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RESEARCH ARTICLE

THE STUDY OF THE CURRENT STATUS AND FUTURE TREND OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE: BIBLIOMETRIC ANALYSIS

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ABSTRACT

Artificial Intelligence (AI) is one of the relevant areas of technology that is transforming the agriculture sector by reducing the consumption and use of resources. This research shows the development and directions of agricultural AI research between 2000 and 2024. The study analyzes the total 2,245 research papers from Scopus and the Science Citation Index Expanded (SCIE), a sub-database of the Web of Science Core Collection (WoSCC) using bibliometric analysis, with a focus on AI applications in fields including crop monitoring, irrigation optimization, and precision farming. The study found that the number of AI-related agricultural studies has increased significantly since 2017 with China, India, and the United States leading in research output. AI technologies like machine learning and remote sensing play a significant role in enhancing agricultural productivity and sustainability. However, challenges remain, including data privacy and the need for stronger collaborations between researchers globally. This study highlights key research clusters and suggests future directions for AI integration in sustainable agriculture.

KEYWORDS

Artificial Intelligence; Machine learning, Precision agriculture; bibliometric analysis

1. INTRODUCTION

Modern technologies like Artificial Intelligence (AI), machine learning, and big data analytics are driving a digital revolution in agriculture in response to pressing global concerns like population growth and climate change (de Oliveira, et al., 2023; Xu, et al., 2024). Artificial intelligence applications in agriculture offer practical means of enhancing resource management production and sustainability (Rose, et al., 2021). Precision farming has taken in a new era in which decisions are based on data rather than intuition improving efficiency and minimizing waste (Jha, et al., 2019; Holmes, et al., 1994). The population of the globe is expected to increase ~9.7 billion by 2050; which puts more intense on agricultural systems and causes worries about food security (Talaviya, et al., 2020; Elahi, et al., 2019). The Food and Agriculture Organization FAO estimates that food yield needs to improver by 70% to meet rising demands (Kouadio, et al., 2018; Yang, et al., 2021). AI technologies could play an important role in addressing these challenges by optimizing agricultural processes and improving the direction of resources such as water, soil, and fertilizers (Maloku, eta l., 2020; Linaza, et al., 2021).

The combination of AI with big data analytics the Internet of Things (IoT) and other technologies has led to the development of smart farming systems. These devices let farmers make data-driven decisions that increase productivity (Ali, et al., 2021; Esposito, et al., 2021). Sustainable farming techniques are made possible by these technologies which allow for real-time monitoring of environmental parameters including soil moisture and weather patterns (Rasmussen, et al., 2021; Meroni, et al., 2021). AI-based predictive models are being used to predict crop yields and improve planting plans (Soylu, et al., 2021; Pazouki, 2021). These developments enable farmers to make more informed decisions which increase the yields (Ahmed, et al., 2023; Cheng, et al., 2023). Artificial Intelligence is important in sustainable agriculture, mainly in making it less harmful to the environment (Ahmed, et al., 2023). AI applications in disease detection and pest control have ability to lower the usage of hazardous pesticides and environmentally friendly farming practices (Karthikeyan, et al., 2020; Liakos, et al., 2018).

The application of AI in agriculture still faces several obstacles despite these developments. Additionally, to guarantee that everyone has fair access to AI-driven solutions, data privacy, and labor (Shamshiri, 2018; Balaska, et al., 2023). Research on AI applications in agriculture has developed farming techniques (Liakos, et al., 2018). Recent research has highlighted the crucial role AI may play in food security concerns and improving sustainable agriculture (Shamshiri, 2018). AI-driven innovations are being incorporated into smallholder farming systems to increase efficiency (Balaska, et al., 2023). AI-enabled drones are also being used for precision spraying which reduces the chemical and safe the environment (Balaska, et al., 2023). These uses highlight how artificial intelligence (AI) can help with sustainable farming at different levels of agricultural tillage operation (Mohr, and Kühl, 2021).

Simultaneously there is increasing interest in bibliometric studies that link the many disciplines to analyze the effects of these collaborations and their impact on the research community. Since bibliometric studies provide a clear indication of interest in a given topic academia generally finds them to be quite interesting. The Gu study is an example that demonstrate the format and scientific model for researchers around the

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globe as well as the connections between author synergy, quality, and references (Publishers, 2004). More precisely in the area of artificial intelligence the work examines how it has changed over time using a variety of bibliometric indicators derived from the citation of research on knowledge-based systems (Cobo et al., 2015).

This paper is a formal investigation into the scientific invention of several areas of research exposing the current significance of this synergy to the scientific community. Scopus and the Science Citation Index Expanded (SCIE), a sub-database of the Web of Science Core Collection (WoSCC) was used to conduct a content analysis to calculate the number of publications. The scientific journals in which they are published, however, researchers who are most pertinent in terms of the quantity of these, in addition to an examination of the works place of interest in these topics worldwide.

2. Material and Methods

2.1 Data sources and search strategy

Data from Scopus and the Science Citation Index Expanded (SCIE), a sub-database of the Web of Science Core Collection (WoSCC) was used to do bibliometric analysis. It is considered the best database for bibliometrics and contains 28,000 of the highest-impact quality scientific international journals offering comprehensive statistics on publications (Marina, and Sterligov, 2021). Scopus was used for collection of the data from all publications from 2000 to 12 September 2024 including articles and reviews in this discipline from the previous 25 years. The search approach was as follows we conducted a thorough bibliometric study on the subject "Investigating the Development and Prospects of Artificial Intelligence in Agriculture Research" by taking the subsequent actions, Step 1) Determine of idea Machine learning OR artificial intelligence. Step 2) Find Related and Synonyms, Agriculture = (Precision Agriculture, Machine Learning, Irrigation Optimization. Step 3) Utilizing Boolean Operators Combine Terms Boolean operators (AND OR) are used to combine the terms to generate a thorough search query (Table 1). Put exact phrases in quote marks. Thus, the Scopus Sample Search Query was (Artificial intelligence OR Machine learning) AND (Precision Agriculture) AND (Irrigation optimization) publications identified were the English language. To avoid bias and omissions the search approach was independently replicated twice by two researchers and cross-checked. The search was conducted in both databases, and the selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The complete literature selection process is presented in Figure 1. Since this analysis was based solely on secondary data from published articles, ethical approval was not required.

2.2 Inclusion and exclusion criteria

All papers that were used for bibliometric analysis complied with these requirements (1) The publications were published between 2000– 12 September 2024. (2) English was used as the publication language. The procedure for searching and choosing literature is shown in Figure 1.

