JPB REVIEW
INTERNATIONAL JOURNAL OF PROFESSIONAL BUSINESS REVIEW
ISSN: 2525-8654
OPEN ACCESS

AGRICULTURE STARTUPS (AGTECHS): A BIBLIOMETRIC STUDY

Jéssica Alves Justo Mendes[A], Lucas Olegário Bueno[B], Arthur Yassine Oliveira[C], Mateus Cecílio Gerolamo[D]

ARTICLE INFO

Article history:

Received 30 December 2021

Accepted 07 February 2022

Keywords:

AgTech;
Agribusiness;
Bibliometric analysis;
SciMAT;
Vosviewer.

ABSTRACT

Purpose: Conduct a bibliometric study on agricultural startups (AgTech) and the main concepts related to them in the literature.

Theoretical framework: The agribusiness sector has the challenge of producing food sustainably to ensure food security for the planet's population by 2050. In this context, there is an exponential growth in investments in agriculture technology (Kakani et al., 2020). Most of these technologies are developed and marketed by AgTechs, the technological startups in agribusiness. AgTechs are expressive in the 4.0 agriculture scenario, where more precise and environmentally sustainable technologies are sought (Dutia, 2014. However, despite the growing number of AgTechs, few studies present their main concepts in the scientific literature.

Design/methodology/approach: The Web of Science (WoS) and Scopus databases were used together with softwares: SciMAT and VOSviewer to develop the bibliometric study. The SciMAT was used to clean up raw bibliographic data, analyze, and configure the analysis. The maps generated were produced at VOSviewer and based on co-citation for the periods defined in the SciMAT.

Findings: The results showed that the theme is not well consolidated in the literature, but it is in a dizzying growth, with 71.3% of the articles having been published in the last threeyears in 79 journals and with publications covering 44 countries.

Research, Practical & Social implications: the AgTech theme is consolidating in literature where digital and disruptive technologies are concerned, however, the human factors, business models, and management aspects involved in this topic are being neglected, which resulted in the proposal of a Research Agenda that can help both academics and practitioners to analyze AgTechs aspects that appear to not be in focus rightnow.

Originality/value: The study brought important contributions to a better understanding of the term AgTech in the literature and to the improvement of concepts related to this ecosystem.

Doi: https://doi.org/10.26668/businessreview/2022.v7i2.312

[A] *PhD (in progress) in Production Engineering from the University of São Paulo (USP), São Carlos campus, under the supervision of Mateus Cecílio Gerolamo. E-mail: jessy.a.j.mendes@usp.br Orcid: https://orcid.org/0000-0003-0251-0023*

[B] *Researcher at the Master's level in the Graduate Program in Environmental Engineering Sciences at the School of Engineering of São Carlos. E-mail: lucasbueno@usp.br Orcid: https://orcid.org/0000-0001-8099-5295*

[C] *Graduation in Aeronautical Engineering in progress (USP - EESC). Institution: University of São Paulo (USP - EESC). E-mail: arthuryo@usp.br Orcid: https://orcid.org/0000-0002-8230-9161*

[D] *Associate Professor at the University of São Paulo (USP). Graduated in Production Engineering in 2000 from the São Carlos School of Engineering (EESC-USP), where he completed his Masters (2003) and Doctorate (2007) in Production Engineering on the themes of Management of Organizational Change and Improvement, and Management of Performance in Regional Cooperation Networks of Small and Medium Enterprises (SMEs). E-mail: gerolamo@sc.usp.br Orcid: https://orcid.org/0000-0002-6535-0904*

STARTUPS DA AGRICULTURA (AGTECHS): UM ESTUDO BIBLIOMÉTRICO

RESUMO

Objetivo: Realizar um estudo bibliométrico sobre as startups da agricultura (AgTech) e os principais conceitos relacionados a elas na literatura.
Referencial teórico: O setor de agronegócios tem o desafio de produzir alimentos de forma sustentável para garantir a segurança alimentar da população do planeta até 2050 (Kakani et al., 2020). Neste contexto, há um crescimento exponencial nos investimentos em tecnologia. A maioria dessas tecnologias é desenvolvida e comercializada pelas AgTechs, startups de base tecnológica do agronegócio. As AgTechs são expressivas no cenário agrícola 4.0, onde busca-se tecnologias mais precisas e ambientalmente sustentáveis (Dutia, 2014). Entretanto, apesar do crescente número da AgTechs, poucos estudos apresentam seus principais conceitos na literatura científica.
Desenho/metodologia/abordagem: As bases de dados Web of Science (WoS) e Scopus foram utilizadas em conjunto com softwares: SciMAT e VOSviewer para realização do estudo bibliográfico. O SciMAT foi utilizado para limpar dados bibliográficos brutos, analisar e configurar a análise. Os mapas gerados foram produzidos no VOSviewer e baseados em co-citação para os períodos definidos no SciMAT.
Resultados: Os resultados mostraram que o tema não está bem consolidado na literatura, mas está em um crescimento vertiginoso, com 71,3% dos artigos tendo sido publicados nos últimos três anos em 79 periódicos e com publicações abrangendo 44 países.
Pesquisa, implicações práticas e sociais: o tema AgTech está se consolidando na literatura no que diz respeito às tecnologias digitais e disruptivas, entretanto, os fatores humanos, modelos de negócios e aspectos de gestão envolvidos neste tópico estão sendo negligenciados, o que resultou na proposta de uma Agenda de Pesquisa que pode ajudar tanto acadêmicos quanto profissionais a analisar aspectos das AgTechs que parecem não estar em foco neste momento.
Originalidade/valor: O estudo trouxe contribuições importantes para uma melhor compreensão do termo AgTech na literatura e para o aprimoramento de conceitos relacionados a este ecossistema.

