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A.I. in Agriculture – A Bibliometric Approach

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Abstract. *The aim of this paper is to analyze the connection between Artificial Intelligence and agriculture from a bibliometric approach. The main goal is to showcase the newest trends and the evolution of research in this domain. The fast development of A.I. technologies and its integration are more frequent in many diverse sectors, including agriculture. Therefore, the potential of implementing A.I. may help in resolving global problems, like global food security, the management of resources and also climate changes. Looking at a rising population level worldwide and the challenges that the food chains face, Artificial Intelligence may come as an opportune and efficient solution in optimizing agricultural processes. The method used in this research consists in a bibliometric analysis, which was conducted based on the data from the Web of Science database. A total number of 14,482 documents were first identified, and after further filtering based on categories, 6,883 documents remained. The analysis took into account many important indicators, like the number of scientific papers published, the authors the authors with highest contributions and also the geographical distribution of research. The results imply a significant growing interest regarding A.I. in agriculture, especially after the year 2020, fact that highlights the growing importance of digitization in this field. This emphasizes the role of A.I. in developing productivity, sustainability and improving the decision-making processes in agriculture. This paper concludes that A.I. is helpful in agriculture and that this study can provide solid insights in understanding the current research trends and future similar studies.*

Keywords: artificial intelligence, a.i., agriculture, bibliometric analysis, co-occurrence, food security.

Introduction

The main reason for which this study was conducted consists in researching the influence and the relationship between artificial intelligence (A.I.) and agriculture from a bibliometric perspective. Therefore, the general premise of this study is that A.I. and the agriculture sector have faced growing interest over the years, and that the relationship between the two presents recent growing in conducting research, which in this case, is mainly represented by the number of existing scientific documents.

In the context in which society has already entered an era of knowledge for some time now, A.I. is seen as the tool that has the potential to revolutionize the digital era from a technological perspective, this aspect representing an important step that determines the large-scale transformation of emerging productive forced (Qu & Jing, 2025). In these times, it is estimated that the global population will reach 10 billions by the end of the year 2050, which implies that the food production levels need to rise by at least 60% in order to satisfy demands and to achieve the Zero Hunger objective initiated by the United Nations. Besides, the Covid-19 pandemic affected the logistic chains in agriculture and brought additional risks in the market due to lack of working power. Even though it was a difficult period, this circumstance can be seen as an opportunity to implement new technologies in agricultural processes. Artificial intelligence can be seen as a god

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solution, viable, in facing such challenges, presenting great potential in optimizing production related strategies in agricultural production, based on the high processing power and the used of big data. This could mark a turning point for agriculture as we knew it until now (Bhagat et al., 2022; Yang et al., 2025).

Moreover, looking at the fact that fairness in agriculture becomes a subject more and more discussed, and that research in this domain began to rise in numbers quite significantly from 2018 (Ion et al., 2024), A.I. can offer a possible solution in enhancing the way in which unfair commercial practices are relented and solved within the agricultural sector.

The main purpose of this research is to analyze data from the Web of Science in order to identify the recent actual trends that are related to the study of artificial intelligence in agriculture. To achieve this, a bibliometric analysis was conducted, which consisted in finding and presenting the number of documents published, the main authors who took part in the said research, and also their distribution based on the country at a global level. Based on these findings, subsequent conclusions were drawn and other arguments were presented.

The study of A.I. in agriculture from a bibliometric approach is a subject of growing interest. The theme of such research connects agriculture, a field that is essential in people's social and economic life and which was studied a lot over the years, and artificial intelligence, which over the past recent years became more present and used in our everyday life.

Therefore, it is clear that A.I. can be used in agriculture for a better and more optimized functioning of agricultural processes. This contributes to achieving food security and safety. For a better understanding in how much effort is put into integrating A.I. in agriculture, a bibliometric analysis is very promising in offering a clearer image regarding the intentions for such integration, at least when it comes to researching and publishing documents in these fields.

