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FROM THE FIELD TO THE VIRTUAL: A SYSTEMATIC REVIEW OF THE USE OF THE METAVERSE IN AGRICULTURE

DO CAMPO AO VIRTUAL: UMA REVISÃO SISTEMÁTICA DA UTILIZAÇÃO DO METAVERSO NA AGRICULTURA

DEL CAMPO A LO VIRTUAL: UNA REVISIÓN SISTEMÁTICA DEL USO DEL METAVERSO EN LA AGRICULTURA

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ABSTRACT

The present study focuses on exploring the possibilities of using the metaverse as a tool to support and enhance the agribusiness contexto of agribusiness, considering its potential, applications, and challenges. Based on an analysis of publications found in the Web of Science (WOS) and Scopus databases, the research seeks to understand how this technology, in interaction with digital tools such as digital twins, blockchain, virtual and augmented reality, artificial intelligence, the Internet of Things (IoT), and advanced 6G networks, can contribute to the modernization of agricultural management, strengthening sustainable practices and increasing the sector's competitiveness. The main findings highlight that the metaverse can enhance agricultural productivity through simulations, real-time monitoring, and strategic planning, while also reducing environmental impacts and operational costs. However, challenges such as the need for digital infrastructure, professional training, and overcoming cultural and financial barriers limit its widespread adoption. This study reinforces the relevance of the topic, considering the scarcity of specific research on the use of the metaverse in agriculture, and suggests that future empirical studies deepen the understanding of its practical implementation. Thus, the metaverse emerges as a transformative and promising element for the future of agribusiness, aligned with the demands for innovation and sustainability.

Keywords: Metaverse. Agribusiness. Sustainability. Technological Innovation. Agriculture 4.0.

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RESUMO

O presente estudo tem como foco explorar as possibilidades da utilização do metaverso como ferramenta de auxílio e melhoria no contexto do agronegócio, considerando suas potencialidades, aplicações e desafios. A partir de uma análise baseada em produções encontradas nas bases Web of Science (WOS) e Scopus, buscou-se compreender como essa tecnologia, em interação com recursos digitais como gêmeos digitais, blockchain, realidade virtual e aumentada, inteligência artificial, Internet das Coisas (IoT) e redes avançadas 6G, pode contribuir para a modernização da gestão agrícola, fortalecendo práticas sustentáveis e a competitividade no setor. Os principais resultados destacam que o metaverso pode melhorar a produtividade agrícola por meio de simulações, monitoramento em tempo real e planejamento estratégico, além de reduzir impactos ambientais e custos operacionais. Os desafios como a necessidade de infraestrutura digital, capacitação profissional e superação de barreiras culturais e financeiras limitam sua ampla adoção. Este trabalho reforça a relevância do tema, considerando a escassez de estudos específicos sobre o uso do metaverso na agricultura, e sugere que futuras pesquisas empíricas aprofundem o conhecimento sobre sua implementação prática. Assim, o metaverso emerge como um elemento transformador e promissor para o futuro do agronegócio, alinhado às demandas por inovação e sustentabilidade.

Palavras-chave: Metaverso. Agronegócio. Sustentabilidade. Inovação Tecnológica. Agricultura 4.0.

RESUMEN

Este estudio se centra en explorar las posibilidades de utilizar el metaverso como herramienta para ayudar y mejorar el contexto agroindustrial, considerando su potencial, aplicaciones y desafíos. A partir del análisis de producciones encontradas en las bases de datos Web of Science (WOS) y Scopus, buscamos comprender cómo esta tecnología, en interacción con recursos digitales como gemelos digitales, blockchain, realidad virtual y aumentada, inteligencia artificial, Internet de las cosas (IoT) y redes 6G avanzadas, puede contribuir a la modernización de la gestión agrícola, fortaleciendo las prácticas sustentables y la competitividad del sector. Los hallazgos clave destacan que el metaverso puede mejorar la productividad agrícola a través de simulaciones, monitoreo en tiempo real y planificación estratégica, al tiempo que reduce los impactos ambientales y los costos operativos. Desafíos como la necesidad de infraestructura digital, capacitación profesional y la superación de barreras culturales y financieras limitan su adopción generalizada. Este trabajo refuerza la relevancia del tema, considerando la escasez de estudios específicos sobre el uso del metaverso en la agricultura, y sugiere que futuras investigaciones empíricas profundicen el conocimiento sobre su implementación práctica. De esta forma, el metaverso surge como un elemento transformador y prometedor para el futuro del agronegocio, alineado con las demandas de innovación y sostenibilidad.

Palavras-chave: Metaverso. Agronegocios. Sostenibilidad. Innovación Tecnológica. Agricultura 4.0.

1 INTRODUCTION

The rapid changes in the global landscape, driven by the advancement of technologies and the intense circulation of information, require new strategies for process management and decision-making. The constant technological advancement has caused profound impacts on different segments of the economy, including agribusiness, these impacts translate into challenges and opportunities to modernize practices and increase the efficiency of the sector.

