IoT agriculture articles

No	Keywords	Occurrences	% Contribution	% Cumulative
1	internet of things	231	30%	30%
2	agriculture	105	14%	44%
3	wireless sensor networks	97	13%	57%
4	precision agriculture	85	11%	68%
5	smart agriculture	65	7%	75%
6	sensors	49	6%	81%
7	cloud computing	28	4%	85%
8	smart farming	27	4%	89%
9	irrigation	20	3%	92%
10	blockchain	16	2%	94%
11	monitoring	15	2%	96%
12	machine learning	12	2%	98%
13	crops	11	1%	99%
14	automation	10	1%	100%
	Total	771		

3.2 Network Analysis of Co-occurrence Keywords in IoT Agriculture Articles

Network analysis of co-occurrence keywords is one approach in analysing the linkage of bibliometric indicators in scientific articles (Zelbst et al., 2020; Rejeb et al., 2022). It can expose the article's primary substance and explain the structure of a scientific field. Close linkage will result in a cluster of keywords. The weight of a big occurrence inside a cluster will be the focal point of the research theme's findings and subsequent debate. All keywords from the sample database of articles are extracted into the Mendeley desktop tool to initiate the study. Then, analyse and evaluate the consistency of the written keywords. For instance, the phrases "internet of things," "wireless sensor networks," and "sensors," among others. The letters must be written identically, without acronyms or abbreviations. The subsequent step is to conduct an analysis. The analysis tool employs the VOSviewer application. The format of the article sample database file is RIS. In the process of configuration, VosViewer employs the full counting grouping method (Rejeb et al., 2022). Then, by setting the minimum keyword frequency to 5, keywords will be examined with a minimum count of 5.

Figure 2's six groups with various color markers are depicted by the analysis's findings. Using the description, it can be seen that each node represents a keyword, and its size indicates how frequently that keyword occurs. As a result, the distance between the two nodes reveals the degree of proximity. The proximity of two nodes depends on their respective distances from one another.

The following step is to examine and understand a few of each group's most popular terms. Figure 3 presents the most keyword list for each group. The designation of a group's name follows, and it is determined by the size of the node keywords that stand out and are connected.

