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ORIGINAL

Analysis of the scientific production on the implementation of artificial intelligence in precision agriculture

Análisis de la producción científica sobre la implementación de la inteligencia artificial a la agricultura de precisión

Verenice Sánchez Castillo[1]

[1]Universidad de la Amazonia. Florencia, Colombia.

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ABSTRACT

The implementation of artificial intelligence is having a transformative impact on precision agriculture by optimizing agricultural resources and minimizing environmental impact, with a focus on sustainable development. The objective of the research is to analyze the scientific production on the implementation of artificial intelligence in precision agriculture. The research was conducted under the quantitative paradigm, using a descriptive and retrospective approach, and its implementation was carried out through a bibliometric study. It was conducted in SCOPUS database in the period 2014 - 2024 without language restriction. The behavior of the research was positive with a maximum peak of 112 researches where research articles in the area of computer science predominated. The most productive country was India with 79 research papers, while the most productive affiliation with 18 research papers was the University of Florida in the United States. Four lines of research and the periods with the highest number of citations in the subject were identified, where it was evidenced that the greatest boom was from 2019. Precision agriculture is an agricultural management tool that integrates a group of advanced technologies such as global positioning systems, geographic information systems, remote sensors, drones, internet of things and artificial intelligence, with an impact on optimizing agricultural resources and minimizing environmental impact in terms of territorial development and the fulfillment of sustainable development objectives.

Keywords: Precision Agriculture; Bibliometric Analysis; Artificial Intelligence; Scientific Production.

RESUMEN

La implementación de la inteligencia artificial está teniendo un impacto transformador en la agricultura de precisión al optimizar los recursos agrícolas y minimizar el impacto ambiental, con un enfoque en el desarrollo sostenible. El objetivo de la investigación es analizar la producción científica sobre la implementación de la inteligencia artificial a la agricultura de precisión. La investigación se realizó bajo el paradigma cuantitativo, mediante un enfoque descriptivo y retrospectivo, y su implementación se realizó mediante un estudio bibliométrico. Se realizó en base de datos SCOPUS en el período 2014 - 2024 sin restricción idiomática. El comportamiento de las investigaciones fue positivo con un pico máximo de 112 investigaciones donde predominaron los artículos de investigación en el área de las ciencias de la computación. El país más productor fue la India con 79 investigaciones, mientras que la filiación más productora con 18 investigaciones fue la Universidad de Florida en Estados Unidos. Se identificaron cuatro líneas de investigación y los períodos de mayor cantidad de citas en el tema, donde se evidenció que el mayor auge fue a partir del 2019. La agricultura de precisión es una herramienta de gestión agrícola que integra un grupo de tecnologías de avanzadas como sistemas de posicionamiento global, sistemas de información geográfica, sensores remotos, drones, internet de las cosas e inteligencia artificial, con un impacto al optimizar los recursos agrícolas y minimizar el impacto ambiental en función del desarrollo territorial y al cumplimiento de los objetivos de desarrollo sostenible.

Palabras clave: Agricultura de Precisión; Análisis Bibliométrico; Inteligencia Artificial; Producción Científica.

INTRODUCTION

Precision agriculture (PA) is an innovative practice that combines advanced technologies[1] with the objective of optimizing agricultural resources and minimizing environmental impact.[2,3] This innovative form of agricultural management allows producers to make informed and specific decisions for each section of their fields[4] and to adjust inputs according to the real needs of the crops.[5] In this sense, production linkages[6] and short marketing circuits play an important role.[7] PA has proven to be a powerful tool to increase agricultural productivity.[8] By analyzing detailed data on soil conditions, weather, and crop conditions so as to properly apply fertilizers, pesticides, and water.