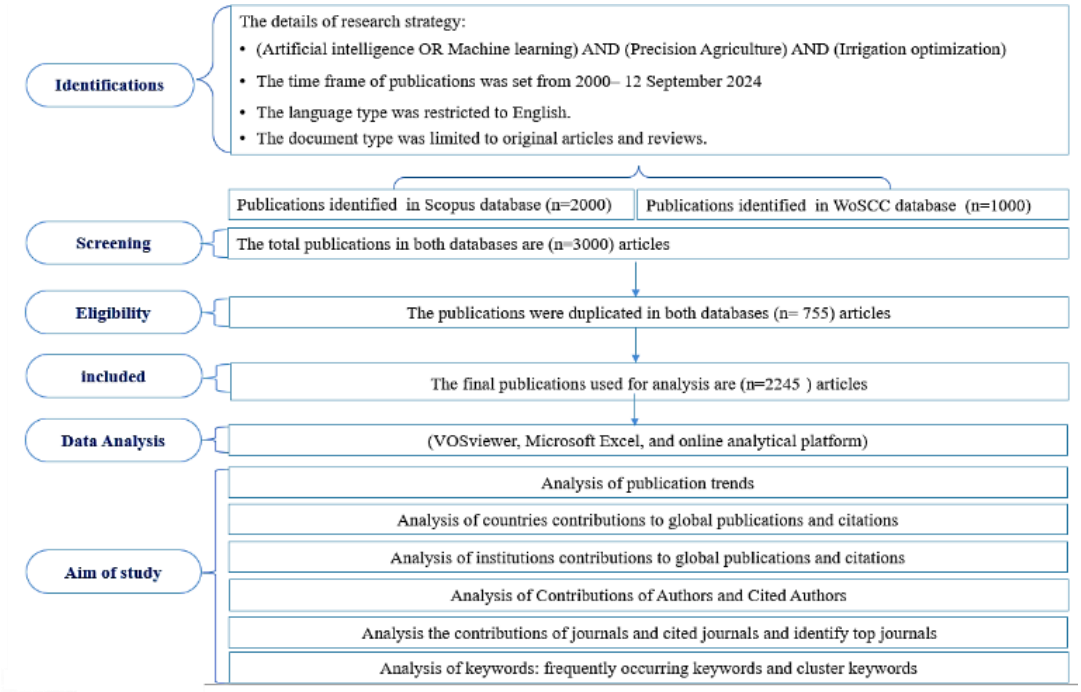

Figure 1: Flow chart for bibliometric analysis of processed data

2.3 Data collection

The terms and phrases were automatically retrieved from the titles and abstracts of all publications in the datasets used to generate maps such as network and density visualizations based on textual data (van Eck, et al., 2010), found from the 2245 relevant documents. These papers were stored as full records citing references and original text generating the source files for bibliometric analysis. The search was conducted on 9 September 2024 and the literature databases used to find scientific content were ScienceDirect, Scopus, Springer, IEEE Xplore, and MDPI. The keywords for artificial intelligence, precision agriculture, synonyms, and subareas were combined into a search string using logical operators such as (OR) and (AND). The search strings that were defined based on the inclusion criteria are displayed in Table 1. This query string was inserted in an advanced search camp of the assessment of the database.

Table 1:Search String

Search String
(Artificial intelligence OR Machine learning) AND (Precision Agriculture) AND (Irrigation optimization)

2.4 Data processing software and statistical analysis

2.4.1 Microsoft Excel

Microsoft Excel was use for data pre-processing duties which included finding and correcting faulty recordings and eliminating files that were incongruous with the research area (Carrión-Mero, et al., 2021). Additionally, Microsoft Excel was employed to create statistical graphs illustrating trends in paper publications, as well as tables that provided detailed information about authors, research areas, and the quantity and quality of the papers.

2.4.2 VOS viewer

VOSviewer is a powerful tool for mapping scientific knowledge (Linnenluecke, et al., 2013). It makes it possible to create and analyse networks visually using data from literature, showing the composition, development, and cooperative interactions among different knowledge fields (Oyewola, et al., 2022). "Co-occurrence clustering" which holds that things that appear together are related, is the fundamental theory of VOSviewer. Different groups can be identified by clustering because of the variety, strength, and direction of these associations (Ding, et al., 2022). Clustering analysis of authors, journals, countries, institutions, and keywords is carried out using VOSviewer. in additional an online analytical platform (https://bibliometric. com/) were used to perform bibliometric analysis and data visualization.

2.5 Statistical analysis

Descriptive statistical analyses were performed using SPSS version 21.0 (IBM Corp. Armonk, NY, USA) and Microsoft Excel 2019. Categorical variables were presented as frequencies and percentages.

3. Results and Discussion

3.1 Publication Trend

A total of 2245 papers were included in our analysis after a search of the Scopus database and the removal of unrelated publications. Making a chart to examine the annual number of publications using Excel in the field of artificial intelligence and precision agriculture. The number of articles increased between 2000 to 20 September 2024. The publications are relatively low in the span of 2000 to 2016. The publications in AI started to rise in 2017 and get a high increase to 2024. This indicates a significant increase in field research and development particularly in the recent several years (Figure 2). There is a strong growth trend in the number of artificial intelligence publications as indicated by the green line and the red dotted line provides an exponential model that fits the real data. The equation $y=0.4502\ e^{0.3711x}$ models this growth predicting that the number of publications will continue to rise exponentially. The model fits the observed data quite well accounting for around 94% of the variation as indicated by the R^2 value of 0.9395. The first research in this area to be published was on An ecology of DSS reflections on managing wheat crops in the northeastern Australian grains region with WHEATMAN in 2002 (Hayman, and Easdown, 2002). Research in this field subsequently spread widely. Starting in the 2005s, researchers in various countries began to explore the use of AI in agriculture, with only a few annual publications on agriculture practicing and water requirements for crops (Turpin, 2005). In 2011, research focused on machine learning algorithms and sensor-based irrigation control strategies to improve agricultural productivity (Im et al., 2012; Dariane and Sarani, 2013; Frey and Rusch, 2013; Kulkarni, Förster, and Venayagamoorthy, 2011). From 2017 to the present, research in this field has begun to focus on the study of the application of AI agriculture and deep learning, machine learning, IOT techniques, remote sensing, and different sensors to improve how to automate and increase the agriculture yield (Kulkarni, Förster, and Venayagamoorthy, 2011; Boursianis et al., 2022).The authors used the bibliometric theory and Scopus database to understand the growth pattern of literature related to artificial intelligence at home and abroad in a time series.

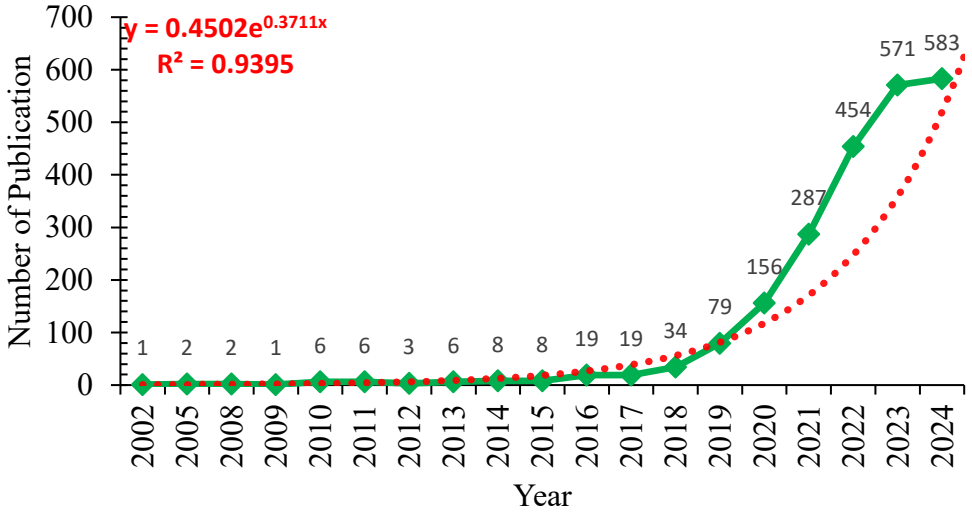

Figure 2: Future Trend of Publication

3.2 Contributions of countries to global publications

China has the most publications on AI in agriculture (518) followed by India (439). Third with 283 publications is the United States. These three countries are the key participants for 61% of the total publications in this area of study (Figure 3A). The significance of this topic in these countries promise to enhance the productivity and efficiency to improve the profitability of the agriculture sector. A second group with significant countries includes Saudi Arabia (131 publications), Spain (128 publications), Iran (119 publications), Australia (112 publications) and Italy (109 publications). The contributions of countries like Malaysia and Canada, where agriculture profitability percentage of their economy are also considerable.

