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Internet of Things (IOT) in Smart Agriculture: A Scientometric Analysis

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Abstract
This article reviews scientific articles on smart agriculture IoT. The aim is to explore both areas of research and practice. We compared annual growth, country production, and trending topics in publications by focusing on the topics most relevant to IoT in the smart agriculture industry. The analysis first selected publications from the period 2014-2023. Because this comparative analysis between smart agriculture scientometric data is new, the findings from this study can represent the basis for future research to identify new research opportunities for IoT. This study provides scholars with a better understanding of IoT research in the field of smart agriculture while expanding entrepreneurial knowledge in this field. Practitioners may benefit from this review to understand new and underexplored opportunities.
Keywords: IOT, Scientometric Analysis, Topic Detection, Research Dynamics, Smart Agriculture Industry

Introduction

The role of information systems is growing around the world, especially in the smart agriculture industry (Pivoto et al., 2018). From automated farming to agricultural business platforms based on cloud technology, the agricultural industry has always benefited from information technology (Elijah et al., 2018). With the development of information technology, information systems have become the key to improving smart agriculture and its management (Mohamed et al., 2021). This has led to a search for new technological models aimed at promoting better efficiency for all actors involved through greater information flow and technological innovation.

The Internet of Things (IoT) is one of the latest IT applications in smart agriculture. The Internet of Things can be regarded as the interconnection of smart objects or devices through the Internet, resulting in new applications and innovative services (Sinha & Dhanalakshmi, 2022). These objects have the ability to improve industrial production efficiency. Agricultural producers can improve work efficiency and reduce manpower through these Internet of Things applications Production costs (Ayaz et al., 2019). For example, drones and automated harvesters controlled by IoT technology can replace the work efficiency of dozens or even hundreds of people. Some conditions of crops can be judged more accurately through sensing devices than human eyes. Based on the Internet of Things Smart agriculture, acting on the entire value chain, will trigger a revolution in the agricultural field (Deepa et al., 2021).

In the past ten years, many researchers have studied projects related to the Internet of Things in smart agriculture. IoT research is developing rapidly, especially research involving the application of innovative products in smart agriculture (Heideker et al., 2020; Kumar, 2021). Researched IoT-based smart agriculture industry applications and trends (Lakhwani et al., 2019). Their research analyzes various IoT and smart agriculture policies and regulations around the world to determine how they contribute to economies and societies in terms of sustainable development (Quy et al., 2022). However, so far, there are many literature reviews on the use of IoT in smart agriculture (Tao et al., 2021). But we found a few people who have started to use bibliometric techniques to study the literature on the application of IoT in smart agriculture (Kushartadi et al., 2023; Patil et al., 2023).

Unlike previous studies, our exploratory work aims to analyze the research field of IoT in smart agriculture industry. By drawing visualizations of trending topics, our work is designed to provide practitioners and researchers with more practical answers. In fact, our research questions are: Q1: What is the main key conceptual subfields of research about IoT in the smart agriculture industry and how have they evolved? Q2: What are the development prospects of smart agriculture in the field of IoT? The main theoretical contribution of this article therefore lies in identifying a new approach to analyzing the evolution of issues in academia. This makes it possible to predict the impact of emerging research topics on the industrial sector and the information contained in publications.

The study is elaborated below. Section 2 presents a literature review of the role of IoT in smart agriculture. Section 3 presents the research materials and methods we used to collect and analyze the data. Section 4 presents the main findings, and Section 5 discusses these findings and implications for the research.

Literature Review

IoT in Smart Agriculture

When Kevin Ashton attempted to link items to the Internet using RFID tags (intended to make it simpler for computers to manage objects) in 1999, the Internet of Things was formed (Bandyopadhyay & Sen, 2011; Li et al., 2015). In the literature, there are several definitions of IoT. Others focus on object types (services and applications) and their application areas (smart agriculture, smart cities, transportation congestion, waste management, structural health, safety, emergency services, logistic (Marcu et al., 2020; Symeonaki et al., 2020).