Agricultural production in Brazil, especially grains, has been showing constant growth in the agribusiness scenario, accompanied by the expansion of the use of technological resources in the agricultural sector. This transformation requires suppliers, producers, and customers to adapt to new technological innovations, which facilitate the management and control of agricultural production.

Innovation is a topic widely explored in scientific research, especially in countries such as China, India, the United States, Saudi Arabia, and Brazil, which stand out for investing in technological solutions to face the challenges imposed by market competitiveness and the growing demand for efficiency in food production.

However, the adoption of new technologies in the agricultural production sector often faces initial resistance and can be a time-consuming process. However, once accepted and used consistently, technologies, such as those already in use, such as *drones*, sensors, and *software*, offer significant opportunities such as optimizing processes, increasing production, reducing costs, and maximizing producers' profits.

In this technological context, the term "Metaverse" arises, which is a word that originated from the junction between "metá" which comes from Greek and means (in addition to) and "verse" (in addition to the "universe"), referring to the new innovative digital virtual universe built beyond the real world. This concept originated in science fiction, in Neal Stephenson's 1992 novel "*Snow Crash*".

> The metaverse refers to a shared virtual world or worlds that offer interactive, immersive, and collaborative experiences through innovative digital technology. Users access a "metaverse" using headsets and controllers or gloves to interact with a variety of games and digital worlds. It can also include a user-created avatar to travel within and between different digital worlds. (Miner, Micah; 2025, p.1)

In the context of agribusiness, the Metaverse represents shared virtual platforms that enable interactive and dynamic experiences aimed at simulating, planning, and managing agricultural activities. It is a three-dimensional and immersive evolution of the internet, in which users interact directly in digital environments that reproduce real field conditions,

allowing real-time visualizations and tracking, technical training, more accurate decision-making, and optimization of production processes.

The main characteristics of the Metaverse include immersion, real-time connection, accessibility, persistence, and the integration between the virtual and real worlds. It is a combination of Virtual Reality (VR), Augmented Reality (AR), Artificial Intelligence (AI), 5G, registration technology, digital simulations and spatial computing. The Metaverse aims to be a persistent, always-on, real-time ecosystem, overcoming geographical limitations.

> It is a collective virtual shared space created by the convergence of physical and virtual reality, facilitated by networked computers. The Metaverse is not just a single entity, but a complex network of interconnected digital spaces and ecosystems. (WEBISOFT, 2023, p. 1)

For this junction between physical and virtual reality to happen, the metaverse is composed, among other technologies, Virtual Reality (VR), which offers the user the possibility of interacting with simulated three-dimensional environments, providing immersive experiences that can be explored in different contexts, including the agricultural sector. According to Tori (2010, p. 6), (LR) can be understood as:

> An advanced user interface that allows real-time navigation and interaction with three-dimensional computer-generated environments, which may or may not simulate real environments, offering the user a sense of immersion and presence in this virtual space.

This capacity for simulation and interaction significantly expands the possibilities in agribusiness, allowing access to practical and strategic experiences previously limited by physical, financial, or environmental barriers, facilitating more assertive and sustainable decision-making.

Like (VR), Augmented Reality (AR) is a technology that enables the insertion of virtual elements in the physical environment in real time, promoting the integration between the real and digital worlds in the context of agribusiness.

According to Tori (2010), (AR) consists of the superimposition of computer-generated virtual three-dimensional objects on images of the real environment, captured by cameras or mobile devices, such as *drones*, allowing producers and technicians to simultaneously view virtual information and the real agricultural scenario in an interactive way.

This technology expands the sensory and cognitive perceptions of field professionals, favoring more accurate decision-making and improved practical experiences, especially in processes such as crop monitoring, crop management, and technical training.

In addition, we have the *Internet* of Things (IoT), which consists of the interconnection of devices and sensors capable of collecting, transmitting, and processing data in real time, enabling the monitoring and automation of processes. In agribusiness, this technology enhances the management of agricultural production by providing accurate information about the soil, climate, and machinery, contributing to more efficient and sustainable decisions (MORAES; SILVA, 2021).

Still in this technological context, another important technology to be mentioned is *blockchain technology*, in which it can be integrated into the metaverse in agribusiness to ensure transparency, traceability, and security in virtual transactions. With this technology, it is possible to record everything from the origin of products to negotiations in digital environments, promoting trust in supply chains and agricultural trade.

According to Kang *et al.* (2023), the application of emerging technologies such as *blockchain* in the metaverse can revolutionize the agri-food sector, offering transparency and real-time traceability, especially in the control of product origin, logistics, and smart *contracts*.

The metaverse is an emerging technology and has great potential to be implemented in large corporations, including the agricultural sector, assisting in processes such as management, monitoring, planning, and sales (KANG *et al*., 2023). However, this technology can also benefit companies of different sizes, as long as there is the necessary technological investment for its use.

The innovation represented by the metaverse is a promising and underexplored topic, especially in agribusiness, with few publications that investigate the use of this technology in this context. Studies such as the one by Kang *et al*. (2023), mention the concept of "*Agriverse*", highlighting the opportunities for integrating the metaverse with different disciplines of knowledge. This scenario opens space for relevant research that can fill the existing gaps and expand the use of this tool in different areas.