This paper is structured in several sections. In the first section is presented the specialized literature, through which some general concepts are explained regarding agriculture and artificial intelligence, and also precise examples of how A.I. can be implemented in such fields. The second section follows the methodology of the study: which databases were used, which software was chosen to process the data, as well as the reasoning behind how and why the data was processed. Explicitly, it is also outlined the number of scientific publications for each subject (agriculture and A.I.) and the ones regarding the relation between the two, as well as the number of authors who conducted research in these fields. The study continues with the results that were found and the subsequent discussions. The paper ends with conclusions based on the main findings, the limitations and, lastly, bibliography.

Literature review

General concepts regarding A.I. in agriculture

In general terms, artificial intelligence means that some human characteristics and behaviors, such as teaching, our way of thinking, our ability to plan, are mimicked as closely as it can by machines. A.I. can be used from a software point of view, such as virtual assistants or other analytical apps, as well from a hardware point of view, by integrating it in internet-related systems, cars, phones and other bots available. In the last years, the capacities of A.I. surpassed all expectations and evolved dramatically. Therefore, its importance grew substantially due to its computing power and also by the use of larger data sets (European Commission, 2025).

At the same time, digitization had a crucial role in shaping agriculture. This transformation comes many innovations that can enhance agricultural practices, but also the way in which resources are efficiently used and the great potential to make agriculture more sustainable (Abbasi

et al., 2022). By using robots and data analytics, crop-monitoring technologies and artificial intelligence, digitization can offer both farmers and other specialists in the field the necessary instruments to face off challenges and find efficient solutions in due time. In this context, two main concepts often occur: smart farming and precision agriculture. Firstly, smart farming refers to the "knowledge" which machines possess in order to make relatively autonomous decisions, based on their management systems. Secondly, precision agriculture implies the use of digital data in order to make better informed and founded decisions. The development of smart sensors and agricultural robots made sure that there are better adaptations to climate change, soil types, humidity, plant diseases and others. By integrating A.I. algorithms, advanced solutions in precision agriculture are more frequent, and also robotic systems will play a bigger role in harvesting crops and pest control (Linaza et al., 2021).

Specific – modern examples of how A.I. can be implemented in agriculture

Artificial intelligence can be used in creating new crop-conditional semantic segmentation systems, with the intent of detecting plant diseases. This system integrates contextual data regarding crops into deep learning models, which helps with increased precision in diagnosing diseases for different types of plants. Unlike traditional methods, this model offers better results with less human resources, reducing at the same time subjectivity and other human errors (Picon et al., 2025).

Another example relates to soil organic matter (SOM), an essential component for soil quality and sustainability in agriculture. A bibliometric analysis highlighted the existence of 739 scientific documents with monitoring SOM being the main focus through remote sensing. This number increased from 2018, China and USA being the biggest contributors. Among the most important findings there's improved prediction accuracy with high frequency covariates (soil PH, temperature, etc.), data processing methods, and the transition from conventional practices to newer ones that are based on machine learning (Chen et al., 2025).

For wheat crops, a system which adjusts automatically the seed quantity for sowing based on speed control has been implemented. This system uses speed radar technologies to adjust in real time sowing rates without the need of human contact. Calibration tests indicated a higher precision, with a consistency variation of $\leq$3.9% and a stability coefficient of variation of $\leq$1.3%, clearly surpassing traditional methods. Therefore, this intelligent system offers superior performances overall (Wang et al., 2025).

Methodology [Times New Roman, 14, bold, capitalize first word, justified]

The bibliometric analysis was first proposed and used in the year 1969 by Alan Pritchard. This method had great success and became more often used in the scientific world because it showed a good depiction regarding the study in chronological order of different subjects. Practically, this analysis is a quantitative research method which is the statistical analysis of scientific documents and other kinds or publications with the purpose of finding and representing their scientific activity over years. In such a process, limitations of a study can be found, but also new directions based on subject and the most determined authors in the field can be determined (Lungu, 2024; Sterie et al., 2024).

In order to make this research possible, the Web of Science (WoS) database was used because it offers access to the best documented scientific papers worldwide. Therefore, such a database offers better trust and relevance within the scientific world, both in the authenticity of the documents but also in the integrity of the authors who conduct such studies. The database was accessed on 28 January 2025, by using the search query *("artificial intelligence" or "AI" or "A.I" or "A.I.") and "agriculture"*. Choosing this query made sure to include for certain most of the documents that

focused on the chosen subject, including all kinds of abbreviations and acronyms often used. From now on, whenever documents based on the terms "Artificial intelligence" are mentioned, it will be understood that it refers to the whole search query which was previously mentioned.