The analysis of citations shows that India leads by 14,373 citations and is closely followed by the United States and China with 13,585 and 11,120 citations respectively. However, the contributions of countries such as Australia, the United Kingdom, Malaysia, Spain, Greece, Saudi Arabia, and Italy where agriculture makes up a big part of the economy (Figure 3B).

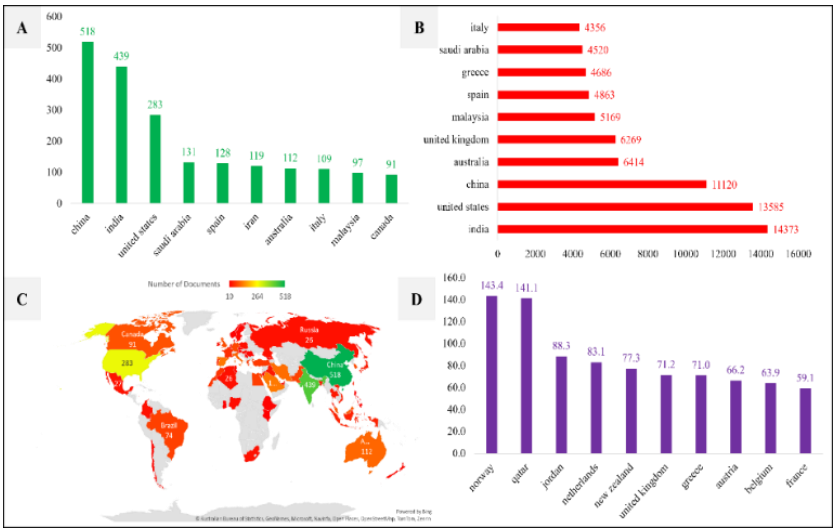

Figure 3: A) Top 10 Countries of publications B) Top 10 Cited Countries C) Distribution of country according to the number of publications in the world D) Average citation of top 10 countries

To enhance the observation of publication quantities among various countries and the collaborative efforts within this academic area, authors

utilized the Co-authorship-Countries function of VOS Viewer to analyze and visualize data, establishing a maximum of 25 countries per article. The authors included countries that published more than five papers in the field of Artificial Intelligence in Agriculture Research from 2000 to September 12, 2024. The analysis of the study identified 76 countries, with their distribution illustrated on the world map (Figure 3C). Figure 3D illustrates the top ten countries ranked by average citation counts, with Switzerland prominently at the forefront at 340.4 citations. Norway and Qatar had 143.4 and 141.1 citations, respectively. The other countries,

such as Jordan, the Netherlands, and Hong Kong, exhibit averages between 88.3 and 71. The graph illustrates a significant decline following the top three, indicating a considerable discrepancy in citation impact among the countries.

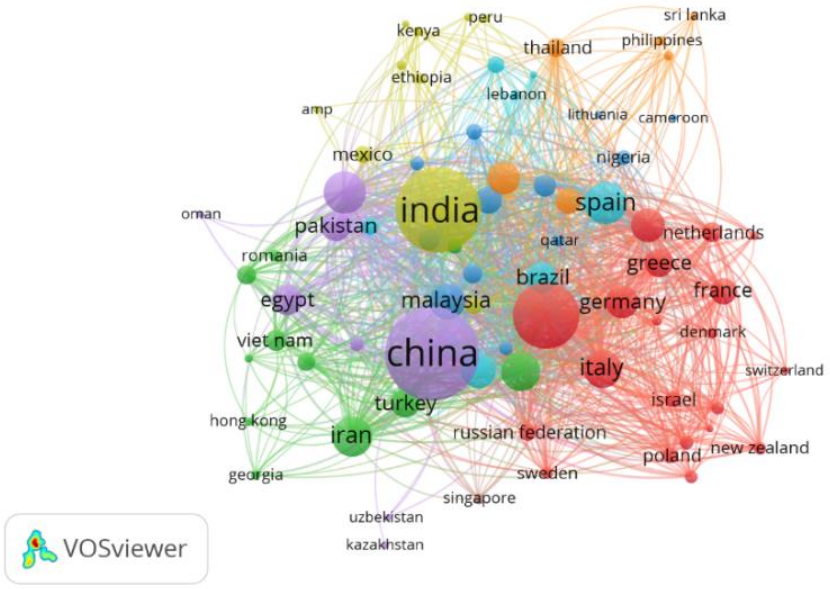

Figure 4: Country Visualization Chart

Figure 4 illustrates global collaboration patterns, with clusters indicating countries that show robust connections. China is leading the purple cluster comprising Iran, Pakistan, and Turkey, underscoring regional alliances in Asia. India leads the yellow-green cluster, establishing worldwide connections with nations such as Malaysia and Egypt. The red cluster focuses on European nations, namely Spain and Germany, and signifies regional collaboration. The blue cluster comprises Southeast Asian nations, like Malaysia, and international collaborators like Brazil. Peripheral nations, such as Kenya and Uzbekistan, provide specialized knowledge, enhancing the diversity of the network.

3.3 Contributions of institutions to global publications

Numerous both private and public organizations are distributing knowledge via field experiments and research articles on artificial intelligence in agriculture. This list is mainly dominated by entities from China. Half of the twelve principal organizations originate from China (China Agricultural University, University of Chinese Academy of sciences, Sichuan University, Environment and Sustainable Development in agriculture, and Chinese Academy of agricultural sciences), one from Egypt (Mansoura University), one from Vietnam (Duy tan university), one from Iran (university of Tabriz), and there is also one from Bangladesh. Mansoura University has the greatest number of publications (13). Mansoura University, Egypt is a premier educational institution recognized for its expertise in subjects such as engineering, science, and agriculture.

Table 2: Institutions promoting research

Rank	Institution	Country	Publications	Total citations	Average Citations
1	Mansoura university	Egypt	13	175	13.5
2	China agricultural university	China	9	655	72.8
3	University of Chinese academy of sciences	China	9	157	17.4
4	Sichuan university	China	8	90	11.3
5	Duy tan university	Vietnam	7	222	31.7
6	University of Beira interior	Portugal	7	132	18.9
7	university of Tabriz	Iran	7	151	21.6
8	Begum Rokeya university	Bangladesh	6	217	36.2
9	Environment and sustainable development in agriculture	China	6	70	11.7
10	Chinese academy of agricultural sciences	China	6	141	23.5

It is among Egypt's premier universities, significantly contributing to research and innovation in multiple fields. The institution possessing the second highest volume of publications is China Agricultural University (9 publications) CAU, from Beijing, is a Double First-Class University according to the Chinese Ministry of Education, specializing in agriculture, engineering, economics, management, and social sciences. Although considering the citation count, the leading university in the ranking is the University of Chinese Academy of Sciences (Articles of 9; 157 citations), Sichuan University (Articles of 8; 90 citations), Duy Tan University (Articles of 7; 222 citations), and University of Beira interior (Articles of 7; 132 citations). All these institutions are deeply dedicated to AI research within the agricultural sector.