The present research proposes to investigate the gap in how the metaverse can be used in agribusiness. The central problem is: How can the metaverse contribute to agribusiness as an innovative tool in agribusiness?

The overall objective of the study is to explore the possibilities of using the metaverse as an innovative tool for agribusiness. The specific objectives include: (I) defining the concept of metaverse and its application as a technological innovation in agribusiness; (II) identify and present key metaverse-related technologies that can be applied to agriculture; and (III) analyze the benefits of the metaverse for agricultural management.

This work is divided into 06 topics to support the systematic review: Introduction; Methodology, which supports and describes the path taken to carry out the research,

according to the protocol of Cronin *et al*. (2008); Theoretical Framework (with subtopics: *Agriverse,* which presents its concept and use; Planting Innovation, which shows the evolution of technology in agribusiness; and Agricultural Virtual World, which demonstrates the use of new technologies); Analysis of Results, which confirm the citations and point out findings in the research; and Conclusion, which concludes the work by emphasizing the importance of the theme, limitations and possible gaps for other research.

2 METHODOLOGY

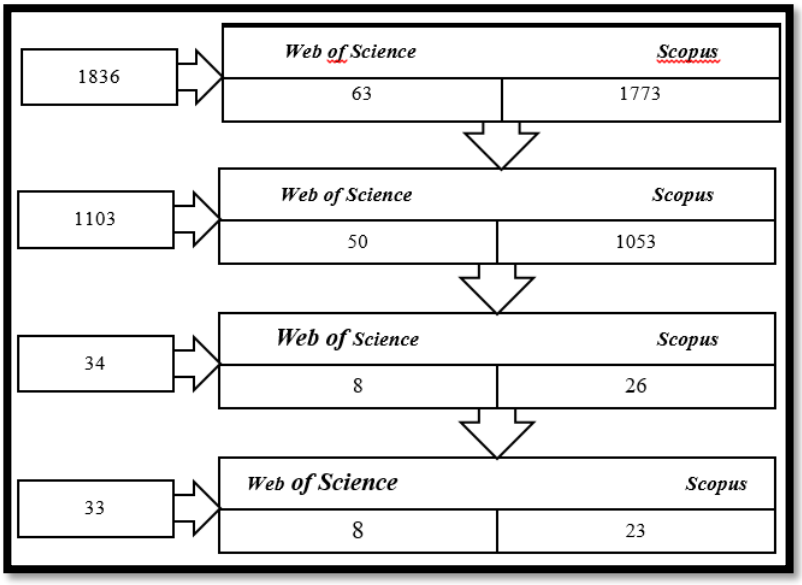
This research adopted the methodology of the systematic review of literature to investigate the potential of the Metaverse in Agribusiness, following the protocol proposed by Cronin *et al*. (2008). Data collection was carried out in the *Scopus and Web of Science* (WOS) databases on 01/15/2025, and *a total of 1,836 articles* were found by the keywords "metaverse*" AND "*agriculture", considered important references for scientific research.

Filters were applied to select only articles and reviews published between 2020 and 2025, thus ensuring the timeliness of the analyzed works. The keywords used were "*metaverse*" *AND "agriculture*", allowing the identification of relevant studies that relate the metaverse to the agricultural sector, in a total of 1,103 articles published.

The *Scopus* database provided the largest number of publications linked to the keywords, while *the WOS* offered more targeted and specific results for the theme. This combination enabled a comprehensive and qualified panorama for the review.

Figure 1

Phases of article filters



Source: Prepared by the author, 2025.

After these filters, the abstracts were read and the articles that had the most adherence to this research were selected. The introduction and discussions were also analyzed. In the end, 34 articles were selected, and one duplicate was found (presented in both databases), totaling 33 final works analyzed, as shown in Figure 1.

For the analysis of the articles, a final selection was made for the works, and a table was created (contained in the previous topic) with the main technologies linked to the use of the metaverse and the benefits of the metaverse for management, taken from the selected final articles.

An analysis of the countries that most research on the topic of the metaverse in agriculture was also carried out, using the *VOSviewer* software to present the results.

3 THEORETICAL FRAMEWORK

3.1 AGRIVERSE

Currently, the metaverse can be used in several segments, offering a wide field of research and improvements for business processes. This technology contributes to increasing the sustainability of economic activities and the quality of management in different areas (SHARDEO *et al*., 2024).

The use of the metaverse in agriculture was presented in the studies of Kang *et. al.*(2023), with emphasis on environmental control in greenhouses, allowing real-time monitoring of temperature, humidity, and ventilation. In addition, the metaverse makes it possible to search for producers and suppliers, identifying market offers and demands.

In agriculture, the metaverse can pave the way for new discoveries and interactions between producers and consumers. In his study by Kang *et. al* (2023), he points out that greenhouse cultivation, especially in complex environments in terms of space and time, can be facilitated by the metaverse, which offers support in training, monitoring plant growth, and pest management.

The metaverse shows great potential in agricultural management, by assisting in the management of rural establishments, offering tools for monitoring soil quality through data and enabling simulations of different production scenarios.

