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Bibliometric Analysis and Literature Review on Digitalisation and Geopolitical Impact of the Agri-Food System

Ana-Maria BADEA[1], Anamaria HOLOTĂ[2*], Cristina DRĂGOI[3]

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Abstract

The phenomenon of globalisation does not bypass the agri-food industry, in which companies are under pressure to incorporate new knowledge to improve efficiency, food safety, and sustainability. Digitalisation is an essential aspect of this transformation, driving significant progress through the integration of artificial intelligence, robotics, and 5G technology. The aim of this research is to analyse existing studies on the digitalisation of the agri-food sector, identify trends, and create an overview of the interest given to the field. The study also addresses the geopolitical influences that stand in the way of the digitalisation of the industry. Although digitalisation offers many benefits, it also presents several challenges that must be addressed. This study aims to highlight both the advantages and drawbacks of digitalisation in the agri-food industry.

Keywords: digitalisation trends, agro-food industry, geopolitical challenges, precision agriculture.

JEL Classification: Q1, O3.

1. Introduction

Today, agriculture plays an important role in shaping global economy by providing food security. The agriculture system is undergoing a transformative phase that has led to new innovations and modernisation. Digital technology, or what we call digitalisation, is rapidly changing our world, and agriculture is not an exception. The digitalisation of the agriculture industry will help farmers improve productivity

[1] Bucharest University of Economic Studies, Bucharest, Romania, anamaria.badea@ase.ro.
[2] Bucharest University of Economic Studies, Bucharest, Romania, holotaanamaria17@stud.ase.ro.
* Corresponding author.
[3] Bucharest University of Economic Studies, Bucharest, Romania, cristina.dragoi@rei.ase.ro.

and increase their yields, as well as create more efficient supply chains for more sustainable food production.

In the first part of the paper, the theories highlighted in the specialised literature regarding the digitalisation of the agri-food industry and the influence of geopolitical factors on industry digitalisation are presented. The second part of the paper comprises a bibliometric analysis of 1.613 studies concerning the digitalisation of the agri-food industry, extracted from the Web of Science database. Within the analysis, the following aspects were examined: the evolution of publications on the digitalisation of the agri-food industry, countries with the highest number of publications, the most popular authors in the field, the evolution of topics addressed over the years, and the most frequently used keywords by authors in their works.

The conclusions reveal that the agricultural industry is progressively adopting sophisticated technologies and computational techniques. Numerous scholars are currently investigating the capabilities of precision agriculture, automation, machine learning, robotics, artificial intelligence, and deep learning as potential solutions to the challenges faced by the agricultural sector. Keywords identified offer significant information on current research trends and priorities.

2. Problem Statement

The agri-food industry serves a crucial function in sustaining the lives of millions of people, ensuring food security, and shaping global economies. As technology advances and the interconnectedness of our world increases, the way we conduct business and produce food will inevitably change. The integration of digital technology into various aspects of the agri-food system will lead to transformational changes and address some serious issues that plague us today. However, as digitalisation grows in importance in the agri-food sector, it is important to understand its geopolitical impact. Understanding the geopolitical impact of the agri-food system refers to the ways in which digitalisation impacts global food security and shapes the relationships between nations by influencing global trade patterns. This raises a significant problem which requires thorough investigation and analysis. The findings of this study will contribute to a better understanding of the complex dynamics between digitisation, geopolitics, and the agri-food system. This knowledge can be used to inform decision-making processes.

2.1 Trends Regarding the Digitalisation of the Agri-Food System

The implementation of digitalisation within the agricultural industry is a crucial and necessary advancement that must be undertaken to effectively address the projected food security challenges communicated by the United Nations and Food and Agriculture Organisation. Farmers and agribusinesses can receive valuable support from the latest technologies such as artificial intelligence (AI) and robotics, the Internet of Things (IoT), and 5G (European Commission, 2022). Smart agriculture encompasses more than just the initial stages of crop cultivation, exerting its influence throughout the entire agricultural value chain, encompassing aspects

such as sustainability and environmental considerations (Șerbănel, 2021). The digitalisation of the agri-food value chain has been impacted by the crisis resulting from the COVID-19 pandemic. This global health emergency has increased the urgency for digital transformation within the sector, primarily due to the increased recognition of the significance of remote work and contactless transactions. Additionally, the crisis has precipitated alterations in consumer behaviour and preferences, subsequently leading to an increased demand for online food delivery services and e-commerce platforms (Ancin et al., 2022).