PA has proven to be a powerful tool for increasing agricultural productivity.[8] By analyzing detailed data on soil conditions, climate, and crop status, fertilizers, pesticides, and irrigation water can be applied efficiently. This leads to better utilization of resources,[9] reducing production costs[10] and maximizing yields.[8]

In addition to improving productivity, it contributes significantly to environmental sustainability. [11] By applying inputs only where they are needed and in the right amounts, waste and soil contamination are reduced. This helps to preserve natural resources and mitigate the negative impact of agricultural practices on the environment.[12] Its implementation not only has an individual but also a collective impact, focused on agricultural territorial development.[13] However, it is a challenge as it demands investment in education, research, and development.[1]

The main enabling technologies of precision agriculture are:

- Global Positioning Systems (GPS) and Geographic Information Systems (GIS) allow mapping and georeferencing fields, as well as identifying variations in terrain, crop yield, etc.[14]
- Remote sensors and unmanned aerial vehicles (drones), which, by collecting satellite images, monitor crop condition, vegetative vigor, water stress, pest detection, etc.[15]
- Field sensors and wireless sensor networks that measure variables such as soil moisture, temperature, nutrients, etc., to make decisions on irrigation, fertilization, and other practices.[16]
- The Internet of Things (IoT) and cloud computing enable the connection and integration of devices, sensors, and systems for remote monitoring and control.[17]
- Artificial Intelligence (AI) and Machine Learning tools process large volumes of data to generate predictive model recommendations and automate processes.[18]

In Colombia, these technologies have been implemented for the function of meeting the Sustainable Development Goals (SDGs); in the specific case of AI, the IBM Watson tool has been used to perform more than 5 000 soil analyses in the fields where the data is processed. Personalized recommendations on fertilization, irrigation, and cultivation practices are generated to optimize productivity.[19] Also, artificial intelligence systems based on neural networks that, with the use of satellite images, can identify with high precision the areas suitable for agriculture in different regions of the country. [20]

The implementation of AI is having a transformative impact on precision agriculture[21] as it contributes significantly to the fulfillment of the United Nations 2030 Agenda[22], where significant impacts are evident are SDG 2 of ending hunger and achieving food security, SDG 6 with sustainable water management, SDG 12 through a focus on responsible production and consumption and SDG 15 that promotes the protection of terrestrial ecosystems, elements that drive research, training and knowledge transfer, for the achievement of resilient infrastructures and fostering innovation.

In this sense, the research aims to analyze the scientific production of the implementation of artificial intelligence in precision agriculture.

METHOD

The research was conducted under the quantitative paradigm[23] using a descriptive and retrospective approach, and its implementation was carried out by means of a bibliometric study.[24,25] The database used was SCOPUS (https://www.scopus.com/) due to its impact at the international level, and it was conducted independently by two researchers. The scientific production was analyzed in the period 2014 - 2024 without language restriction.

The search formula was:

- TITLE-ABS-KEY (“artificial intelligence” and “precision agriculture”) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE,”ar”) OR LIMIT-TO (DOCTYPE,”re”)).

The review was performed on May 28, 2024, and a total of 457 investigations (N=457) were collected. For the analysis of the information, the file was downloaded in “RIS” format and processed by one of the researchers in the EndNote X8 bibliographic manager.

For the description of the publications, the following bibliometric indicators were analyzed:

- Scientific production per year: studies the behavior of research and its frequency over time. The trend line adjusted for the highest R2 value was used.

- Number of research studies by type of document: the number of documents is analyzed according to their type.
- Number of research studies by area of knowledge: the number of documents by area of knowledge is analyzed.
- Number of publications by country: the number of documents by country is analyzed.
- Number of publications by institutional affiliation: the number of documents by institutional affiliation is analyzed.

Source of information: trend and scientific production indicators are obtained from the SCOPUS database. XLSX files were downloaded in Excel format and processed in Microsoft Excel.

Vosweiver software was used to create the knowledge maps, where initially, a correlation analysis was performed between countries and their main grouping clusters, a keyword co-occurrence analysis was performed, and the network bibliometric map was obtained in order to identify the main lines of research; this analysis was contrasted with the keyword frequency and density analysis obtained from the Lens platform (https://www.lens.org/). Finally, an analysis of authorial collaboration and the authors with the most recent publications was carried out using the bibliometric overlay map. Complementary to this, an analysis of citations in the Lens database was performed.

RESULTS AND DISCUSSION

The behavior of research in the period 2014 - 2016 was heterogeneous, with a decrease of two types of research, while from the year 2017, the trend was positive and towards increase, characterized by a polynomial function with a confidence level of 89,95 % and a maximum peak in the year 2023 of 112 types of research, while in 2024 there are already 85 types of research, an element that reflects that the trend may exceed the previous periods.