Palavras-chave: AgTech, Agronegócios, Estudos Bibliométricos, SciMAT, Vosviewer

STARTUPS AGRÍCOLAS (AGTECHS): UN ESTUDIO BIBLIOMÉTRICO

RESUMEN

Objetivo: Realizar un estudio bibliométrico sobre las startups agrícolas (AgTech) y los principales conceptos relacionados con ellas en la literatura.
Marco teórico: El sector agroalimentario tiene el reto de producir alimentos de forma sostenible para garantizar la seguridad alimentaria de la población del planeta en 2050. En este contexto, hay un crecimiento exponencial de las inversiones en tecnología agrícola (Kakani et al., 2020). La mayoría de estas tecnologías son desarrolladas y comercializadas por las AgTechs, las startups tecnológicas de la agroindustria. Las AgTechs son expresivas en el escenario de la agricultura 4.0, donde se buscan tecnologías más precisas y ambientalmente sostenibles (Dutia, 2014. Sin embargo, a pesar del creciente número de AgTechs, pocos estudios presentan sus principales conceptos en la literatura científica.
Diseño/metodología/enfoque: Se utilizaron las bases de datos Web of Science (WoS) y Scopus junto con los softwares: SciMAT y VOSviewer para desarrollar el estudio bibliométrico. El SciMAT se utilizó para limpiar los datos bibliográficos en bruto, analizar y configurar el análisis. Los mapas generados se produjeron en VOSviewer y se basaron en la co-citación para los períodos definidos en el SciMAT.
Resultados: Los resultados mostraron que el tema no está bien consolidado en la literatura, pero está en un crecimiento vertiginoso, con el 71,3% de los artículos publicados en los últimos tres años en 79 revistas y con publicaciones que abarcan 44 países.
Investigación, implicaciones prácticas y sociales: El tema AgTech se está consolidando en la literatura en lo que respecta a las tecnologías digitales y disruptivas, sin embargo, los factores humanos, los modelos de negocio y los aspectos de gestión involucrados en este tema están siendo descuidados, lo que dio lugar a la propuesta de una Agenda de Investigación que puede ayudar tanto a los académicos como a los profesionales a analizar los aspectos AgTechs que parecen no estar en el foco ahora mismo**.**
Originalidad/valor: El estudio aportó importantes contribuciones para una mejor comprensión del término AgTech en la literatura y para la mejora de los conceptos relacionados con este ecosistema.

Palabras clave: AgTech, Agribusiness, Análisis bibliométrico, SciMAT, Vosviewer.

INTRODUCTION

From the Industrial Revolution onwards, the agricultural model followed a highly industrialized pattern with large-scale commercial farms (Wezel et al., 2014). This model proved unsustainable and new practices with unprecedented approaches were adopted to solve these problems (Miranda et al., 2019). In recent years, the development of technologies in the agricultural sector has sought to modernize, facilitate, and improve agricultural operations to meet the growing needs to feed the world population in the coming decades (Liu et al. 2018).

In this scenario known as the digital revolution, the information technology and artificial intelligence applied to agriculture have pushed technologies such as drones, robots, and sensors that are capable of performing image capture and identification services, tracking field conditions, soil, water, nutrients, and even operate machines and equipment remotely (Pham; Stack, 2019; Boursianis et al., 2021). This new model of agriculture is applied to large and small-scale farms, transforming operations in the field and the farmer, consumer, and social life (Miranda et al. 2019).

Technology-based startups focused on agribusiness solutions, known as AgTechs (Dutia, 2014), are looking for specific solutions to improve yields and reach the goal of sustainable food supply for the coming decades (Kakani et al., 2020). According to Dutia (2014), the AgTechs have great potential to transform the agricultural sector through increases in technologies that help in greater productivity in the field, associated with a reduction in the environmental and social costs of production practices.

In recent years, due to the highly active risk environment in the country and the strong appetite for technological integration of agribusiness players, the AgTech ecosystem in Brazil has shown exponential growth. According to Figueiredo et al. (2021), between 2020 and 2021, Brazil had about 1574 startups considering the upstream and downstream segments of productive activities (before the farm, on the farm, and after the farm). Despite this growth, there is a gap in the literature regarding bibliometric studies, which led to the following research questions: “What are the thematic clusters related to AgTech?” and “How is the topic of Brazilian AgTechs represented in the literature?”. Thus, in this work, our main goal is to discuss the operational model of AgTechs, the main terms related to their performance, and how Brazil is represented in this context. For this, a bibliometric study was carried out that aimed to contribute scientifically to a better understanding of the term AgTech in the literature and the improvement of concepts related to this ecosystem.

LITERATURE REVIEW

Bibliometric studies

Bibliometric studies, in which a particular field of knowledge is studied through quantitative and statistical analyzes to describe publication patterns (Ratnatunga and Romano, 1997), have been widely used by scholars to probe the past and present state of research interests for several purposes (Akbar and Zaim, 2019), with bibliometric studies based on specific topics being one of the most common in the literature (Laengle et al., 2018). Topic-based bibliometric studies aim to analyze various issues, such as the performance of authors, journals, universities, and countries about a specific topic (Laengle et al., 2018).

Thus, bibliometric methods allow researchers to base their findings on aggregated bibliographic data produced by other scientists working in the field who express their opinions through citation, collaboration and writing (Zupic and Cater, 2015) with the input of the bibliometric study being the collection of scientific articles from a database of world-renowned scientific literature (Akbar and Zaim, 2019) and the output being insights into the structure of the field of knowledge, networks, and identification of current and rapidly growing topics (Zupic and Cater, 2015), which is consistent with the development of this article, which seeks to assess the development of the theme of AgTechs in academic literature.

AgTechs

The trends in the global technology market first emerged in Silicon Valley, in the United States. From this environment of innovation, agribusiness has been one of the most prominent sectors in the use and creation of technologies for production processes, which has attracted an exponential number of investments, which configures the AgTech revolution, a term that refers to companies that develop new technologies applied to agribusiness (StartAgro, 2016). In the context of digital transformations, AgTechs drive new business models and enable new forms of collaboration.

According to the quantitative survey of Brazilian agro startups carried out by Radar AgTech Brasil 2020/2021 (Figueiredo et al., 2021), considering the upstream and downstream segments of productive activities (before the farm, on the farm, and after the farm), currently around 1570 AgTechs operate in Brazil. Of these, 757 are located in the state of São Paulo and, specifically in the municipality of Piracicaba, the region known as Vale do Piracicaba (AgTech Valley) is located. The region has become an important

center for generating knowledge and producing technologies for the Brazilian agricultural sector, creating a base and boosting important AgTechs with trained entrepreneurs, disruptive ideas, and potential economic impact, making it an attraction for investors (Dias et al., 2019).

METHODOLOGY

The Web of Science (WoS) and Scopus databases were used to search the strings: “AgTech” OR “Agritech” OR “Agrotech” OR “Agriculture Startup” OR “Agricultural Startup” OR “Agriculture Startup” OR “Agricultural Startup” in order to find all publications that addressed the following topic: "startups aimed at agribusiness". After, SciMAT and VOSviewer software were used to carry out the other steps of the bibliometric study described below.