Such simulations can contribute to the redefinition of processes, the adaptation of strategies, and the review of initial projects, promoting increased sustainability and the reduction of carbon dioxide (CO_2) emissions, especially in the transportation of inputs and products (SARKAR *et al*., 2024).

3.2 PLANTING INNOVATION

The use of the metaverse in agriculture is also linked to other innovations and *software* as pointed out in Chart 1, such as digital twins, *Internet* of Things (IoT) and *blockchain* (HAJIAN, et al., 2024; BÜYÜKAKIN, SOYLU, 2023; KANG *et al*., 2023).

It is verified, therefore, that this set of artificial intelligence, *internet* of things, virtual reality, augmented reality, and *blockchain technologies* forms an ecosystem within the metaverse, which has been consolidating in the agricultural sector by offering new possibilities for experimentation, management, and training in agricultural environments (SARKAR *et al*., 2024).

In this way, the virtual world can be integrated with agriculture, which is inserted in the physical context, contributing to training, improvement of management in agricultural establishments and systematization of data aimed at precision agriculture, such as irrigation control. These actions can be monitored in real time, favoring more efficient and assertive decision-making (KRISHNAN *et al*., 2024).

However, to adapt to *Agriverse,* producers need to transform their conception of the management of agricultural activities. In addition, its establishments must undergo structural and financial changes, since the implementation of these technologies requires investments in training and understanding of resources.

3.3 AGRICULTURAL VIRTUAL WORLD

Relatively recent changes in the mindset of a significant portion of Brazilian farmers have driven investments in research and development (R&D) in the agricultural sector. This transformation is directly associated with the search for greater efficiency, sustainability, and technological innovation in agricultural activities.

According to Vieira Filho and Silveira (2016), investments in R&D were decisive for the technical progress of the sector, contributing to the increase in the added value of production and to the economic development of several agro-export regions of the country.

This evolution highlights a promising scenario for the adoption of new technologies, such as the *Agriverse,* as the field increasingly opens up to digital innovations.

Investments in Brazil for technology were mapped Kalaitzandonakes *et al*. (2018), which presented historical data on private investment in agriculture, reaching, by 2012, a value of US$ 394 million in R&D.

The research by Dwivedi *et al*. (2022), brought together researchers who present transportation management points and warehouses that innovate the sectors. In warehouses, the use of augmented reality to simulate spaces stands out, helping in the construction and

strategic definition of the location of these structures, as well as obtaining the *ideal layout for the space to be built, which generates process optimization* and cost reduction.

Strategic investments in innovation and technology have also reached the areas of management in the agricultural sector, promoting greater efficiency and sustainability in the field, contributing significantly to increasing the sustainability of agricultural activities. This update occurs through tools aimed at controlling and monitoring production, especially those that consider the environmental impact of the practices adopted.

As Wang *et al.* (2022), the use of experiments in virtual planting scenarios allows simulating different situations and predicting environmental consequences, optimizing production processes and assisting in more conscious and sustainable decision-making.

Thus, the metaverse can directly contribute to the reduction of CO_2 emissions, by optimizing logistics and transport processes in the agricultural sector. This technology enables the implementation of sustainable practices, such as encouraging clean and efficient work, in addition to minimizing waste and waste along the production chain.

As pointed out by Sarkar *et al.* (2024), the use of the metaverse in this context represents a promising strategy to align technological innovation with increasingly urgent environmental requirements.

4 ANALYSIS OF RESULTS

The articles analyzed reflect a growing demand for research that addresses the metaverse in agriculture. Studies such as those by Kang *et al*. (2023), Sarkar *et al*. and Guarda (2024), highlight that the possibilities for improvements in the agricultural sector through these technologies are incalculable.

However, the authors also point out the urgent need to include innovation in a structured and accessible way in the agricultural context. The ecosystem in which the metaverse is inserted has links in each technological innovation, providing a break with traditional production models. The most cited technologies, such as 6G, Digital Twins, *Citespace*, *Blockchain* and *Internet* of Things (IoT), will be detailed in this topic, in which it presents an analysis of articles that specifically discuss these technological advances in agribusiness.

