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Computer-Aided Design and Applications

Visual Analysis of the Development Trajectory of Agricultural Artificial Intelligence Based on CiteSpace

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Abstract. This study aims to conduct a comprehensive analysis of the current state and emerging trends in agricultural artificial intelligence research. It seeks to gain a deep understanding of the developmental stages and distinctive features of relevant research conducted globally. To achieve this, the study utilizes the bibliometric tool CiteSpace to visually and quantitatively analyses the agricultural artificial intelligence literature available in the Web of Science core database from 2013 to 2023. The analysis is undertaken from three distinct angles, including research cooperation networks, literature citations, and keyword analysis. The results of the study are as follows: The United States, India, and China are the prominent nations in agricultural artificial intelligence, exhibiting notable levels of productivity. These countries demonstrate a strong inclination towards collaboration, fostering partnerships across diverse organizations and scientists. The focal points of research predominantly center around theoretical methodologies, namely artificial intelligence, machine learning, and deep learning. In the last ten years, the domain of agricultural artificial intelligence has undergone two discernible stages: an initial period characterized by relative steadiness, followed by a subsequent phase marked by robust advancements and progress.

Keywords: Agriculture, Artificial intelligence, CiteSpace, Visual analysis, Deep learning.
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1 INTRODUCTION

The agricultural sector has experienced significant transformative developments in parallel with the ongoing progress of science and technology. Artificial intelligence (AI) has emerged as a pivotal technology in the field of agriculture, offering novel prospects and presenting a range of complex issues [6]. In recent years, there has been notable advancement in the field of agricultural artificial intelligence, which has introduced novel approaches to enhance the efficiency [15], sustainability [5], and food safety of agricultural production [4]. At the national strategic level, prominent developed nations such as the United States and Canada commonly perceive agricultural artificial intelligence as a crucial domain for national competition. Consequently, they have progressively intensified their research endeavors and are dedicated to fostering industrial innovation and enhancing structural advancements. China's research in the field of agricultural artificial intelligence has demonstrated significant and swift progress, positioning the country as a prominent global leader in this domain. While there is a considerable body of research on agricultural artificial intelligence, it tends to be focused on specific sub-disciplines, resulting in a dearth of comprehensive and thorough exploration of the development trajectories of agricultural artificial intelligence. It is important to acknowledge that agricultural artificial intelligence, being a constantly advancing and highly impactful field, necessitates the use of diverse scient metric techniques to thoroughly extract and examine literature data. Hence, this study employs bibliometric software to perform a thorough examination and detailed analysis of the prominent areas of research, evolutionary trajectory, and contextual framework within the domain of agricultural artificial intelligence, with the objective of offering novel academic insights and perspectives to advance the development and exploration of this field.

2 METHODOLOGY

2.1 Problem Definition

This article examines the dynamics and evolution trajectory of agricultural artificial intelligence's overall development over the past decade. The analysis is based on journal documents, with a focus on information integration and data mining from the scientific research cooperation network and literature. The study emphasizes the use of highlighted words and keywords to summaries the progress made in agricultural artificial intelligence research. The development features, which encompass a comprehensive comprehension of the dynamics and focal issues within a particular field, provide significant reference value for scientific researchers engaged in conducting important theoretical investigations.

2.2 Dataset Preparation

The literature data analyzed in this paper are sourced only from the primary database of Web of Science, a prominent international repository of scholarly knowledge. The period frame for the journal is defined as 2013-2023, with the search date specified as October 15, 2023. The search query is formulated as"= "Ai (Topic) and agricultural (Topic)". A grand total of 534 records were obtained.

2.3 Research Methods and Instruments

Initially, a total of 534 scholarly articles were evaluated using criteria such as the publication volume and impact factor of journals within the domain of agricultural artificial intelligence. The CiteSpace software was employed to do a visual study of academic publications of international significance, utilizing a text information extraction methodology and qualitative analysis. By integrating quantitative methodologies, it is possible to identify the prevailing areas of research in agricultural artificial intelligence worldwide, as well as to elucidate its developmental path and emerging trends.