SciMAT

Developed by Secaba Lab at the University of Granada (Spain), SciMAT is an Open-Source software (GPLv3) that incorporates the necessary functionalities to carry out all steps of a bibliometric study, from loading the data to interpreting the outputs, incorporating methods, algorithms, and measures to obtain the different analyzes and visualizations. (Moral-Muñoz et al., 2020). The SciMAT creates scientific maps by analyzing the co-occurrence of keywords that characterize the publication, allowing the monitoring of the scientific field, delimiting the areas of investigation, and providing an understanding of the intellectual, social, conceptual, and cognitive development, as well as the analysis of its structural evolution over time (Martinez et al., 2014).

The software was developed based on the scientific mapping approach divided into four stages (Cobo et al., 2011): (1) through a bibliometric analysis for each studied period, detect the substructures contained in the research field; (2) visually display the results of the first step (clusters); (3) analyze the evolution of the clusters detected over the different periods studied to detect the main areas of evolution in the field of investigation, their origins and their interrelationships; and (4) carry out a performance analysis of the different periods, clusters and areas of evolution, through bibliometric measures.

In addition, the SciMAT software has three important features: (a) a powerful pre-processing module to clean raw bibliographic data that makes it possible to detect duplicate files and spelling errors, organize the data chronologically, among other

important pre-processing functions; (b) the use of bibliometric measures to study the impact of each element studied as maximum, minimum and average citations, as well as the use of advanced bibliometric indices, such as h-index (Alonso et al., 2009; Hirsch, 2005), G-index (Egghe, 2006), HG-index (Alonso et al., 2010) and q^2-index (Cabrerizo et al., 2010); and (c) an analysis setup wizard that allows the analyst to easily select algorithms, methods, and measures to be used in the bibliometric analysis (Cobo et al., 2012).

Regarding the SciMAT software, in this work, (a) the exclusion of duplicate articles, correction of spelling errors in keywords, the addition of keywords with the same meaning (example, "IOT", "Internet of Things" and “Internet-of-Things”) and combination of plural and singular keywords (example: “Change” and “Changes”); (b) the presentation of results was performed according to the h-index, as indicated by Rincon-Patino et al. (2018); and (c) the parameters proposed by Van Eck and Waltman (2007), Cobo et al. (2012) and Rincon-Patino et al. (2018), as detailed below.

Table 1 - Parameters used on the SciMAT software

Analysis Period:	1996 to 2021
Unit of Analysis:	Keywords
Frequency for Data and Network Reduction:	Minimum standard frequency (1)
Type of Network:	Co-occurrence
Standardization Measure:	Strength of association
Clustering Algorithm:	Simple Centers Algorithm, with a maximum network size of 10 and a minimum of 1
Documment Mapper:	K-mapper of 1
Bibliometric Quality and Performance measures:	H-Index and Sum of Citations
Measure for Construction of Evolution and overlay maps:	Association Strength

VOSviewer

VOSviewer is a software developed by the Center for Science and Technology Studies (CWTS) of Leiden University (Netherlands) and created for the construction and visualization of bibliometric networks, with individual researchers, journals, or publications as main actors, based on - citation, bibliographic coupling or co-authorship relationships (Van-Eck; Waltman, 2010). The VOSviewer builds maps based on a three-step co-occurrence matrix (Van-Eck; Waltman, 2010): (1) similarity matrix, to apply the VOS mapping technique (Waltman; Van Eck; Noyons, 2010) using the strength of

association (Van-Eck; Waltman, 2007); (2) VOS mapping technique, to build a map reflecting the similarity between items; and (3) translation, rotation, and reflection, to correct the optimization problem described in the literature (O'Connell; Borg; Groenen, 1999).

The tool has network, overlay, and density as three map visualization resources, which can be saved as different file formats, facilitating the editing and handling by the analyst. Noteworthy is the zoom and scroll option that facilitates a detailed examination of the generated map. The maps generated in this work were based on co-citation and used the publications found between 2013 to 2021 (174 publications).

RESULTS AND DISCUSSION

Figure 1 shows the analysis of the growth of the AgTechs theme over time. Eight periods were analyzed by SciMAT: 1996 to 2000 (4 articles), 2001 to 2003 (5 articles), 2004 to 2006 (6 articles), 2007 to 2009 (7 articles), 2010 to 2012 (4 articles), 2013 to 2015 (8 articles), 2016 to 2018 (42 articles), and finally 2019 to 2021 (124 articles). Dutia et al. (2014) were the first to cite the term AgTech to refer to agricultural startups in 2014, when the AgTech sector gained visibility and the US invested $2.36 billion, involving 264 deals in AgTechs (Tilney et al., 2015). From 1996 to 2013, only 27 articles cited the term AgTech and, however, referred to the abbreviation for “agricultural technology”. Thus, this study considers only the last 3 periods were considered (174 articles) for the discussion of the results.

Analyzing the 3 last periods there is a vertiginous growth of the AgTechs theme in the last decade. The period of 2019 to 2021, specifically, showed 71.3% of the articles published, while the period of 2016 to 2018 has 24.1%, and the period of 2013 to 2015 only 4.6%. This demonstrates the growing interest in the thematic which seems to accompany the growing number of AgTechs both nationally (Figueiredo et al., 2021) and internationally (AgFunder, 2021).