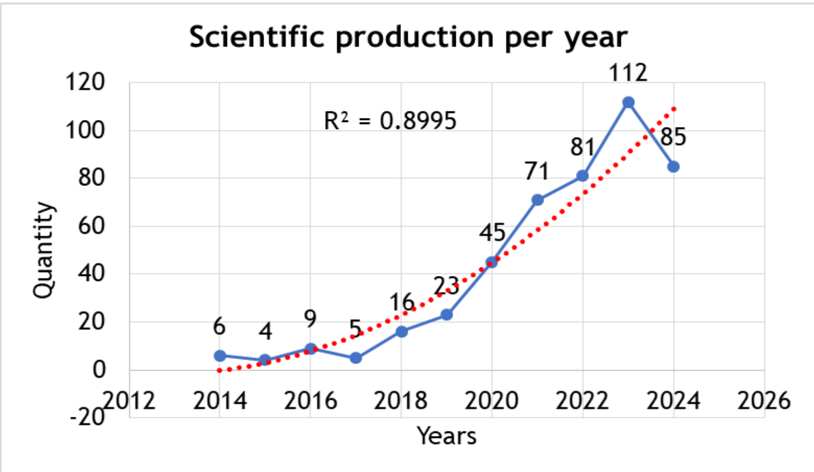

Figure 1. Scientific production by year

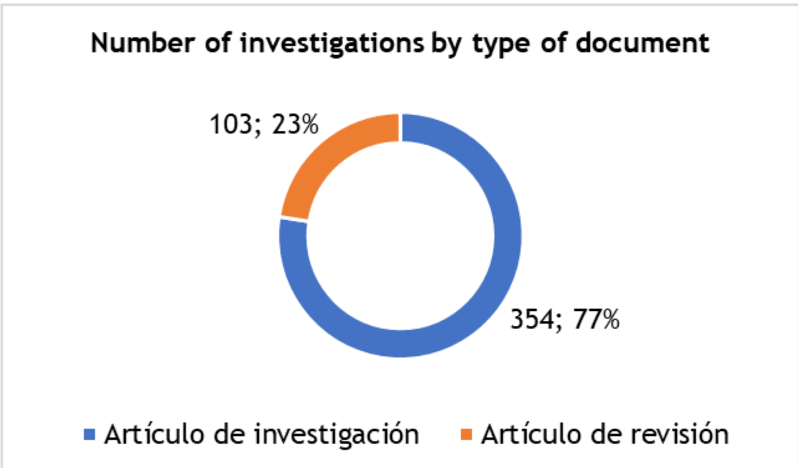

Figure 2. Number of investigations by type of document

Figure 2 shows an analysis of the scientific production by type of documents, where 77 % of the articles (354) were research articles, and the remaining 23 % (103) were review articles.

A study of research by area of knowledge was carried out, where initially, a total of 23 areas were identified; table 1 shows an analysis of the areas with more than 30 researches representing 86,46 % of the total. Computer science, with 220 types of research, was the most representative (23,45 %), followed by biological and agricultural sciences and engineering, with 192 and 144, respectively.

Table 1. Number of research projects by area of knowledge

Area of knowledge	Quantity	Percentage
Computer Science	220	23,45
Biological and agricultural sciences	192	20,47
Engineering	144	15,35
Environmental sciences	54	5,76
Earth and Planetary Sciences	51	5,44
Physics and Astronomy	46	4,90
Social sciences	37	3,94
Materials Science	34	3,62
Biochemistry, Genetics and Molecular Biology	33	3,52
Sample	811	86,46
Total	938	100

The research was identified in 87 countries; an analysis of the countries with more than 20 publications figure 3 showed that India, with 79 studies, was the largest producer, followed by the United States and China, with 75 and 55 studies, respectively. In the geographic area of Latin America, Brazil stood out with 29 research studies, followed by the United States and China with 75 and 55, respectively.