Following the search, a total of 14,482 documents were initially found. In order to cover as many relevant documents as possible, all types of scientific documents were chosen which are: 11,193 articles, 2,396 proceeding papers, 1,203 review articles, 106 editorial materials, 66 book chapters, 32 data papers among others. The results were later filtered according to the categories found in WoS. Therefore, the categories considered to be relevant in the agricultural field and as well for A.I. were: Agriculture Multidisciplinary with 1,978 documents, representing 14.55% of the total, Agronomy with 1,528 documents (10.47% of the total), Computer Science Artificial Intelligence with 1,411 documents (9.66% of the total), Environmental Sciences with 1,228 documents, Food Science Technology with 1,169 documents, Agricultural Engineering with 624 documents, Green Sustainable Science Technology with 229 documents, Ecology with 271 documents, Environmental Studies with 247 documents. In addition, categories related to Economy were included, more precisely Management, Business and Economics. The results sorted based on these categories made possible to include not only the documents related only to A.I. and agriculture, but the ones related to the economic field, therefore making sure to encompass the subject of this research. After applying these filters, a total number of 6,883 documents remained. In order to maintain a dataset that is both representative and easy to follow, but takes into account the bulk of the specialized literature, the first 2,000 documents were chosen to process based on relevance. The reasoning behind this decision resides in prioritizing the documents with strong keyword connection and the number of citations and their impact. The results were processed through the Vos Viewer Software after these steps.

Results and discussions

Accessing the Web of Science database, a total of 14,482 documents were found regarding the connection between Artificial Intelligence and agriculture. The query used was <<("artificial intelligence" or "AI" or "A.I" or "A.I.") and "agriculture">>. These words appear as keywords at least once in the document's keyword list, abstract, or title. The results were sorted based on the categories mentioned in the methodology.

Based on the data in Table 1, by the start of the year 2000 (the period 1974-1999), there were already almost 31,000 registered publications that contained the keyword "artificial intelligence", which represents almost 6% of the total. On the other side, for the agricultural domain there were almost 80,000 documents registered, which sums up around 13% of the total. When it comes to the connection between the two subjects, 502 documents were identified. In the period 2010-2019, the interest increased: the documents regarding A.I. rose to 16.14% (84.221 documents), and the ones for agriculture represented 3.28% (20.045 documents). The documents which aimed for A.I. in agriculture registered 5.55% of the total (804 documents). For the years 2010-2019, interest grew even more for A.I. related documents, to a percentage of 30.32% (158.160 documents), and the ones regarding agriculture to 40.39% of the total (246.575 documents). The documents for A.I. in agriculture represented 28.73% of the total, with 4,160 registered documents. After the year 2020 until now, the increase became even more obvious: 47.6% (248,313) of the total for A.I. related documents and 43.3% (264,316 documents) for the agriculture ones. Looking at the connection between the two, the number registers a total of 9.016 documents, which represents 62.26% of the total. Therefore, even though A.I. and agriculture were research subjects in the past, current research truly focuses on their connection starting with the year 2020.

Table 1. Number of scientific papers containing terms related to Artificial Intelligence, Agriculture and the relation between the two existing the WoS database

Year	No. articles for "Artificial Intelligence"	%	No. articles for "Agriculture"	%	No. articles for "A.I. in Agriculture"	%
2020-2025	248313	47.60	264316	43.30	9016	62.26
2010-2019	158160	30.32	246575	40.39	4160	28.73
2000-2009	84221	16.14	20045	3.28	804	5.55
1974-1999	30976	5.94	79508	13.02	502	3.47
Total	521670	100%	610444	100%	14482	100%

Source: Authors' own representation based on the data extracted from the WoS database.

For a better understanding of the situation, specifically the relationship between artificial intelligence and agriculture, the number of documents was first extracted and represented for a better comparative analysis between the two.