The Internet of Things is already a reality in many industries, but it is still a relatively new concept in smart agriculture (Cyman et al., 2021). This might be due to the fact that agriculture, as a conventional manufacturing business, takes longer to change and update. Different IoT-based smart agriculture turns old agricultural systems into smarter agricultural systems that are closer to the demands of farmers due to the constant development of smart irrigation systems and drones (EG & Bala; Nayyar et al., 2020). It employs IoT innovation to shift away from traditional labor-intensive practices and towards a new behavior centered on automated manufacturing. The Internet of Things technology enables circumstances for agricultural production labor to be liberated, productivity to be increased, and production costs to be reduced, radically transforming the agricultural business (Saiz-Rubio & Rovira-Más, 2020).

Therefore, in the context of smart agriculture, the Internet of Things can be defined as a network of smart sensing devices and physical objects that are digitally connected to collect, monitor, and control agricultural production equipment data (Dhanaraju et al., 2022). In fact, by installing detection sensors in smart production equipment (automatic irrigation systems, drones, unmanned harvesters, etc.) and connecting to tablets or smartphones via wired or wireless networks, producers themselves can instantly consult the results of agricultural production data (Chen et al., 2021; Lanje et al., 2022).

Many researchers have highlighted the importance of IoT playing a role in different aspects of agriculture. How IoT can improve agricultural management through an innovative market-depth assessment that includes vendor analysis, growth drivers, industry value chain and quantitative assessment, writes Williams (2013). Ayaz et al. (2019) believes that the Internet of Things can automate smart agriculture provides a high degree of insight into the value of agricultural production. At the same time, Abbassi and Benlahmer (2021) wrote that the Internet of Things has reduced agricultural production costs and led to the emergence of new agricultural production systems.

In addition, IoT provides the smart agriculture industry with the means to improve operational efficiency (Agarwal et al., 2017). By using IoT innovations, producers are able to optimize information flows, facilitate communication with markets and institutions, and integrate various data related to agriculture, even if these data come from other producers or centers in the network (Lezoche et al., 2020). This will improve the response speed of agriculture to the market.

Scientometric Analysis for Exploring Research

Ray (2017) published a literature review on the Internet of Things (IoT) for smart agriculture. It covers potential IoT applications, wireless communication technologies, and sensor-enabled systems for improved farming. The paper also includes case studies and identifies future directions for IoT in agriculture. However, specific information on challenges, examples, and benefits of IoT in agriculture is required to answer the questions.

Armenta-Medina et al. (2020) is a cutting-edge area for scholars who use bibliometric methods for scientific measurement. This thesis paper presents a bibliometric analysis of publications related to advanced information and communication technologies in agriculture over the past 25 years. Analyzes included co-word analysis of map science, a topic selection procedure, and use of the SnowballC library to select relevant terms and reduce redundant terms. The results are presented in the form of a strategy diagram that groups research topics in a two-dimensional space based on their density and centrality in the network. References to specific publications and tools used in the analysis are also included.

In 2022, Rejeb et al. (2022) comprehensively analyzes the current research status of the interaction between the Internet of Things and agriculture. This article covers bibliometrics, sustainability, challenges and precision agriculture. It also explores potential future research directions exploring the intersection of IoT and agriculture.

At present, there is no clear research framework either from the perspective of entrepreneurship and innovation, or from the perspective of regulators, professionals and users. This article attempts to close this gap by examining data from academic papers. Scientific data, including articles and scientific outputs, must be quantitatively analyzed in the field of scientometrics. Salatino et al. (2020) proposed a method that combines semantic technology with machine learning to analyze, track, and predict the flow of knowledge between academia and industry. In contrast to this contribution, we examine the patterns of publications and identify the development of research fronts.

As a scientometric software tool, we used the Bibliometrix R package (Aria & Cuccurullo, 2017). According to a recent study on bibliometric software tools, Bibliometrix "stands out because of the variety of different analyzes it incorporates" and the availability of the Biblioshing online interface (Moral-Muñoz et al., 2020). For example, it enables the creation of a bibliometric network for the visualization of conceptual, intellectual and social knowledge structures, as well as the performance analysis of three independent units (journals, authors and documents) using impact metrics. In addition, Bibliometrix performs geographical, spectral/RPYS and longitudinal conceptual (burst detection and topic evolution) analysis.