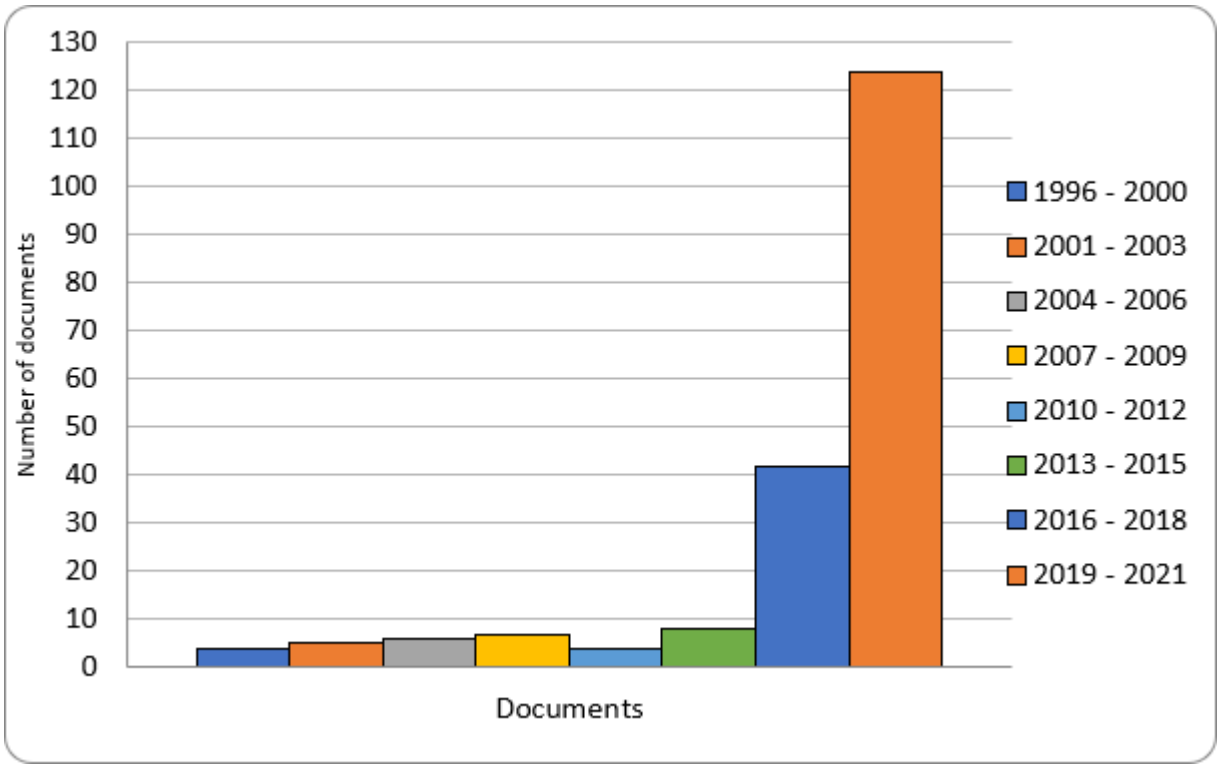

Figure 1 – growth of the AgTechs theme over time

Figure 2 presents the holistic view of terminological evolution and longitudinal understanding of the behavior of keywords in the last three periods. The circles represent the number of keywords used in a given period, the up arrow (leaving the circle) represents the number of keywords that are no longer used, the down arrow (entering the circle) corresponds to the new words keywords that are being used and the arrow that leaves one circle and enters another corresponds to the keywords that are being shared between periods. The number of keywords linked to the theme of AgTechs has increased dramatically over time, from a total of 95 keywords to 826 over an 8-year period (2013-2021), which equates to an increase of 785%. Despite the increase of keywords shared between the periods having a negligible (from 0.07 to 0.13), was evident that the thematic area of AgTechs is not consolidated (due to the large volume of word transients which are used only at a given time and then no longer) and is under intense development principally in the last years.

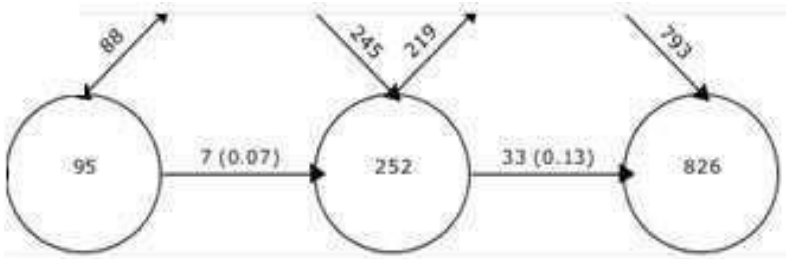

Figure 2 - terminological evolution in the last three periods

Figures 3 and Table 2 show the authors who published more than one article on this theme and the publication density by country, respectively. In agreement with the fact that the theme seems to be expanding and consolidating in recent years, the results show that the main publications related to the topic of AgTechs are limited to only seven authors, specifically from 2018 onwards. Forty-four countries have published something on the AgTechs theme. Table 2 summarizes the number of articles published and the number of citations per country.

Figure 3 - Authors with the highest number of published articles

Table 2 - Density of publications per country

Country	Number of Articles Published	Country	Number of Citations
United States	18	United States	40
India	11	Malaysia	32
Australia	8	Australia	30
England	7	India	28
Netherlands	5	Netherlands	27
Russia	5	New Zealand	23
Germany	4	Denmark	21
Brazil	4	England	18
China	4	South Korea	16
Italy	4	Indonesia	16
Malaysia	4	Vietnam	16

The United States also led the number of publications (18) and the number of citations (40), which seems consistent with the fact that the United States is currently the country that invests the highest amount of money in both agriculture technologies and agriculture startups (AgFunder Report, 2022). Despite being among the countries with the highest number of publications, Brazil had only two citations. This demonstrates the importance of investing in high-impact research and seeking partnerships with countries that develop research about AgTechs themes. As for the means of publication, 79 (45.4%) were published in journals and 95 (54.6%) in congresses, workshops, or annals. The leading journals, number of publications, and impact factor were presented in Figure 5. From 2019 to 2021, the Sustainability journal has the most significant number of publications on the topic of AgTechs, while the Journal of Rural Studies has the biggest impact factor. The Scientia Agricola, a Brazilian journal published by the Luiz de Queiroz School of Agriculture (ESALQ), which impact factor's is 1.108, was the only Brazilian journal to have a publication on the subject of AgTechs.

