Trends in science, technology, and innovation in the agri-food sector

Juan Manuel Vargas-Canales a, b, José de Jesús Brambila-Paz b, Verónica Pérez-Cerecedo b, María Magdalena Rojas-Rojas c, María del Carmen López-Reyna b and José Miguel Omaña-Silvestre b

a Departamento de Estudios Sociales, División de Ciencias Sociales y Administrativas Campus Celaya-Salvatierra, Universidad de Guanajuato, Salvatierra, Guanajuato, Mexico; b Posgrado en Socioeconomía, Estadística e Informática-Economía, Colegio de Postgraduados-Campus Montecillo, Texcoco, Mexico; c Posgrado en Ciencia y Tecnología Agroalimentaria, Universidad Autónoma Chapingo, Chapingo, México.

ABSTRACT
The aim of this research was to map the state of the art on studies of new technologies in the agri-food sector through a systematic literature review in order to explore world trends. The systematic review method consisted of obtaining information from the Scopus database, with the search strategy limited by subject. Thirty-four keywords related to the topic were used and the search was limited only to title of scientific articles. For the coding and extraction of data and results, the VOSviewer software was used to generate, group and visualize networks and identify scientific fields and trends. In recent years there has been significant growth in the development of new technologies in the agri-food sector, concentrated in a few countries, institutions and disciplines. The results allow to identify changes in scientific paradigms and consolidate different scientific fields. It is possible to perceive that the fields of robotics, automation, artificial intelligence, among others, are gaining interest, and that genomics, biotechnology, and genetic improvement are losing dynamism. In addition, there is little research related to economic and social analysis and their relationship to the environment.

Tendências em ciência, tecnologia e inovação no setor agroalimentar

RESUMO
O objetivo desta pesquisa foi realizar um estado da arte sobre os estudos de novas tecnologias no setor agroalimentar por meio de uma revisão sistemática da literatura, a fim de explorar as tendências mundiais. O método de revisão sistemática consistiu na obtenção de informações na base de dados da literatura científica Scopus, com a estratégia de busca limitada por tema.

KEYWORDS
Agriculture 5.0; smart agriculture; big data; artificial intelligence; genetic improvement

PALAVRAS-CHAVE
agricultura 5.0; agricultura inteligente; big data; inteligência artificial; melhoramento genético

PALABRAS CLAVE
agricultura 5.0; agricultura inteligente; big data; inteligencia artificial; mejoramiento genético

CONTACT
Juan Manuel Vargas-Canales juan.vargas@colpos.mx Departamento de Estudios Sociales, División de Ciencias Sociales y Administrativas Campus Celaya-Salvatierra, Universidad de Guanajuato, Boulevard Bicentenario S/N carretera Salvatierra-Acámbaro, Salvatierra, Guanajuato C. P. 38900, Mexico © 2022 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

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Foram utilizadas 34 palavras-chave relacionadas ao tema e a pesquisa limitou-se apenas ao título de artigos científicos. Para a codificação e extração de dados e resultados, o software VOSviewer foi utilizado para gerar, agrupar e visualizar redes e identificar campos científicos e tendências. Nos últimos anos, tem havido um crescimento significativo no desenvolvimento de novas tecnologias no setor agroalimentar, concentrado em alguns países, instituições e disciplinas. Os resultados permitem identificar mudanças nos paradigmas científicos e consolidar diferentes campos científicos. É possível perceber que os campos da robótica, automação, inteligência artificial, entre outros, vêm ganhando interesse e questões relacionadas à genômica, biotecnologia e melhoramento genético estão perdendo dinamismo. Além disso, existem poucas pesquisas relacionadas à análise econômica e social e sua relação com o meio ambiente.