3.4 Contributions of authors and cited authors.

Numerous indications can be considered by bibliometric analysis when analyzing an author's relevance to a particular topic. This study

concentrated on two elements: the number of publications which indicates the researcher's engagement in the field of study and the impact of publications with a total number of citations that are used by other researchers as reference in their research. In terms of the number of publications, the Scopus database (Figure 5). The most significant author is Professor (19 publications, Citations of 349) with an average citation of 18, and the second most significant author is Professor Gong, (13 publications, Citations of 307), jin, (11 publications, Citations of 411);

yaseen, (10 publications, Citations of 655); and wu, (10 publications, Citations of 101); elsherbiny, (10 publications, Citations of 108); kisi, (10 publications, Citations of 333); elbeltagi, (9 publications, Citations of 239) and lloret, (9 publications, Citations of 141) (Jaime et al., 2020; Ahmed at el., 2020; Ozgur et al., 2016; Osama et al.2023; Zongjun, et al., 2023; Mundher et al., 2019; Xiuliang at el., 2017; Daozhi et al., 2022; Cui Ningbo et al., 2019).

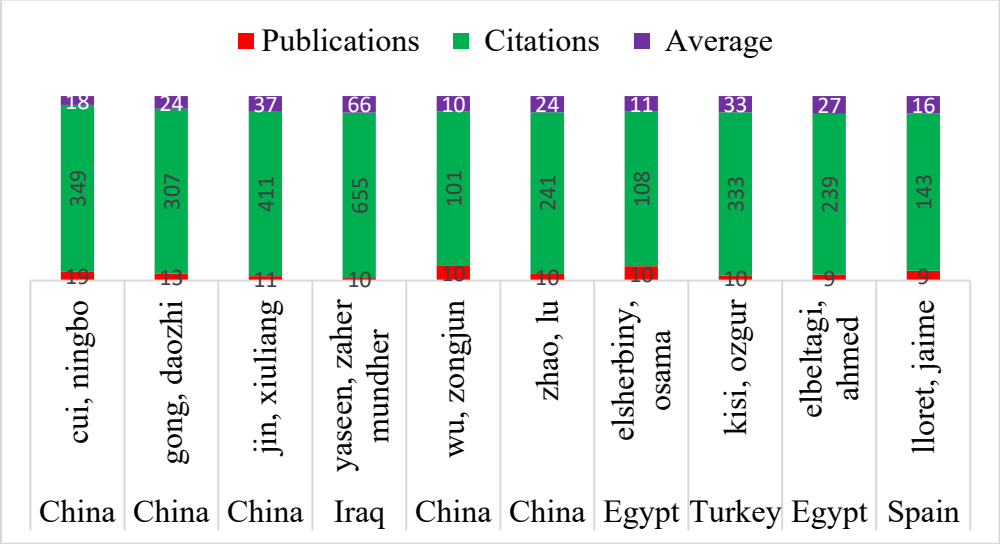

Figure 5: Top 10 Authors publication, citations and Average citation per publications

Finally, in order to grasp the complete strength of the co-authorship ties with other authors, the minimum number of documents of one author was established at two articles. In total, 309 authors out of 9718 fulfill this level (Figure 6). The cumulative strength of co-authorship connections with other authors was computed for each individual. The largest collection of interconnected authors comprises 19 links. Certain clusters may be emphasized, such as the one directed by cui, Ningbo (Blue color); Jin and xiulinag, (pink color); Costa and Corrado. (green) kama-Pinto, alejandro (brown) Grvanitis and Konstantinosg. (red); Gupta and Deepali (orange); Gaspar and Pedrod. (purple); and gao, chao (grey).

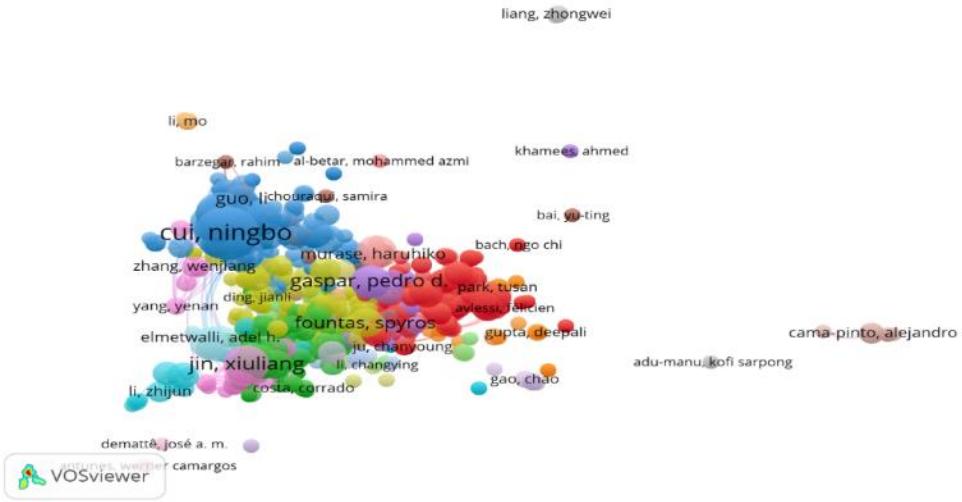

Figure 6: Co-citation map based on bibliographic data

3.5 Contributions of journals and cited journals

During the identification of very most relevant journals that published the issues related to AI in agriculture, it observed that numerous journals were in different research areas. These journals were primarily dedicated to Information and Communications Technology including fields such as computing and engineering. However, these are journals that concentrate on topics such as agriculture, environmental studies, resource management, remote sensing, Sensors and hydrology. This represents the importance of this topic which developed the interest in different fields since it is a cutting-edge issue coming from the merging of different areas of expertise. As shown in according to the impact factor , Computers and Electronics in Agriculture (CEA) is the most influential journal for artificial intelligence (AI) in Agriculture (110 publication ,6669 citations and Average is 61); remote sensing (102 publication ,2593 citations and Average is 25); agronomy (87publication ,1401 citations and Average is 16) however other journal IEEE Access (69 publications, 6175 citations, Average 89, Impact Factor 3.4), Sensors (62 publications, 1272 citations, Average 21, Impact Factor 3.7), Sustainability (51 publications, 941 citations, Average 18, Impact Factor 3.6), Applied Sciences (50 publications, 1375 citations, Average 28, Impact Factor 2.7), Agriculture (50 publications, 738 citations, Average 15, Impact Factor 3.5), Frontiers in Plant Science (49 publications, 1194 citations, Average 24, Impact Factor 4.1), Agricultural Water Management (43 publications, 1094 citations, Average 25, Impact Factor 5.9) are also showing the contribution in journal impact .

Table 3: Top 10 Journal and its impact

Journal	Publications	citations	Average	Impact Factor
Computers And Electronics in Agriculture	110	6669	61	7.7
Remote Sensing	102	2593	25	4.9
Agronomy	87	1401	16	3.7
IEEE Access	69	6175	89	3.4
Sensors	62	1272	21	3.7

Table 3 (cont): Top 10 Journal and its impact				
Sustainability	51	941	18	3.6
Applied Sciences	50	1375	28	2.7
Agriculture	50	738	15	3.5
Frontiers In Plant Science	49	1194	24	4.1
Agricultural Water Management	43	1094	25	5.9

Figure 7: Visualization of journal article volumeis visualizes the distribution of journals with the size of the nodes denoting the number of articles. In all 83 Journal out of 654 satisfy this threshold. Computers and electronics in agriculture and sensor (Red); agriculture water management, journal of hydrology and applied water research (Blue); remote sensing and precision agriculture (Green).