Table 1

Technologies cited in the research articles

AUTHOR	*YEAR*	*TITLE*	TECHNOLOGY LINKED TO THE USE OF THE METAVERSE

Kaur, H.; Bhatia, M.	2025	*Digital twins: A scientometric investigation into current progress and future directions*	Digital Twins, *Citespace* and Industry 4.0.
Sharma, R.; Sundarakani, B.; Manikas, E.	2025	*Integration of industry 4.0 technologies for agri-food supply chain resilience*	*Big Data Analytics, IoT* and Cloud Computing.
Rathee, G.; Saini, H.; Chakkravarthy, S.; Maheswar, R.	2025	*An Intelligent and Trust-Enabled Farming Systems With Blockchain and Digital Twins on Mobile Edge Computing*	*Blockchain* and Digital Twins.
Naudé, D. H.; Hugo, L.; Jordaan, H.; Lombard, Washington	2024	*Extended Reality in Agricultural Education: A Framework for Implementation*	*XR,* Agriculture 4.0 and XR-AgriEdu *Framework*
Jin, S. V., Ryu, E.	2025	*Unraveling the dynamics of digital equality and trust in AI-empowered metaverses and AI-VR-convergence*	Metaverse powered by *AI,* AI-VR *convergence,* and *blockchain*.
Singh, G.; Roy, S. K.; Apostolidis, C.; Quaddus, M.; Sadeque, S.	2025	*Identifying the metaverse value recipe (s) affecting customer engagement and well-being in retailing*	Methodologies for identifying critical factors that can utilize the metaverse
Jobe, P.; S,Yilmaz, M.; Ilgın, He	2024	*A roadmap for a Metaverse-based digital governance: A case of the Gambia*	Digital Infrastructure and Digital Literacy.
El Hajji, M.; Es-saady, Y.; Ait Addi, M.; Antari, J.	2024	*Optimization of agrifood supply chains using Hyperledger Fabric blockchain technology*	*Blockchain, Hyperledger Fabric, Web platform* with *QR Codes* for real-time tracking and Caliper Tool for performance measurement (throughput and network latency).
Sze, L. B.; Salo, J.; Tan, T. M.	2024	*Sustainable innovation in the metaverse: Blockchain's role in new business models*	Blockchain-based Metaverse , *Blockchain*, Persistent Synchronous Virtual Environment, Interoperable Networks, Hybrid and Decentralized Digital Structure.
Ecer, F.; Yaran Ögel, İ.; Dinçer, H.; Yüksel, S.	2024	*Assessment of Metaverse wearable technologies for smart livestock farming through a neuro quantum spherical fuzzy decision-making model*	Metaverse and Wearable Devices (Smart Cattle Collars - *WSCs*).
Alsamhi, S. H.; Hawbani, A.; Sahal, R.;	2024	*Towards sustainable industry 4.0: A survey on greening IoE in 6G networks*	*Blockchain,* Digital Twins, Drones (UAVs), *Machine Learning (ML)* and 6G Networks.

... Guizani, M.; Curry, E.			
Lee, L.-H.; Braud, T.; Zhou, P. Y; Bermejo, C.; Hui, P.	2024	*All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda*	*XR, AI, Blockchain*, Computer Vision, *IoT*, Edge and Cloud Computing, 5G and Future Networks.
Sarkar, B. D.; Shardeo, V.; Mir, U. B.; Negi, H	2024	*Harvesting success: Metaverse adoption in agriculture sector as a sustainable business strategy*	*VR/AR*, *AI, Blockchain* and Digital Platforms.
Tirlangi, S.; Babu, BH, Meenakshi, S.; ... Manikandan, R.; Dhanraj, JA	2024	*Smart farming in 6G navigating security challenges for agricultural innovations*	6G Networks, *IoT* and Cybersecurity.
Xu, J.; Li, E.; Zhang, M.; Zhang, S.	2024	*Sustainable agriculture in the digital era: Past, present, and future trends by bibliometric analysis*	Digitalization, Digital Intelligence, Geospatial Analysis.
Zheng, X.; Keoy, K. H.; Lim, A. F.	2024	*Unlocking the Potential of Metaverse Integration in Supply Chains: A Literature Review*	*Blockchain*, Digital Twins, *VR/AR, AI,* Simulation and Modeling.
Hasan, R. H.; Madine, M.; Musamih, A; Yaqoob, E.; Omar, M.	2024	*Non-fungible tokens (NFTs) for digital twins in the industrial metaverse: Overview, use cases, and open challenges*	*Non-Fungible Tokens* (*NFTs*), Digital Twins, Advanced Simulation and Algorithms, *AI*, and Data Processing.
Tan, M.; Meng, S.; Lu, M.; Gu, X.; Liang, D.	2024	*An Immersive Course Training System Based on NFT and Metaverse*	*VR*, Gamification, *NFTs,* and Educational Metaverse.
Kumar, A.	2024	*The role of simulation and modeling in artificial intelligence: A review*	Simulation and Modeling and *AI.*
Chen, Z.; Gan, W.; Sol, J.; Wu, J.; Yes, PS	2024	*Open Metaverse: Issues, Evolution, and Future*	*IoT,* Cloud and Edge Computing, *Blockchain* and Immersive Virtual Worlds.
El Jaouhari, A.; Arif, J.; Jawab, F.; Samadhiya, A.; Kumar, A.	2024	*Unfolding the role of metaverse in agri-food supply chain security: current scenario and future perspectives*	Immersive Virtual Worlds, *AR,* AI, and *IoT*.
Nguyen, A.; Francisco, M.; Windfeld, E.; Lhermie, G.; Kim, K.	2024	*Developing an immersive virtual farm simulation for engaging and effective public education about the dairy industry*	*VR,* Immersive Simulation, and User Feedback.