The transition from conventional agricultural approaches to smart agriculture methods can also be attributed to the expanding global population and the escalating demands of the agri-food sector (Abbasi et al., 2022). Moreover, other authors are of the opinion that the circular economy is based on environmentally friendly technologies and the minimal use of resources. Sustainable agriculture should focus on innovative reduction of greenhouse gases through actions that contribute to the net zero goals. But sustainable agricultural business models do not only involve the use of green technologies that promote the protection of natural capital. There is also a need for multidisciplinary research and intersectoral development, through which dysfunctions can be addressed at the inter and intra system level (Petrariu et al., 2021).

The adoption of digitalisation within the agricultural sector offers multiple advantages to both farmers and the environment. One notable benefit is the enhanced operational flexibility provided by digital technologies, which enable real-time monitoring and predictive systems. This empowers farmers and agricultural experts to respond promptly to potential changes in environmental and water conditions, thereby safeguarding crops (Abbasi et al., 2022). Moreover, smart agricultural practices contribute to the conservation of resources, as they help reduce water consumption, mitigating soil erosion, and minimising greenhouse gas emissions. Furthermore, digitisation plays a crucial role in improving product quality and maximising farm productivity by providing farmers with precise data on crop yields, soil health, and weather patterns (Nezamova, Olentsova, 2022). According to Amentae and Gebresenbet (2021), the main opportunities that emerge in the agri-food sector as a result of digitisation processes include increasing productivity and competitiveness, ensuring a more sustainable use of resources, optimising farm production processes, improving risk management, predicting market trends, and enhancing strategic decision-making capabilities. Additionally, digital technologies can automate certain tasks such as planting and harvesting, reducing labour costs and increasing productivity.

Although digitalisation has great potential for fostering environmentally sustainable agriculture, certain researchers have voiced concerns regarding its potential negative impacts on agro-ecology. These concerns encompassed several aspects, namely: the potential for a continued decline in biodiversity and detrimental effects on environmental assets; possible adverse impacts on soil structures and fertility; the potential for unfavourable alterations to established cultural landscapes; and the risk of negative consequences for resource utilisation and ecological balance

(Zscheischler et al., 2022). Additionally, there are concerns regarding the potential risks associated with data misuse and the emergence of data imbalances. Despite farmers sharing their personal farm management data, they possess limited knowledge regarding the storage and utilisation of this data, as well as their level of control and influence over these processes (Jayashankar et al., 2018). These concerns were substantiated by the observation that the utilisation of digital data and technologies often prioritises productivity gains rather than optimising sustainability outcomes. For instance, the introduction of lightweight and intelligent field robots might result in the cultivation of previously uncultivated land, putting ecological residual niches at risk of disappearance. Additionally, there is a growing trend toward larger and heavier agricultural machinery, leading to soil compaction that negatively impacts soil erosion and the water balance. Worries also arose regarding potential rebound effects and alterations to the cultural landscape (Zscheischler et al., 2022).