This article is a small study based on the Internet of Things and smart agriculture. This article mainly refers to the research results of Lakhwani et al. (2019) and conducts a literature review and discussion in a small direction on this basis.

Materials and Methods

We reviewed the fields of research (publication) to put the IoT in Smart Agriculture. From 2014 to 2024, we searched the Web of Science database thoroughly to find all the papers on smart homes and acceptance to Collection the data.

The database of the Scientific Network was searched. Scientific publications, included in the platform's most complete connected data set (Bergeron et al., 2018). To find the English documentation, we used “smart agriculture” and “IoT” in the title, summary and keyword fields from all.

We used some exclusion criteria. Use the Bibliometrix program to download data in BibTex format, filter it, and then check it (Sjöberg et al., 2020). It is currently considered to be the most comprehensive, integrated and user-friendly Type A. Belfiore et al bibliometric tool, it is an open-source tool for scientific measurement and quantitative research of book measurements (Kang et al., 2021).

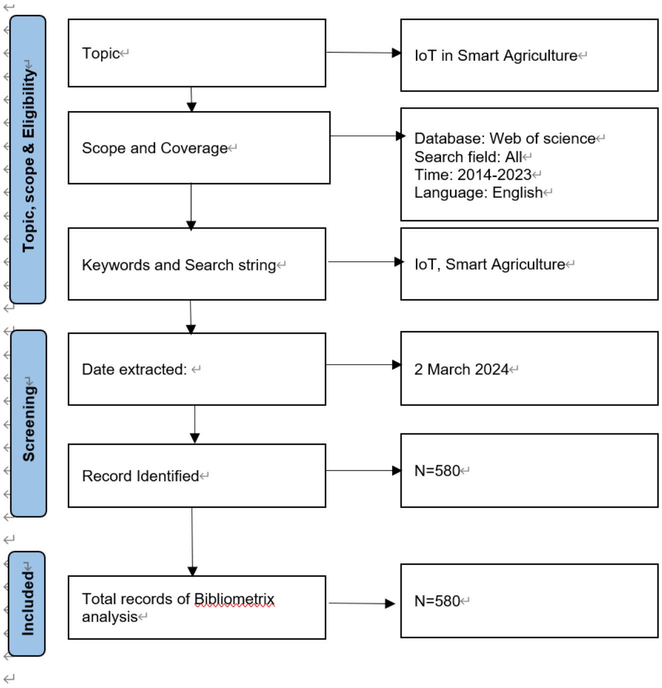

Figure 1. PRISMA Framework

Open the R run environment and enter "bibliometrix::biblioshiny".Run the code, pop up a network window, click "import row file(s)" on the data loading page, select the database type "Web of Science", load the previously filtered literature data, and click the Start button.

The article analyzes Bibliometrix's measurement approaches to analyze and judge the feasibility and future trends in the discipline through intuitive scientific analysis (Yurui & Abdullah, 2024).

Results and Discussions

Topic Trend

As can be judged from the tree diagram in Figure 2, the current outlook for the study faces mainly systemic and managerial difficulties. More topics in the literature are related to these two themes. It can also be seen that more and more information technology is being integrated and upgraded with traditional agriculture. Smart agriculture is currently facing an upgrade in systems and technology compared to traditional types of agriculture. The biggest challenge is how to manage and deploy them.

Based on the data in the tree diagram, we can summarise the trends and general outlook for the smart agriculture and IoT sector.

- Importance of management and automation: Management was a prominent theme, suggesting that effective management systems are key to implementing smart agriculture solutions. With the development of IoT technology, we can expect management strategies to rely more and more on automation and real-time data.
- Adaptation and sustainability: Adaptation and food safety showed their centrality, emphasising the importance of adapting to climate change and securing the food supply chain. More research and technological innovation are expected to support these areas in the future.