3 RESULTS AND ANALYSIS

3.1 Analysis of Paper Distribution and Published Journals

A comprehensive examination of the yearly production of 524 scholarly articles in the field of agricultural artificial intelligence is conducted subsequent to the aforementioned data cleansing process. For further specifics, please refer to Fig. 1. As depicted in Fig. 1, the aggregate count of publications pertaining to agricultural artificial intelligence research exhibited a consistent trend between the years 2013 and 2018. Between the years 2018 and 2023, there was a notable increase in the literature pertaining to relevant disciplines. The emergence of international research on agricultural artificial intelligence in 2013 was accompanied by a limited number of research outcomes, a circumstance that may be linked to two primary issues. On one side, there is a need for further enhancement in global theoretical research and cognitive theoretical models within the realm of artificial intelligence. This implies that numerous theoretical concerns remain unanswered, necessitating additional comprehensive investigation and advancement in comprehending and simulating the implementation of artificial intelligence in the agricultural domain. An further factor to consider is that the scope of research is constrained by technological resources, including technology, software, and data availability. Prior to 2013, the technological instruments and infrastructure within the domain of agricultural artificial intelligence were comparatively underdeveloped, hence impeding researchers from engaging in comprehensive investigations and experiments within this realm. Nevertheless, as time has progressed and technological instruments have continuously advanced and improved, research in the domain of agricultural artificial intelligence has steadily thrived and attained noteworthy research outcomes.

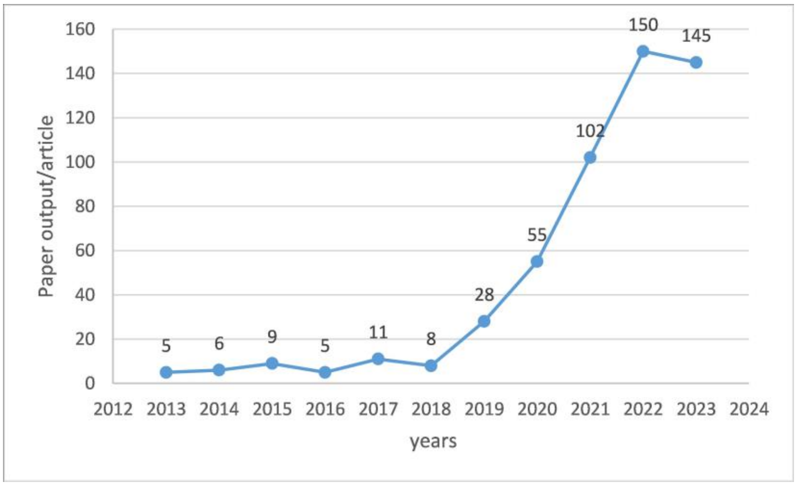

Figure 1: Distribution of annual output of agricultural artificial intelligence papers.

The year 2018 witnessed a significant proliferation of machine learning applications in the field of agriculture [3]. The utilization of image recognition technology has been employed to automatically identify and categories various agricultural afflictions such as crop diseases, insect pests, and weeds [13]. This application aims to assist farmers in enhancing their land management practices. The utilization of unmanned aerial vehicles (UAVs), also known as drones, in the field of agriculture is experiencing a significant surge in growth. With the utilization of multi-spectral sensors, these devices possess the capability to be employed in the monitoring of crop health, management of fertilization and irrigation, as well as the collecting of crop images. These technologies are considered innovative due to their ability to enhance agricultural production efficiency while simultaneously promoting sustainable agriculture and resource management in response to the increasing global food demand. These technologies are anticipated to aid farmers in enhancing their ability to adjust to climate change and address environmental concerns more effectively. Subsequently, there has been a substantial increase in both the amount and impact of research findings in the field of agricultural artificial intelligence, accompanied by a continuous surge in its level of attention. By the year 2022, it is projected that the growth rate of published papers will experience a substantial increase of 1775%, reaching unprecedented levels.

3.2 Distribution Statistics of High-yield Countries in Agricultural Artificial Intelligence Research

Select the Country option within the panel, while leaving the remaining options at their default system values. The knowledge map of countries engaged in high-yield agricultural artificial intelligence research worldwide can be accessed. For detailed information, please refer to Fig. 2. In the depicted diagram, each individual node symbolizes a distinct nation, while the line that connects two nodes signifies the link existing between the respective countries. Furthermore, the magnitude of each node is indicative of the quantity of postings associated with it. To enhance comprehension of the node level within this domain, additional data mining was undertaken. The specifics of this analysis are presented in Table. 1.

Figure 2: Visualized knowledge map of countries with high yields in agricultural artificial intelligence research.

