# AI-Powered Agriculture: A Scientometric Review of Technological Trends

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**Abstract.** Considered a key element in addressing the current challenges facing the agricultural sector related to food production and climate change, Artificial Intelligence (AI) is successfully helping to optimize human processes or tasks in several sectors. In this study, we present a scientometric analysis to answer the question, what are the technological trends of the application of artificial intelligence in agriculture? We use references indexed in the Scopus, a scientometric methodology, and software tools to perform the research. We identify that the countries with the highest number of publications are India, China, and the United States through document analysis. China is a country with more authors and institutions collaboration. The institution with the highest published number of papers was China Agricultural University. Finally, we identified that Ontology and Sentinel-2 refer to technologies to apply artificial intelligence and information technologies in agriculture. Also, we identify that the Internet of Things (IoT), decision support systems and machine learning is still a mandatory topic in these applications.

**Keywords.** Artificial intelligence, Agriculture, Scientometry, Technological Trends

## 1. Introduction

Sustainable agriculture is not a choice but a necessity[1]. Agriculture is one of the major contributors to environmental degradation and resource depletion[2]. To transform our current agricultural systems into more sustainable ones, we need to optimize the use of natural and human resources[3]. Leading international organizations presently argue that a transition to smart agriculture is an obligatory task to ensure food supply for an anticipated nine billion people by 2050.[4]

Intelligent agriculture is a growing trend that uses IoT devices such as drones and sensors to collect and analyze data. This enables farmers to optimize their production and management, reduce costs and environmental impacts, and improve soil health. AI applications such as irrigation, weeding, spraying, and harvesting can also enhance the efficiency and quality of farming. AI can help save water, pesticides, and herbicides, and reduce human labor[5].

This work presents a scientometric review of technological trends in AI applied to agriculture. It analyzes the growth of document production, the types and distribution of publications, the top journals, countries, institutions, and authors. It also provides a thematic map of the main areas of interest and application of AI in agriculture.

## 2. Methodology

This research involved a scientometric analysis, following Michán and Muñoz-Velasco's five-stage methodology,[6] which consists of recovery, migration, analysis, visualization, and interpretation. Initially, we selected the relevant digital databases and formulated queries using logical operators and specific criteria. Next, we meticulously extracted metadata from the chosen studies and integrated it into a new database. The quantitative analysis phase involved using specialized software tools, such as ScientoPy and Bibliometrix, and querying the database to obtain valuable insights. We harnessed various techniques such as bibliometric indicators, mathematical methods, statistical analyses, social network assessment, and text mining. Visualizing the results was crucial, achieved through the creation of Figures, graphs, diagrams, and maps, providing a clear representation of trends and outcomes. Lastly, we interpreted the results within their context, allowing us to establish research trends, identify influences, and draw comparisons in diverse aspects of the study.

# 3. Results

This section presents our analysis results by stage of the methodology.

## 3.1 Information Sources, Search, and Selection of Literature

The Scopus database was selected to perform the scientometric analysis. Scopus was considered a high-quality, curated multidisciplinary coverage data source for bibliometric and academic research.[7]

We conducted a systematic literature review to explore the current state of AI applications in agriculture. We used the MeSH database of the NCBI web portal to find relevant terms for our search query, which was: what are the trend technologies of AI application in agriculture? The MeSH database suggested the following terms: AI, Artificial intelligence, computational intelligence, computer reasoning, computer vision systems, knowledge acquisition, knowledge representation, machine learning, agriculture, farming, development, and agricultural. We used these terms to search for articles in various databases and analyzed them according to predefined criteria.[8]

The terms were used to form the following string: ((ai OR "artificial intelligence" OR "computational intelligence" OR "computer reasoning" OR "computer vision systems" OR "knowledge acquisition" OR "knowledge representation" OR "machine learning") AND (agriculture OR farming OR agricultural OR "agricultural development")). This string was applied to Scopus topic search, including the paper title, abstract, and keywords. The search results yielded data from 1939 to 2023 and the research query was conducted on September 2023.

The retrieval data consists of various tags related to citation information, bibliographic information, abstract and keywords, funding details, conference information, and references.

Given that the general question was oriented to know the academic overview of AI application in agriculture, the search results yielded 19061 documents between 1939 and 2023. Of these, the documents published in 2023 (about 3342 documents) were omitted because the year has not been completed. Therefore, 15719 references were selected between 1939 and 2022.