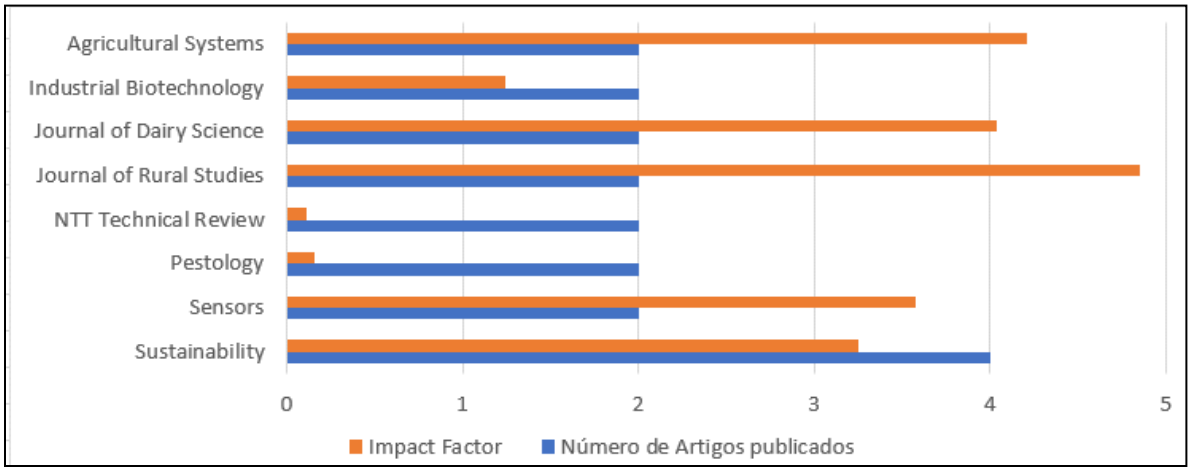

Figure 5 - journals, number of publications and impact factor

Considering that the period of 2019 to 2021 presents most studies and keywords, it was decided to analyze the strategic diagrams and clusters in the same period. Figure 6 shows the strategic diagram in order of factor h and citation. The strategic diagram consists of a two-dimensional graph of four quadrants intercepted by the 'x' and 'y' axes, representing the centrality and density of the themes, respectively. The diagram's quadrants represent the importance and development of themes for the study area, according to the degree of centrality and density of each cluster. The quadrant (A) comprises motor themes, that is, those with high density and centrality, characterizing the most developed themes in the area. The quadrant (B) represents the basic or transversal themes, with a low density of connections with other themes but with strong centrality. The quadrant (C) constitutes the emerging or declining themes, and their low degree of development requires a qualitative analysis to identify whether each theme in the quadrant is emerging or declining in the field of study. Finally, the quadrant (D) represents highly developed themes but isolated, with high density in relationships and few links with other themes in the study area (Furstenau et al., 2020b; Sott et al., 2020).

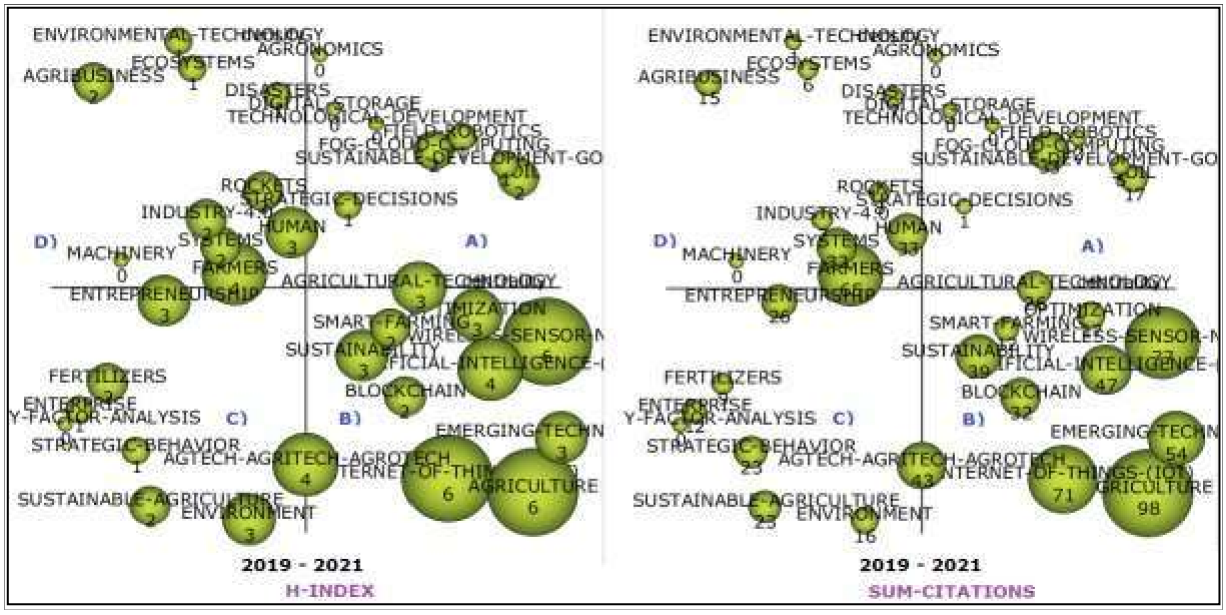

Figure 6 - strategic diagram for the period 2019 to 2021

The highly developed themes in the area are those that present, in order of citation and factor h: "farmers", "human", "systems", "agribusiness", "industry 4.0", "sustainable technologies", and "ecosystems". The most significant driving themes in the area were: "robotics" and "sustainable development". The basic or transversal themes, with high density, are represented by: "agriculture", "the internet of things", "sensors", "artificial intelligence", "sustainability", "blockchain", "agricultural technology", "emerging technologies", "smart farms", and "sensors". Thus, the cross-cutting themes can be divided into "agriculture", "disruptive technologies" (which includes the internet of things, sensors, artificial intelligence, blockchain, agricultural technology, emerging technologies, and sensors), "sustainability" and “smart farms”. The most relevant thematic networks (cluster networks) related to disruptive technologies and sustainability were analyzed in greater depth below.

Technologies related clusters

The prominence of the concept "smart-agriculture-smart farm" was identified, which refers to the science that incorporates the technological advances to the body of solutions of traditional agribusiness aiming at new model intelligent properties with intensive application of information and communication technologies (Colezea et al., 2018). Moreover, the concept of “Agriculture 4.0", which refers to the agricultural revolution sustained by the tremendous technological advances (Zhai et al., 2020), was also highlighted. When considering that these concepts are inseparable, one understands the importance of keywords related to innovative technologies in this study. Terms such as: “agricultural technology,” “disruptive technology,” and “4.0 technology” were the most used terms to indicate a range of enabling technologies being developed by AgTechs and disseminated to the field. These data reflect the reality of the provision of services by agricultural startups globally, as around 54% of AgTechs with international prominence are providers of technological services for agriculture 4.0 (Graff et al., 2019).

Figure 7 shows the correlations between “agricultural technology” and “smart agriculture-smart agriculture.” Regarding "intelligent agriculture," a significant interrelationship between the keywords is visible, contrary to the term "agricultural technology," which presented two more isolated groups, one more specifically related to performance management combined with efficiency and control, while the second is more about the digital age in general.