In terms of scholarly publication output, the United States, India, and China have emerged as the leading contributors in the domain of agricultural artificial intelligence. Notably, the disparity in paper output among the seven nations under consideration is rather little. Fig. 2 illustrates that China's research in agricultural artificial intelligence commenced at a comparatively later stage.

Ranking	*Countries*	*Count*	*Countries*	*Centrality*
1	USA	102	NETHERLANDS	0.7
2	INDIA	96	SPAIN	0.38
3	CHINA	73	MALAYSIA	0.36
4	CANADA	29	MEXICO	0.34
5	SAUDI ARABIA	28	SWEDEN	0.33
6	ENGLAND	27	BELGIUM	0.26
7	ITALY	27	GERMANY	0.25
8	SPAIN	26	AUSTRALIA	0.24
9	GERMANY	23	IRELAND	0.23
10	PAKISTAN	22	RUSSIA	0.22

Table 1: Top 10 high-producing countries ranked by number of articles and centrality.

There exists a discernible disparity in terms of fundamental research and technology between the United States and other entities. Nevertheless, significant advancements have been achieved, leading to a more comprehensive and thorough exploration of the subject matter. Research on agricultural artificial intelligence in the United States commenced at an earlier stage compared to other countries. Notably, certain literature produced in the United States played a pivotal role in advancing the field of agricultural artificial intelligence [14]. This factor may serve as a significant catalyst for the accelerated growth of the agricultural artificial intelligence sector. Alternatively, considering centrality, nodes possessing a centrality value of 0.3 or above are deemed essential nodes. These nodes are commonly recognized as influential variables contributing to shifts within the research domain. According to the data presented in Table 1, the document centrality values for the Netherlands, Spain, Malaysia, Mexico, and Sweden are all equal to or greater than 0.3. These six nations possess significant innovative capabilities and exert substantial influence in the domain of agricultural artificial intelligence.

3.3 Distribution Statistics of High-yield Institutions in Agricultural Artificial Intelligence Research

Execute the software application and proceed to choose the Institution option in order to obtain the distribution map depicting high-yield institutions, as illustrated in Fig. 3. The presence of multiple interconnecting lines among the circles depicted on the map suggests a high degree of inter-connectedness among the various organizations.

The collaboration network of high-performing institutions comprises a total of 263 nodes and 260 edges. Each individual node inside the system symbolizes the numerical quantity of academic publications attributed to a specific institution. The linkages symbolize the reciprocal partnership among institutions. As the level of collaboration increases, there is a corresponding increase in the degree of cooperation between this organization and other organizations. The analysis of Fig. 3 reveals a significant level of collaboration among different institutions. This collaboration enables the effective utilization of literature from various universities and scientific research units, leading to the exploration of new research perspectives and facilitating in-depth and expedited research endeavors. The entities responsible for issuing units mostly consist of higher education institutions such as colleges and universities, as well as research institutions. Prominent research institutions with a strong emphasis on productivity include Texas A&M University, the Agricultural University of Athens, Pennsylvania State University, the Thapar Institute of Engineering & Technology, the Chinese Academy of Sciences, Wageningen University & Research, the University of California, Davis, and the University of Florida, among others. American institutions hold a significant presence in the field of agricultural artificial intelligence, as evidenced by their representation in 50% of the top ten institutions in terms of published paper frequency.

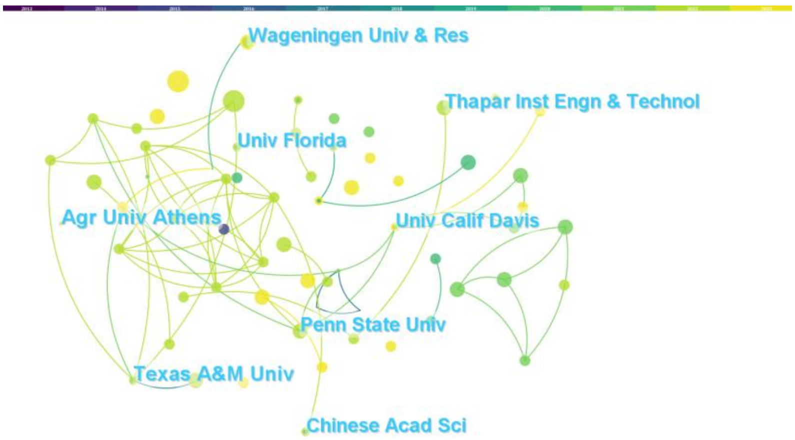

Figure 3: Cooperation map of high-yield institutions.