## 3.2 Extraction, Cleaning and Loading

We used Scopus to search for relevant literature and saved the metadata in RIS format, a common format for citation software. We then used Rayyan QCRI, a tool for screening titles, abstracts, and duplicates in systematic reviews, to curate the data.[9] We removed duplicate references, retracted papers, and unrelated documents, eliminating 1328 documents. We converted the curated Scopus data to a CSV file and loaded it into ScientoPy (version 2.1.3), a tool for scientometric analysis based on Python;[10], and into Bibliometrix (version 3.0.2), an R tool that allows for quantitative research in scientometrics and bibliometrics.[11] Both tools were used because they include different visualization tools; for example, while ScientoPy offers a table listing the countries' production, Bibliometrix offers a graphical way of displaying this information (e.g., maps).

## 3.3 Analysis, Visualization and Interpretation

The queries related to the introduction questions were executed to answer the main question about AI applications in agriculture. ScientoPy and Bibliometrix software tools were used for analysis and visualization.

Next, each section presents the analysis, the visualization is performed (table, map, or graph), and finally, the interpretation of each result is made.

## 3.4 Publication and document growth analysis

Figure 1 shows the distribution of papers published by year related to the application of AI in agriculture.

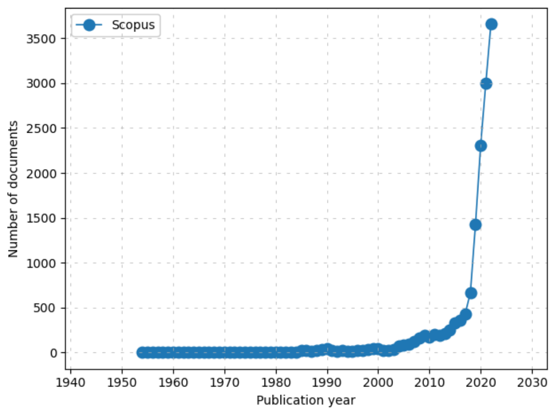



**Fig. 1** - Visualization of scientific production, distributed annually from 1954 to 2022.

The first papers identified were published in 1976. In those papers, Flores and Register present the development of an experiment to evaluate procedures for estimating wheat acreage in Kansas, utilizing pattern recognition systems in satellite images.[12] Later this year, IEEE realized a symposium on adaptive processes, the Conference on Decision and Control including Agricultural Models.[13] In 1977, Parrish Jr. and Goksel presented a rudimentary experimental system for automated apple harvesting.[14] In 1982, Tinney and Estes developed a knowledge-based expert system for rice crop identification.[15] It is notable an exponential growth until nowadays, demonstrating big importance and interest for academia and industry. Compared to previous works on this subject,[8] the number of documents published during the two last years has tripled (2021 and 2022) with 3310 and 4148 compared to (2019 and 2020) with 889 and 918 documents, respectively. Simultaneously, 77.48% (12179) of the total publications of AI in agriculture were written in the last five years (2018-2022).

According to their type, the article, or journal paper was the most frequently identified, with 7841 documents, representing 50.70% of the total number of documents. These publications are followed by conference papers, of which a total of 5836 documents were identified, which represents 37.74%, followed by 740 review papers (7.48%), 665 book chapters (4.30%), and 381 conference reviews (2.46%). Finally, 256 documents (1.65%) were classified as others: data papers, letter papers, editorial notes, and notes. The dominant language in the documents is English. Computers and Electronics in Agriculture is the journal with the largest number of AI publications in agriculture.

## 3.5 Country, Institution, and Author

The analysis identified, as shown in Figure 2, the top ten productive countries in terms of the number of documents published, with the percentage of documents published in the last years (2020 to 2023) in AI applications in agriculture. Countries with the highest number of publications is India, with 2756 documents, representing 17.53%, with an h-index of 74. China follows it with 2460 (15.64%), h-index of 85, and the USA with 2427 (15.43%), recording the higher h-index of 102, and to a lesser extent Germany, Australia, United Kingdom, Italy, Brazil, Spain, and Canada. It is noticeable that most documents were published after 2020.

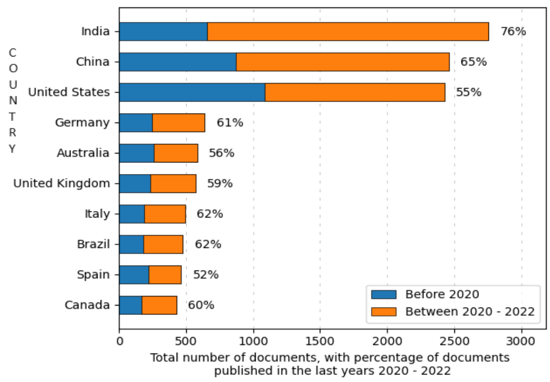



**Fig. 2** – Graphic representation of the top ten countries where the most papers that use AI in agriculture are published with the percentage of documents published in the last years 2020-2022.

Several affiliations were identified, where the universities were the most participative. China Agricultural University has the leadership, followed by the Zhejiang University.