- Growth of the Internet of Things: The Internet of Things (IoT) appears as a high-frequency topic in the dendrogram, implying that the use of IoT technologies in agriculture will continue to grow, especially in precision agriculture and smart irrigation systems.
- Expansion of Smart Agriculture: Smart agriculture related topics such as precision agriculture and soil management will continue to expand with the application of more advanced sensors and data analytics to improve crop yield and quality.
- Environmental concerns: Topics such as climate change, soil management and emissions reduction reflect the environmental anxieties of agricultural research. More innovations are expected to be used to reduce the environmental impact of agriculture.

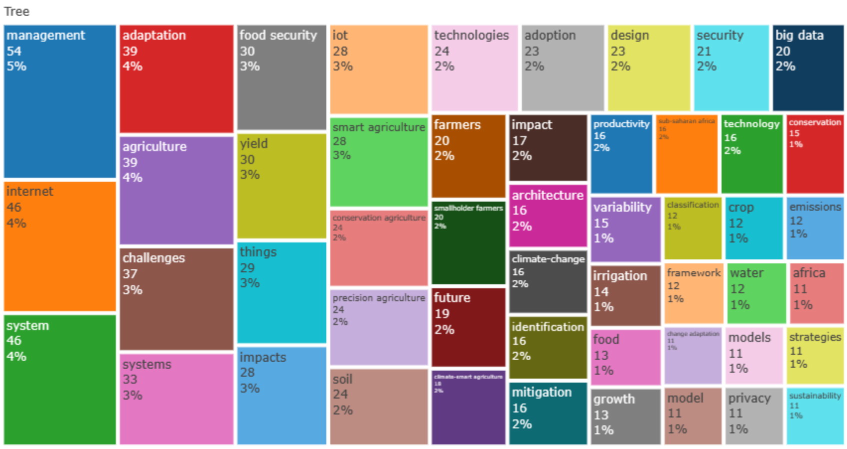

Figure 2. Threemap

Based on the provided Figure 3, we can analyze the prospects for the development of topics in the field of smart agriculture and the Internet of Things as follows:

- The centrality of food safety and conservation agriculture: The high concentration and influence of the topics "food safety" and "conservation agriculture" in the diagram reflects an important trend in research to improve the sustainability of food production and resilience to environmental change. It is likely that these areas will continue to lead the way for smart agricultural technologies in the future.
- The key role of IoT technology: The Internet of Things (IoT) and 'Internet' themes show a high degree of concentration and influence in the graph, signaling a continued expansion of IoT applications in smart agriculture. As technology advances, the use of IoT for data collection, processing, and real-time monitoring is likely to become more prevalent and efficient.
- Trends in systems integration and data analytics: systems-related themes suggest that integrating different technologies and systems will be key to future developments. Integrated systems enable more efficient decision-making and may optimize crop management and resource utilization through data analytics.
- Acceleration of technological innovations: Technology-related themes suggest that emerging agricultural technologies such as sensor networks, automation tools and machine learning algorithms will continue to gain research and development attention. These technological innovations will accelerate the deployment and improvement of smart agriculture solutions.

Overall, the high level of correlation and concentration reflected in the coupling diagram indicates that research in these areas is not only mature but also deep, while also revealing possible directions for future research and technology development. The outlook for smart agriculture and IoT is very positive, and it is expected that more innovative solutions will emerge to address the challenges facing global food production and to drive agriculture in a smarter and more sustainable direction.