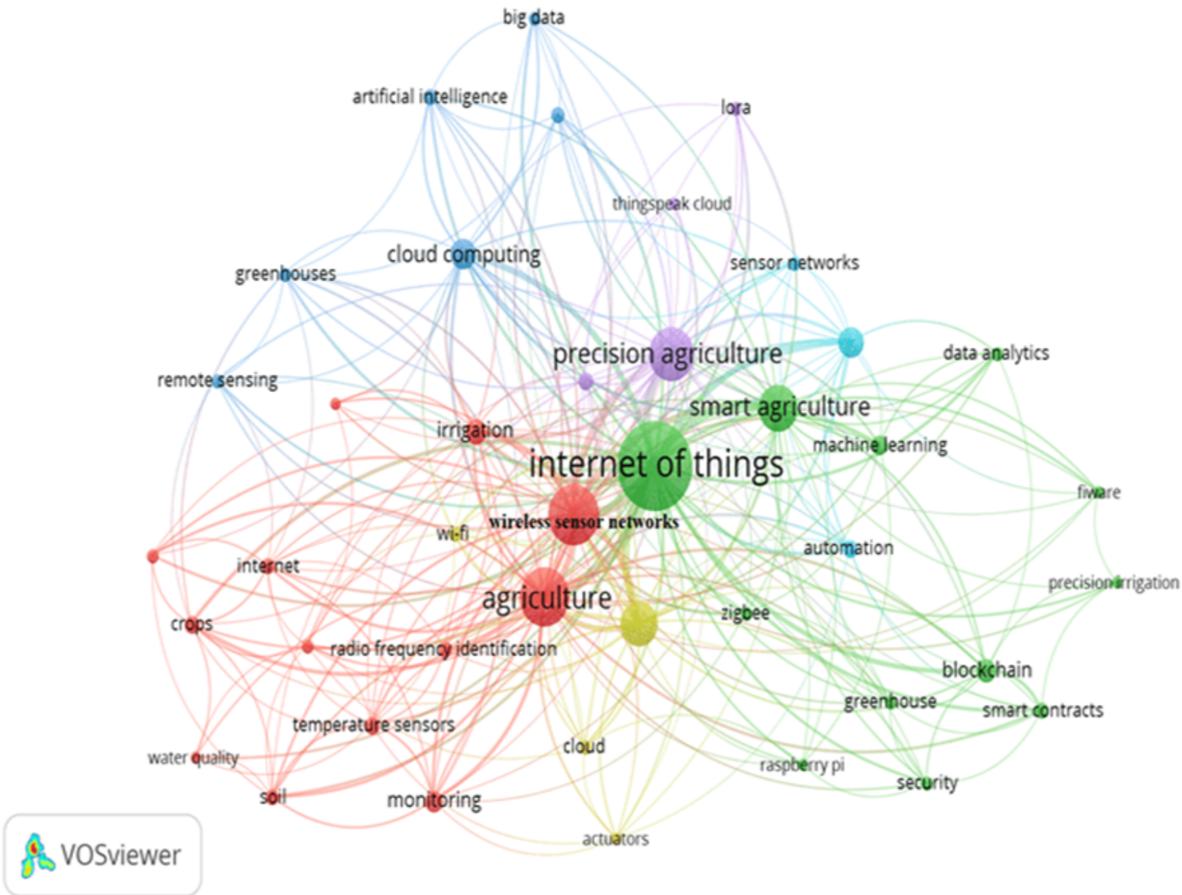


Figure 2. Network analysis co-occurrence keywords of the research IoT agriculture.

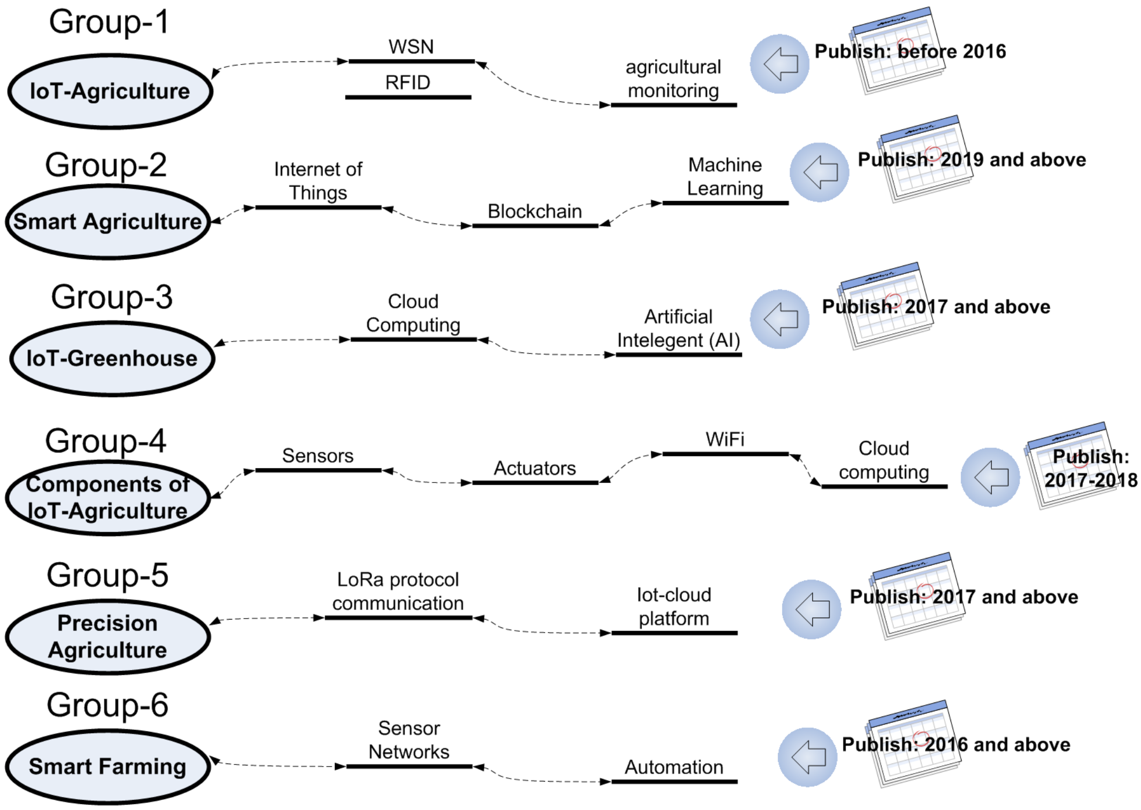


Figure 3. The focus of the research group IoT agriculture.