Table 1 shows the five authors with the most publications in the area and the related Article Fractionalized value, necessary to avoid double-counting publications at an institutional level and refers to complete-normalized fractional counting in which credit for a given article is divided evenly among its authors. All five authors in publications on AI applications in agriculture are from China. Among those publications, the latest work related to AI in Agriculture involves precipitation retrieval,[16] global socioeconomic risks of wildfire, [17] root zone moisture prediction, [18] vigor identification of seeds[19], and identification of pests.[20]

**Tab 1**. - List of the five top authors with the highest number of publications and their related Article Fractionalized value.

| No. | Source | Papers | Article Fractionalized |
|---|---|---|---|
| 1 | Zhang, Y | 121 | 23.94 |
| 2 | Wang, Y | 119 | 25.94 |
| 3 | Li, Y | 111 | 22.57 |
| 4 | Wang, J | 109 | 22.25 |
| 5 | Zhang, J | 108 | 23.63 |

The most cited paper is "Big Data in Smart Farming – A review, by Sjaak Wolfert from Wageningen University and Research and Information Technology Group, Wageningen University.[21]

## 3.6 Trend Analysis

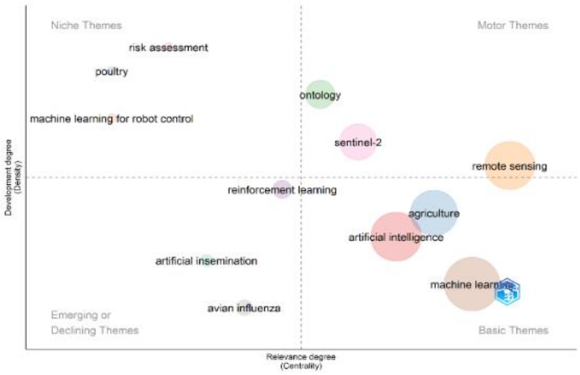
To identify the topics and trends of the application of AI in agriculture. We performed an analysis of the author keywords with the Bibliometrix software, from which we obtained a thematic map and a cloud of words (see Figures 5 and 6).

Figure 3 presents a cloud of author keywords most cited in the papers. The most important keywords were precision agriculture, random forest, remote sensing, classification, and image processing.


**Fig. 3** - Cloud of keywords given by the authors in the references analyzed.

In Figure 4, we present a thematic map based on co-word network analysis and clustering. This map is based on the method proposed by Cobo et al. for detecting, quantifying, and visualizing the evolution of a research field.[22] A thematic map allows four typologies of themes to be defined according to the quadrant in which they are placed.

**Fig. 4** - The most relevant themes of the application of AI in Agriculture according to the keywords provided by researchers.




The motor themes in the first quadrant (I) are the core topics of the research field. They have high centrality and density, which means they are well-connected and important. Some examples of motor themes are ontology, a theme that deals with the representation and manipulation of knowledge using various techniques, such as expert systems, natural language processing, knowledge acquisition, semantic web, and human-robot interaction.[23][24][25][26] Sentinel-2 is a theme that focuses on the use of satellite imagery from the Sentinel-2 mission to monitor and analyze various aspects of the Earth's surface, such as vegetation, soil, land use, and land cover. [27][28][29][30] Sentinel-2 images are processed using tools like Google Earth Engine, digital soil mapping, and Sentinel-1 data. Remote sensing involves the application of machine learning and data mining methods to remote sensing data, such as images, radar, and lidar.

The themes in the second quadrant (II) are niche themes that are highly developed and isolated. They have a high density of internal links, meaning they are well-connected within themselves, but a low centrality of external links, meaning they are not very influential or relevant to the field as a whole. Some examples of niche themes are risk assessments, poultry, machine learning for robotics, reinforcement learning, and AI-based methods.

The third quadrant (III) of the map contains the emerging or declining themes. These themes are not central or dense in the network, which indicates that they are not well-established or influential. Some of the themes in this quadrant are reinforcement learning, AI-based methods, artificial insemination, and avian influenza. These topics may represent new or fading areas of research that have not yet gained or lost much attention or impact.

The fourth quadrant (IV) contains primary and transversal themes, which have high centrality and low density. These themes represent the core and the breadth of a research field, covering general topics that span across different research areas. Some examples of these themes are artificial intelligence (which includes the Internet of things[31], smart agriculture[30], smart farming, big data, sensors, and robotics), agriculture (which involves decision support systems, climate change, irrigation, precision farming, gis, food security, fuzzy logic, sustainable agriculture),[32] remote sensing (which employs random forest, support vector machine, prediction, SVM, artificial neural network, data mining, decision tree, soil moisture), [33] and machine learning (which uses deep learning, precision agriculture, classification, image processing, computer vision, convolutional neural network, CNN, neural network). [34]

# 4. Discussion

In this study, we perform a scientometric analysis to answer the following question: What are the technological trends of AI applications in agriculture? To perform the analysis, we use the Scopus database and the software tools ScientoPy and Bibliometrix software.