Currently, several prevalent digital technologies are being widely employed in the field of agriculture. These technologies include augmented and virtual reality, the Internet of Things (IoT), computer vision, robotics, sensors, and machine learning. Augmented and virtual reality enable farmers to simulate and visualise agricultural scenarios, facilitating decision-making processes. The Internet of Things allows for seamless connectivity among various agricultural devices and systems, enabling efficient data collection and management. Computer vision technology aids in the analysis and interpretation of visual data, helping to perform tasks such as crop monitoring and disease detection. Robotics finds utility in tasks such as automated harvesting and precision spraying. Sensors play a crucial role in collecting real-time data on environmental conditions, soil moisture levels, and other relevant parameters. Finally, machine learning algorithms are employed for data analysis and predictive modelling, enabling personalised insights and optimised decision-making in agriculture (Nezamova, Olentsova, 2022). Abbasi et al. (2022) revealed how digitalisation plays a pivotal role in enhancing sustainability within the agri-food sector through the improved monitoring and management of vital natural resources like water, soil, and energy. It also facilitates the adoption of precision agriculture practices that effectively minimise the use of inputs and mitigate environmental repercussions. The concept of precision agriculture introduces an innovative approach that leverages AI principles to enhance agricultural practices and add value to the industry. By utilising this technology, farmers can gain a deeper understanding of their land and crops through the acquisition of information and data pertaining to crops, weather forecasts, soil conditions, crop quality, and fertiliser management. Furthermore, the implementation of digital tools such as robotics and autonomous machines enables farms to minimise expenses, thereby reducing costs (Mentsiev et al., 2020). Furthermore, digital technologies provide valuable support for implementing circular economy principles, such as reducing food waste and promoting resource recovery. In summary, the integration of digitalisation has the potential to improve the economic, social, and environmental sustainability of agro-food supply chain management.

Nevertheless, transitioning from digitisation to digital transformation in the agricultural sector seems to present challenges as a result of a range of internal and external obstacles. Several reviews have outlined these barriers, which encompass factors such as limited internal resources within firms, complexities associated with data management, concerns regarding data transfer and privacy, inadequate internet connectivity, absence of suitable incentives, and a legislative operating environment that may not fully support digital initiatives in the industry (Ancin et al., 2022).

The widespread lack of digital literacy among the population poses a significant obstacle to the successful implementation of digitalisation in agriculture. Insufficient understanding of the benefits and effective use of digital technologies may hinder adoption. Moreover, concerns about cost and unfamiliarity with the technology may lead some farmers to be hesitant in adopting new digital tools. Another challenge lies in the requirement for reliable Internet connectivity, which may be limited in rural areas, hampering the effective use of digital technologies. Furthermore, there are valid concerns about the potential negative effects of digitalisation on employment and social equity within rural communities. Addressing these challenges requires a collaborative effort involving policymakers, researchers, industry stakeholders, and other relevant parties to ensure the realisation of digitalisation's benefits while minimising potential risks (Ramazanov et al., 2022).

Farmers can improve their understanding of their land and crops by using technology, which provides valuable information and collects data on various aspects such as crop conditions, weather forecasts, soil quality, crop quality, and fertiliser management. For example, a Berlin-based agricultural technology start-up (Plantix) has created an application that revolutionises soil crop monitoring by simply taking photos. Through the utilisation of machine learning and the Internet of Things (IoT) principles, the software analyses the photos, identifies soil defects, detects pests in the land, and reveals patterns related to crop efficiency. This breakthrough application serves as a crucial tool for making informed decisions to enhance agricultural practices (Sridhar et al., 2022).

The use of digital twins has the potential to enable an interoperable and sustainable agricultural transformation. Digital twins can be enhanced with data from sensors and cameras on the ground to optimise water usage, accurately spread seeds and fertilisers, and reduce the need for harmful pesticides by creating virtual representations of physical assets such as fields, animals, or machinery. There are various advantages of adopting digital twins in farming, including increased efficiency and productivity, less waste and environmental impact, and greater decision-making capabilities for farmers. Furthermore, digital twins can be used to evaluate novel farming practices and technologies, decreasing the need for costly and time-consuming trial-and-error operations. (European Commission, 2022). In the actual context, where the whole Planet tries to reduce waste, innovative agriculture systems need to be developed, like, for example, rooftop farming, which is of high interest for urban communities. This innovative farming example aims to contribute to the end-to-end greening of the agri-food value chain. It could have an

important contribution to reaching the Sustainable Development Goals of the United Nation and other similar initiatives (Constantin et al., 2021).

The agricultural sector will gain significant advantages from advancements in digital technologies, particularly in the field of artificial intelligence (AI). With the increasing responsibility of agriculture to ensure food security, food safety, and environmental sustainability, AI has the potential to address these challenges. By harnessing AI, the agricultural sector can meet the demands of a growing global population while contributing to the achievement of the United Nations' Sustainable Development Goals (SDGs). Despite the immense potential, the adoption of AI in agriculture has been relatively slow. We suppose that this sluggish uptake can be attributed to the diverse ways in which AI impacts the agri-food industry, considering the variations in food types, supply chains, climates, and land within the agricultural sector (Ryan et al., 2023).