Regarding the graphical representation in Figure 1, a relatively similar trend can be observed, more precisely a growth from the year 1974 to the year 2025 in terms of the number of published scientific documents, both for artificial intelligence and agriculture. It should also be specified that the year 2025 has just begun, but there are already over 5,000 documents for each subject. It is observed that for most analyzed years the keyword "agriculture" appears more frequently and registers substantially more documents than the ones regarding artificial intelligence. Even so, there are two notable periods of time in which A.I. related documents surpasses in numbers the ones for agriculture. The first such period consists of the time period between 2004-2008. This circumstance is not necessarily surprising because the beginning of the 2000s marked the start of the digital era. In this context, the focus shifted towards the service sector, opposite of the agriculture sector. Among the factors that contributed there's the development in hardware, such as: bigger processing power, access to more data, the apparition of graphic processing units (GPUs) and many others. The second period represents present times, starting with the year 2023. Neither this occurrence is surprising because this period marks the moment in which artificial intelligence as we know it today was born. For instance, the biggest A.I. platform considered and used by large audiences is ChatGPT, a chatbot that was launched worldwide in 2022. With this opening towards wider audiences, A.I. was perfected and and improved dramatically across many other fields, including agriculture. Even though this sector can be often shadowed by the service sector, it can't be denied the fact that it remains essential in people's lives.

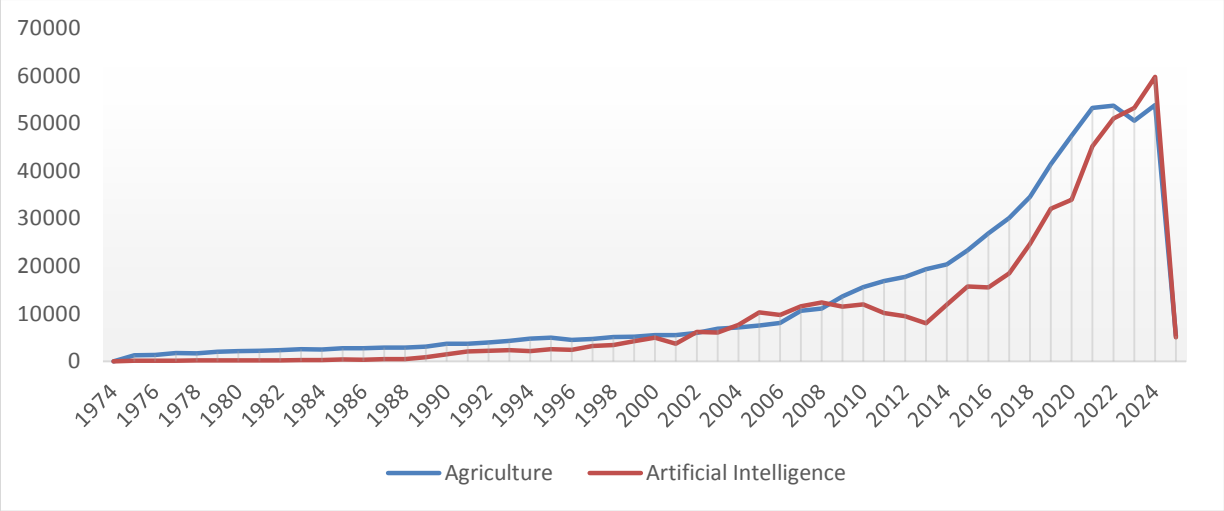

Figure 1. Number of documents published in WoS based on the keywords "agriculture" and "artificial intelligence"

Source: Authors' own representation based on the data extracted from the WoS database.

The next step of the research focused on the relationship between A.I. and agriculture. In order to highlight the main structure of keyword-occurrences associated wtih A.I. in agriculture, the keywords that occurred at least 15 times in the extracted documents were chosen.

In total, 121 keywords were identified regarding the subject, while the graphical representation from Figure 2 shows the presence of six clusters, differentiated by color. The central cluster is represented by green and it regards the keyword "artificial intelligence". Besides, it also covers concepts related to climate change, crop productions and water management, which suggests climate risks and the need of optimizing productions.

The red clusters refer to smart farming and digital transformation. Those concepts are closely drawn towards automation and the use of big data in precision agriculture. Also concepts such as sustainability and technology are present, a fact that implies the development of agriculture through A.I.