1. Introduction

At present, global demographic trends (population growth, population aging, migration and urbanization) have important implications for economic and social development and for environmental sustainability (United Nations 2019). Rapid population growth and changes in its demands exert strong pressure on all agri-food systems. In other words, it is necessary to produce more food, food with specific characteristics, to be more efficient in the use of natural resources and inputs, and to conserve the environment. In this sense, the only way to produce them, in sustainable agri-food systems, is with the development of science, technology, innovation, paired with vast political will (Godfray, Beddington, et al. 2010; Godfray, Crute, et al. 2010; Vargas-Canales et al. 2020).
It is necessary to mention that the scientific and technological development of the agri-food sector is impressive. In other words, the constant evolution and adaptation of the sector to changes and transformations has allowed its productivity to increase constantly. The use of technology in agriculture is essential to improve agricultural practices and thus being able to respond to the incessant changes of the agri-food world. The use of technological tools allows farmers to improve agribusiness management and achieve a better level of productivity and food security (Carpio Santos 2018).

On the other hand, since the beginning of the twenty-first century, the tendency to offer products and services appropriate to the characteristics, circumstances, tastes, and preferences of each consumer can be identified. This is, for example, one of the trends in genomic medicine and nutrigenomics (Brambila Paz 2011). These disciplines seek to influence the prevention or reversal of health problems in the population, but the conditions we face today are changing. The current crisis and the growing demand for food in terms of quality and quantity have increased the need for industrialization and intensification of the agri-food sector (Farooq et al. 2020).

In this sense, new technologies, which have been mainly developed in other sectors, have emerged and have adapted very well to the agri-food sector – for example, the use of sensors to monitor crops, drones to carry out monitoring activities and application of agrochemicals, and robots to carry out activities that put humans at risk (Guzev et al. 2021; Kovács and Husti 2018; Saiz-Rubio and Rovira-Más 2020). Another important technology that emerged was remote sensing, which is a useful tool for monitoring spatio-temporal variations in the morphological and physiological state of crops and for supporting practices in precision agriculture (Lu et al. 2020).

Likewise, the Internet of Things (IoT), which is a very promising technology that offers innovative solutions to modernize the agricultural sector, was rapidly incorporated due to its ability to offer services to producers and consumers in real time (Farooq et al. 2020). Currently, given confinement conditions, digital technologies will have an important growth in all areas of our lives. In addition, the combination of digital technologies and mobile devices in agricultural practices has become a political priority around the world (Chuang, Wang, and Liou 2020). Hence, we now talk about digital agriculture which encompasses communication, information, and spatial analysis technologies that allow rural producers to plan, monitor, and manage the operational and strategic activities of agri-food systems (Bolfe et al. 2020). This is possible through the massive use of data that is being measured and collected on the biological parameters of crops, which will allow solutions and/or recommendations to be given in real time.

On the other hand, for some years protected agriculture in controlled or artificial environments has been positioning itself in the sector in important ways, as an agricultural production system developed with the aim of providing plants with ideal (optimal) conditions for their development and with this expressing their maximum productive potential (Vargas-Canales et al. 2018). In addition, with technological evolution, the development of farmers has been greatly enhanced and a large-scale database collection system has been established in the field of agricultural production. Safety and efficacy have become two important issues in the agri-food sector (Li, Wang, and Li 2020; Niknejad et al. 2021).

Currently, agriculture 4.0 and 5.0 discussions focus on including and integrating the latest developments based on digital technologies. These help improve the decision-
making process, are more timely and effective since they are based on objective data, and even include artificial intelligence to offer optimal solutions. In this sense and considering that humanity faces an economic, environmental, food, and health crisis, it is essential to develop adequate policies to face the challenges based on a deep knowledge of this phenomenon. As the world population continues to grow, the pressure on the agri-food system increases to double food production by 2050 (Dani 2015) and the use of novel technologies can help overcome crises.

One perspective on new technologies is that many decades are needed before they can be commercially implemented in the agri-food sector. On the other hand, there is a clear vision of how they are being adopted and how they should be in the future. These visions often reflect the popular imaginary of fully automated production systems with drastically reduced human intervention (Legun and Burch 2021). The reality is that the technology exists and is being used in different parts of the world and in various activities. In addition, the existing literature is very heterogeneous and there is no clarity about development, the current situation, and the trends that this rapidly evolving phenomenon will follow. Derived from the above, the question that guided this research was: what are the current state and global trends of science, technology, and innovation in the agri-food sector? In this sense, the objective of this research is to carry out a state of the art mapping of the current state of knowledge and research on new technologies through a systematic literature review, in order to explore world trends.