2.2 Geopolitical Influences on the Digitalisation of the Agri-Food System

The global agricultural and food network operates as a complex and interdependent system, wherein disturbances in one part can reverberate throughout the entire network, often leading to unintended outcomes. According to Archer (2008), the primary influences on agricultural systems are globalisation and narrow profit margins. The author underscores the need to understand the impact of social and political factors on agriculture. There is a sense of complacency with regard to the availability and affordability of commodities, especially within the realm of agriculture. However, there have been instances where food has served as a catalyst for economic and humanitarian crises. We observe a growing recognition that agriculture plays a dual role, both as an instigator and as a victim of geopolitical volatility (Chu, 2022). The global demand for food has escalated due to factors such as population growth, increasing prosperity, and evolving consumption patterns, particularly in emerging economies. However, the supply side has faced challenges such as sluggish productivity growth, crop failures, and extreme weather events, leading to a tightening of the global food market and record-high food prices in recent years. The spike in prices for staple foods has even contributed to social unrest and political instability in various regions worldwide. In North Africa, for instance, high food prices played a role in the 'Arab Spring' uprisings that led to the downfall of autocratic regimes. Moreover, this situation has triggered a surge in land grabbing, where foreign investors acquire large-scale farmland, particularly in Africa, potentially adversely affecting local farmers and global food security. In response to these concerns, countries are increasingly prioritising food security and formulating policies to protect the necessary resources for agriculture and food production. As population growth, increasing prosperity, and changing consumption patterns continue to drive demand, the interdependence of food, agriculture, and raw materials becomes more evident The Hague Centre for Strategic Studies (HCSS), 2013). Digitalisation plays a key role in securing resources, thoughtful analysis, and planning in the field of food, agriculture, and raw materials.

Agrifood supply chains are affected by global economic forces and agricultural bargaining, and risk management mechanisms are needed to reduce uncertainty and risk, according to Shkolnyi (2020).

While some countries have taken steps to ensure their access to natural resources from abroad, others have aimed to decrease their reliance on international markets and enhance domestic self-sufficiency. These actions have been driven by concerns about the potential effects of food prices or food insecurity on domestic political stability and the risk of social unrest. Concurrently, climate change and evolving resource dynamics are influencing the distribution of material power among nations, with traditional export leaders in the Global North facing competition from emerging agricultural forces such as Brazil, China, India, and Russia (Zhoul et al., 2020). Without enough governmental support, digitisation may have a negative impact on the sector, such as diminishing employment, worsening disparities, and further exploiting already scarce resources. Policymakers must act quickly, comprehensively, and thoughtfully to guarantee that the digital transformation of agriculture benefits both stakeholders and societies (Bahn et al., 2021).

3. Aims of the Research

This paper represents a comprehensive bibliometric analysis and literature review aimed to gain insights into the digitalisation of the agri-food industry. In order for this research to succeed, the examination of academic papers and relevant studies was used to understand digitalisation trends and the impact of geopolitical factors. The objectives of this research are: identifying key sources from specialised literature by analysing the relevant academic works on the digitisation of the agri-food industry, analysing the extent of digitisation and its trends in the agri-food industry, and examining the geopolitical factors influencing the agri-food system.

4. Research Methods

To accomplish the research objectives, this study combines the literature review with a bibliometric analysis and articles referring to the digitalisation of the agri-food industry, which were extracted from the Web of Science database, resulting in a number of 1.613 published papers and the usage of the VOSviewer 1.6.19 software in order to analyse the extracted data. To determine the most pertinent articles in the field, a range of keywords were used to emphasise the most significant articles within the domain. The Web of Science database was utilised to conduct a keyword search, which yielded the following results: “precision agri-food” (600 articles), “agricultural robotics and automation” (871 articles), “artificial intelligence in the agro-food industry” (51 articles), “digitalisation of supply chain management in the agro-food industry” (9 articles), “digitalisation of the farmers' management system” (58 articles), and “digitalisation in agro-food industry” (24 articles). To conduct our study, only relevant articles referring to the agri-food domain were taken into account. When selecting articles from the Web of Science, filters were applied to exclude articles from other fields that are not the subject of our study.