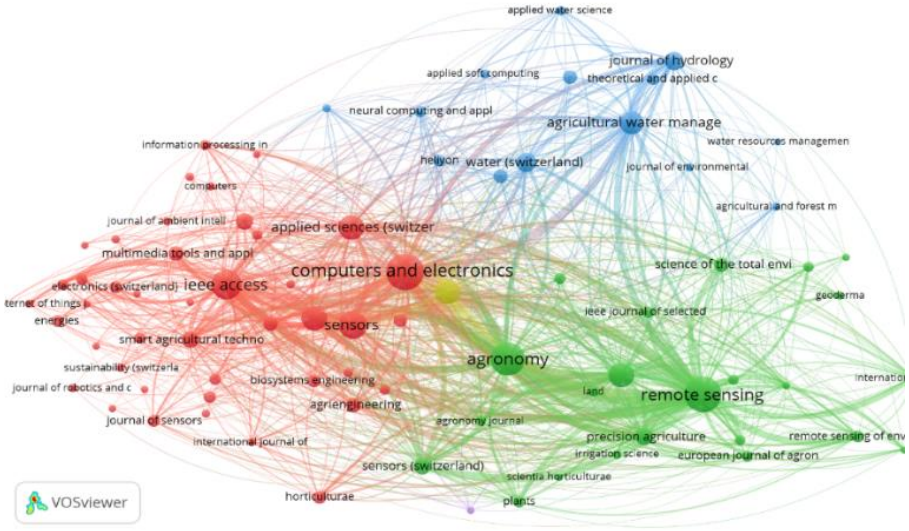

Figure 7: Visualization of journal article volume

3.6 Analysis of keyword

A co-occurrence link is established between two keywords when they appear in the same publication. The leading 15 keywords with a frequency exceeding 167 occurrences in Figure 8. Keywords exhibiting an active co-occurrence relationship can more accurately highlight research hotspots than individual keywords when utilizing VOS Viewer (Figure 9). Keywords highlighting the significance of emerging technologies in agriculture with Machine Learning, Artificial Intelligence, remote sensing, sensors, computer-based algorithms, and IoT as the most extensively studied areas. Precision agriculture, resource optimization, crop monitoring, and weather- and yield-prediction capabilities are enabled by Internet of Things (IoT), remote sensing, and machine learning technologies (Zhou et al., 2022; Senoo et al., 2024). Artificial neural networks and deep learning techniques have been applied to complex problem-solving tasks, including decision-support systems and crop disease detection (de Oliveira and de S. e Silva, 2023; Qasem et al., 2019; Frey and Rusch, 2013). In our graphic representation strongly, related keywords were colored the same indicating that they could share anything in common.

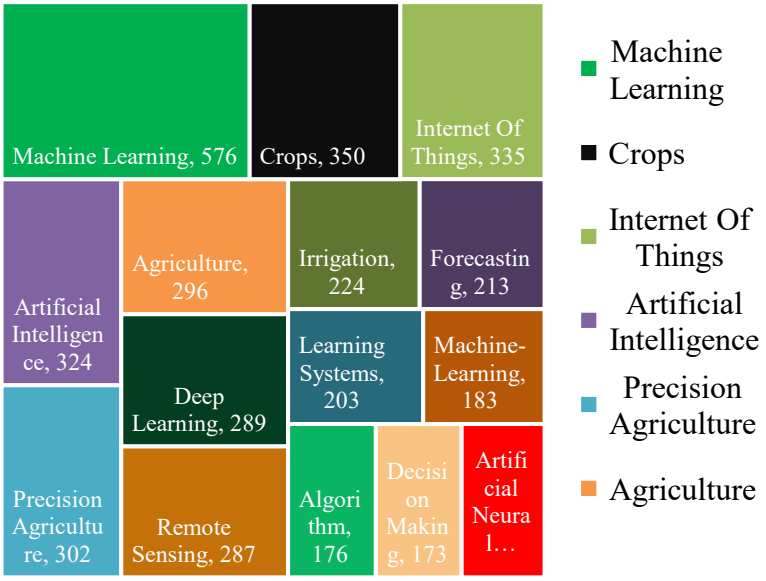

Figure 8: High-frequency keyword in the platform

In our graphic representation, strongly related keywords were colored the same to indicate shared concepts. Keywords highlighted in yellow are associated with machine learning, deep learning, computer vision, and epidemiology (Ghazal, Munir, and Qureshi, 2024; Bhargava et al., 2024). These terms point to extensive applications of UAVs and AI for automating critical agricultural processes such as crop-health monitoring, disease detection, and yield prediction (Raj et al., 2024; Modica et al., 2021; Niu et al., 2020). This automation optimizes resources and facilitates early

interventions. The blue cluster emphasizes the use of remote sensing, UAVs, and deep learning for crop monitoring, yield forecasting, and vegetation assessment—where drones collect airborne data and deep learning algorithms analyze it to provide insights on crop health, growth patterns, and soil conditions, improving real-time farm management (González Perea et al., 2024; Melzer, Onic, and Huemer, 2016; Youssef et al., 2024). The green cluster highlights sustainability and water management, enhancing water use efficiency and drought forecasting (García et al., 2020; Zhou et al., 2022; Senoo et al., 2024).Whereas the red cluster highlights artificial intelligence, the Internet of Things, and intelligent agriculture, automating agricultural operations through sensor networks and real-time data analysis.

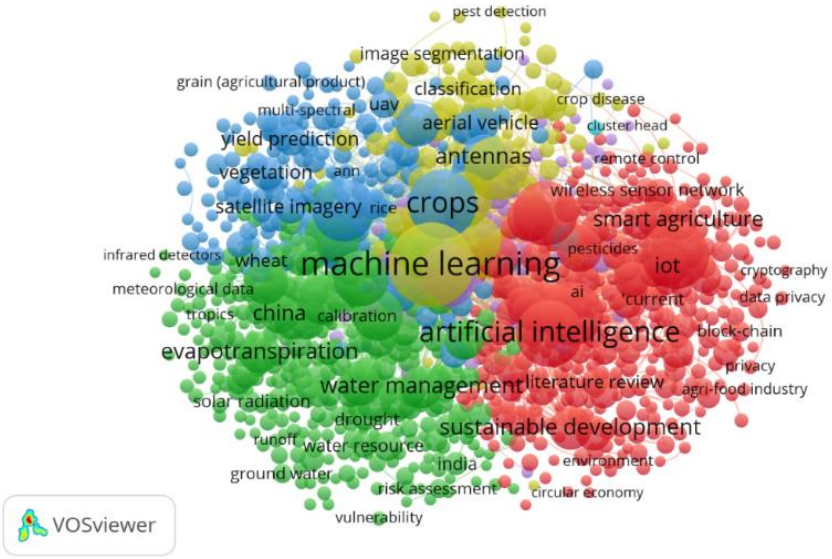

Figure 9: Map based on the co-occurrence of the authors' keywords

3.7 Analysis of 6 clusters

Cluster 1 focuses on how advanced technologies like 5G, AI, and automation are applied to agriculture and environmental management. It highlights their roles in precision farming, robotics, and data analytics, aiming to improve productivity and sustainability. Key topics include energy efficiency, digital agriculture, and resource management.

Cluster 2 focuses on methods and models for assessing environmental and agricultural conditions. It includes topics like accuracy assessment, data-driven models, and machine learning techniques such as neural networks and decision trees. The cluster emphasizes the use of algorithms for forecasting and modeling climate conditions, water resources, and soil properties. Key areas are data assimilation, error analysis, and performance evaluation in agricultural and environmental contexts.

Cluster 3 centers on the application of remote sensing and imaging technologies in agriculture. It includes the use of aerial photography, drones, and satellite imagery to monitor and analyze crop production, water stress, and vegetation. Key topics involve high-resolution imaging, hyperspectral and multispectral data, and the assessment of biophysical parameters like leaf area and chlorophyll content. The focus is on how these technologies enhance precision agriculture and plant phenotyping.