2. Methodology

2.1. Analysis method

To carry out the state of the art or current state of knowledge mapping of new technologies in the agri-food sector, a systematic review was carried out; mainly, a review of existing literature designed to locate, evaluate and synthesize the best available evidence related to a specific research topic (Boland, Cherry, and Dickson 2017). It consists of an orderly and explicit evaluation of the literature, accompanied by an in-depth and analytical analysis, using different tools, and a qualitative summary of the evidence (García-Perdomo 2015). This is particularly useful when the body of literature has not yet been thoroughly reviewed, or exhibits a complex or heterogeneous nature that is amenable to review (Peters et al. 2015).

2.2. Information collection

The information search was carried out in March 2021. The documents were tracked in the Scopus scientific database taking into consideration the powerful features of its search engine, the volume and quality of the information stored, the wealth of metadata, as well as the capacity for downloading associated files (Cruz-Ramírez et al. 2020). Also, it is generally considered among the most complete databases of scientific literature (Baier-Fuentes et al. 2019; Mongeon and Paul-Hus 2016).

For the database search, a search strategy limited to “subject” was used, specifically in the title of the document (TITLE), with a combination of 34 keywords to make the search
more precise. Search words are associated with new technologies in the agri-food sector (Agriculture 4.0, Agriculture 5.0, Smart agriculture, Smart farms, Smart greenhouses, Big data in agriculture, Artificial intelligence, Digital farming, Digital agriculture, Internet of things, 5G technology, Use of sensors, Robotics, Remote sensing, Drones, Precision farming, Precision agriculture, LEDs, Geomatics, Digital platforms, Blockchain technology, Electronic commerce, E-commerce platforms, Genomic medicine, Nutrigenomics, Nutraceutical, Genetically modified organisms, Genetic engineering, Genetic improvement, GMO, Transmutation, Agriculture in controlled environments, Smart storage facilities and Agricultural automation). In all cases, they were connected using the Boolean operator “OR.” Furthermore, to make the search more precise, two fields were added with the Boolean operator “AND,” in all the fields of the documents (ALL FIELDS) with the words Agricultural and Livestock, with the intention of ruling out those studies in other sectors. Finally, the massive download of metadata in a CSV file was requested with which the database was built.

2.3. Inclusion and exclusion criteria

The search was restricted by document type to scientific articles and was filtered by keyword matching only in the title. That is, the search in keywords, abstract, or in any other part of the document was not considered, the above in order to obtain greater certainty about choosing documents on the exact research topic. Lectures, books, book chapters, and reviews were excluded. Regarding the publication timeframe, no limitation was set with the intention of locating the evolution of publications on these topics since the research on them began. Likewise, there were no restrictions on the language, country of origin, and discipline or subject area, the intention being to analyze the largest number of documents related to the topic of interest. Finally, a first review of the articles was carried out to include only those investigations that consider “new technologies” as the central theme.

2.4. Coding and extraction of data and results

The results obtained from the Scopus database were processed and the information obtained allowed constructing statistical data on the origin and evolution of the research, the countries that carry out this type of research, the institutions or research centers where they are carried out, and thematic clusters. Subsequently, the VOSviewer software was used to generate, group and visualize networks (van Eck and Waltman 2010). VOSviewer allows one to view existing clusters in relation to co-authors, citations, co-occurrences of words in the title and keywords, in addition to a detailed internal analysis of each cluster (Cruz-Ramírez et al. 2020). These clusters were identified as groups with similar disciplinary interests and as scientific fields.

Once the selection was completed, the different clusters were analyzed in relation to their research main approaches. In addition to the aforementioned data, the risk of bias in the articles was evaluated, since the conclusions of a systematic review may be valid to the extent that the studies that compose it, i.e. the primary studies, are reliable (Moreno et al. 2018). Likewise, a brief summary was made that describes the main
characteristics and findings with the evidence that allows to clearly identify the knowledge gaps and the lines or trends that the field or area of knowledge presents.