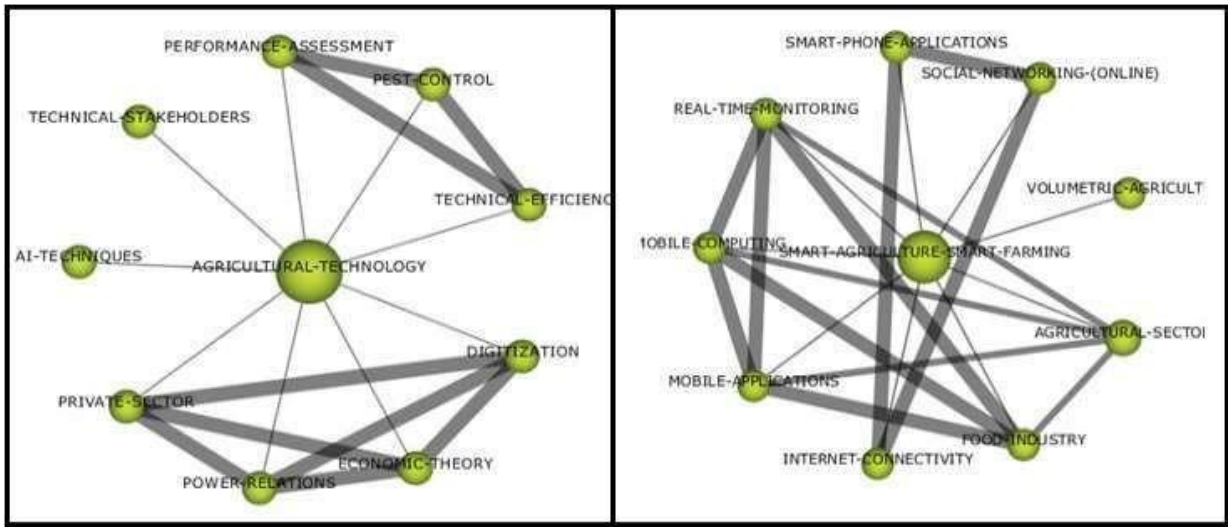

Figure 7 - technologies related clusters

In this context, the most prominent enabling technologies, according to Mendes et al. (2021) are the Internet of Things (IoT); Smart devices; Big data; Cloud computing; Robots; Blockchain; ICT (Information and Communication Technologies), Physical Cyber Systems (CPS); Sensors; and, artificial intelligence. There is great emphasis on the adoption of mobile technologies and smartphones, continuously associated with the internet of things (IoT) and digitization to increase technological efficiency in the field (Schulz et al., 2021). However, according to Yoon et al. (2021) the adoption of any of these disruptive technologies, to be successful, requires careful consideration of their usefulness to farmers, aiming at the development of these technologies based on meeting the basic needs or problems faced by farmers.

Sustainability related clusters

The sustainability related clusters are presented in Figure 8. The term "N-oriented-innovation" specifically relates directly to "agricultural-change" and "Food-Sytems-Transformation". These terms together are related to the changes and transformations of the 4.0 era and the entire ecosystem proposed by AgTechs in the constant search to employ solutions and technologies for humanity to obtain the necessary food supply until 2050 in an ecologically correct manner (Kakani et al., 2020). The term “responsible-innovation” was directly related to “agricultural-trends” and “future-prospects”. These are related to the need for more responsible and sustainable future agricultural systems and, in this sense, the application of techniques such as Physical AgTech, Cyber AgTech, and Cyber-physical, corroborate the prospecting of the agriculture of the future and the redesign of a more sustainable agricultural production

(Lampridi et al. 2019). Machine learning and the use of computational techniques to record, analyze, model, and predict factors that can improve field yields, as well as plant and precision farming data analysis to improve productivity and contribute to food supply sustainably, has been the best of several AgTechs (Kakani et al., 2020).

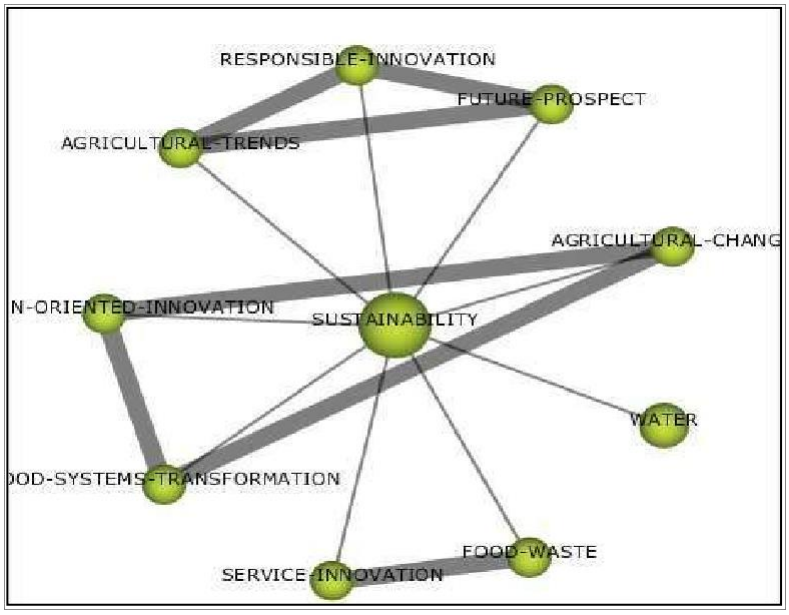

Figure 8 - sustainability related cluster

Furthermore, the term "services-innovation" was also related to sustainability and is made through the use of artificial intelligence services and technologies such as robotic machines, more accurate irrigation systems, and data analysis and decision support software in the agricultural sector that provide greater productivity and production optimization (Koaudio et al., 2018; Miranda et al., 2019). In this way, farmers can map and monitor their crops and implement more proactive, resilient, and sustainable practices (Spanaki et al., 2021).

It is also worth mentioning that, in the sense of service innovation, Agripreneurs - a new generation of agribusinesses - seek to combine knowledge and experience of business and management in agriculture to fill the gaps in agricultural practices based on agribusiness principles such as sustainability (Carayannis et al. 2018). According to Spanaki et al. (2021), advances in AgTechs research solutions in the last decade have significantly contributed to the understanding and implementation of sustainability criteria in agriculture. In this way, it is expected that any farmer can become an Agripeneur shortly and produce more sustainably, combining technologies and more sustainable agricultural operations.

Finally, the terms "water" and "food-waste" were also related to the term sustainability since one of the biggest concerns in sustainable production is the conservation of essential natural resources such as soil and water. In this sense, Kakani et al. (2020) mention that the combination of new computational and robotic technologies formulates a new approach to crop management, enabling, for example, irrigation with greater precision and less water consumption. Therefore, sustainability is one of the main pillars for the success of AgTechs, because as sustainability becomes more complex, the Sustainable Development demanded by stakeholders also becomes more challenging and expensive for agricultural entrepreneurs (Spanaki et al., 2021).