4. The Focus of The Research Group IoT Agriculture

Group-1 consists of wireless sensor networks (WSN) and radio frequency identification (RFID) for agricultural monitoring. Research on the topic of the IoT in agriculture employs WSN and RFID to track agricultural activities such as irrigation, water quality, crops, and soil fertility. In Figure 2, it is indicated by red markers. The red nodes utilize keywords: wireless sensor networks (WSN) and radio frequency identification (RFID), monitoring technology to link to agriculture. These terms have the highest group-1 occurrence weight. The majority of articles were written before 2016. WSN and RFID are two technologies that are crucial to group-1. WSN is a collection of different sensors that are connected in order to gather and send data through a wireless network. Such that the physical state or agricultural environment can be monitored and controlled remotely using WSN (Kumar and Ilango, 2018). WSN can broadcast and receive data in large quantities and at high frequencies. Research findings about WSN, for monitoring environmental conditions (Rasooli et al., 2020), soil condition monitoring (Kiani and Seyyedabbas, 2018). Employing the WSN underground technique to find pest insects to identify diseases, insects, and weeds (Bayrakdar, 2019). Employing WSNs buried in the ground to monitor plant growth (Sambo et al., 2020). Irrigation management system and Aeroponic agriculture using the WSN technology for monitoring and remote control (Lakhiar et al., 2018). Low energy consumption, typically low costs, scheduling agricultural activities, monitoring agricultural data and remote sensing and control are benefits of employing WSN technology. When it first debuted, WSN's power sources were constrained to non-rechargeable batteries with short lifespans. Solar energy technologies may be used in the creation of power sources. Which is able to make the sensor network lifetime much longer than 5.75 days to 115.75 days and the network throughput also increases from 100 K bits/sec to 160 K bits/sec (Sharma et al., 2019).

The application of RFID technology for IoT in agriculture is the focus of the following group-1. RFID is utilized in agriculture for monitoring, tracking and identification. It is made possible by the combination of sensors with RFID tags. IoT agriculture has used RFID technology in several research. The identification and sensing of the production yield using an integrated RFID and sensor as a result, the procedure is more effective and efficient (Wasson et al., 2018). In the early 2000s, Wang et al. (2006) had already begun using RFID for agricultural system traceability. In terms of progress to date, RFID has emerged as one of the technologies that is still utilized in blockchain IoT-based agriculture supply chain management (Bhat et al., 2022).

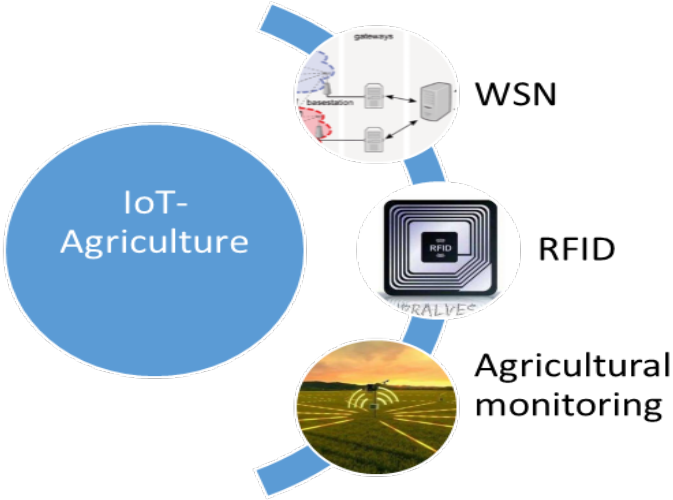


Figure 4. Group-1: IoT agriculture consists of WSN and RFID for agricultural monitoring.