3.4 Distribution Statistics of High-yield Authors of Agricultural Artificial Intelligence

A visual analysis was undertaken on the author collaboration map of 524 papers (as depicted in Fig. 4 to enhance the representation of key authors and their significance in the domain of agricultural artificial intelligence.

In Fig. 4, the size of each node corresponds to the quantity of papers published by the respective author, while the connections between nodes indicate reciprocal collaboration relationships. Price's law posits that those who have written more than three papers are considered to be the key authors. Based on statistical data, the sample literature consists of a collective of 8 primary writers. The authors who have achieved the highest rankings are Arvanitis, Konstantinos G, Bueno-Crespo, and Andres. In the realm of agricultural artificial intelligence, it is observed that there exists a strong collaborative bond among researchers, leading to a concentrated research effort and a cohesive network of scholars. A comprehensive investigation into this discipline holds considerable importance.

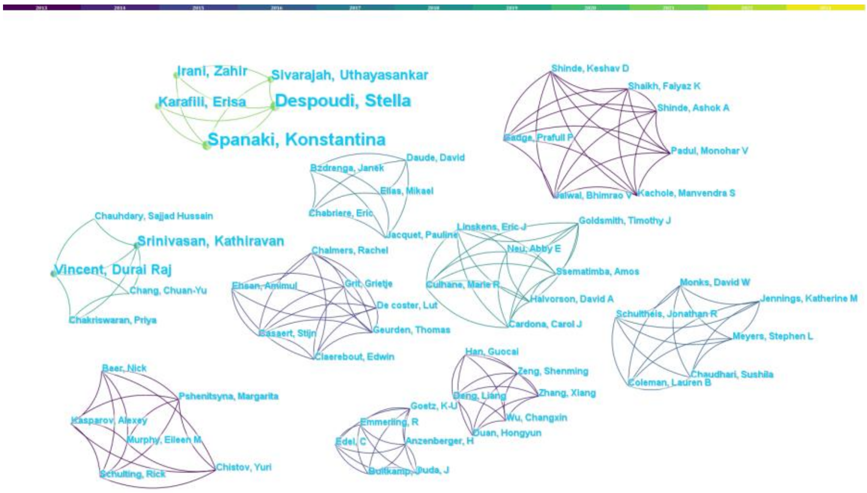

Figure 4: Collaboration chart of highly productive authors.

3.5 Research on Agricultural Artificial Intelligence Hotspots and Trends Based on Visual Analysis of Highlighted Words

By utilizing the Detect Bursts feature of the software, one can identify a notable surge in the usage of specialized terminology within a condensed timeframe throughout a particular year. This enables the observation of significant shifts in the progression of knowledge and understanding. Fig. 5 illustrates the word map that has been constructed from a collection of sample documents, with certain words being highlighted. The analysis of the highlighted words reveals a discernible pattern in the duration of their hotspots, which exhibits a gradual decrease from longer to shorter durations.

Between the years 2013 and 2023, notable terms that have garnered attention include drought and aridity index, with a significant duration of 5 to 7 years. In the specific year of 2014, noteworthy terms encompassed artificial insemination, aridity index, avian influenza virus," and food security, with an average duration of 3 years. Over the course of the period spanning from 2016 to the present, there has been a notable emphasis on significant terms such as mechanism, growth, and plant. The aforementioned highlighted terms indicate the contextual framework and patterns pertaining to agricultural artificial intelligence.

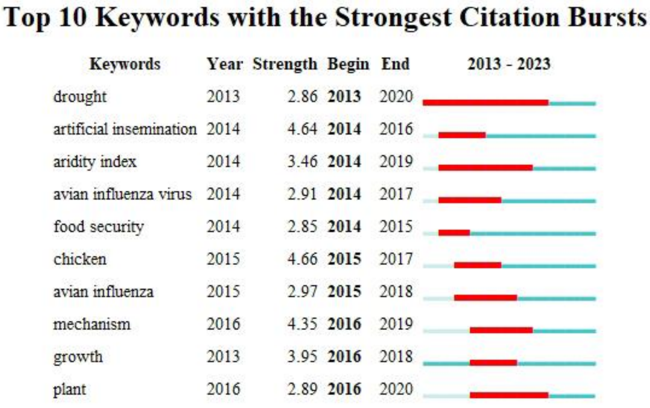

Figure 5: Top 10 most prominent words.