3. Results

1026 documents were found, including articles, books, chapters, conferences, reviews, letters, and notes related to the object of study. However, applying the exclusion criteria, the articles lowered the number to 652. The first document related to the objective of the research was published in 1971. It is possible to observe a long period of time, approximately 25 years, in which investigations on new technologies were limited, and even several years during which nothing was published. In 1996 there is a slight increase, until 2011, and from this year onwards there is an exponential increase in scientific articles on new technologies in the agri-food sector (Figure 1).

Regarding the countries where research related to new technologies is carried out, the United States and China stand out as the leaders, but in an aggregate way; since, at present, the countries that stand out by number of publications are China and India. The above considers only the 15 countries that feature the most publications. There is a second group in order of importance made up of Australia, India, Italy, Netherlands, Germany, United Kingdom, and Canada (Figure 2). On the other hand, countries such as Kenya and South Africa appear as some of the main countries that are developing research on the subject.

Regarding the institutions that focus on research on new agri-food technologies stand outs include: Wageningen University with 17%, the Chinese Academy of Sciences with 15%, International Livestock Research Institute Nairobi with 12%, and the Ministry of Agriculture of the People’s Republic of China with 11%. These four institutions concentrate more than 50% (Figure 3) of articles. Wageningen University, as one of the forerunners,
focuses on research from technical to social issues. In addition, we highlight the participation of institutions from China in the development and research of new technologies in the agri-food sector.
Of the 652 articles that were published according to the Scopus classification by subject area, 36% of the articles were published in the Agricultural and Biological Sciences area and 18% in Environmental Science; these contribute to more than 50% of the scientific production, and to a lesser extent the rest (Figure 4). If the last few years are analyzed, however, publications are more concentrated in the area of Computer Science and Engineering, which suggests that the trend is focused on research related to automation, the use of sensors, and robotics.

The visualization network of the analysis of co-occurrences of the 77 items produced nine clusters or scientific fields, identified with different colors (Figure 5). The size of the label and circle of an article is determined by the weight of the search word. The greater the weight of the search word, the larger the label and the circle. The color is determined by the group to which the search each word belongs related to the research carried out (van Eck and Waltman 2020).

Cluster 1 (red) is made up of research related to plant and animal genetic improvement, focusing on genetic selection, cloning, crossbreeding, genetic evaluation, genetic parameters, heritability, selection, selection index, and response to selection. Cluster 2 (green) is made up of research related to the use of remote sensors that includes data fusion, drones, evaluation of parameters such as drought, evapotranspiration, grazing intensity, irrigation, and includes topics related to remote sensing and geographic information systems.

Cluster 3 (blue) is made up of investigations related to satellite image reception and processing systems. That is, the monitoring of different parameters such as climate variability, deforestation, land cover change, land degradation, forest systems, and

Figure 4. Main thematic areas where research on new technologies in the agri-food sector is carried out (2021).
vegetation indices. Cluster 4 (yellow) is made up of research related to the adoption and adaptation of technology, climate change, climate-smart agriculture, and food security. Cluster 5 (purple) is made up of studies related to artificial intelligence; this group includes the Internet of Things, cloud computing, big data, and autonomous learning.

Cluster 6 (light blue) is made up of a small number of investigations related to animal welfare, automatic milking systems, genetic engineering, and heat stress. Cluster 7 (orange) is made up of investigations that are oriented to agricultural robotics. This group also includes climate-smart agriculture, precision agriculture, precision ranching, resilience, and sustainability. Cluster 8 (brown) is made up of studies related to the environment, genetically modified organisms (GMOs), land use, and regulatory issues. Finally, Cluster 9 (pink) is made up of a small group of investigations related to the analysis of grazing, methane, vegetation indices, and their modeling.

In Figure 6, it is possible to identify the evolution and trends in the areas of greater interest from 2010 to 2020. In this sense, the clear formation of three large groups on the dynamics of worldwide research is observed. The first, which is the oldest, is related to plant and animal genetic improvement, genetic evaluation, genetic selection, and evaluation of genetic parameters. The second group, which is in the center and is the one that presents the highest dynamism and research, is related to the beginning of remote sensing, the use of drones and remote sensors to evaluate different parameters in crops, and the use of geographic information systems (GIS). The third group is made up of the most recent research, which is oriented to Big Data, Internet of Things, climate-smart agriculture, drones, and artificial intelligence.
4. Discussion