Research on the topic of smart agriculture with IoT, blockchain, and machine learning is the focus of group-2. The majority of the articles in this cluster were released in 2019 or later. In Figure 2, it is indicated by green markers. The green nodes utilize keywords: blockchain, machine learning, and IoT technology to link to smart agriculture. These terms have the highest occurrence weight. Smart agriculture refers to a method that is widely used by farmers and is expanding quickly. Due to the availability of low cost, low power wireless sensors, automation, remotely control, monitor, and report on plant, weather, and field conditions based on the internet of things. In the most recent advancement, farmers may perform future prediction analysis with Artificial Intelligence (AI). Conventional agriculture is being transformed by the combination of IoT and AI technologies (Qazi et al., 2022). One sort of AI that is frequently utilized in agricultural analysis techniques is Machine Learning (ML). ML in IoT agriculture to detect weeds, plant diseases, pests (Chang and Lin, 2018), agricultural guiding systems (Niranjan et al., 2019), and increased agricultural yield (Kalimuthu et al., 2020).

Blockchain technology will be the subject of additional investigation into group-2. Blockchain, in accordance with is a data format that is employed to generate transactions for digital ledgers and then distributed to the nodes of the blockchain network. The distributed ledger, data transparency, smart contract, security, consensus, and asset management are the six fundamental components of blockchain technology. This technology has a recent use, and integration into the IoT agriculture system is expanding. Combining blockchain with IoT agricultural enables real-time performance improvement, transparent information sharing between sections, and secure privacy. Managing sensor-connected IoT devices and mining the blockchain, however, present difficulties (Devi et al., 2019). In order to boost transaction security and data transparency, blockchain technology uses distributed ledgers that are contained on each node of the system. The blockchain network is closed and only accessible to its members, therefore there are no unauthorized users on it. Therefore, no unlawful users are engaging in fraudulent activities. Consensus and the ability to execute smart contracts make this possible.

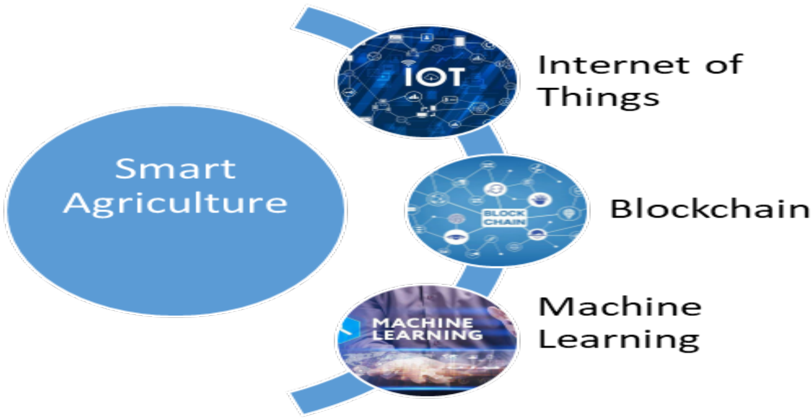


Figure 5. Group-2: Smart agriculture with IoT, blockchain, and machine learning.

Group-3 consists of research with cloud computing and AI technology with an emphasis on the Greenhouses IoT subject. It is used for smart irrigation, remote sensing, and managing big data agricultural greenhouses. Studies on this cluster have typically been published since 2017. Figure 2 depicts group-3, which is highlighted in blue. It shows integrating IoT, cloud and IoT, AI technology in agricultural greenhouses. Agriculture products will be closely related to the role of IoT Cloud-AI for greenhouse environmental solutions. Because environmental factors, such as air gases, climate and temperature are directly affected greenhouses. This is in line with (Ray, 2017) IoT cloud integration for remote monitoring, control, and sensing of greenhouse parameters, such as pH, temperature, CO_2. Renting a cloud server is required in order to do remote monitoring, control, and sensing tasks. Various IoT cloud server service systems for agriculture are currently available. Whether they are related or not is one service parameter that can be utilized as a factor in selecting a platform. Real-time data capture, data visualization, cloud service type, data analytics, and developer cost. Free cost parameters are a viable choice. IoT cloud service platform with free services like ThingSpeak (https://thingspeak.com/), Xively (https://xively.com/), Plotly (https://plot.ly/) dan Nimbits (www.nimbits.com/).

The integration of AI in the IoT agriculture system is the main topic research on group-3. The implementation of IoT-AI is proved to make agriculture smart. According to Gia et al. (2019), creating artificial intelligence using the Convolutional Neural Network (CNN) method based on image compression that is integrated into a sensor network device, Brunelli et al. (2019) employed computer vision algorithms, Gobalakrishnan et al. (2020) and Merchant et al. (2018) which incorporates system learning into IoT devices to boost processing speed and memory to detect insect pests in real-time. The study demonstrates the use of IoT-AI in agriculture, enhancing the capacity to act independently and find solutions. Future demand will migrate away from cloud-computing solutions and toward edge computing solutions. Because farmers are better able to receive solutions more quickly and directly. Additionally, the availability of 5G internet technology will increase the capacity of better solutions in the future (Alsamhi et al., 2022). The reason is, the 5G internet technology has the capacity to have greater data speeds.