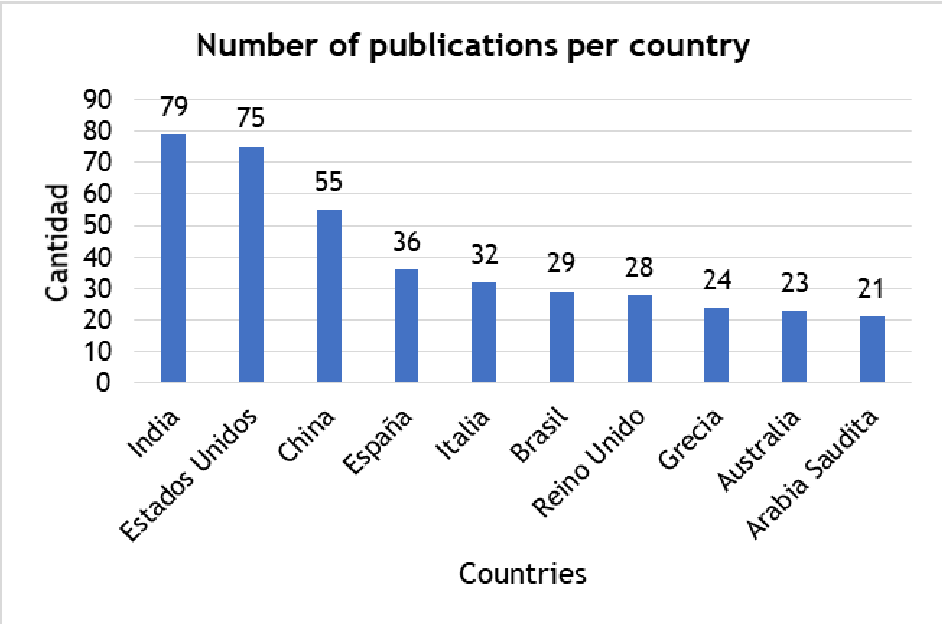

Figure 3. Number of publications by country

Figure 4 shows an analysis of the number of publications by institutional affiliation; where of the 160 affiliations that published at least one article, the University of Florida stood out with 18 research papers, followed by the University of Florida Institute of Food and Agricultural Sciences and the Chinese Academy of Sciences with 14 and 8 papers, respectively.

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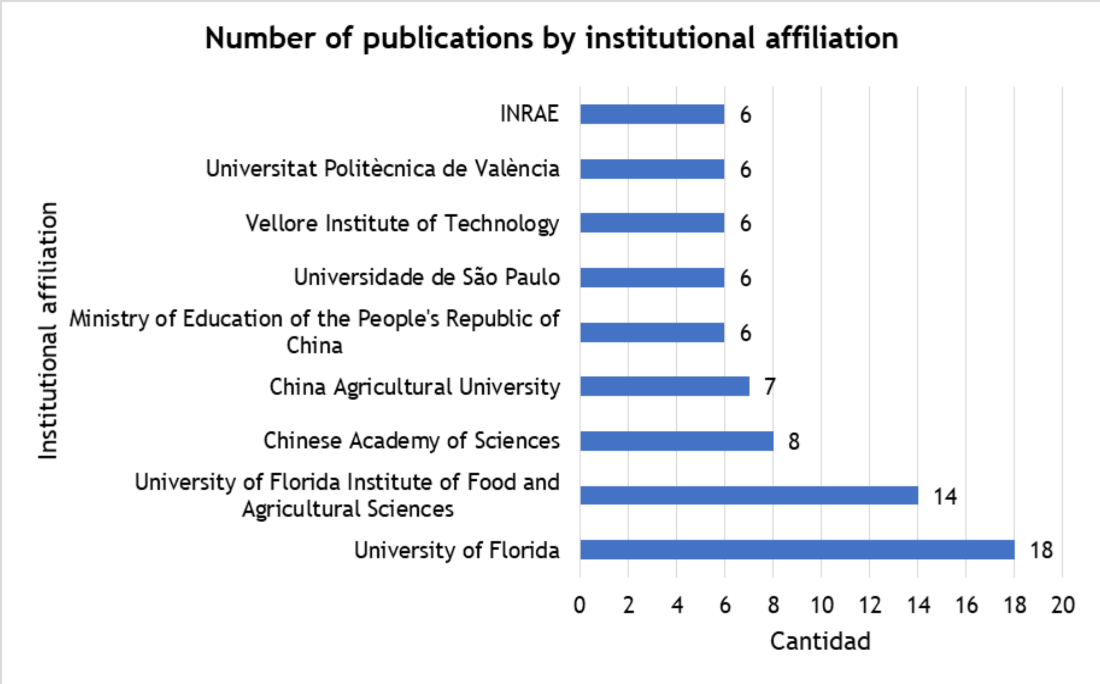

Figure 4. Number of publications by institutional affiliation

A correlation analysis was performed between countries figure 5, with a level of cooccurrence greater than or equal to five (n≥5), where four clusters and 33 items were identified; in the center was found India, which was related to China, Canada, South Korea, and Egypt, on the other hand, the United States was related to Australia and the Netherlands. In contrast, the cluster where Brazil is located branched more than seven countries collaborating and points of contact between their researches.