The agri-food sector has undergone impressive changes and transformations over time. It is possible to identify at least five stages of scientific and technological development that have revolutionized the sector (Guzev et al. 2021; Kovács and Husti 2018; Saiz-Rubio and Rovira-Más 2020). The first is identified as agriculture 1.0 (Colonia - 1940), a situation that lasted until the beginning of the twentieth century and was characterized by being labor-intensive agriculture, with low levels of productivity and an extremely low growth rate. Agriculture 2.0 (1920–2000) consisted in the introduction of improvements in agronomic management practices and was known as the Green Revolution, which was characterized by improved seeds, agrochemical fertilizers, and specialized machinery, which allowed an impressive increase in productivity, reduction of labor and presented high growth rates.

Agriculture 3.0 (1990–2010) is identified as precision agriculture and was characterized by Global Positioning System (GPS) used for manual vehicle orientation, with the detection and control of some activities such as the fertilization, and telematics for vehicle monitoring. Agriculture 4.0 (2000 to date), also called digital agriculture, is based on the use of sensors and the intelligent use of mass data and communications to use intelligent control devices and automation of facilities. Finally, agriculture 5.0 (2010 to date) is in its germinal stages, offering highly interconnected and data-intensive computational technologies oriented to robotics and some form of artificial intelligence, autonomous decision-making systems in real time, and environmental protection.

Derived from the above, it is possible to identify the emergence, development, and exhaustion or conclusion of certain scientific paradigms in the agri-food sector in which knowledge gaps are gradually filled which allows a paradigm to be exhausted or terminated naturally; a kind of crisis that, as a consequence, marks the beginning of another naturally occurring paradigm (Kuhn 1971). This gives rise to what was called
the techno-economic paradigm (Pérez 2001), which tries to explain the process that begins with the generation of new knowledge and ends with its application in the productive sector, and its transformation into innovation and economic growth: a continuous process that is recurring and essential to current economic dynamics.

In the agri-food sector, there have been profound structural changes with the incorporation of science and technology; for example, the Green Revolution as one of the techno-economic paradigms that have most influenced the world economy (Pivoto et al. 2018). In this case, the changes that have occurred in the agri-food sector are evident, which are related to clear moments in the development of world economic life. That is to say, the evolution of scientific and technological development comes, on the one hand, from the accumulation of knowledge and facts, and on the other, from certain circumstances and intellectual possibilities subject to change (Kuhn 1971) that are linked to the cumulative technological culture. The above refers to the increase in the efficiency and complexity of tools and techniques that are developed and evolved in human populations over generations and constantly improve (Osiurak and Reynaud 2019; Vitrano 2017). Consequently, the result of this recurrent process is a gradual rejuvenation of the entire productive structure, so that mature and even updated industries can again behave like new industries, in terms of dynamism, productivity, and profitability (Pérez 2001).

On the other hand, it is clear how the development and consolidation of certain scientific fields with well-defined objectives occurs over time. The trajectory of each of the scientific fields depends a lot on the nature of each discipline and, as a result, there is a great heterogeneity in the evolutionary process between the different scientific fields and their dynamics (Coccia 2022). This is mainly due to the fact that between each field there are inequalities and imbalances of power associated, for example, with obtaining resources to develop research. In these scientific fields, research is carried out within a social space of relationships that maintains a certain autonomy in the development of science, within which scientific authority is achieved and a specific form of interests is produced and assumed (Bourdieu 1976).

In this sense, clearly identifying the scientific domains from their co-occurrence in the documents allows identifying and analyzing the groups of concepts that represent the subareas of the scientific field studied (Tosi and dos Reis 2021). It is important to mention that, in general, all scientific fields maintain a certain relationship between them and also share benefits mainly derived from their interaction and cooperation (Albert and Kleinman 2011). These scientific fields respond to a logic and dynamics of organized creation that seeks to legitimize itself (Kreimer 2017). Another important aspect related to the above is the internal constitution of each one, since very different actors converge, including teaching staff, researchers, students, universities, companies, and even legislators. The expression of the above implies developing very different capacities within each scientific field. Therefore, it is hard to think about the neutrality of science and technology (Ward 1989).