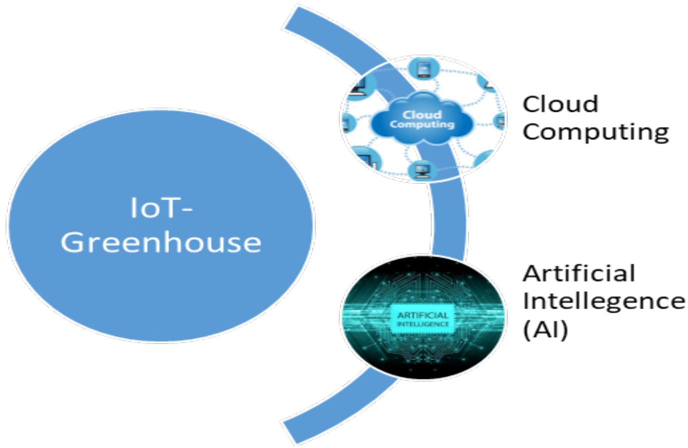


Figure 6. Group-3: Cloud computing and AI technology with an emphasis on the Greenhouses IoT.

Group-4 has studied IoT related components of agricultural technology, such as sensors, actuators, WiFi, and cloud computing. These cluster articles are often published in 2017–2018. The four article keywords with the highest importance and occurrence weight. Where is highlighted in yellow on Figure 2. This outcome is consistent with the conclusions done by Qazi et al. (2022), that the four components can be integrated to develop smart agriculture. Due to the fact that wireless sensors can transmit agricultural data to be acquired over a WiFi. Then comes support for actuators for automatic work execution that serve as controls. Cloud computing, which offers big database storage, remote sensing, and remote-control capabilities. Sensors that are frequently utilized in agriculture, including soil sensors (pH sensors, moisture sensors), gas sensors (O_2 sensors, CO_2 sensors), light-sensors (light dependent resistor sensors, ultra violet sensors), motion sensors (passive infrared receiver (PIR) sensors), temperature-humidity sensors (detection humidity temperature (DHT): DHT11 sensors, DHT22 sensors) and air pressure sensors (barometric pressure sensors) (Farooq et al., 2020). WiFi is used to transmit sensor data with minimal energy consumption and high data transfer rates. The transmission range is less than 100 feet. Its development is to expand the transmission distance and data transfer capacity. Currently, WiFi has been merged with cloud technologies. According to Jiménez-Buendía et al. (2021) which blends WiFi, Cloud, sensor data can be transmitted and stored on a cloud server for mobile real-time visualization, and subsequent analysis.

Group-4 research focuses on the usage of actuators are supporting devices that serve as control instruments. The actuators are connected to the microcontroller board and coordinated with the sensors in a specific circuit design. Popular microcontroller board include ATMega328P Arduino, ESP8266 NodeMCU, 18F458 PIC (Pernapati, 2018). Microcontrollers typically feature an embedded WiFi module that networks may access. Logic program has been generated and uploaded to the microcontroller board via a port attached to an IDE application, such as the Arduino integrated development environment (Arduino IDE). The work process between sensors, actuators, WiFi, and the cloud can begin.

There are companies offering services for agriculture sensors systems. As a factor to consider while picking an agriculture sensors system. There are including location (indoor/outdoor), sensor kind, internet of things (active/inactive), cloud technology (supported/not supported), software application form (yes/no), and application type (irrigation, gardens, aquaponics). IoT parameters must be active and cloud-supported in the IoT agriculture application. Several agriculture sensors system solutions, such as Biponics (http://www.Bitonics.com), Edyn (https://www.edyn.com), PlankLink (http://myplantlink.com/), HarvestGeek (http://www.harvestgeek.com/), Koubaci (www.koubachi.com), and Niwa (www.getniwa.com).