5. Findings

The employment of digital technologies and data-driven methodologies in the realm of agriculture and food production has gained significant traction among scholars in recent times. The interest in digitisation within the agri-food sector stems from its potential to yield various benefits, such as heightened efficiency, enhanced productivity, optimised management, and improved food safety. The graphical representation in Figure 1 depicts the trajectory of scholarly works and references pertaining to the digitalisation of the agri-food sector, spanning the years 1987 to 2023. The total number of papers analysed in this study amounts to 1.613. The year 2021 witnessed the greatest number of publications, with a total of 191 papers, whereas the period spanning from 1987 to 1995 saw the lowest level of publications, with an annual range of 0 to 4 articles published. The surge in the quantity of articles published post-1996 indicates the acknowledgement of the digitalisation's potential in tackling significant issues in the agri-food sector such as catering to the needs of an expanding worldwide populace, guaranteeing food security, and curbing agriculture's environmental impact.

Furthermore, a noteworthy yearly increase in the number of citations for publications pertaining to digitalisation within the industry has been observed. The reason for this is that the aforementioned papers lack relevance in the absence of a solid empirical research base. The cumulative number of citations has reached 21,075 between 1991 and the current period.

Figure 1. The evolution of papers and citations regarding the digitisation of the agri-food industry

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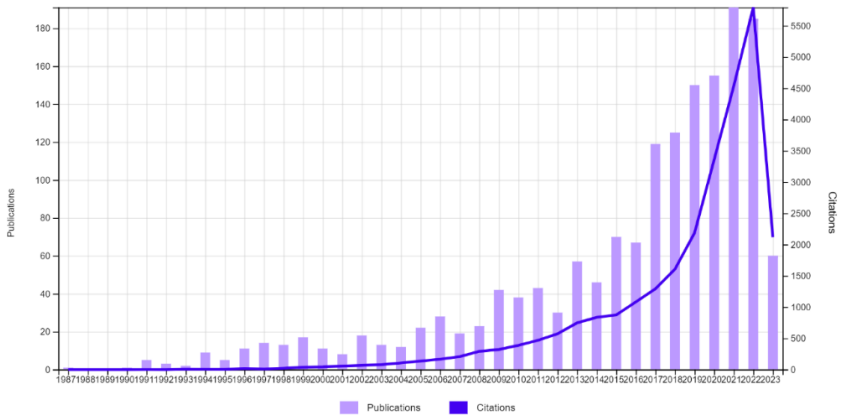
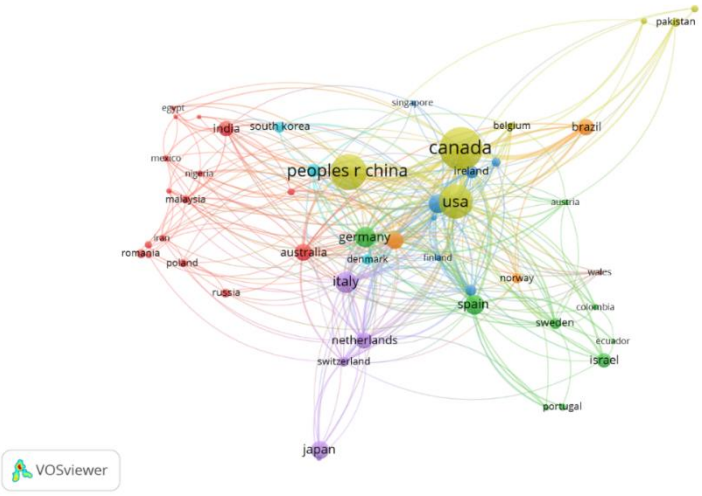


Source: Web of Science.