Consequently, scientific fields and communities with common objectives and interests are being consolidated over time. In this case, by the 1970s and 1980s, research related to the genetic improvement of plants and animals and related economic issues stand out (Bichard 1971; Brascamp 1973; McConnell 1986). These investigations were the pioneers related to the object of study and are still valid today. Likewise, in the 1990s the emergence of another scientific field related to robotics in the agricultural and livestock
sectors began (Frost 1990; Harrell et al. 1990), with a very slow growth and with a predo-
minance of research concerning genetics, which is currently one of the trends.

By the 2000s, research related to the works described above continued with certain
dynamism, but the idea of increasing efficiency, precision agriculture, and monitoring
by sensors arose (Masek et al. 2001; Todd, Mishoe, and French 2004; Washington-Allen,
West, and Douglas Ramsey 2006). We mention that studies on precision agriculture
allow or incorporate the obtaining and use of information for decision-making, thereby
optimizing the use of resources and inputs and reducing negative impacts on the environ-
ment (Nyaga et al. 2021).

One of the themes that emerges as a central point in the most recent research is
related to digital agriculture that has its origins at the beginning of 2000 and integrates
practically all technologies, including the use of sensors and the Internet of Things for pre-
cision agriculture (Syrový et al. 2020). It is important to mention that the Internet of Things
is one of the disruptive technologies that are being adopted in the management of the
food supply chains and is aligned with the objectives of green agriculture (Ray 2017)
and ecological studies (Sheriza, Nurul, and Ainuddin 2020), and for the livestock part, it
is aimed at improving animal welfare and the operational efficiency of farms (Michie
et al. 2020).

In addition, another important aspect arise that include climatically smart agriculture,
digital agriculture, robotics, among others that have been developed since the beginning
of 2000 and continue to date. Its importance lies in a considerable turn of the future of
agriculture and food security and sovereignty, particularly on the ability to adapt to con-
stant changes and its capacity for resilience. The evaluation of this technology provides
information on the improvement in the well-being of farmers and highlights the potential
to optimize productivity (Mujeyi, Mudhara, and Mutenje 2021). In the last 20 years, it is
possible to identify a transition from digital agriculture and its different orientations,
and aspects to reaching artificial intelligence, which is even perceived as the basis for
the environmental restoration of ecosystems (Yin et al. 2021).

In another topic but in the same sense, some research related to public policies and
economic analysis has emerged (Lajoie-O’Malley et al. 2020). With less dynamism,
socio-economic research has been carried out related to the adoption of innovations
and their economic impacts (Kurgat et al. 2020), climatically smart agriculture economic
analysis (Komarek et al. 2019), its adoption in smallholder agricultural systems (Makate,
Makate, and Mango 2018), and the relationship of their adoption and its in-
fluence on family income (Mango et al. 2018).

It appears that studies related to improving the physical and chemical characteristics of
agri-food products, such as proteomics (Watanabe, Losák, and Vollmann 2018), have
become less dynamic and interesting among researchers. Some isolated studies on nutra-
ceuticals in some plant species stand out (Ofori-Boateng and Lee 2013), and on some pro-
ducts of animal origin for the benefit of human health (Stankus 2008), as well as in the
improvement of processes such as egg production, egg quality, and the physiological
characteristics of laying hens (Marume et al. 2020). In the same sense, one of the impor-
tant divergences is that genomics, biotechnology, and genetic improvement are being
abandoned, or at least seem to have become less important or less dynamic. This does
not mean that they do not exist or are disappearing. There have been important advances
in the last 20 years in various plant and animal species (Sun et al. 2022). However, the rates
of growth or production of knowledge are slower than in other scientific fields. This situation may be due to the fact that this research requires years and presents greater uncertainty. That is, the possibility of finding the desired results after a breeding cycle of several years is low.

The foregoing could be seen as a contradiction, since it is not possible to increase animal or plant productivity without continuing to carry out research on crosses, hybridizations, mutations, and genetic engineering, among other techniques to generate species that present better characteristics and yields. In other words, plant and animal species are genetically conditioned and once they show their maximum productive potential, increasing their productivity would be very complicated. The truth is that the new technologies will undoubtedly help most plants and animals to express their maximum productive potential, whether through improvements in their management, modification of the environment, or the automation of their processes. It is convenient to mention that for very few crops worldwide has it been possible to obtain the maximum productive potential.