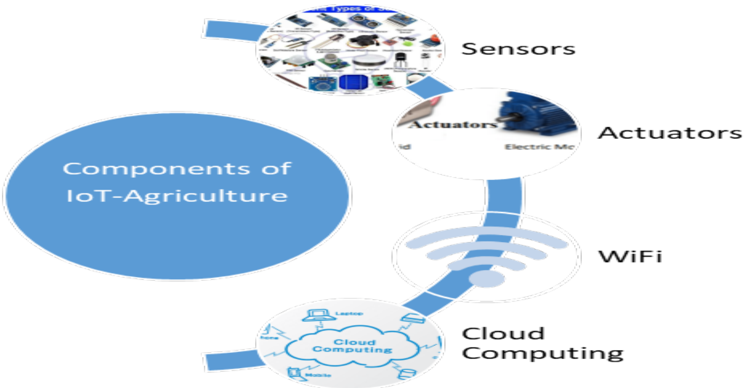


Figure 7. Group-4: Components of IoT agriculture include sensors, actuators, WiFi, and cloud.

Group-5, this cluster research theme focuses on creating precision agriculture by using LoRa communication networks and IoT cloud service providers. This cluster article is published in 2017 up until now. Based on Figure 2, this cluster is marked in purple. Low Power Long Range (LoRA) is a technology at the physical layer for data communication between IoT transceivers (Kontogiannis et al., 2017; Ray, 2017). LoRa has enabled IoT devices to modulate spectrum distribution to communicate up to 12 kilometers apart. But it has poor data rates that are approximately 100 Kb/sec. Another of the types of IoT communication networks are LoRa-WAN, RFM69, Zigbee, Bluetooth, Narrow Band IoT, WiMax, and Cellular networks (Partel et al., 2019; Munir et al., 2018; Qazi et al., 2020; Rayhana et al., 2020). According to Rejeb et al. (2022), LoRa and Zigbee technologies are wireless networks most suitable to be applied to Smart Agriculture Systems. Because the two technologies are straightforward to implement, have low latency and consumption power, and have sufficient transfer rate data. It is vital to have a communication range that meets requirements, particularly LoRa for long range and Zigbee for short range. Group 5's next objective is to utilize the cloud IoT agriculture service provider. ThingSpeak cloud is the most commonly used provider (Ray, 2017). This provider offers service parameters that include a free developer fee, data analytics, a public cloud service type, data visualization, real-time data capturing, capturing all sensor data in Microsoft Excel format, and retrieving it from a smartphone (Bachuwar et al., 2018).

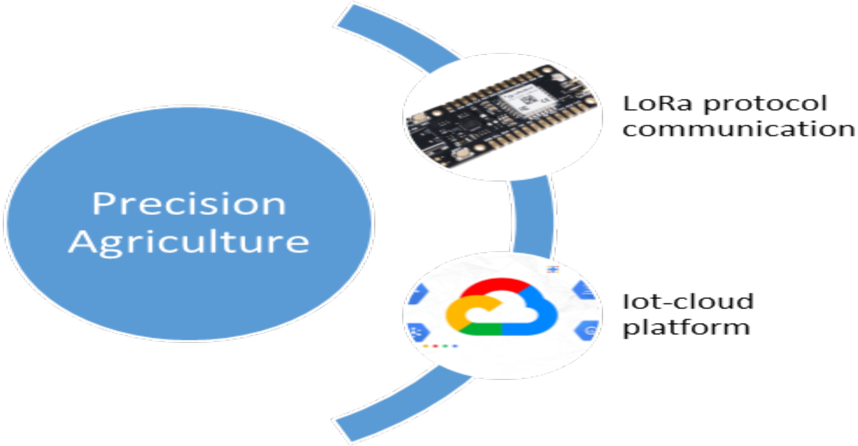


Figure 8. Group-5: Precision agriculture using LoRa communication networks and IoT cloud service providers.

