frontiers | Frontiers in Sustainable Food Systems

TYPE Review
PUBLISHED 29 January 2024
DOI 10.3389/fsufs.2024.1344357

# Science, technology, agri-food systems, health, and wellbeing: logic, dynamics, and relationships

Juan Manuel Vargas-Canales[1]*, Sergio Orozco-Cirilo[1], Salvador Estrada[2], Perla Shiomara del Carpio-Ovando[3], Joaquín Huitzilihuitl Camacho-Vera[4], Daniela López-Carmona[1], Nicasio García-Melchor[1], Benito Rodríguez-Haros[1], Alberto Valdés-Cobos[3], Yolanda Sánchez-Torres[5], Jonathan Fresnedo-Ramírez[6], María Isabel Palacios-Rangel[7], Jorge Gustavo Ocampo-Ledesma[7], Octavio Tadeo Barrera-Perales[7], Joel Pineda-Pineda[8], Pablo Kreimer[9], Juan Carlos García-Cruz[10], Dulce María Reyes-Barrera[1], Julio César Montiel-Flores[2], Tzatzil Isela Bustamante-Lara[11], Edgar Iván García-Sánchez[12], Belen Hernández-Hernández[7], Virginio Escárcega-Quiroga[1], César Simón-Calderón[1], José de Jesús Brambila-Paz[13], Sergio Ernesto Medina-Cuéllar[14] and Rebeca de Gortari-Rabiela[15]

[1]Departamento de Estudios Sociales, Universidad de Guanajuato, Salvatierra, Mexico, [2]Departamento de Finanzas y Administración, Universidad de Guanajuato, Celaya, Mexico, [3]Departamento de Estudios Culturales, Demográficos y Políticos, Universidad de Guanajuato, Celaya, Mexico, [4]División de Estudios de Posgrado, Universidad de la Sierra Sur, Miahuatlán de Porfirio Díaz, Mexico, [5]Instituto de Ciencias Económico Administrativas, Universidad Autónoma del Estado de Hidalgo, Pachuca, Mexico, [6]Departament of Horticulture and Crop Science, The Ohio State University, Wooster, OH, United States, [7]Centro de Investigaciones Económicas, Sociales y Tecnológicas de la Agroindustria y la Agricultura Mundial, Universidad Autónoma Chapingo, Texcoco, Mexico, [8]Departamento de Suelos, Universidad Autónoma Chapingo, Texcoco, Mexico, [9]Centro de Ciencia, Tecnología y Sociedad, Universidad Maimónides, Buenos Aires, Argentina, [10]Departamento de Producción Económica, Universidad Autónoma Metropolitana, Ciudad de México, Mexico, [11]Departamento de Ciencias Sociales, Universidad Autónoma de Ciudad Juárez, Ciudad Juárez, Mexico, [12]Centros de Investigaciones Interdisciplinarias sobre Desarrollo Regional, Universidad Autónoma de Tlaxcala, Tlaxcala, Mexico, [13]Posgrado en Socioeconomía, Estadística e Informática—Economía, Colegio de Postgraduados-Campus Montecillo, Texcoco, Mexico, [14]Departamento de Empresa y Arte, Universidad de Guanajuato, Salamanca, Mexico, [15]Instituto de Investigaciones Sociales, Universidad Nacional Autónoma de México, Ciudad de México, Mexico

The agri-food sector worldwide is the most important for life. The recent pandemic made it clear that the best way to resist, overcome and adapt to health problems is by maintaining a healthy, adequate and balanced diet. Currently, food comes almost entirely from agri-food systems, the problem is that the agri-food sector subordinated to an economic and scientific model with very clear interests and objectives. In this sense, the aim of this work was to carry out an analysis of the logic, dynamics and relationship between science, technology, agri-food systems, health and wellbeing from the perspective of Social Studies of Science and Technology. With what is intended contribute to the debate on the future and the strategic transformation of agri-food systems. As a first point, an exploration of the evolution and trends of science

EDITED BY
Christian Bux,
University of Bari Aldo Moro, Italy

REVIEWED BY
Franco da Silveira,
Federal University of Rio Grande do Sul, Brazil
Eloy Hontoria,
Polytechnic University of Cartagena, Spain
Stanislav Škapa,
Brno University of Technology, Czechia