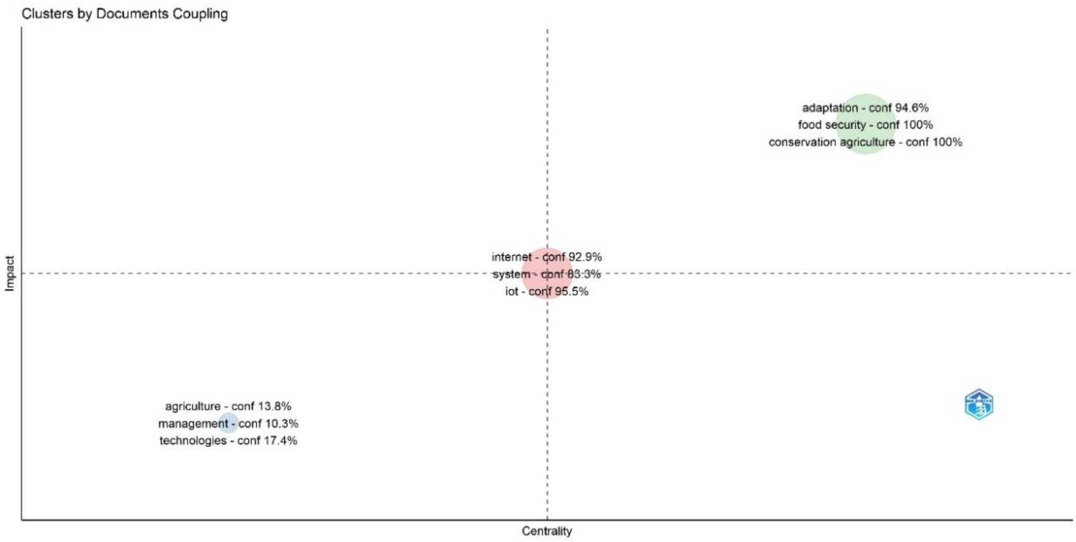

Figure 3. Coupling Map

By jointly considering the treemap and the coupling map of the literature, we can analyze the trends in the topic of smart agriculture and IoT as follows:

- Treemap analysis: The treemap shows the frequency and relevance of the keywords "management", "internet", "system", "agriculture" and "adaptation". " and "adaptation" feature prominently. This reflects the strong emphasis in research and practice on integrating management systems, Internet technologies, and responsive systems, all of which are cornerstones of smart agriculture development. Terms directly related to the IoT, such as 'Internet of Things' (IoT) and 'smart agriculture', also featured, signaling the growing use of the technology. The focus on 'food security', 'yield' and 'challenges' points to core motivations in agricultural research, including improving productivity and addressing issues such as climate change.

- Literature coupling analysis map: The Literature Coupling Analysis (LCA) diagram shows the relevance of the research themes and their centrality within the research area. In this figure, the themes "food safety" and "conservation agriculture" show 100 per cent coupling confidence, suggesting that they are central to smart agriculture research. The "Internet of Things" and "Internet" themes also show a high degree of centrality, signaling the continued expansion of technology integration and application in this area.

The "systems" related theme also shows a high level of coupling confidence, pointing to the importance of systemic solutions in the development of smart agriculture. Analyzing these two views together, the following trends and evolutionary processes can be identified:

- Technology integration: with the increasing use of IoT and internet technologies in agriculture, the future trend is towards better integration of various technologies and

systems, which includes not only farm management systems, but also supply chain management and food safety monitoring.
- Responsiveness and Adaptation: research is focused on developing agricultural systems that can adapt to changing environmental conditions and market demands. This includes climate change adaptation strategies and improved crop resilience.
- Productivity improvement: The use of IoT and big data analytics to optimize crop production and improve the efficiency of land and water use is the way forward.
- Integration of sustainability: The emphasis on conservation agriculture suggests that future agricultural technologies will focus more on environmental sustainability while meeting productivity and food safety requirements.

Overall, the outlook for the topic of smart agriculture and the Internet of Things looks positive and is expected to continue to evolve towards integrating more advanced technologies, improving sustainability and resilience, and enhancing production efficiency. Research and practice in this area is likely to progressively deepen, and as the global demand for food safety and environmental protection grows, smart agriculture will become even more important

Hematic Evolution
Based on Fig. 4, we can analyze the evolution of themes in the field of smart agriculture and IoT.
- Technology-driven efficiency gains: Themes such as "Efficiency", "Internet" and "Internet of Things (IoT)" show a year-on-year increase, indicating that technology plays a key role in improving agricultural efficiency. This may reflect automation and digitalization technologies. This may reflect the trend towards deeper and deeper use of automation and digitalization in agriculture.
- Ongoing research on adaptation: As the global climate changes, the theme "Adaptation" suggests a continuing focus on how to adapt agricultural systems to these changes to ensure the stability and sustainability of agricultural production.
- Long-term focus on food safety: Food safety has been an ongoing area of concern, suggesting that research is not only focused on increasing yields, but also on how to safeguard the resilience of the food supply chain.
- Data analytics and the rise of big data: While not the most prominent theme, the presence of 'big data' suggests that data-driven decision-making is becoming increasingly important in smart agriculture.
- Environmental and climate change response: Themes such as 'climate change' and 'mitigation' appear in the trend graphs, suggesting that the smart agriculture sector is seeking strategies to address environmental issues and climate change.