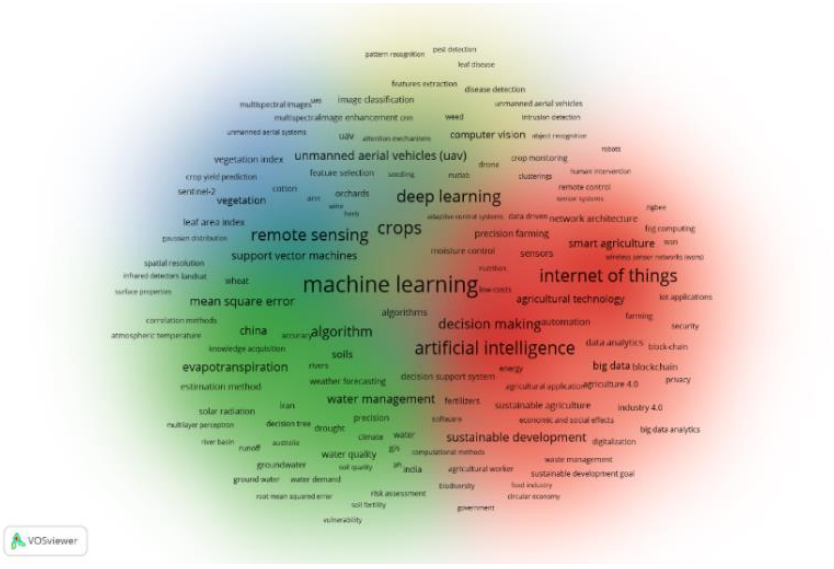

Figure 10: Cluster density Classification on the co-occurrence of the authors' keywords.

Cluster 4 focuses on machine learning and computer vision techniques for agricultural diagnostics. It includes methods such as convolutional neural networks (CNNs), deep learning, and data augmentation for tasks like crop disease detection, yield prediction, and image classification. Key areas feature extraction, object detection, and predictive analytics, emphasizing the application of these techniques for improved crop management and disease control.

Cluster 5 focuses on optimization and intelligent systems applied to agriculture. It includes methods such as adaptive control systems, fuzzy logic, and bio-inspired algorithms like ant colony optimization and genetic algorithms. Key topics are optimization techniques for crop management, water distribution, and irrigation systems. The cluster emphasizes the use of artificial intelligence and heuristic algorithms for improving agricultural processes and decision-making.

Cluster 6 emphasizes advanced optimization and intelligent systems for agricultural applications. It covers techniques such as reinforcement learning, swarm intelligence, and simulated annealing for optimizing water distribution, irrigation, and crop productivity. The focus is on using these sophisticated algorithms to enhance efficiency and decision-making in agricultural systems.

4. Conclusion

Artificial intelligence (AI) in agriculture has the potential to significantly improve sustainability, resource management, and productivity. This study's bibliometric analysis reveals an increasing interest in AI-driven solutions, particularly in fields like precision farming, irrigation optimization, and crop monitoring. The importance of AI in addressing global agricultural challenges, such as food security and environmental sustainability, is reflected in the growing output of research, especially from China, India, and the United States. However, Researchers must work together more closely and pay close attention to issues like data privacy if they are to fully realize AI's promise. Future innovation in AI technology is projected to change agriculture further, making it more efficient and sustainable.

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Declarations

Ethics Approval

Because this study was a bibliometric analysis, ethical approval was not obtained.

Consent to Participate and Consent for Publication

All authors agreed with the content and gave explicit consent to submit it. They obtained consent from the responsible authorities at the institute/organization where the work was carried out.

Conflict of Interest

The authors declare no competing interests.

Data Availability

The raw data can be obtained from the Scopus database

References

Aggarwal, N., and Singh, D., 2021. Technology-assisted farming: Implications of IoT and AI. IOP Conference Series: Materials Science and Engineering, 1022(1), 012080. https://doi.org/10.1088/1757-899X/1022/1/012080

Ahmed, M. W., Hossainy, S. J., Khaliduzzaman, A., Emmert, J. L., and Kamruzzaman, M., 2023. Non-destructive optical sensing technologies for advancing the egg industry toward Industry 4.0: A review. Comprehensive Reviews in Food Science and Food Safety, 22(6), Pp. 4378–4403. https://doi.org/10.1111/1541-4337.13227

Ali, Q., Abbas, A., Jamil, A., Rasheed, R., Ahmad, M., and Malik, W., 2021. Research advances and applications of biosensing technology for the diagnosis of pathogens in sustainable agriculture. Environmental Science and Pollution Research, 28(8), Pp. 9002–9019. https://doi.org/10.1007/s11356-021-12419-6

Balaska, V., Adamidou, Z., Vryzas, Z., and Gasteratos, A., 2023. Protección sostenible de cultivos a través de soluciones de robótica e inteligencia artificial. Machines, 11(8), Pp. 1–15. (No DOI provided — please verify if available)

Bhagat, P. R., Naz, F., and Magda, R., 2022. Artificial intelligence solutions enabling sustainable agriculture: A bibliometric analysis. PLoS ONE, 17(6), e0268989. https://doi.org/10.1371/journal.pone.0268989

Bhargava, A., Shukla, A., Goswami, O. P., Alsharif, M. H., Uthansakul, P., and Uthansakul, M., 2024. Plant leaf disease detection, classification, and diagnosis using computer vision and artificial intelligence: A review. IEEE Access, 12, Pp. 37443–37469. https://doi.org/10.1109/ACCESS.2024.3373001

Boursianis, A. D., Papadopoulou, M. S., Diamantoulakis, P. D., Liopa-Tsakalidi, A., Barouchas, P., Salahas, G., Karagiannidis, G. K., Wan, S., and Goudos, S. K., 2022. Internet of Things (IoT) and agricultural unmanned aerial vehicles (UAVs) in smart farming: A comprehensive review. Internet of Things, 18, 100187. https://doi.org/10.1016/j.iot.2020.100187

Carrión-Mero, P., Montalván-Burbano, N., Morante-Carballo, F., Quesada-Román, A., and Apolo-Masache, B., 2021. Worldwide research trends in landslide science. International Journal of Environmental Research and Public Health, 18(18), 9445. https://doi.org/10.3390/ijerph18189445

Cheng, C., Fu, J., Su, H., and Ren, L., 2023. Recent advancements in agriculture robots: Benefits and challenges. Machines, 11(1), Pp. 1–24. https://doi.org/10.3390/machines11010048

Cobo, M. J., Martínez, M. A., Gutiérrez-Salcedo, M., Fujita, H., and Herrera-Viedma, E., 2015. 25 years at Knowledge-Based Systems: A bibliometric analysis. Knowledge-Based Systems, 80, Pp. 3–13. https://doi.org/10.1016/j.knosys.2014.12.035

Dariane, A. B., and Sarani, S., 2013. Application of Intelligent Water Drops Algorithm in reservoir operation. Water Resources Management, 27(14), Pp. 4827–4843. https://doi.org/10.1007/s11269-013-0441-x

de Oliveira, M. F., dos Santos, A. F., Kazama, E. H., de S. Rolim, G., and da Silva, R. P., 2021. Determination of application volume for coffee plantations using artificial neural networks and remote sensing. Computers and Electronics in Agriculture, 184, 106096. https://doi.org/10.1016/j.compag.2021.106096

de Oliveira, R. C., and de Silva, R. D. S. E., 2023. Artificial intelligence in agriculture: Benefits, challenges, and trends. Applied Sciences, 13(13), Article 7405. https://doi.org/10.3390/app13137405