The blue cluster focuses on crop monitoring with the help of artificial intelligence. The yellow cluster shifts towards prediction and optimizing, which accentuated the role of A.I. in making decisions. The last two clusters, purple and light blue, are small compared to the others and they refer to the connection between data collection and running diagnostics with the help of A.I. within a well put together infrastructure.

With the present clusters and associated concepts, the ways in which A.I. can be applied in agriculture are shown, from automation to sustainability. Often these directions are in opposition to one another regarding results and different agricultural practices are needed. Therefore, future research could explore the way in which A.I. can be improved and implemented in order to obtain a developed and also sustainable agriculture.

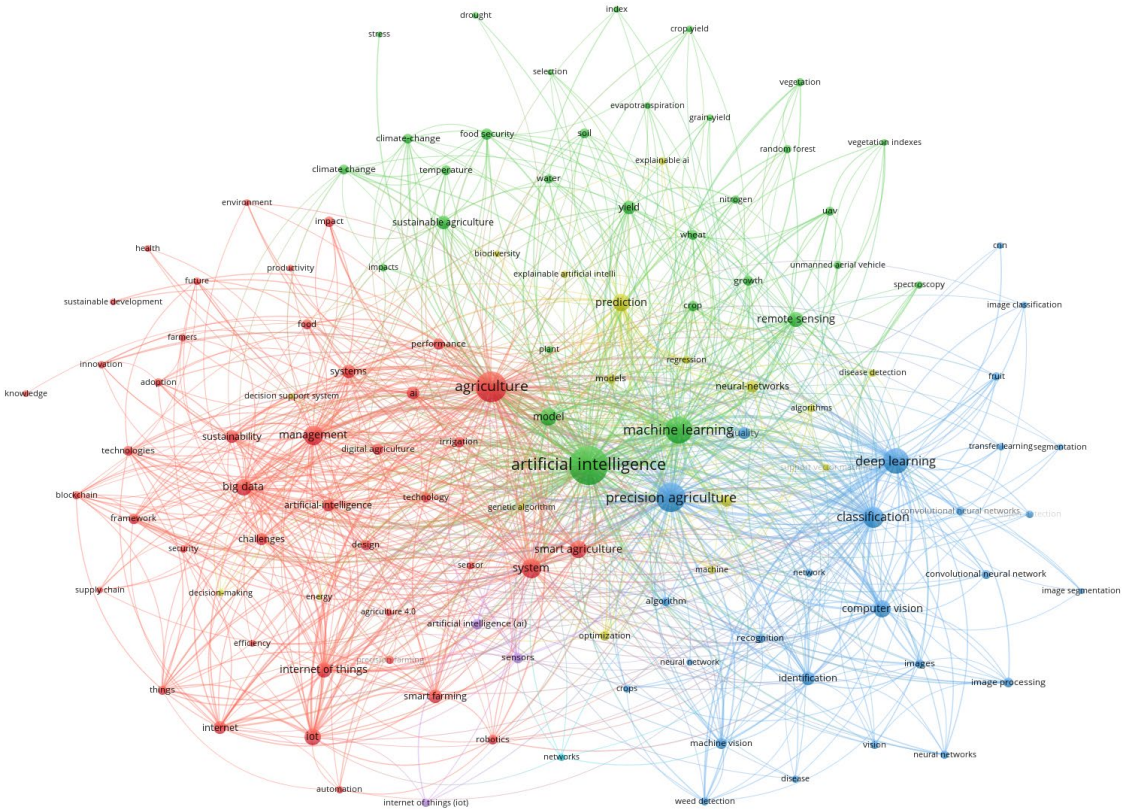

Figure 2. The network of cited keyword co-occurrence for artificial intelligence in agriculture
Source: Author's own graphical representation based on the data extracted.

From the total number of selected keywords, none were deleted because all of them are closely related to the subject of the study and there was no need for a more refined sorting. These keywords were categorized in six clusters, each with their own theme, as shown in Table 2.