Derived from the above, much more work and research needs to be done to implement strategies that allow the transition to digital agriculture in a fairer way (Rotz et al. 2019). In addition, it is convenient to think about the benefits that could be obtained from technological convergence. In other words, digital technologies can favor the development of all scientific fields in the agri-food sector and even in the development of research. For example, it can help address current-system environmental issues through software-based solutions (Cobby Avaria 2020). This facilitates the monitoring and control of all processes, particularly in compliance with environmental regulations and care (Prause, Hackfort, and Lindgren 2021). In addition, a bottom-up development should be considered, where researchers and producers define a common path to sustainability (Cobby Avaria 2020).

Despite the fact that digital technologies are currently being used throughout the entire value chain in the agri-food sector (Prause, Hackfort, and Lindgren 2021), it is important to consider the conditions, characteristics, and capacities of all the parties involved (Ebrahimi, Schillo, and Bronson 2021). This is important because current policies are not sufficient and adequate to respond to rapid technological changes and it is necessary to create new approaches for policy design, especially at the regional level (Parra-López et al. 2021). Otherwise, these technologies can increase inequalities between different types of producers (Rotz et al. 2019). In addition, there is a lack of evidence on the economic viability of investing in digital technologies (Parra-López et al. 2021) and it is necessary to analyze the effects of exclusion or access in the different regions and between the different types of agriculture (Klerkx and Rose 2020).

Most of the technologies are complementary and require pairing with others. For example, the use of remote sensors and 5G technology are the essential elements for the operation of other technologies. On the other hand, it is important to note that there is few economic, social, and environmental research that shows evidence of its advantages. In addition, there is no clarity on the infrastructure to be able to implement massively these new technologies. Much less explored are alternative mechanisms that could encourage its adoption, such as subsidies or financing. This could be attractive for young researchers interested in joining the activities of the agri-food sector (Rijswijk et al. 2021).
In general, there is an important growth in research aimed at the design and implementation of new technologies in the agri-food sector. This will evidently be potentiated due to the health emergency commenced by SARS-CoV-2 (COVID-19); from this event, the use of digital technologies is rapidly increasing in practically all areas of our lives and has increased the infrastructure for its implementation.

5. Conclusions

In recent years there has been a significant growth in the development of new technologies in the agri-food sector although they are concentrated in few countries, institutions, and disciplines. Studies on new technologies in the agri-food sector present clearly defined changes in scientific paradigms and over time different scientific fields with extremely specific topics and interests have been consolidated. It is important to mention that there is little research related to economic and social analysis of their relationship with the environment.

It is possible to perceive that the fields of study on robotics, automation, artificial intelligence, and autonomous decision-making are currently gaining interest. At the same time, topics related to genomics, biotechnology, genetic improvement, among others, lose dynamism; nevertheless, all scientific fields are crucial to achieving the objective of increasing food production, and greater collaboration is necessary to achieve sustainability in agri-food systems.

The basis for the adoption and adaptation of new technologies in the agri-food sector enable incorporating sensors in production systems for the collection and transfer of information, and the use of 5G technology will allow the massive use of data and information for analysis and to help decision-making.

For future research related to the subject, it would be pertinent to analyze the limitations related to access to new technologies derived from high costs, carry out clear economic, social, and environmental evaluations on the advantages of their use, analyze the infrastructure available for their implementation en masse, and explore the supporting mechanisms for its adoption, such as subsidies or financing.

Notes on contributors

Juan Manuel Vargas-Canales was born in Hidalgo, Mexico. He is an Agronomist Specialist in Fitotecnia, Master of Science in Horticulture and Doctor of Agroindustrial Economic Problems at the Chapingo Autonomous University. He is currently a Full Time Professor in the Department of Social Studies of the Division of Social and Administrative Sciences Campus Celaya-Salvatierra belonging to the Universidad de Guanajuato and conducts Doctorate studies in Sciences, Research Modality in the Postgraduate Degree in Socioeconomics, Statistics, and Informatics with Orientation in Economics at the College of Postgraduates. His main lines of research are science, technology, society, and innovation in the agri-food sector and intensive agricultural production systems. In addition, he has been a member of the National System of Researchers (SNI) since 2018 and currently has the distinction of National Researcher Level 1 of the National Council of Science and Technology (CONACYT).