3.6 Research Hotspot Analysis Based on Keyword Co-occurrence

Keywords serve as a means to depict the interconnectedness among different subjects that are to be portrayed in the literature, and they constitute the fundamental synopsis of the article. The examination of keywords is advantageous for investigating prominent areas within this particular sector. Execute the software application in order to generate the agricultural artificial intelligence keyword co-occurrence map, as depicted in Fig. 6. The magnitude of each node in the graph corresponds to the frequency of occurrence of the respective term. As the frequency of events rises, the circumference of the circle will progressively expand. The most often occurring keywords, with a frequency more than 20, are artificial intelligence, machine learning, and deep learning, which have 141, 72, and 71 instances respectively. In summary, scientists in the field of agricultural artificial intelligence primarily concentrate on ten prominent areas of interest: artificial intelligence, machine learning, deep learning, system, precision agriculture, agriculture, management, neural network, internet of things, and categorization. High-frequency keywords exhibit a strong correlation with the terms that are placed highest in the central position. In other words, as the frequency increases, the center becomes more pronounced. Centrality has the capacity to include significant locations and pivotal moments to a certain degree.

When conducting literature analysis, it is possible to categories keywords into two distinct groups: technical keywords and agricultural application keywords. Technical keywords are an essential aspect of academic discourse. Artificial intelligence (AI), machine learning, deep learning, big data, Internet of Things (IoT), neural network, computer vision, technology, impact, and the internet are all topics of interest in the academic field. These subjects have been extensively studied and researched, as seen by the numerous references [1],[7],[9],[16-20]. The aforementioned technical terms encompass the fundamental technologies and infrastructure within the realm of agricultural artificial intelligence. The agricultural sector has witnessed significant advancements with the introduction of technologies such as artificial intelligence, machine learning, and deep learning. These technologies have revolutionized agricultural systems, enhancing their intelligence and efficiency. Simultaneously, the use of big data and Internet of Things (IoT) technology assumes a significant role in facilitating data collecting [8] and enhancing decision-making capabilities [11].

The following agricultural application keywords are emphasized: Precision agriculture [17], Agriculture, Management [10], Classification [12], Smart agriculture, Model, Prediction, Challenge, Smart farming [2], Climate change. This paper examines the various uses and associated themes of artificial intelligence in the field of agriculture. The utilization of artificial intelligence in agriculture has the potential to enhance production efficiency and sustainability through the application of precision agriculture, agricultural management, and data categorization and prediction techniques. The advancement of intelligent agricultural systems and models offers farmers and agricultural managers an expanded array of tools and resources to effectively tackle many challenges, including climate change.

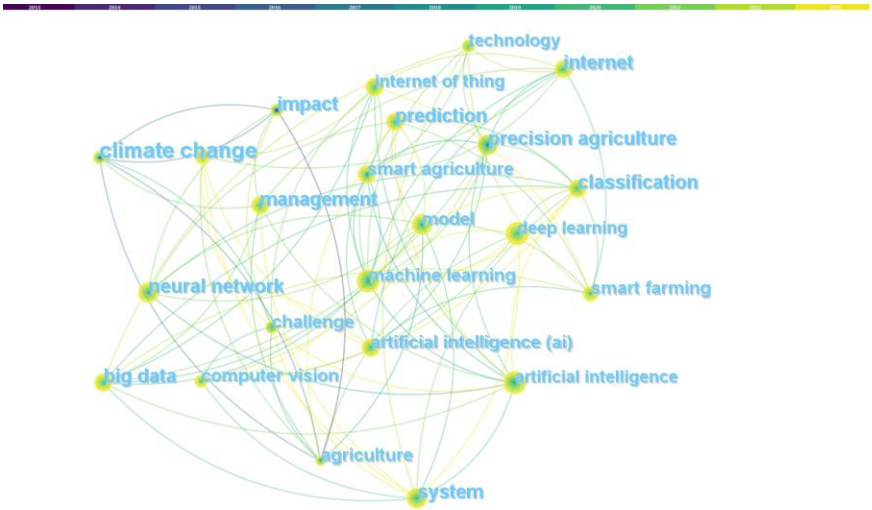

Figure 6: Keyword clustering diagram.

The simultaneous presence of these two categories of terms indicates that agricultural artificial intelligence transcends being merely a technological advancement, but rather has evolved into a multifaceted domain of application, presenting substantial prospects for the agricultural sector. The integration of sophisticated technology with agricultural practices holds the potential to enhance agricultural production in terms of intelligence, efficiency, and sustainability. This convergence is anticipated to exert a substantial influence on the future progression of the worldwide agricultural sector.