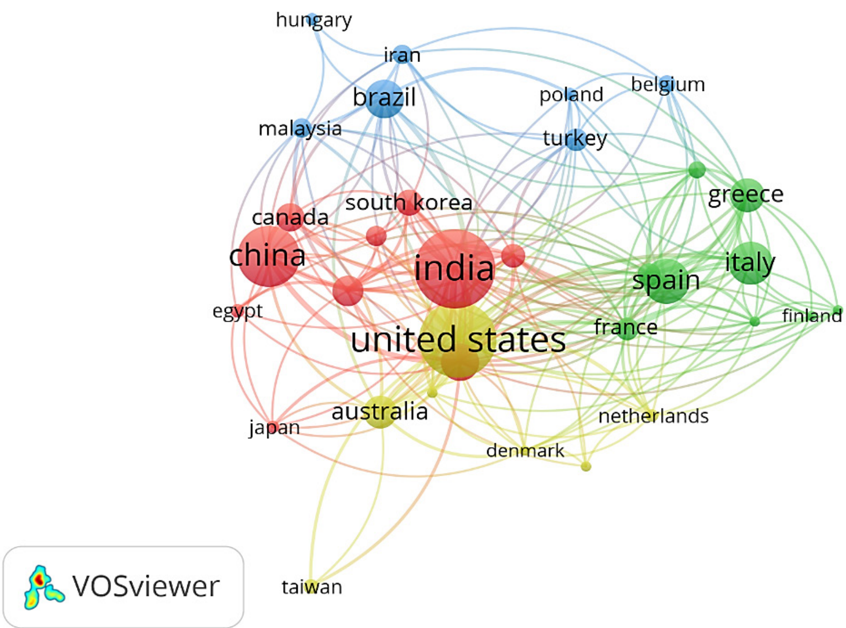

Figure 5. Correlation analysis between countries (n≥5)

Figure 6 shows the network of cooccurrence of keywords, with a level greater than or equal to 24, where four clusters and 27 items were identified; from the study of the lines of research, four lines of research were identified table 1.

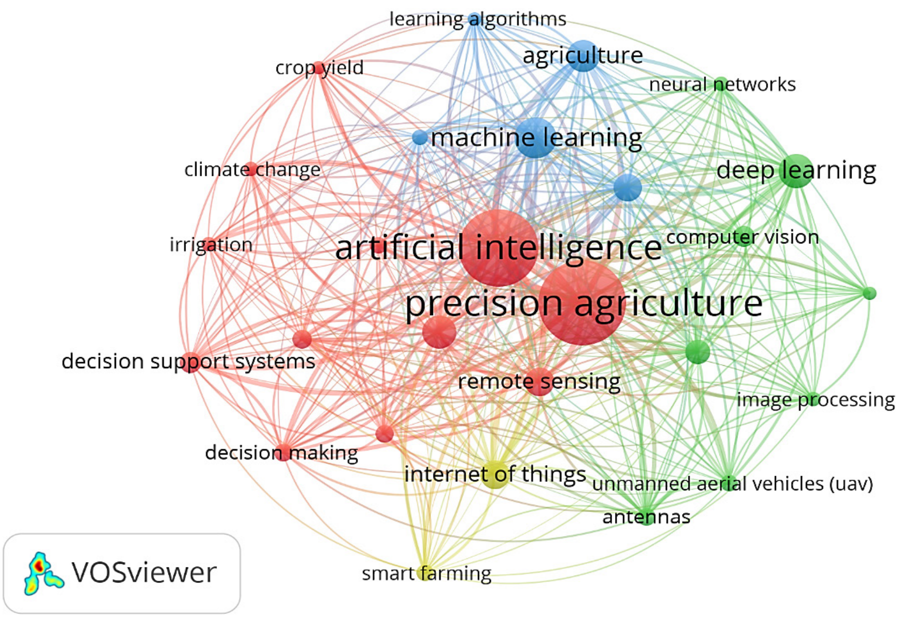

Figure 6. Keyword cooccurrence analysis (n≥24)