Ding, X., and Yang, Z., 2022. Knowledge mapping of platform research: A visual analysis using VOSviewer and CiteSpace. Electronic Commerce Research, 22(3), Pp. 787–809. https://doi.org/10.1007/s10660-020-09410-7

Elahi, E., Weijun, C., Zhang, H., and Nazeer, M., 2019. Agricultural intensification and damages to human health in relation to agrochemicals: Application of artificial intelligence. Land Use Policy, 83, Pp. 461–474. https://doi.org/10.1016/j.landusepol.2019.02.023

Elbeltagi, A., El-Shafie, A., Shalby, N., Abou El-Magd, I., and Alam, M. M., 2020. The impact of climate changes on the water footprint of wheat and maize production in the Nile Delta, Egypt. Science of the Total Environment, 743, 140770. https://doi.org/10.1016/j.scitotenv.2020.140770

Espinel, R., Herrera-Franco, G., Rivadeneira García, J. L., and Escandón-Panchana, P., 2024. Artificial intelligence in agricultural mapping: A review. Agriculture, 14(7), 1071. https://doi.org/10.3390/agriculture14071071

Esposito, M., Crimaldi, M., Cirillo, V., Sarghini, F., and Maggio, A., 2021. Drone and sensor technology for sustainable weed management: A review. Chemical and Biological Technologies in Agriculture, 8(1), 17. https://doi.org/10.1186/s40538-021-00217-8

Feng, Y., Hao, W., Li, H., Cui, N., Gong, D., and Gao, L., 2020. Machine learning models to quantify and map daily global solar radiation and photovoltaic power. Renewable and Sustainable Energy Reviews, 118, 109393. https://doi.org/10.1016/j.rser.2019.109393

Frey, U. J., and Rusch, H., 2013. Using artificial neural networks for the analysis of social-ecological systems. Ecology and Society, 18(2). https://doi.org/10.5751/ES-05202-180240

Gaagai, A., Djidel, M., Amour, N., Benhaoua, H., and Djemili, L., 2023. Application of water quality indices, machine learning approaches, and GIS to identify groundwater quality for irrigation purposes: A case study of Sahara Aquifer, Doucen Plain, Algeria. Water, 15(2), 289. https://doi.org/10.3390/w15020289

García, L., Parra, L., Jimenez, J. M., Lloret, J., and Lorenz, P., 2020. IoT-based smart irrigation systems: An overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture. Sensors, 20(4), 1042. https://doi.org/10.3390/s20041042

Ghazal, S., Munir, A., and Qureshi, W. S., 2024. Computer vision in smart agriculture and precision farming: Techniques and applications. Artificial Intelligence in Agriculture, 13, Pp. 64–83.

https://doi.org/10.1016/j.aiia.2024.06.004

González Perea, R., Camacho Poyato, E., and Rodríguez Díaz, J. A., 2024. Attention is all water need: Multistep time series irrigation water demand forecasting in irrigation districts. Computers and Electronics in Agriculture, 218, 108723. https://doi.org/10.1016/j.compag.2024.108723

Hayman, P. T., and Easdown, W. J., 2002. An ecology of a DSS: Reflections on managing wheat crops in the northeastern Australian grains region with WHEATMAN. Agricultural Systems, 74(1), Pp. 57–77. https://doi.org/10.1016/S0308-521X(02)00018-5

Holmes, G., Donkin, A., and Witten, I. H., 1994. WEKA: A machine learning workbench. In Proceedings of the Australian and New Zealand Conference on Intelligent Information Systems (pp. 357–361). IEEE. https://doi.org/10.1109/ANZIIS.1994.396988

Hu, Z., Feng, Q., Zhang, Y., Liu, Q., Hu, Y., and Li, X., 2022. CCHZ-DISO: A timely new assessment system for data quality or model performance from Da Dao Zhi Jian. Geophysical Research Letters, 49(23), e2022GL100681. https://doi.org/10.1029/2022GL100681

Im, J., Lu, Z., Rhee, J., and Quackenbush, L. J., 2012. Impervious surface quantification using a synthesis of artificial immune networks and decision/regression trees from multi-sensor data. Remote Sensing of Environment, 117, Pp. 102–113. https://doi.org/10.1016/j.rse.2011.06.024

Jha, K., Doshi, A., Patel, P., and Shah, M., 2019. A comprehensive review on automation in agriculture using artificial intelligence. Artificial Intelligence in Agriculture, 2, Pp. 1–12. https://doi.org/10.1016/j.aiia.2019.05.004

Jin, X., Kumar, L., Li, Z., Feng, H., Xu, X., and Yang, G., 2018. A review of data assimilation of remote sensing and crop models. European Journal of Agronomy, 92, Pp. 141–152. https://doi.org/10.1016/j.eja.2017.11.002

K.A. Publishers., 2004. Global knowledge management research: A bibliometric analysis. Scientometrics, 61(2), Pp. 171–190. (Note: The citation is based on the DOI in the URL: https://doi.org/10.1023/B:SCIE.0000041647.01086.f4)

Karthikeyan, L., Chawla, I., and Mishra, A. K., 2020. A review of remote sensing applications in agriculture for food security: Crop growth and yield, irrigation, and crop losses. Journal of Hydrology, 586, 124905. https://doi.org/10.1016/j.jhydrol.2020.124905

Kouadio, L., Deo, R. C., Byrareddy, V., Adamowski, J. F., Mushtaq, S., and Nguyen, V. P., 2018. Artificial intelligence approach for the prediction of Robusta coffee yield using soil fertility properties. Computers and Electronics in Agriculture, 155, Pp. 324–338. https://doi.org/10.1016/j.compag.2018.10.014

Kulkarni, R. V., Förster, A., and Venayagamoorthy, G. K., 2011. Computational intelligence in wireless sensor networks: A survey. IEEE Communications Surveys and Tutorials, 13(1), Pp. 68–96. https://doi.org/10.1109/SURV.2011.040310.00002

Liakos, K. G., Busato, P., Moshou, D., Pearson, S., and Bochtis, D., 2018. Machine learning in agriculture: A review. Sensors, 18(8), 2674. https://doi.org/10.3390/s18082674

Linaza, M. T., Saéz, J. A., López-de-Ipiña, D., García-Serrano, A., Álvarez, A., Mtz de Irujo, A., and Gaitán, A., 2021. Data-driven artificial intelligence applications for sustainable precision agriculture. Agronomy, 11(6), 1227. https://doi.org/10.3390/agronomy11061227

Linnenluecke, M. K., and Griffiths, A., 2013. Firms and sustainability: Mapping the intellectual origins and structure of the corporate sustainability field. Global Environmental Change, 23(1), Pp. 382–391. https://doi.org/10.1016/j.gloenvcha.2012.07.007

Linnenluecke, M. K., Marrone, M., and Singh, A. K., 2020. Conducting systematic literature reviews and bibliometric analyses. Australian Journal of Management, 45(2), Pp. 175–194. https://doi.org/10.1177/0312896219877678

Maloku, D., Balogh, P., Bai, A., Gabnai, Z., and Lengyel, P., 2020. Trends in scientific research on precision farming in agriculture using science mapping method. International Review of Applied Sciences and Engineering, 11(3), Pp. 232–242. https://doi.org/10.1556/1848.2020.00086

Marina, T., and Sterligov, I., 2021. Prevalence of potentially predatory publishing in Scopus on the country level. Scientometrics, 126(6), Pp. 5353–5375. https://doi.org/10.1007/s11192-021-03899-x

Melzer, A., Onic, A., and Huemer, M., 2016. Online phase-noise estimation in FMCW radar transceivers using an artificial on-chip target. IEEE Transactions on Microwave Theory and Techniques, 64(12), Pp. 4789–4800. https://doi.org/10.1109/TMTT.2016.2614808