3.7 Discussion

The domain of agricultural artificial intelligence is presently undergoing a phase of accelerated advancement. The integration of technology is a prominent contemporary phenomenon, encompassing the extensive utilization of many technologies such as machine learning, deep learning, Internet of Things, and big data analysis. The integration of various technologies facilitates the collection, analysis, and utilization of substantial volumes of data within agricultural systems, hence enhancing the efficiency of production and the effective allocation of resources. The application of precision agriculture holds significant importance within the agricultural sector. By utilizing intelligent sensors, satellite-derived data, and machine learning algorithms, farmers and agricultural managers are able to enhance their ability to monitor and regulate crop development, soil conditions, and meteorological variables. This enables them to minimize resource inefficiencies, optimize yields, and mitigate expenses. The subject of concern is the environmental impact. The integration of artificial intelligence (AI) in the agricultural sector has the potential to enhance sustainability by addressing the adverse environmental effects associated with agricultural practices. This can be achieved through improved resource allocation and less reliance on pesticides.

In next years, there will be an increased use of agricultural artificial intelligence, encompassing developing nations. Automation and robots will emerge as predominant themes, while the advancement of intelligent supply networks will also be pursued. Agricultural artificial intelligence (AI) is not solely a technological advancement, but rather a multifaceted domain of application that holds immense potential for the agricultural sector. Its anticipated impact on the future development of the worldwide agricultural business is substantial.

4 CONCLUSIONS

This study utilizes the Cite Space program to conduct qualitative and quantitative analysis of worldwide journals within the research field, leading to the following results. Based on the statistical visualization outcomes pertaining to the distribution of high-producing countries, institutions, and authors in the field of agricultural artificial intelligence, it can be observed that the countries exhibiting high productivity in this domain are primarily the United States, India, China, Canada, and Saudi Arabia. Furthermore, the research institutions that have demonstrated the highest number of publications are Texas A&M University, Agricultural University of Athens, The United States exhibits a prominent position in academic research on agricultural artificial intelligence, as evidenced by its high rankings in terms of high-yield countries, high-yield institutions, and high-yield authors.

The current research landscape in agricultural artificial intelligence predominantly centers around the utilization of artificial intelligence, machine learning, and deep learning methodologies. Despite notable advancements in these domains, there remains a need for further exploration of the extensive utilization of agricultural artificial intelligence technologies. Insufficient study has been conducted in the domain of advanced intelligence domains, specifically pertaining to agricultural intelligent decision-making and intelligent resource allocation. Given the significant influence of these technologies on the socioeconomic and agricultural domains, there is a notable emphasis on conducting comprehensive investigations into these facets as a prominent area of future scholarly inquiry. Based on an analysis of the evolutionary traits and historical progression of scholarly investigations, it can be shown that agricultural artificial intelligence has undergone two distinct phases: a period of relative stability and a subsequent phase characterized by significant advancements, commencing in 2013. The evolution of early theoretical concepts into practical applications, and subsequently their extensive utilization in artificial intelligence, machine learning, deep learning, and related domains, has garnered considerable interest within the realms of social and economic studies.

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REFERENCES

[1] Almeida, L.; Santos, F.; Oliveira, L.: Structuring Communications for Mobile Cyber-Physical Systems, In: Guerrieri, A., Loscri, V., Rovella, A., Fortino, G. (eds) Management of Cyber Physical Objects in the Future Internet of Things. Internet of Things. Springer, Cham. https://doi.org/10.1007/978-3-319-26869-9_3

[2] Alwis, S. D.; Hou, Z.; Zhang, Y.; Na, M. H.; Ofoghi, B.; Sajjanhar, A.: A survey on smartfarming data, applications and techniques, Computers in Industry, 138, 2022, 103624. https://doi.org/10.1016/j.compind.2022.103624

[3] Attri, I.; Awasthi, L. K.; Sharma, T. P.: Machine learning in agriculture: a review of cropmanagement applications, Multimedia Tools and Applications, 2023, https://doi.org/10.1007/s11042-023-16105-2

[4] Awuchi, C. G.: Haccp, quality, and food safety management in food and agricultural systems, Cogent Food & Agriculture, 2023, 9(1), 2176280. https://doi.org/10.1080/23311932.2023.2176280