Cluster (C)	Items	Line of research	Reference
C1	12	Application of decision support systems based on artificial intelligence and remote sensing for precision agriculture and optimization of crop yields in the face of climate change.	(26,27,28,29)
C2	8	Development of artificial vision systems based on convolutional neural networks and deep learning for agricultural robots and unmanned aerial vehicles (drones).	(30,31,32,33,34,35)
C3	5	Development of machine learning systems for the optimization of agricultural practices.	(36,37,38,39,40,41)
C4	2	Implementation of intelligent agriculture systems (Smart Farming) based on the Internet of Things (IoT).	(42,43,44,45,46,47)
Total	27		

Table 2. Main lines of research

A keyword frequency and density analysis was performed figure 7, where computer science was the most repeated word 1 220 times, followed by artificial intelligence (762) and agriculture (597). In addition, studies related to agricultural productivity[40,48] deep learning applied to agricultural development,[49,50] and the use of cloud computing while remote sensing systems applied to geo-plots are evident.[51]

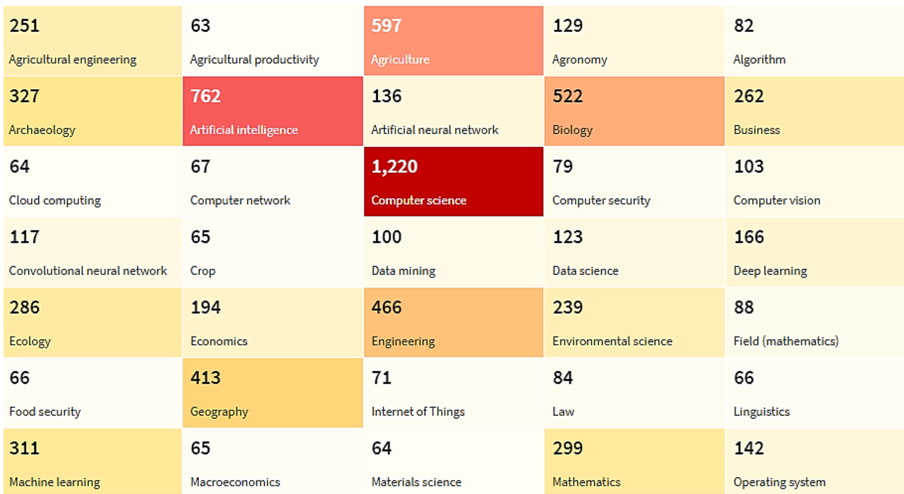

Figure 7. Frequency and keyword density analysis

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Figure 8 shows an analysis of authorial collaboration with a frequency greater than or equal to four (n≥4), where three main clusters were identified, and the most representative authors were Ampatzidis, Y., Costa, L., Patel, V., Lu, Y. and Osco, L.P.

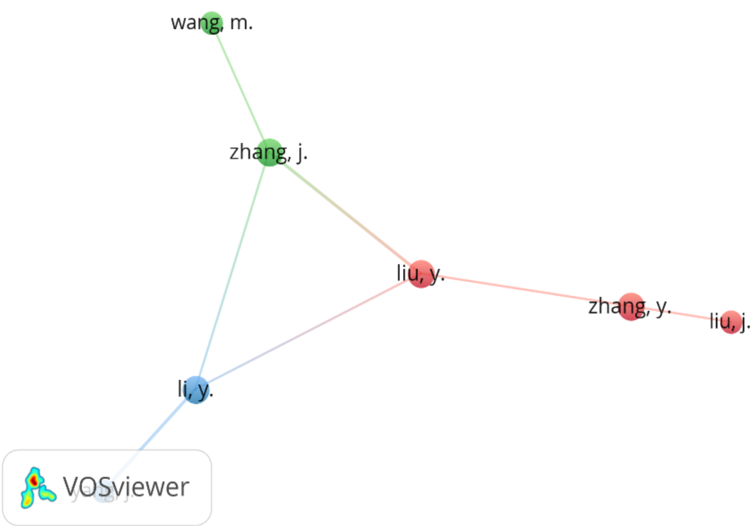

Figure 8. Author collaboration analysis (n≥4)

An analysis of citations was performed figure 9; in the period 2004 - 2019, the research did not exceed 200 citations and citations of articles not in access predominated; from the year 2020, citation levels increased up to 600, and open access article citations predominated with a maximum peak of 1 500 citations.