Taken together, the evolution of the smart agriculture and IoT themes reflects the following trends: firstly, the use of technology to increase the efficiency and automation of agricultural production; secondly, the need to ensure resilience and food safety in agricultural systems while maintaining productivity; thirdly, the growing use of data analytics and big data, which may play a greater role in future agricultural research; and finally, the environment and climate change are an ongoing concern that is expected to drive future innovation and policy development. These evolutionary trends suggest that smart agriculture and the Internet of Things will continue to be a dynamically evolving and rapidly adapting field as technology develops and global challenges intensify.

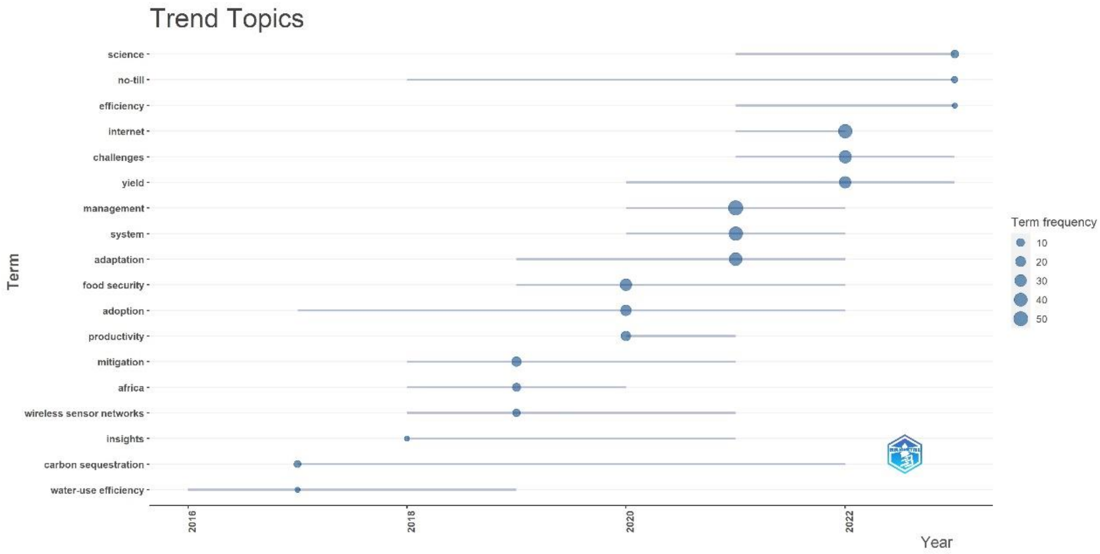

Figure 4. Trend Topics Map

From the data in Figure 5, the following thematic evolution can be distilled: Adaptation and systematization: As core research areas, 'adaptation', 'agriculture' and 'systems' indicate stability and depth of research, and the maturation of these areas suggests that future technologies and approaches will focus more on systemic adaptation to environmental change. The maturity of these areas suggests that future technologies and approaches will focus more on systemic adaptation to environmental change. Development of smart management systems: The management-related themes are located in the base theme area but, when combined with the other core themes, point to a future in which agricultural management will continue to evolve into smarter and more integrated systems, potentially including automated decision support and precision farming practices.