Meroni, M., Waldner, F., Seguin, L., Kerdiles, H., and Rembold, F., 2021. Yield forecasting with machine learning and small data: What gains for grains? Agricultural and Forest Meteorology, Pp. 308–309, 108555. https://doi.org/10.1016/j.agrformet.2021.108555

Modica, G., De Luca, G., Messina, G., and Praticò, S., 2021. Comparison and assessment of different object-based classifications using machine learning algorithms and UAVs multispectral imagery: A case study in a citrus orchard and an onion crop. European Journal of Remote Sensing, 54(1), Pp. 431–460. https://doi.org/10.1080/22797254.2021.1951623

Mohr, S., and Kühl, R., 2021. Acceptance of artificial intelligence in German agriculture: An application of the technology acceptance model and the theory of planned behavior. Precision Agriculture, 22(6), Pp. 1816–1844. https://doi.org/10.1007/s11119-021-09814-x

Niu, H., Hollenbeck, D., Zhao, T., Wang, D., and Chen, Y., 2020. Evapotranspiration estimation with small UAVs in precision agriculture. Sensors, 20(22), Pp. 6427. https://doi.org/10.3390/s20226427

Oyewola, D. O., and Dada, E. G., 2022. Exploring machine learning: A scientometrics approach using bibliometrix and VOSviewer. SN Applied Sciences, 4(5). https://doi.org/10.1007/s42452-022-05027-7

Pazouki, E., 2021. A practical surface irrigation design based on fuzzy logic and meta-heuristic algorithms. Agricultural Water Management, 256, 107069. https://doi.org/10.1016/j.agwat.2021.107069

Qasem, S. N., Alazba, A. A., El-Shafie, A., and Ghumman, A. R., 2019. Modeling monthly pan evaporation using wavelet support vector regression and wavelet artificial neural networks in arid and humid climates. Engineering Applications of Computational Fluid Mechanics, 13(1), Pp. 177–187. https://doi.org/10.1080/19942060.2018.1564702

Raj, M., N. B., H., Gupta, S., Atiquzzaman, M., Rawlley, O., and Goel, L., 2024. Leveraging precision agriculture techniques using UAVs and emerging disruptive technologies. Energy Nexus, 14, 100300. https://doi.org/10.1016/j.nexus.2024.100300

Rasmussen, J., Azim, S., and Nielsen, J., 2021. Pre-harvest weed mapping of Cirsium arvense L. based on free satellite imagery – The importance of weed aggregation and image resolution. European Journal of Agronomy, 130, 126373. https://doi.org/10.1016/j.eja.2021.126373

Rose, D. C., Wheeler, R., Winter, M., Lobley, M., and Chivers, C. A., 2021. Agriculture 4.0: Making it work for people, production, and the planet. Land Use Policy, 100, 104933. https://doi.org/10.1016/j.landusepol.2020.104933

Saiz-Rubio, V., and Rovira-Más, F., 2020. From smart farming towards agriculture 5.0: A review on crop data management. Agronomy, 10(2), Pp. 207. https://doi.org/10.3390/agronomy10020207

Senoo, E. E. K., Raji, I. A., Zungeru, A. M., Ismail, A. F., Odu-Oji, O., and Abubakar, A. I., 2024. IoT solutions with artificial intelligence technologies for precision agriculture: Definitions, applications, challenges, and opportunities. Electronics, 13(10), Article 1894. https://doi.org/10.3390/electronics13101894

Shamshiri, R. R., Kalantari, F., Ting, K. C., Thorp, K. R., Hameed, I. A., Weltzien, C., Ahmad, D., and Shad, Z. M., 2018. Research and development in agricultural robotics: A perspective of digital farming. International Journal of Agricultural and Biological Engineering, 11(4), Pp. 1–11. https://doi.org/10.25165/j.ijabe.20181104.4278

Sharma, R., Kamble, S. S., Gunasekaran, A., Kumar, V., and Kumar, A., 2020. A systematic literature review on machine learning applications for sustainable agriculture supply chain performance. Computers and Operations Research, 119, 104926. https://doi.org/10.1016/j.cor.2020.104926

Soylu, S., and Çarman, K., 2021. Fuzzy logic based automatic slip control system for agricultural tractors. Journal of Terramechanics, 95, Pp. 25–32. https://doi.org/10.1016/j.jterra.2021.03.001

Talaviya, T., Shah, D., Patel, N., Yagnik, H., and Shah, M., 2020. Implementation of artificial intelligence in agriculture for optimization of irrigation and application of pesticides and herbicides. Artificial Intelligence in Agriculture, 4, Pp. 58–73. https://doi.org/10.1016/j.aiia.2020.04.002

Turpin, K. M., Peterson, G. A., Westfall, D. G., and Sherrod, L. A., 2005. Using multivariate adaptive regression splines (MARS) to identify relationships between soil and corn (Zea mays L.) production properties. Canadian Journal of Soil Science, 85(5), Pp. 625–636. https://doi.org/10.4141/S04-062

van Eck, N. J., Waltman, L., Noyons, E. C. M., and Butler, R. K., 2010. Automatic term identification for bibliometric mapping. Scientometrics, 82(3), Pp. 581–596. https://doi.org/10.1007/s11192-010-0173-0

Wang, L., Kisi, O., Zounemat-Kermani, M., Salazar, G. A., Zhu, Z., and Gong, W., 2016. Solar radiation prediction using different techniques: Model evaluation and comparison. Renewable and Sustainable Energy Reviews, 61, Pp. 384–397. https://doi.org/10.1016/j.rser.2016.04.024

Wu, Z., Liu, J., He, Z., Wang, J., Li, Z., Liu, Y., and Liu, Y., 2024. Inversion of large-scale citrus soil moisture using multi-temporal Sentinel-1 and Landsat-8 data. Agricultural Water Management, 294, 108718. https://doi.org/10.1016/j.agwat.2024.108718

Xu, J., Li, Y., Zhang, M., and Zhang, S., 2024. Sustainable agriculture in the digital era: Past, present, and future trends by bibliometric analysis. Heliyon, 10(14), e34612. https://doi.org/10.1016/j.heliyon.2024.e34612

Yang, S., 2021. Retraction: Analysis on the competitiveness of global agricultural remote sensing research based on artificial intelligence technology (J. Phys.: Conf. Ser. 1852 032046). Journal of Physics: Conference Series, 1852(3), 032072. https://doi.org/10.1088/1742-6596/1852/3/032072

Yaseen, Z. M., Sulaiman, S. O., Deo, R. C., and Chau, K. W., 2019. An enhanced extreme learning machine model for river flow forecasting: State-of-the-art, practical applications in water resource engineering area and future research direction. Journal of Hydrology, 569, Pp. 387–408. https://doi.org/10.1016/j.jhydrol.2018.11.069

Youssef, M. A., Elbeltagi, A., Elshorbagy, A., Hefny, M., Abdel-Mageed, M. S., and Ibrahim, M. G., 2024. Enhancing irrigation water management based on ETo prediction using machine learning to mitigate climate change. Cogent Food and Agriculture, 10(1), 2348697. https://doi.org/10.1080/23311932.2024.2348697

Zhou, Y., Xia, Q., Zhang, Z., Quan, M., and Li, H., 2022. Artificial intelligence and machine learning for the green development of agriculture in the emerging manufacturing industry in the IoT platform. Acta Agriculturae Scandinavica, Section B — Soil and Plant Science, 72(1), Pp. 284–299. https://doi.org/10.1080/09064710.2021.2008482