The evolution of works related to the digitalisation of the agri-food industry has gone through various periods, depending on the subjects of interest for researchers. In the period of 1987-2000, scientific works focused on the application of digital technologies in several areas of the agri-food industry. The topics addressed included the development of computerised tools for data management, inventory, supply

chain optimisation, and the automation of various agri-food production processes, such as automated milking systems, automatic irrigation, and early concepts of precision agriculture. In the early 2000s, a new trend emerged in scientific works – the use of digital technologies to optimise crop management, reduce waste, increase yield, and improve food safety. The research focused on tracking the entire agri-food supply chain from farm to consumer. With the exponential growth in data collection and storage capabilities, scientific works from the period of 2010-2015 increasingly focused on Big Data and Analytics in the agri-food industry. The researchers explored methods of using large datasets for decision-making, predictive modelling, and risk analysis. The topics included data-driven crop management, yield forecasting, prediction of pests and diseases, and supply chain optimisation through data analysis. With the rise of the Internet of Things (IoT) in the period 2015-2020, the emphasis shifted to application development. Topics such as precision agriculture using IoT for real-time monitoring of crops, farm animals and environmental conditions through drones and other Internet-connected devices were explored. In the last three years, scientific work has increasingly focused on the integration of artificial intelligence (AI) and Blockchain technologies in the agri-food industry. Artificial intelligence is being studied to automate tasks traditionally performed by humans, such as crop monitoring, yield estimation, and quality assessment. Blockchain technology has also been explored in the agri-food industry to enhance traceability and transparency of food origins, contributing to the authentication and certification of food products.

Figure 2. Countries with the most publications

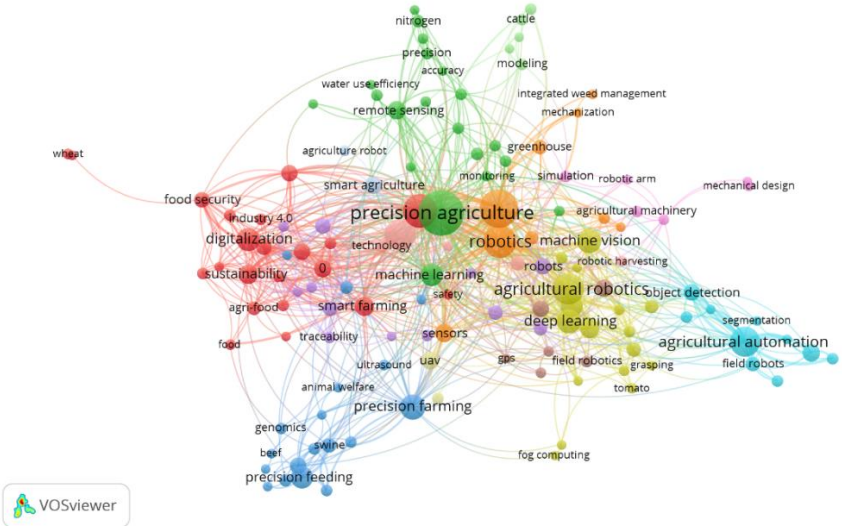


Source: After entering the data in VOSviewer 1.6.19.

Regarding the countries with the most publications in the field, according to the analysis conducted using VOSviewer 1.6.19, Canada emerged as the most productive country in terms of publications, with 396 works in the field and

10.870 citations. This indicates that digitalisation of the agri-food industry is a priority for Canada, with a great deal of attention being given to research in this area. Additionally, the publications from Canada serve as an important source of inspiration for many researchers, given the high number of citations. Other countries that have shown high productivity in writing articles on the digitalisation of the agri-food industry include the USA with 249 articles and 7.828 citations, China with 274 articles and 1.796 citations, the United Kingdom with 74 articles and 2,068 citations, Italy with 96 articles and 2.388 citations, and Germany with 91 works and 1.707 citations. The most popular authors in the field, who have focused their research on the digitalisation of the agri-food industry, have also been identified. The most popular author is Candido Pomar, who has written 26 articles in the field with 279 citations, followed by Luciano Hauschild, with 14 articles and 87 citations, and Aline Remus, who has written 12 articles with 44 citations. By using keywords, we can identify the most popular topics addressed in the work of researchers in the field. Thus, a keyword map was created using VOSviewer 1.6.19, utilising the "Author keywords" function. Through this analysis, frequently occurring keywords or those with high-centrality measures in the authors' works were identified, revealing important subjects that receive significant attention and represent critical aspects of the field.