Saleem, M. F.; Raza, A.; Sabir, R. M.; ... Al Ansari, M. S.; Hussain, S.	2024	*Applications of sensors in precision agriculture for a sustainable future*	Soil, Weather and Harvest Sensors, *Drones*, Precision Agriculture and *AI.*
Guarda, T.	2024	*Metaverse and Agriculture Sustainability*	IoT*,* AI *and Machine Learning,* VR/AR *and* Blockchain *sensors*.
Almessabi, H.; Al-kfairy, M.	2024	*Unlocking the Future of Farming: A Review of Metaverse Integration in Agriculture*	Immersive Metaverse, Climate Scenario Simulation, VR, and *Blockchain*.
Aradhya, S.; Navya, V.	2024	*Unlocking the Future of Farming: A Review of Metaverse Integration in Agriculture*	VR platform, Interactive Simulations and Digitalization of Agricultural Markets.

Source: Prepared by the author, based on research in WoS and *Scorpus*, 2025.

The analysis carried out in this research focused on the identification of *software* and technological innovations linked to the metaverse to provide means of access to the improvement and optimization of processes in the virtual world.

Digital twins are examples of digital replicas of tangible assets and their associated processes, allowing integration and optimization in various sectors, especially for simulations in agribusiness (HASAN *et al*.; ZHENG *et al*.; ALSAMHI *et al*., 2024; RATHEE *et al*.; KAUR, BHATIA, 2025).

To ensure traceability and security in the virtual world of the metaverse, *blockchain* is a technological base that integrates with the metaverse, creating trust in the platform with certified products, being the most cited technology in research (RATHEE *et al*.; JIN, RYU, 2025; EL HAJJI *et al*.; SZE *et al*.; ALSAMHI, *et al*.; LEE *et al*.; SARKAR *et al*.; ZHENG *et al*.; CHEN *et al*.; GUARD; ALMESSABI, AL-KFAIRY, 2024).

The research reports immersive experiences within the virtual field with augmented, extended and virtual reality, which provide a link of real actions for soil analysis and control and plant cultivation, according to Lee *et al*.; Naudé *et al*., (2024). To improve technological processes, Artificial Intelligence acts as one of the main drivers for the progress of the metaverse (JIN, RYU, 2025; LEE *et al*.; ZHENG *et al*.; SALEEM *et al*., 2024).

The research of Alsamhi *et al*.; Tirlangi *et al* (2024), mention that the use of 6G Networks will offer greater speed in the analysis processes, ensuring stability and receipt of sensory data in real time for decision making.

In this context, another research states that the simulation of climate scenarios, through immersive and predictive technologies, can play a fundamental role in the strategic

management of agricultural activities, contributing significantly to more assertive decision-making.

By predicting climate variations and enabling the anticipation of risks, these tools offer important subsidies for quick and effective actions, reducing losses and promoting more efficient production.

This immediate response capacity provides producers with a new mentality focused on sustainability, encouraging the conscious use of natural resources, the fight against waste, and the implementation of agricultural practices that respect environmental cycles and the balance of ecosystems (SALEEM *et al*., 2024).

Drones are technological equipment increasingly used in the agricultural sector, they can be improved and adapted for data collection and optimization of agricultural resources (ALSAMHI *et al*., 2024). Like *drones*, the *3D display* is also prominent because they are widely used for a three-dimensional view in the metaverse (LEE *et al*., 2024).

The work of Hasan *et al*. (2024) points to the use of *Tokens* for the purpose of authenticating and protecting agricultural products with certificates and monetization opportunities, being widely used in data processing.

Finally, *IoT* leverages innovation in the exchange of knowledge of science in the world of the metaverse, and it should be noted that equipment with this technology is already used in the agri-food supply chain (SHARMA *et al*., 2025).

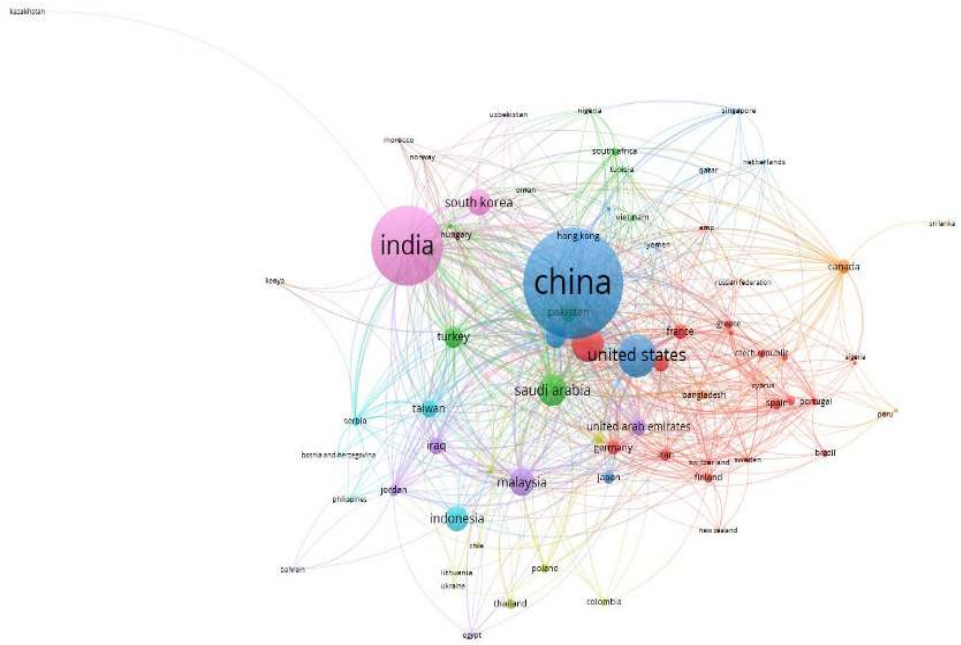
The benefits found in the research are considerable, enhancing innovation in the agricultural sector; providing and contributing to make agricultural activity more sustainable by enabling the practice of carrying out simulations, reducing errors and optimizing planning processes in various agricultural chains; expanding access to marketing channels; and offering support to monetization (ZHENG *et al*.; EL JAOUHARI *et al*.; SZE *et al*.; SAKAR *et al*., 2024).