CONCLUSIONS

The bibliometric study presented the analysis of the growth of the AgTechs theme over time, which showed a vertiginous growth in the last three years, which shows the growing interest in the thematic area combined with the increasing importance of AgTechs for the development of sustainable agribusiness. Furthermore, the terminological evolution of the area was also discussed through the longitudinal understanding of the behavior of keywords, which also showed a significant increase in the last eight years, concluding that the AgTechs thematic area has constantly been developing in recent years.

Furthermore, the study presented the main authors, countries, and types of publications related to the theme of AgTechs and the strategic diagram for the period 2019 to 2021, and the most relevant cluster networks. In this way, the presented objective was fulfilled. The study brings interesting contributions to better understand the term AgTech in the literature and the improvement of concepts related to this ecosystem.

Analyzing the two main clusters in this research, it was noticeable that there is a substantial amount of theoretical research (Boursianis et al., 2020; Liu et al., 2018; Kakani et al., 2020; Pham and Stack, 2018; Spanaki et al., 2021) and empirical research (Colezea et al., 2018; Kouadio et al., 2018 Lampridi et al., 2019; Schulz et al., 2021; Zhai et al., 2021) regarding agricultural technologies. Furthermore, similar researches (Dutia, 2014; Miranda et al., 2019; Wezel et al., 2014) were found to focus on sustainability (more specifically, sustainable technologies). Thus, by analyzing the literature, it was possible to identify a growing interest in the AgTech theme concerning digital and disruptive technologies, however, the human factors, business models, and management aspects involved in this topic are being neglected, with few articles

tackling these issues (Carayannis et al., 2018; Graff et al., 2019; Mendes et al., 2021; Yoon et al., 2021). Given these findings, we have pointed out new research avenues that could be undertaken in Future Research, as shown in Table 3.

Table 3 - Research Agenda

Cluster	Suggestions for Future Studies
Technology	Research which technologies are being created and commercialized by AgTechs, in different innovation ecosystems
	Research the hurdles faced by consumers (e.g., farmers) when implementing digital and 4.0 technologies
	Research the implication of the usage (by small and medium-sized farms) of the technologies being commercialized
	Empirically explore the applications of the most used 4.0 technologies
	Empirical studies on agriculture digital platforms
	Explore universities' role in the creation of agriculture startups (and their technologies)
	Study the technological maturity of AgTechs
Sustainability	Research on which business models are being used to advance sustainability in AgTechs
	Research on indicators of sustainability to evaluate the technologies and services provided by AgTechs
	Empirical studies on how sustainability concepts are viewed and applied in AgTechs

Despite the large temporal range, our bibliometric study has the limitation of not using a Brazilian database, such as Embrapa's database, which could bring a richer understanding of the Brazilian agricultural innovation ecosystem. Additionally, the use of other databases, such as Google Scholar, could bring other relevant research studies that change the findings of our bibliometric study.

REFERENCES

AgFunder - Agriculture and Agtech Investment Opportunities. (2022). AgFunderAgriFood Tech Investing Report - Year in Review 2021. Available at: https://agfunder.com/research/2022-agfunder-agrifoodtech-investment-report/. Accessed on 27 September of 2021.

Akbar, I., e Zaim, I. A. (2019). Innovations in Service: Probing the Evidence in Sustainable Tourism. The Asian Journal of Technology Management Vol. 12, Nº. 2: 132-148. https://doi.org/10.12695/ajtm.2019.12.2.5

Alonso, Sergio; Cabrerizo, Francisco-Javier; Herrera-Viedma, Enrique; Herrera, Francisco (2009). "h-index: A review focused in its variants, computation and standardization for different scientific fields". Journal of informetrics, v. 3, n. 4, pp. 273-289.

https://doi.org/10.1016/j.joi.2009.04.001

Alonso, Sergio; Cabrerizo, Francisco-Javier; Herrera-Viedma, Enrique; Herrera, Francisco (2010). "hg-index: A new index to characterize the scientific output of researchers based on the h- and g-indices". Scientometrics, v. 82, n. 2, pp. 391-400. https://doi.org/10.1007/s11192-009-0047-5

Boursianis, A. D.; Papadopoulou, M. S.; Diamantoulakis, P.; Liopa-Tsakalidi, A.; Pantelis, B.; Salahas, G.; Karagiannidis, G. K.; Wan, S.; Goldos, S. (2021). Internet of Things (IoT) and Agricultural Unmanned Aerial Vehicles (UAVs) in Smart Farming: A Comprehensive Review. Internet of Things, p. 100187. https://doi.org/10.1016/j.iot.2020.100187

Cabrerizo, Francisco-Javier; Alonso, Sergio; Herrera-Viedma, Enrique; Herrera, Francisco (2010). "q2-Index: Quantitative and qualitative evaluation based on the number and impact of papers in the Hirsch core". Journal of informetrics, v. 4, n. 1, pp. 23-28. https://doi.org/10.1016/j.joi.2009.06.005

Carayannis, E. G., Rozakis, S., & Grigoroudis, E. (2018). Agri-science to agri-business: The technology transfer dimension. Journal of Technology Transfer, 43(4), 837–843. https://doi.org/10.1007/s10961-016-9527-y

Cobo, Manuel J.; López-Herrera, Antonio G.; Herrera-Viedma, Enrique; Herrera, Francisco (2012). "SciMAT: A new science mapping analysis software tool". Journal of the American Society for Information Science and Technology, v. 63, n. 8, pp. 1609-1630. https://doi.org/10.1002/asi.22688

Cobo, Manuel J.; López-Herrera, Antonio G.; Herrera-Viedma, Enrique; Herrera, Francisco (2011b). "An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the fuzzy sets theory field". Journal of informetrics, v. 5, n. 1, pp. 146-166. https://doi.org/10.1016/j.joi.2010.10.002

Colezea M., Musat G., Pop F., Negru C., Dumitrasco A., e Mocanu M. (2018). CLUeFARM: Integrated web-service platform for smart farms Comp. Elec. Agri. 154 134-54. https://doi.org/10.1016/j.compag.2018.08.015

Corallo, A., Latino, ME, Menegoli, M. (2018). From Industry 4.0 to Agriculture 4.0: How Manage Product Data in Agri-Food Supply Chain for Voluntary Traceability, A framework proposed. World Academy of Science, Engineering and Technology International Journal of Nutrition and Food Engineering, 12 (5), 146-150. Open Science Index, Nutrition and Food Engineering Vol:12, No:5, 2018 publications.waset.org/10008961/pd. ISNI:0000000091950263

Dutia, S. G. 2014. Agtech: Challenges and opportunities for sustainable growth. Innovations: Technology, Governance, Globalization, v. 9, n. 1-2, p. 161-193. https://doi.org/10.1162/inov_a_00208

Egghe, Leo (2006). "Theory and practise of the g-index". Scientometrics, v. 69, pp. 131-152. https://doi.org/10.1007/s11192-006-0144-7

Figueiredo, S.S.S.; Jardim, F.; Sakuda, L.O. (Orgs.). Radar AgTech Brasil 2020/2021**:** Mapeamento das Startups do Setor Agro Brasileiro. Embrapa, SP Ventures e Homo Ludens: Brasília e São Paulo, 2021.