José de Jesús Brambila-Paz is a Doctor of Economics from Cornell University and a current member of the National System of Researchers of CONACYT. He has held various positions in the public function, highlighting having been Deputy Director General of Technological Development of FIRA until 2004. He is currently a Senior Research Professor and Representative of the General Research Line
“Bioeconomy Food and Natural Resources” at the College of Postgraduates, he also works as a Full Professor at the Chapingo Autonomous University. He is the author of books such as On the Threshold of a New Agriculture, Bioeconomy: Concepts and Foundations, Bioeconomics: Instruments for its Economic Analysis, among others.

**Verónica Pérez-Cerecedo** is a Doctor in Economics (2018) and holds a Master’s Degree in Agricultural Economics (2006) from the Postgraduate College. She is a founding partner of the firm Consultores en Bioeconomía y Agronegocios S.A. de C.V. where she works as a specialist in topics such as Bioeconomics, Value Added, Finance and Consumer Trends. She has participated as coordinator and researcher of books including Bioeconomia: Conceptos y fundamentos; Bioeconomics: Instruments for its economic analysis and the Threshold of a new agriculture and as an author or co-author in various publications related to the topic of Bioeconomics, value networks, and circular economy and hybrid finance. She currently works as an external researcher within the research line “Bioeconomy Food and Natural Resources” of the Postgraduate College.

**María Magdalena Rojas-Rojas** studied Agroindustrial Engineering at the Universidad Autónoma Chapingo (UACH). She earned her Master and Doctorate of Science degree in Economics from the College of Postgraduates. She is currently a CONACYT Professor assigned to the Postgraduate Program in Agri-Food Science and Technology at Chapingo. Her professional experience has focused on research areas in bioeconomics, agri-food value chains, and economic valuation of projects with scenarios in risk and uncertainty. She is a candidate for national researcher in the National System of Researchers (SNI) of the National Council for Science and Technology (CONACYT).

**María del Carmen López-Reyna** is a specialist in Agribusiness and has been awarded at the “70 Grandes de México” contest, for her training on Agribusiness in Mexico. She is an Agricultural Engineer from the Chapingo Autonomous University. She holds a Master in Economics of the Agri-Food System from the Università Católica del Sacro Cuore, Italy, and a PhD in Agrifood System Economics from the Università degli Studi di Parma, Italy. She was a pioneer in the formation of Agribusiness in Mexico, created and directed the Master of Agribusiness at the Postgraduate College from 2000 to 2017, the first and only program of its kind in Mexico. She is currently a Research Professor of Agribusiness at the Postgraduate College, lecturer and consultant. Her areas of competence are agribusiness; agri-food marketing; agri-food chains; case studies in agribusiness; creation, management and administration of agroindustrial and food companies; development and innovation of new business models based on productive integration; competitiveness strategies for agri-food SMEs; development of collective trademarks and designation of origin; neurosciences applied to business (neuromarketing); and consortiums of cooperatives and quality guardianship of agri-food products.

**José Miguel Omaña-Silvestre** is a Doctor of Agricultural Sciences from the Postgraduate College. He is currently a Senior Research Professor in the Postgraduate Degree in Socioeconomics, Statistics, and Informatics at the Postgraduate College.

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**ORCID**

Juan Manuel Vargas-Canales [http://orcid.org/0000-0003-1918-9395]
José de Jesús Brambila-Paz [http://orcid.org/0000-0001-7640-8203]
Verónica Pérez-Cerecedo [http://orcid.org/0000-0001-7035-7281]
María Magdalena Rojas-Rojas [http://orcid.org/0000-0002-1953-5537]
María del Carmen López-Reyna [http://orcid.org/0000-0001-7820-0801]
José Miguel Omaña-Silvestre [http://orcid.org/0000-0002-5356-549X]
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