Group-6, IoT for smart farming employing sensor networks and automation. The articles were published between 2016 and the present. This group is indicated in light blue in Figure 2. Agricultural operations and communications can be linked regardless of distance or location using sensor networks. Sensor networks incorporate a large number of sensor nodes that are able to detect environmental changes and execute particular actions based on program commands stored in the microcontroller or microprocessor board. Automation, according to Symeonaki et al. (2019) the presence of edge technology in IoT agriculture is the next IoT revolution of development. Wherein all agricultural activities and supply chains will be under automated and intelligent surveillance. Several studies are associated with Edge-IoT-Agriculture, including automated irrigation systems (Bogdanoff and Tayeb, 2020), remotely control farm equipment power switch (Das et al., 2019), devices incorporate edge technologies-blockchain and smart contracts application (Pranto et al., 2021). In addition, the application of a new architecture is the integration of edge-fog-cloud into the IoT agriculture system, yielded comparable outcomes enhancing automation and the Smart Agriculture System's efficiency (Alharbi and Aldossary, 2021). Unlike the previous approach, IoT agriculture now incorporates the cloud layer as well. Due of the vast volume of sensor data that is processed, analyzed, and stored exclusively on the cloud layer. Consequently, it increases the system's load and its energy consumption.

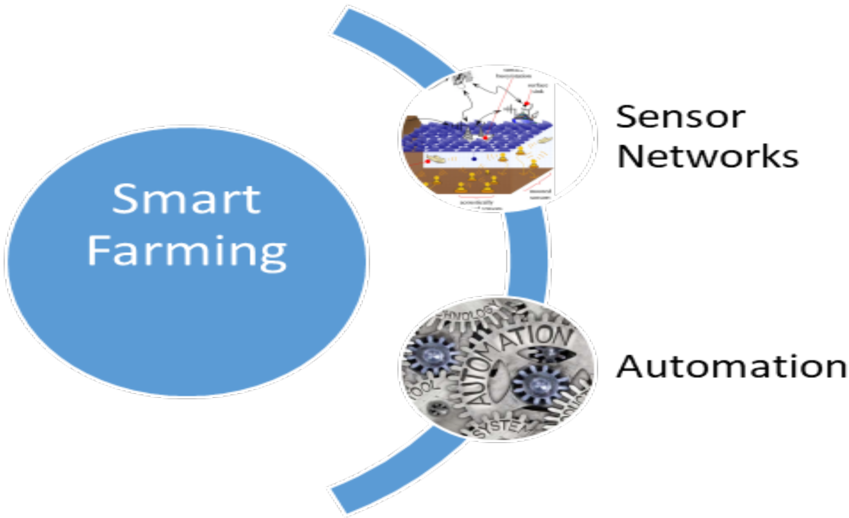


Figure 9. Group-6: Smart farming employing sensor networks and automation.

4. Conclusion

This article's primary purpose is to provide a comprehensive and organized review of IoT research in agriculture themes. To reach this objective, a bibliometric study was conducted on a sample of literature pertaining to IoT in agriculture. The sample includes up to 550 items from the Scopus database. Scholars in this field who will initiate fresh study on the implementation of IoT in agriculture can benefit from the conclusions of this analysis. Although recent research has offered some pertinent information regarding the analysis of IoT applications in agriculture, further information is needed. However, a bibliometric analysis that may identify groups of previously conducted research themes is still required. Significant discoveries from this study's results discovery, the number of research publications on IoT agricultural over the previous two decades, began in 2003. IoT-agricultural application research continues to expand. Specifically in the last decade, between 2015 until now. This is due to the increasing interest in integrating IoT for smart and precision agriculture. The expansion is driven by the advent of cutting-edge technologies that increasingly support IoT agriculture, such as cloud-edge computing, which enables automation, high-speed networks, and rapid remote access to control, monitor, remote data, or remote video. The main result is six groups of research focus themes for IoT agriculture, including (1) IoT agriculture utilizing WSN and RFID for monitoring agricultural activities; (2) Smart agriculture utilizing IoT, blockchain and machine learning; (3) Greenhouses-IoT utilizing cloud computing and artificial intelligence; (4) Components of IoT agricultural include sensors, actuators, Wi-Fi, and cloud computing; (5) IoT platform and LoRa communication network for precision agriculture; and (6) Smart farming utilizing sensor networks and automation. Recommendation, the application of a new architectural system to IoT agricultural technology in the form of edge-fog-cloud integration. This architectural approach increases automation and the energy efficiency also decreases carbon emissions of the agriculture system. Due to the edge layer's ability to collect agricultural data from several sensors that can be processed and analysed in real-time, and to automation. Then, the fog layer will relieve the cloud layer of its weight. In order for the system as a whole to be more effective in agricultural applications and energy usage.

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