Table 2. Core topic and keywords recognized in each cluster for Artificial Intelligence in Agriculture

Cluster	Keywords and Topic
I	42 items: adoption, agriculture, agriculture 4.0, a.i., artificial intelligence, automation, big data, blockchain, challenges, design, digital agriculture, efficiency, environment, farmers, food, framework, future, health, impact, innovation, internet, internet of things, io, irrigation, knowledge, management, performance, precision farming, productivity, robotics, security, sensor, smart agriculture, smart farming, supply chain, sustainability, sustainable development, system, systems, technologies, technology, things Topic: Smart Agriculture and Digital Transformation
II	31 items: artificial intelligence, climate change, climate-change, crop, crop yield, drought, evapotranspiration, food security, grain-yield, growth, impacts, index, machine learning, model, nitrogen, plant, random forest, remote sensing, selection, soil, spectroscopy, stress, sustainable agriculture, temperature, uav, unnamed aerial vehicle, vegetation, vegetation indexes, water, wheat, yield Topic: Climate and Crop Management

III	27 items: algorithm, classification, cnn, computer vision, convolutional neural network, convolutional neural networks, crops, deep learning, disease, fruit, identification, image classification, image processing, image segmentation, images, machine vision, network, neural network, neural networks, object detection, precision agriculture, quality, recognition, segmentation, transfer learning, vision, weed detection Topic: Computer Vision and AI in Agriculture
IV	17 items: algorithms, biodiversity, decision support system, decision-making, disease detection, energy, explainable ai, explainable artificial intelligence, genetic algorithm, machine, models, neural-network, neural-networks, optimization, prediction, regression, support vector machine Topic: Decision Support and AI Optimization
V	3 items: artificial intelligence (ai), internet of things (iot), sensors Topic: IoT and AI Integration
VI	1 item: networks Topic: Network Systems in Agriculture

Source: Author's own research contribution

The first cluster focuses on the transition from a traditional agriculture towards a more digitized and, implicitly, a more intelligent one. Within this group of terms, concepts such as agriculture 4.0, digital agriculture, precision agriculture and automation cand be identified, all of them representing the role of optimizing agricultural processes in order to increase efficiency and productivity. Terms such as blockchain, Internet of Things (IoT) and big data underline the necessary contributions which these emergent technologies can possess in developing a more sustainable agricultural sector. Also, there are concepts that refer to notions like robotics, sensors, food chains, food security and sustainability which suggests the important need of modernization through technology. In the second cluster the focus shifts towards the impact of climate change through the necessity of developing new strategies in the need of crop adaptability to climate challenges. The bulk of this cluster suggests the need to preoccupation with growing crop yields in the face of climate change through methods that imply using new technologies. Terms such as machine learning, remote sensing and model are present, which suggests the use of A.I. in analyzing data from the field. In the third cluster there's a main focus on using A.I. directly in agriculture through decision making, predictions, optimization and decision support systems. By this, development in predictive models is approached for a better and a more efficient resource management through the integration of A.I. in monitoring health-related analytics for crops. In the fourth cluster, it is shown the integration of IoT and A.I. in agriculture, with a depict focus on data collection in real time with the help of sensors. This approach contributes to a more efficient monitoring of crops and more optimized agricultural processes. The last cluster consists only in the term "networks". This aspect may suggest how essential a well put infrastructure is in implementing new, intelligent technologies in agriculture, especially when talking about precision agriculture and automation in general.

Analyzing the co-authorship bibliometrics, certain aspects are observed which offer relevant data regarding involved authors, but also the countries that took part the most in researching about A.I. in agriculture. This information contributes in highlighting the academic interest worldwide for the chosen subject, but also in identifying the most active scientific communities across the globe, where research and use of A.I. in agriculture is strongly encouraged. Based on the number of writers, there's a total number of 8,227 authors, of which only 34 have published at least 5 documents each on the discussed subject. Based on these published documents, the main 5 authors are: Yiannis Ampatzidis, with a number of 19 scientific documents and 943 citations, Mark T. Keane with 12 documents and 275 citations, Yuzhen Lu with 9 publications and