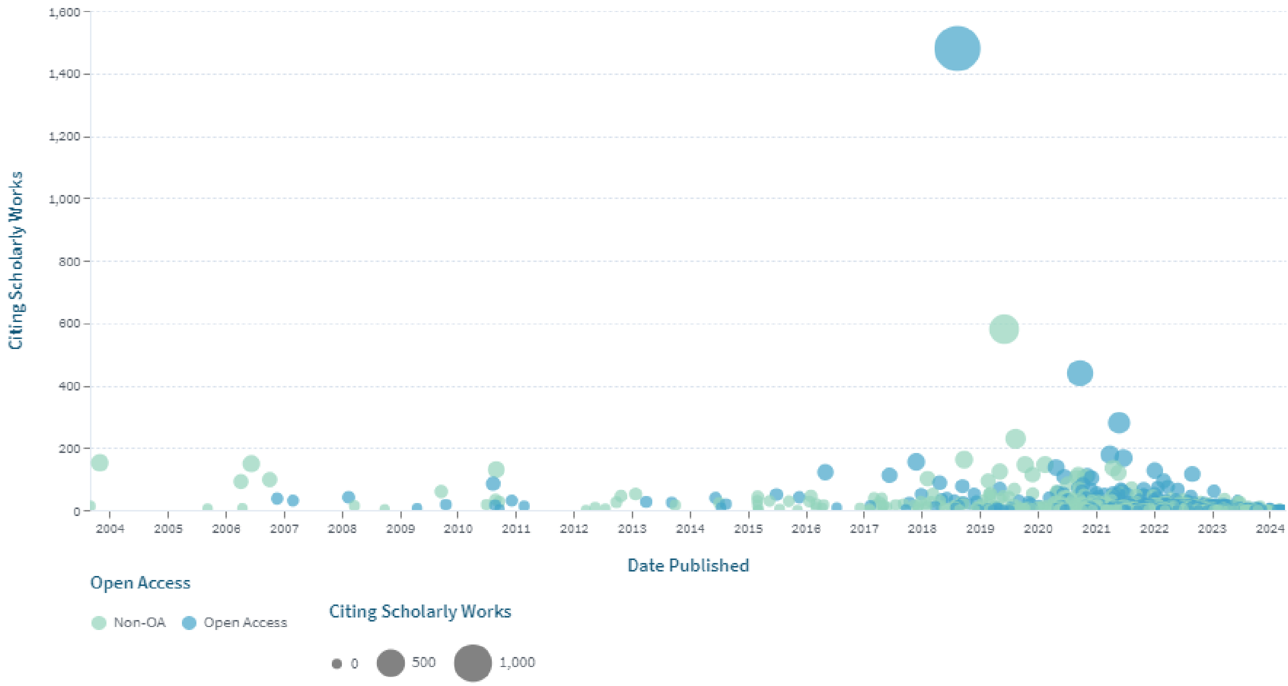

Figure 9. Map of citations

CONCLUSIONS

PA is an agricultural management tool that integrates a group of advanced technologies, such as global positioning systems, geographic information systems, remote sensors, drones, the internet of things, and artificial intelligence, with an impact on optimizing agricultural resources and minimizing the environmental impact in terms of territorial development and the fulfillment of sustainable development objectives.

The research showed an increase over time in terms of the impact of these technologies on the optimization of agricultural production, with a predominance of research articles in the area of research sciences. However, India was the largest producer, and the University of Florida in the United States was the most prominent institution.

A cluster analysis of the keyword co-occurrence mapping study was conducted where four lines of scientific research related to the application of decision support systems based on artificial intelligence and remote sensing for precision agriculture and crop yield optimization in the face of climate change were identified, the development of artificial vision systems based on convolutional neural networks and deep learning for agricultural robots and unmanned aerial vehicles (drones), the development of machine learning systems for the optimization of agricultural practices, and the implementation of intelligent agriculture systems (Smart Farming) based on the Internet of Things (IoT).

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Verenice Sánchez Castillo.
Research: Verenice Sánchez Castillo.
Methodology: Verenice Sánchez Castillo.
Writing - original draft: Verenice Sánchez Castillo.
Writing - revision and editing: Verenice Sánchez Castillo.