The main limitation of this work is the scarcity of studies that directly address the application of the metaverse in the agricultural sector. Although it is a promising technology, its adoption is still incipient, due to the complexity of its implementation and the need for infrastructure, technical training and adequate connectivity in rural areas.

To understand how research is being absorbed in the world, an analysis of the countries that stand out the most in the publication of articles related to this theme was carried out, in which it was found that China ranked first, followed by India and the United States. To this end, the *VOS viewer software was used* to generate the graphic representation shown in Figure 2.

Figure 2

Countries that research the most on metaverse in agriculture



Source: *VOSviewer* with information from the *Scopus* and *Web of Science databases.*

By analyzing the figure above, we can observe that in addition to China, India, the United States, we can highlight Saudi Arabia in the ranking of innovation in research, offering the academic community a greater number of researches on the subject, however, the continuity and resolution of gaps on the subject are still great.

5 CONCLUSION

This study aimed to review the scientific literature on the potential of the metaverse as a transformative tool in agribusiness. The systematic analysis of the literature showed that the virtual environment of the metaverse and emerging technologies, such as digital twins, *blockchain*, virtual and augmented reality, and advanced communication networks, can be integrated into the agricultural field to optimize its management and thus promote sustainability and improve the competitiveness of the sector.

The benefits of the metaverse in agribusiness include reducing carbon emissions, optimizing production processes, increasing efficiency in the use of resources, and improving traceability and data-driven decision-making.

However, it is identified that the implementation of the metaverse in agribusiness faces significant challenges, such as the need for greater investments in technological infrastructure and in the training of professionals in the sector. In addition, it is essential to

emphasize that there is a need to overcome cultural and financial barriers that make it difficult to use this innovation.

Despite the scarcity of specific studies that directly relate agribusiness to the metaverse, there is a growing interest on the part of researchers and investors, motivated by the transformative potential of this technology to drive disruptive innovations in the future of the agricultural sector.

It is concluded with the expectation that this study will bring relevant subsidies to broaden the debate on the use of the metaverse in the agricultural sector, opening the way for new investigations that address its use, strengthening the notion of its importance for agribusiness.

REFERENCES

Almessabi, H., & Al-Kfairy, M. (2024). Unlocking the future of farming: A review of metaverse integration in agriculture. IEEE Engineering Management Review. Advance online publication.

Alsamhi, S. H., Hawbani, A., Sahal, R., Srivastava, S., Kumar, S., Zhao, L., ... & Curry, E. (2024). Towards sustainable industry 4.0: A survey on greening IoE in 6G networks. Ad Hoc Networks, 165, 103610.

Büyükakin, F., & Soylu, Ö. B. (2023). Metaverse: Transformation and future of agriculture. In Metaverse: Technologies, opportunities and threats (pp. 333–355). Singapore: Springer Nature.

Chen, Z., Gan, W., Sun, J., Wu, J., & Yu, P. S. (2024). Open metaverse: Issues, evolution, and future. In Companion proceedings of the ACM on web conference 2024 (pp. 1351–1360).

Cronin, P., Ryan, F., & Coughlan, M. (2008). Undertaking a literature review: A step-by-step approach. British Journal of Nursing, 17(1), 38–43.

Da Silva Júnior, J. J., da Silveira, J. M. J., de Oliveira, A. L. R., Pereira, C. N., da Silveira Bueno, C., & Pray, C. E. (2019). Investimentos em pesquisa e desenvolvimento agrícola: Transformações recentes no Brasil. Revista Brasileira de Inovação, 18(1), 89–120.

Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., ... & Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 66, 102542.

El Hajji, M., Es-Saady, Y., Addi, M. A., & Antari, J. (2024). Optimization of agrifood supply chains using Hyperledger Fabric blockchain technology. Computers and Electronics in Agriculture, 227, 109503.

El Jaouhari, A., Arif, J., Jawab, F., Samadhiya, A., & Kumar, A. (2024). Unfolding the role of metaverse in agri-food supply chain security: Current scenario and future perspectives. International Journal of Food Science & Technology, 59(5), 3451–3460.