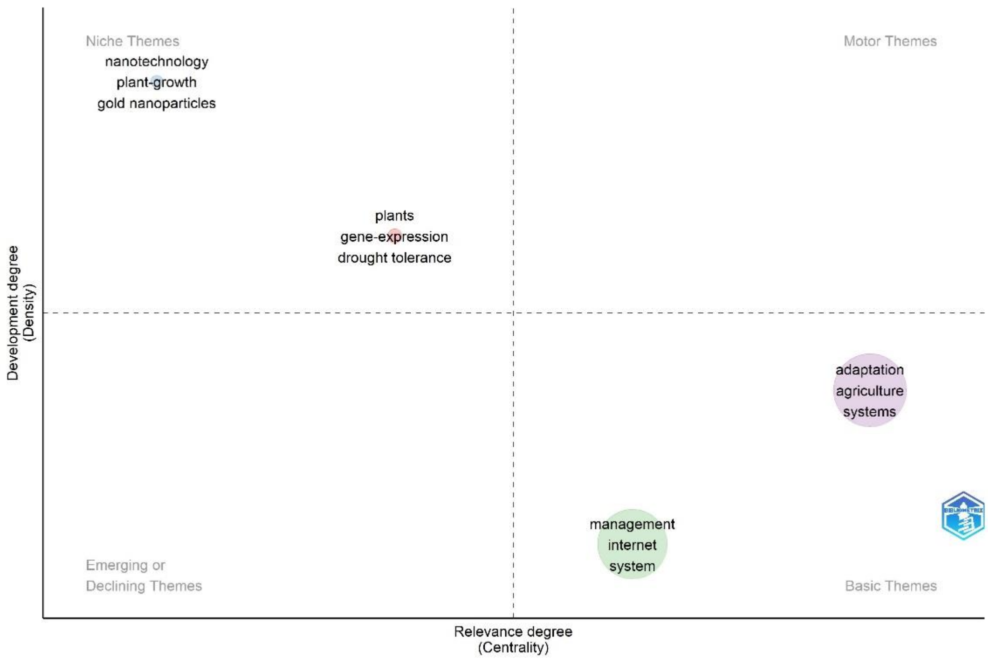

Figure 5. Themes Map

Taken together, the future direction of the smart agriculture and IoT sector is likely to focus on the following areas:

- Further integration of advanced technologies: deeper integration of IoT, big data and AI into agricultural practices to achieve higher productivity and better resource management.
- Ongoing focus on sustainability: research will continue to explore ways to make agricultural practices more sustainable, including reducing resource consumption and addressing the impacts of climate change.
- Expansion of precision agriculture: Precision agriculture-related topics are likely to see more growth, with precision agriculture becoming more widely used globally as technology matures.
- Influence of policy and economic factors: As global food security and climate change topics advance, related policy and economic factors will also influence the direction of smart agriculture research and technology development.

In conclusion, the development of smart agriculture and IoT will continue to evolve into more efficient, adaptable and environmentally friendly agricultural systems.

Future and Conclusion

Key conceptual sub-research areas and their evolution

Key conceptual sub-research areas of Internet of Things (IoT) in the smart agriculture industry include:

- Precision agriculture: real-time monitoring of crop conditions using sensors and IoT devices to accurately manage soil, water, nutrients and pests.
- Resource Management and Sustainability: Optimizing water management, energy conservation and waste reduction through IoT technologies for sustainable agricultural practices.
- Food Safety and Supply Chain Tracking: Leverage IoT to ensure transparency in the origin of food and track food from field to fork.
- Data-driven decision-making: Analyzing large amounts of data collected to guide decision-making in agricultural production.

These areas will evolve over time as technology develops: Technology Integration: IoT is increasingly integrated with traditional agriculture, automating data collection and analysis.

- Intelligence: The IoT enables remote monitoring and intelligent decision-making, improving the efficiency and quality of crop production.
- Environmental Adaptation: Research is advancing to improve agriculture's resilience to environmental change, particularly the impact of climate change on agriculture.

Prospects for Smart Agriculture in IoT

Smart agriculture in the Internet of Things (IoT) has a very promising future:

- Technological Advancement: As IoT technology continues to advance, technologies including sensors, drones, and automated systems will become more advanced and affordable, making smart agriculture more acceptable and widespread.
- Increased productivity: IoT technology is expected to further improve the efficiency of agricultural production, especially in resource-constrained situations, and optimize output through precision management.

- Data analytics and machine learning: With the development of machine learning and artificial intelligence, smart agriculture will be able to make more effective use of collected data to predict and address challenges.
- Sustainability: The application of IoT technologies can help achieve sustainability goals, such as reducing environmental impact through precise regulation of water use and fertilizer application.