[5] Bless, A.; Davila, F.; Plant, R.: A genealogy of sustainable agriculture narratives: implications for the transformative potential of regenerative agriculture, Agriculture and Human Values, 2023, 40, 1379-1397. https://doi.org/10.1007/s10460-023-10444-4

[6] Boursianis, A. D.; Papadopoulou, M. S.; Diamantoulakis, P.; Liopa-Tsakalidi, A.; Barouchas, P.; Salahas,G.; Karagiannidis G.; Wan S.; Goudos S. K.: Internet of things (IoT) and agricultural unmanned aerial vehicles (UAVs) in smartfarming: A comprehensive review, Internet of Things, 2020, 18, 100187. https://doi.org/10.1016/j.iot.2020.100187

[7] Dhanaraju, M.; Chenniappan, P.; Ramalingam, K.; Pazhanivelan, S.; Kaliaperumal, R.: Smart farming: Internet of things (IoT)-based sustainable agriculture, Agriculture, 2022, 12(10), 1745. https://doi.org/10.3390/agriculture12101745

[8] Faiella, A.: Agriculture damage data collection: A model for reconstructing comprehensive damage dynamics, Progress in Disaster Science, 2020, 7, 100112. https://doi.org/10.1016/j.pdisas.2020.100112

[9] Farjon, G.; Liu, H.; Edan, Y.: Deep-learning-based counting methods, datasets, and applications in agriculture: a review, Precision Agriculture, 2023, 24, 1683–1711. https://doi.org/10.1007/s11119-023-10034-8

[10] Giray, G.; Catal, C.: Design of a data management reference architecture for sustainable agriculture, Sustainability, 2021, 13(13), 7309. https://doi.org/10.3390/su13137309

[11] González, X. I.; Bert, F.; Podestá, G.: Many objective robust decision-making model for agriculture decisions (MORDMAgro), International Transactions in Operational Research, 2023, 30(4), 1617-1646. https://doi.org/10.1111/itor.12898

[12] Gupta, A.; Nahar, P.: Classification and yield prediction in smart agriculture system using IoT, Journal of Ambient Intelligence and Humanized Computing, 2023, 14, 10235-10244. https://doi.org/10.1007/s12652-021-03685-w

[13] Yu, H.; Li, D.; Chen, Y.: A state-of-the-art review of image motion deblurring techniques in precision agriculture, Heliyon, 2023, 9(6), e17332. https://doi.org/10.1016/j.heliyon.2023.e17332

[14] Kalyanaraman, A.; Burnett, M.; Fern, A.; Khot, L.; Viers, J.: Special report: The AgAID AI institute for transforming workforce and decision support in agriculture, Computers and Electronics in Agriculture, 2022, 197, 106944. https://doi.org/10.1016/j.compag.2022.106944

[15] Liu, X; Li, X.: The influence of agricultural production mechanization on grain production capacity and efficiency, Processes, 2023, 11(2), 487. https://doi.org/10.3390/pr11020487

[16] Gopal P.S. M.; Chintala, B. R.: Big data challenges and opportunities in agriculture, International Journal of Agricultural and Environmental Information Systems, 2020, 11(1), 48–66. https://doi.org/10.4018/IJAEIS.2020010103

[17] Nyaga, J. M.; Onyango, C. M.; Wetterlind, J.; Söderström, M.: Precision agriculture research in sub-Saharan Africa countries: a systematic map, Precision Agriculture, 2021, 22, 1217–1236. https://doi.org/10.1007/s11119-020-09780-w

[18] Peters, D. P. C.; Rivers, A.; Hatfield, J. L.; Lemay, D. G.; Liu, S.; Basso, B.: Harnessing AI to transform agriculture and inform agricultural research, IT Professional, 2020, 22(3), 16–21. https://doi.org/10.1109/MITP.2020.2986124

[19] Sivaranjani, A.; Senthilrani, S.; kumar, B. A.; Murugan, A. S.: An overview of various computer vision-based grading system for various agricultural products, The Journal of Horticultural Science and Biotechnology, 2021, 97(2), 137–159. https://doi.org/10.1080/14620316.2021.1970631

[20] Zheng, J.; Li, M.; Hu, S.; Xiao, X.; Li, H.; Li, W.: Research on optimization of agricultural machinery fault monitoring system based on artificial neural network algorithm, INMATEH-Agricultural Engineering, 2021, 64, 297-306. https://doi.org/10.35633/inmateh-64-29