Guarda, T. (2024). Metaverse and agriculture sustainability. In International Conference on Computational Science and Its Applications (pp. 324–333). Cham: Springer Nature Switzerland.

Hajian, A., Daneshgar, S., Sadeghi, K., Ojha, D., & Katiyar, G. (2024). From theory to practice: Empirical perspectives on the metaverse's potential. Technological Forecasting and Social Change, 201, 123224.

Hasan, H. R., Madine, M., Musamih, A., Jayaraman, R., Salah, K., Yaqoob, I., & Omar, M. (2024). Non-fungible tokens (NFTs) for digital twins in the industrial metaverse: Overview, use cases, and open challenges. Computers & Industrial Engineering, 110315.

Jin, S. V., & Ryu, E. (2025). Unraveling the dynamics of digital equality and trust in AI-empowered metaverses and AI-VR-convergence. Technological Forecasting and Social Change, 210, 123877.

Kalaitzandonakes, N., Carayannis, E. G., Grigoroudis, E., & Rozakis, S. (2018). From agriscience to agribusiness. Cham, Switzerland: Springer International Publishing.

Kang, M., Wang, X., Wang, H., Hua, J., de Reffye, P., & Wang, F. Y. (2023). The development of AgriVerse: Past, present, and future. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 53(6), 3718–3727.

Kaur, H., & Bhatia, M. (2024). Digital twins: A scientometric investigation into current progress and future directions. Expert Systems with Applications, 125917.

Krishnan, S., Ajikumar, S. A., Shafi, A. R., Krishnan, P., & José, A. (2024). Metaverse in agriculture: Transforming future. IRJAEM, 3(1), 3636–3640.

Lee, L. H., Braud, T., Zhou, P. Y., Wang, L., Xu, D., Lin, Z., ... & Hui, P. (2024). All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda. Foundations and Trends® in Human-Computer Interaction, 18(2–3), 100–337.

Lin, C., Chen, J., & Zhu, H. (2025). A method for compensating prediction errors to improve the orbit prediction accuracy of Starlink satellites. GPS Solutions, 29(1), 17.

Miner, M. (2025). The metaverse: An immersive digital universe. Journal of Virtual Worlds, 10(1), 1–15.

Moraes, J., & Silva, M. (2021). Aplicações da Internet das Coisas no agronegócio: Avanços e desafios. Revista Brasileira de Tecnologia Rural, 10(2), 45–53.

Naudé, D. H., Botha, B. S., Hugo, L., Jordaan, H., & Lombard, W. A. (2024). A framework for implementation. Education Sciences, 14(12), 1309.

Rathee, G., Saini, H., Chakkravarthy, S. P., & Maheswar, R. (2024). An intelligent and trust-enabled farming systems with blockchain and digital twins on mobile edge computing. International Journal of Network Management, e2299.

Saleem, M. F., Raza, A., Sabir, R. M., Safdar, M., Faheem, M., Al Ansari, M. S., & Hussain, S. (2024). Applications of sensors in precision agriculture for a sustainable future. In Agriculture and aquaculture applications of biosensors and bioelectronics (pp. 109–137). IGI Global.

Sarkar, B. D., Shardeo, V., Mir, U. B., & Negi, H. (2024). Harvesting success: Metaverse adoption in agriculture sector as a sustainable business strategy. Journal of Enterprise Information Management, 37(6), 1858–1884.

Shardeo, V., Sarkar, B. D., Mir, U. B., & Kaushik, P. (2024). Adoption of metaverse in healthcare sector: An empirical analysis of its enablers. IEEE Transactions on Engineering Management. Advance online publication.

Sharma, R., Sundarakani, B., & Manikas, I. (2025). Integration of industry 4.0 technologies for agri-food supply chain resilience. Computers in Industry, 165, 104225.

Silveira, J. M. F. J. (2014). Agricultura brasileira: O papel da inovação tecnológica. In A. M. Buainain, E. Alves, J. M. Silveira, & Z. Navarro (Eds.), O mundo rural no Brasil do século 21: A formação de um novo padrão agrário e agrícola (Parte 3, Capítulo 1). Brasília, DF: Embrapa.

Stephenson, N. (1992). Snow crash. New York, NY: Bantam.

Sze, L. B., Salo, J., & Tan, T. M. (2024). Sustainable innovation in the metaverse: Blockchain's role in new business models. Digital Business, 4(2), 100086.

Tirlangi, S., Babu, B. H., Meenakshi, S., Sugumar, D., Manikandan, R., & Dhanraj, J. A. (2024). Smart farming in 6G: Navigating security challenges for agricultural innovations. In 6G security education and multidisciplinary implementation (pp. 232–248). IGI Global.

Tori, R. (2010). Educação sem distância: As tecnologias interativas na redução de distâncias em ensino e aprendizagem. São Paulo, Brazil: Senac São Paulo.

Webisoft. (2023). [Title not provided]. Retrieved July 21, 2025, from [URL or link not provided].

Zheng, X., Keoy, K. H., & Lim, A. F. (2024). Unlocking the potential of metaverse integration in supply chains: A literature review. PaperASIA, 40(4b), 94–113.