Graff, G. D., Silva, F. F., & Zilberman, D. (2019). Venture capital and the transformation of private R&D for agriculture and food. Economics of research and innovation in agriculture, Cambridge: National Bureau of Economic Research. ISBN 978-0-226-77905-8

Hirsch, Jorge E. (2005). "An index to quantify an individual's scientific research output". Proceedings of the National Academy of Sciences of the United States of America, v. 102, n. 46, pp. 16569-16572. https://doi.org/10.1073/pnas.0507655102

Kakani, V.; Nguyen, V. H.; Kumar, B.P.; Kim, H.; Pasupuleti, V.R. (2020). A critical review on computer vision and artificial intelligence in food industry. Journal of Agriculture and Food Research, 2, 2020. https://doi.org/10.1016/j.jafr.2020.100033

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

Laengle, S.; Modak, N. M.; Merigo, J. M.; Zurita, G. (2018). Twenty-Five Years of Group Decision and Negotiation: A Bibliometric Overview. Group. Decis. Negot. 27:505–542. https://doi.org/10.1007/s10726-018-9582-x

Lampridi, M. G., Kateris, D., Vasileiadis, G., Marinoudi, V., Pearson, S., Sørensen, C. G., et al. (2019). A case-based economic assessment of robotics employment in precision arable farming. Agronomy. https://doi.org/10.3390/agronomy9040175

Liu, Y. Ma, X. Y.; Shu, L.; Hancke, G.P.; Abu-Mahfouz, A. M. (2021). From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies, and Research Challenges. IEEE Transactions on Industrial Informatics. DOI: 10.1109/TII.2020.3003910

Mendes, J. A. J.; Careta, C. B.; Zuin, V. G.; Gerolamo, M. C. (2021). In search of maturity models in agritechs. IOP Conf. Series: Earth and Environmental Science 839 022083. IOP Publishing. https://doi.org/10.1088/1755-1315/839/2/022083

Miranda J, Ponce P, Molina A, Wright P (2019). Sensing, smart and sustainable technologies for Agri-Food 4.0. Comput Ind 108:21–36. https://doi.org/10.1016/j.compind.2019.02.002

Moral-Muñoz, José A.; Herrera-Viedma, Enrique; Santisteban-Espejo, Antonio; Cobo, Manuel J. (2020). "Software tools for conducting bibliometric analysis in science: An up-to-date review". El profesional de la información, v. 29, n. 1, e290103. https://doi.org/10.3145/epi.2020.ene.03

Pham, X.; Stack, M. 2018. How data analytics is transforming agriculture. Business Horizons, v. 61, n. 1, p. 125-133. https://doi.org/10.1016/j.bushor.2017.09.011

Ratnatunga, J., e Romano, C. (1997). A "Citation Classics" Analysis of Articles in Contemporary Small Enterprise Research. Journal of Business Venturing 12. 197-212. https://doi.org/10.1016/S0883-9026(96)00062-6

Rincon-Patino, J.; Ramirez-Gonzalez, G.; Corrales, J. 2018. Exploring machine learning: A bibliometric general approach using Citespace. F1000 Research, 7. 1240. https://doi.org/10.12688/f1000research.15619.1

Schulz,P.; Prior, J.; Kahn, L. e Hinch, G. (2021). Exploring the role of smartphone apps for livestock farmers: data management, extension, and informed decision making. The Journal of Agricultural Education and Extension. https://doi.org/10.1080/1389224X.2021.1910524

Spanaki, K.; Sivarajah, U.; Fakhimi, M.; Despoudi, S.; Irani, Z. (2021). Disruptive technologies in agricultural operations: a systematic review of AI-driven AgriTech research. Annals of Operations Research. https://doi.org/10.1007/s10479-020-03922-z

Tilney, M.; Leclerc, R.; Demarest, E. (2015). AgTech Investing Report: YEAR IN REVIEW

2014. AGFUNDER.

Van-Eck, Nees-Jan; Waltman, Ludo (2010). "Software survey: VOSviewer, a computer program for bibliometric mapping". Scientometrics, v. 84, n. 2, pp. 523-538. https://doi.org/10.1007/s11192-009-0146-3

Waltman, Ludo; Van-Eck, Nees-Jan; Noyons, Ed C. M. (2010). "A unified approach to mapping and clustering of bibliometric networks". Journal of Informetrics, v. 4, n. 4, pp. 629-635. https://doi.org/10.1016/j.joi.2010.07.002

Wezel, A., Casagrande, M., Celette, F., Vian, J., Ferrer, A., & Peigné, J. (2014). Agroecological practices for sustainable agriculture A review. Agronomy for Sustainable Development, 34(1), 1–20. https://doi.org/10.3390/agronomy9040175

Yoon, B. K., Tae, H., Joshua A. Jackman, Supratik Guha, Cherie R. Kagan, Andrew J. Margenot, Diane L. Rowland, Paul S. Weiss, e Nam-Joon Cho. (2021). Entrepreneurial Talent Building for 21st Century Agricultural Innovation. ACS Nano, 15, 10748−10758. https://doi.org/10.1021/acsnano.1c05980

Zhai Z, Martínez J F, Beltran V and Martínez N L. 2020. Decision support systems for agriculture 4.0: Survey and challenges Comp. Elect. Agri. 170 105256. https://doi.org/10.1016/j.compag.2020.105256

Zupic, I. and Cater, T. (2015). Bibliometric Methods in Management and Organization. Organizational Research Methods, Vol. 18(3) 429-472. https://doi.org/10.1177/1094428114562629