Based on all results, we could get this conceptual framework:

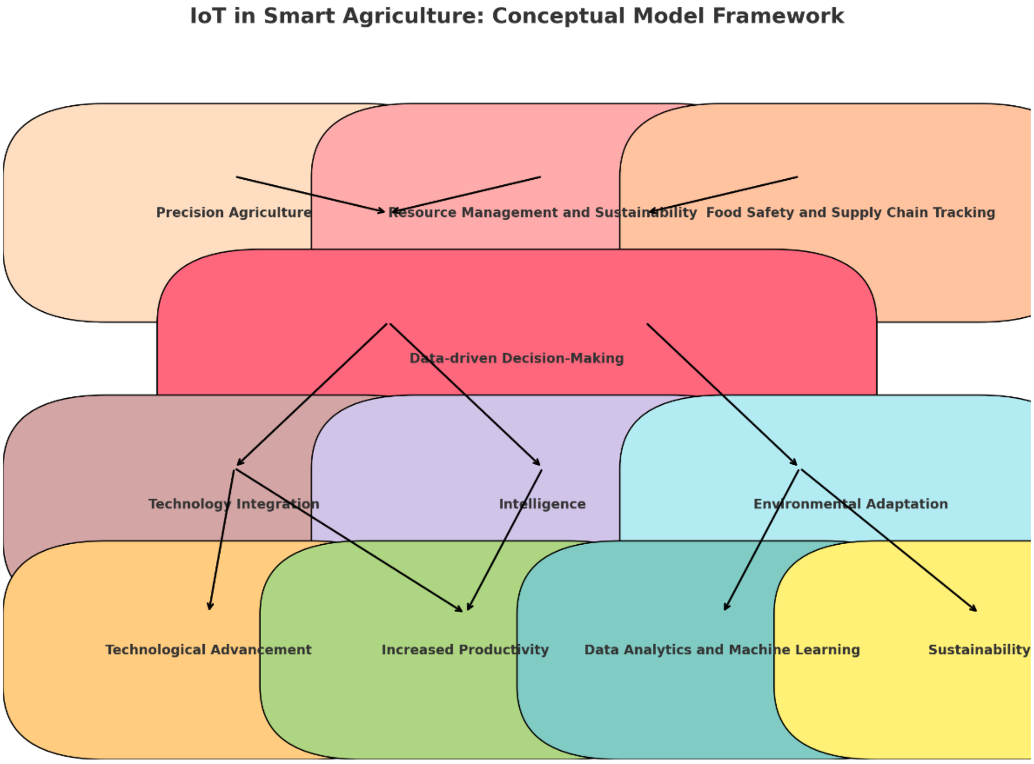

Figure 6. Conceptual Model Framework

In the future, smart agriculture and IoT will go hand in hand. Advances in technology will continue to unlock new potential for smart agriculture, while a growing global population and demand for sustainable practices will further drive innovation in this area. Research will likely focus on optimizing the energy efficiency of IoT devices, improving data processing capabilities, and enhancing the precision and adaptability of algorithms. The expansion of smart agriculture will not only improve crop yields and quality but will also make a significant contribution to global food security and the fight against climate change. However, developments in this field will also need to take into account the pervasiveness of the technology to ensure that farmers across the globe can benefit from these advances. In addition, data security and privacy will be key issues for future research and applications.

Discussion

The use of IoT in smart agriculture is transforming traditional agriculture, improving its efficiency and sustainability through key areas such as precision farming, resource management, food safety and data-driven decision-making. In the future, these areas will evolve with technological advances: precision agriculture will utilize more advanced and affordable sensors and devices combined with machine learning to improve accuracy;

resource management will develop more energy-efficient and adaptive IoT solutions to improve agriculture's resilience to environmental changes; food safety and supply chain tracking will enable more robust traceability systems through blockchain technology; and data-driven decision-making will rely on more powerful data analytics tools and algorithms to improve the ability to predict and respond to challenges. Despite the promise, global ubiquity, data security and privacy, and technological adaptation remain key issues that need to be addressed.

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