The analysis reveals a significant increase in the number of publications related to AI applications in agriculture since the 1970s, with a notable exponential growth trend in recent years. This surge in research activity underscores the growing importance of AI technologies in the agricultural sector. As the world faces the challenge of feeding an anticipated nine billion people by 2050, it is evident that AI-driven smart agriculture is no longer an option but a necessity to optimize food production efficiently and sustainably.

Artificial Intelligence (AI) is an area that emerged more than 60 years ago.[35] However, in our results, it can be seen that one of the first works on the application of agriculture was published in 1976. It was the development of an experiment to evaluate procedures for estimating wheat acreage in Kansas, utilizing pattern recognition systems in satellite images.[12]

The analysis of AI-related publications in agriculture reveals that articles and journal papers are the predominant publication types, indicating a focus on in-depth research in this field. Computers and Electronics in Agriculture is the leading journal for AI publications, underscoring its significance as a platform for disseminating research findings.

India, China, and the USA are the most productive countries in AI in Agriculture, indicating a global commitment to exploring innovative AI solutions. Prolific authors in this field are primarily from China, covering diverse topics from precipitation retrieval to pest identification. Key research themes include precision agriculture, random forest, remote sensing, classification, and image processing, reflecting the central role of data-driven decision-making in optimizing agricultural practices. AI technologies hold great promise in revolutionizing farming by enabling precise resource allocation, reducing waste, and mitigating environmental impacts, aligning with global efforts to address environmental degradation from traditional agriculture.

Derived from this search, we worked with 15,719 papers in one database, while in the previous study, they consulted one database, resulting in 3,832 papers. In our study, we present clusters of topics related to AI technologies in agriculture and analysis related to concerning main topics.

## 5. Conclusion

We present a scientometric analysis based on the 15,719 documents retrieved from the Scopus. The study results enable researchers to identify that documents reporting the use of AI in agriculture have been published since 1939. However, since 2020 the number of publications has an increasing growth. Most of the research documents published have been at journals and conferences. The journal Computers and Electronics in Agriculture has been the most used to report these works. The countries with the highest number of publications are India, China, and the United States. China is a country with more authors and institutions collaboration. The institution with the highest published number of documents was China Agricultural University, followed by Zhejiang University.

Furthermore, we identified two big factors related to the application of artificial intelligence and information technology trends in agriculture. First, the well-connected and important are Ontology and Sentinel-2, how to represent and manipulate knowledge using various techniques such as expert systems, natural language processing, semantic web, and human-robot interaction, and how to use satellite imagery from the Sentinel-2 mission to monitor and analyze different aspects of the Earth's surface, such as vegetation, soil, land use, and land cover, respectively. Second, represents the core and the breadth of a research field, covering general topics that span across different research areas.

Artificial intelligence (AI), agriculture, remote sensing, and machine learning constitute crucial themes in addressing contemporary and future global challenges. AI offers the potential to significantly enhance agricultural efficiency and productivity through the integration of technologies like the Internet of Things, smart agriculture, smart farming, big data, sensors, and robotics. Moreover, agriculture stands to benefit from AI-driven decision support systems, climate change adaptation strategies, precise irrigation management, geographic information systems (GIS), food security initiatives, fuzzy logic applications, and sustainable farming practices.

Remote sensing emerges as a valuable tool in agriculture, providing essential data on parameters such as soil moisture, crop growth, and pest detection. These insights are gleaned through techniques such as random forest analysis, support vector machines (SVM), prediction modeling, artificial neural networks, and data mining, including the use of decision trees.

Machine learning complements these themes by facilitating advanced analysis and interpretation of remote sensing data. Techniques like deep learning, precision agriculture, image classification, image processing, computer vision, convolutional neural networks (CNN), and neural networks empower researchers and practitioners to extract meaningful insights from vast datasets.

The interplay of these interconnected themes holds the potential to drive innovation in the agricultural sector, providing integrated solutions to meet the evolving challenges and demands of the world.

One of the main takeaways from conducting a scientometric study with software tools was that these tools facilitate the researcher's task of analyzing document metadata. However, it is crucial to note that the researcher must also perform a careful data treatment. This is to ensure that the tools generate reliable results. By treatment, we mean filtering the data (e.g., removing duplicate records or documents not related to the topic of interest), verifying that all records have complete data, and checking the consistency of the nomenclature used (e.g., in the names of authors and institutions).

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