417 citations, Corrado Costa with 9 publications and 261 citations and Luciano Ortenzi with 9 documents and 261 citations. Regarding the country distribution based on the existing number of documents, The United States takes the lead, with 358 documents. Next up is China, with 280 documents, India with 276 documents, Italy with 168 documents, Spain with 95 documents, Germany with 89 documents, Brazil with 83 documents, England with 81 documents, Australis with 71 documents and Canada with 69 documents. Regarding the citations, the order does not remain the same. The most citations belong in the case of USA with 6,255 citations, then India with 4,896 citations, China with 4,152 and so on. Regarding the countries present in this ranking, most of them represent either countries with economies that lead in the modern world and/or countries that depend or have depended until recently on the agricultural sector. For instance, USA and Brazil are some of the biggest exporters of foods worldwide and any A.I. insight in food production can offer them a significant lead in the industry. Top universities from the USA, Australia and Canada also attract the best researchers across the world, which explains why there's a high number of scientific publications present in these countries. India and China possess immense populations and depend a lot on agriculture. On top of that, in recent years these countries have made immense efforts in funding development and innovation, including A.I. The same thing can be said about countries members in the European Union, in which such research is strongly supported through precision agriculture programs such as Horizon Europe.

Table 3. Data of co-authorship by country (sorted by no. documents)

Country	No. documents	No. citations	Total link strength
USA	358	6255	135
China	280	4152	81
India	276	4896	73
Italy	168	3254	59
Spain	95	2160	53
Germany	89	1509	57
Brazil	83	1586	35
England	81	2076	68
Australia	71	1500	47
Canada	69	1289	36

Source: Authors' own research contribution.

Based on the discovered results, a series of practical implications can be outlined for all involved actors in the agricultural sector. In the context of an increased interest in using A.I. in agriculture, both in direct implementations and also in researching the subject, the main parties involved are farmers, researchers, but also managers and decision makers. For farmers, solutions based on A.I. contribute in optimizing crop yields, while reducing costs through minimizing waste of source materials, pesticides and so on. For researchers, this study highlights the main trends in potential unexplored aspects about A.I. in agriculture, offering at the same time important opportunities for future research. For decision makers, A.I. implementation in agriculture can imply significant extra costs, adequate funding being a must, but also the development for concrete policies so that existent business models can assimilate such changes.

Conclusion

By conducting this paper, there's a clear view regarding an increased interest in the scientific world for the use of A.I. in agriculture. This aspect is enforced by the widening of the specialized literature in this domain, especially after the year 2020. This analysis highlights essential trends regarding the subject, proving that A.I. represents a key factor in modernizing agriculture through optimizing processes, increasing productions and also supporting sustainability.

Among the most important aspects outlined there's the essential role that A.I. holds in supporting food security worldwide in the context of a rising population. The use of new technologies like machine learning models and automatic data analytics offer opportune solutions in managing resources, facing climate challenges and also lower risk rates in food chains. Also, it should be noted that the study showed that countries with a strong agriculture sector and with significant funding towards research and innovation (such as USA, China, India) are more prone in implementing A.I. and lead in the scientific world with a high number of documents related to the subject studied.

Major results from this research align with the conclusion drawn from other studies on the subject. For instance, in the study *Assessing the impact of Digitization on Progress in Agriculture: A bibliometric Analysis*, by Sterie in 2024, the trend in an increased digitization process in agriculture is confirmed, and also its importance. In a similar way, the study *Artificial Intelligence Solutions Enabling Sustainable Agriculture: A Bibliometric Analysis* conducted by Bhagat in 2022 outlines the same key aspects regarding the importance that sustainability and other technologies possess in precision agriculture in the context of adding artificial intelligence. At the same time, the study presents the countries that have a great role in researching this theme, countries such as the USA, China and India.

Although this study offers a clear image upon present trends regarding A.I. in agriculture, important limitations still exist. First of all, the analysis was based only on the Web of Science database, excluding others like Scopus or Google Scholar. At the same time, some categories from WoS were excluded and therefore this may have removed relevant studies. The main reason for this decision consisted in WoS being a trusted source with enough documents. Even so, this database does not include all data relevant for this theme of research. Often, existing studies are conducted and published based on real life trends or other dominant trends. It should also be noted that the specificity of the subject (artificial intelligence) proves to be challenging in collecting relevant data. Taking this into accounts, the accelerated pace of A.I. evolution can easily surpass the previous conclusions of other studies.

Although there are certain limitations, the research cand offer and be observed as a good starting point for future studies. Also, it can help in developing new strategies of implementing A.I. in agriculture. A strong direction for future studies could encourage including more databases with representative data. Of course, this extension may vary significantly based on the purpose and the subject chosen to research.

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