Figure 3. Map of keywords used most often by authors



Source: After entering the data in VOSviewer 1.6.19.

The findings of Figure 3 reveal that specific terms, including "precision agriculture", "agricultural automation", "machine learning", "agricultural robotics", "artificial intelligence" and "deep learning" are frequently employed by scholars in their scholarly publications. The high frequency of occurrence of these particular keywords suggests their significance and ongoing investigation within the agricultural sector. The study conducted revealed noteworthy attention and interest

toward precision agriculture, agricultural automation, machine learning, agricultural robotics, artificial intelligence, and deep learning. The significant occurrence rate of these specific keywords implies a noteworthy level of focus and fascination towards these particular topics. The prevalent utilisation of the term "precision agriculture" in numerous scholarly publications can be attributed to its robust correlation with technology, data-centric decision-making, efficacy, sustainability, industry acknowledgement, and research imperatives. Precision agriculture has become a thematic field of interest within the academic environment for researchers and practitioners who are exploring the digitalisation of the agri-food industry. The incorporation of specific terms such as "agricultural automation", "machine learning", "agricultural robotics", "artificial intelligence" and "deep learning" suggests that the agricultural sector is embracing sophisticated technologies to enhance their farming methodologies. The implementation of these technologies holds the promise of transforming the agricultural sector through the enhancement of output, effectiveness, and ecological soundness. The employment of these specific terms indicates the multidisciplinary character of investigation and innovation within the field of agriculture. The agricultural sector is confronted with a multitude of challenges that necessitate interdisciplinary cooperation among diverse fields, such as computer science, robotics, data analytics, and agricultural sciences. This implies that interdisciplinary collaboration among experts is essential to effectively tackle challenges and devise innovative solutions for the industry. The agricultural industry is currently experiencing noteworthy trends in the areas of precision agriculture, agricultural automation, machine learning, agricultural robotics, artificial intelligence, and deep learning. The provision of opportunities to optimise resource utilisation, crop management, decision-making, and automation of agricultural operations is observed. These trends are in accordance with the industry's requirement for greater efficiency, sustainability, and productivity.

The utilisation of these specific keywords is expected to persist as endeavours in research and development efforts focus on precision agriculture, which amalgamates the implementation of sophisticated technologies. The forthcoming trajectory entails enhancing agriculture by means of incorporating sophisticated technologies and employing automation, artificial intelligence, and data-centric decision support systems.

6. Conclusions

In conclusion, the significant quantity of scholarly articles pertaining to the digitalisation of the agri-food sector within the WOS database suggests a growing inclination towards the incorporation of digital technologies into agricultural methodologies. The significance of industry digitalisation is substantiated by the authors through scientific papers, wherein they emphasise its various advantages, including heightened efficiency, better sustainability, and improved management of the supply chain. There exists a scarcity of literature that examines the influence of geopolitical variables on the process of digitalisation within the agri-food sector.

Geopolitical factors can exert an influence on the digitalisation of the agri-food industry by affecting technology accessibility, trade patterns, regulatory structures, infrastructure, and data management. Further research is required in the realm of geopolitical influences, as the current body of literature on this topic remains insufficiently explored by scholars. The paper's findings indicate that the agricultural industry is progressively adopting sophisticated technologies and computational techniques. Numerous scholars are currently investigating the capabilities of precision agriculture, automation, machine learning, robotics, artificial intelligence, and deep learning as potential solutions to the challenges faced by the agricultural sector. The keywords that have been identified offer significant insights into the present research trends and priorities. This study provides a comprehensive literature review and bibliometric analysis of published research articles related to the digitalisation of the agri-food industry. Additional research is required to explore the effects of digitisation on systems, particularly with regard to the potential impact on the economic sustenance of individuals residing in rural regions, where agricultural land is situated.

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