*CORRESPONDENCE
Juan Manuel Vargas-Canales
✉ jm.vargas@ugto.mx

RECEIVED 25 November 2023
ACCEPTED 08 January 2024
PUBLISHED 29 January 2024

CITATION
Vargas-Canales JM, Orozco-Cirilo S, Estrada S, del Carpio-Ovando PS, Camacho-Vera JH, López-Carmona D, García-Melchor N, Rodríguez-Haros B, Valdés-Cobos A, Sánchez-Torres Y, Fresnedo-Ramírez J, Palacios-Rangel MI, Ocampo-Ledesma JG, Barrera-Perales OT, Pineda-Pineda J, Kreimer P, García-Cruz JC, Reyes-Barrera DM, Montiel-Flores JC, Bustamante-Lara TI, García-Sánchez EI, Hernández-Hernández B, Escárcega-Quiroga V, Simón-Calderón C, Brambila-Paz JdJ, Medina-Cuéllar SE and de Gortari-Rabiela R (2024) Science, technology, agri-food systems, health, and wellbeing: logic, dynamics, and relationships. *Front. Sustain. Food Syst.* 8:1344357. doi: 10.3389/fsufs.2024.1344357

and technology in the agri-food sector is carried out. Next, an analysis is developed on the importance of agri-food systems and the ways in which they have been configured. Subsequently, the relationship between food and health and the main implications and damage caused by the current agri-food regime are addressed. Based on the above, some alternatives are proposed to improve nutrition, health and wellbeing. These alternatives imply, on the one hand, a profound reconfiguration of technological systems, orienting them toward the reproduction of life. Secondly, and as a consequence of the above, a reorganization of the economic and social systems. To achieve this, it is advisable to design a policy that promotes sustainable agri-food systems and integrate broad work and research groups that allow addressing these problems and proposing alternatives from different perspectives. Finally, it is important to design and implement science dissemination programs on the relationships, controversies, tensions and problems that exist between scientific and technological development and the agri-food sector, health and wellbeing with the aim of having a true impact on the society and a genuine social appropriation of knowledge.

KEYWORDS

**agri-food policies, diseases and agrochemicals, economic model and health, food and health, healing and recovery of agri-food systems, social appropriation of knowledge, sustainable agri-food systems, technological model and agri-food systems**

## 1 Introduction

Currently, global trends such as demographic growth, population aging, poverty, migration, and urbanization have important implications for economic and social development and, above all, for health and environmental sustainability (United Nations, 2019). In addition to changes in the world's population, there is a growing demand for resources (water, soil, air, nutrients, minerals, energy, among others) to ensure that present and future generations have access to food (Dal Moro et al., 2022). Demand for food is estimated to increase by more than 60% by 2050, putting great pressure on agri-food systems (Gaspar et al., 2021).

Another very relevant issue for the agri-food sector is climate change, which is generating changes in weather patterns. Climate change refers to long-term changes in temperatures and the recurring characteristics of the climate. One of the most appropriate definitions involves changes in climate as a distribution over time in relation to regimes of variable external conditions (Werndl, 2016). From certain spheres of knowledge, it is argued that these changes can be both natural and motivated, for example, by variations in solar cycles (fluctuations caused by differences in the amount of energy emitted by the sun). It is not known with certainty to what extent natural conditions modify, affect or contribute to climate change. The exact magnitudes of how much humanity contributes are also unknown. However, when the speed of changes is analyzed, it is evident that since the 19th century, human activities have been the main driver of climate change. Mostly due to the burning of fossil fuels such as coal, oil and gas (Vargas-Canales et al., 2023a).

Furthermore, the 20th century was characterized by being a period of unprecedented economic expansion and the accelerated growth of the population after the world wars was not seen as a problem (Bardi, 2014). However, current climate change projections indicate that it is evolving rapidly and affecting all biological systems in the world (Kamboj et al., 2023). The above is important and relevant because it is directly linked to health and the emergence of pandemics for the future (McLennan, 2022). Likewise, derived from the growth of the population and the demand for goods and services, the scarcity and depletion of resources is increasingly evident. And if we add to the above the current war conflicts and that we are expected to have more, it is possible to infer that the future will be characterized by strong crises and economic instability, which would put food production at risk.

In that sense, the importance of the agri-food sector for society goes far beyond its relevance for the economy; this is the only sector that, in a strict sense, allows the maintenance of life and its reproduction. Furthermore, recent events showed the close relationships that exist between the agri-food sector, health and wellbeing (Vargas-Canales et al., 2023a). The recent pandemic caused by the SARS-CoV-2 virus (COVID-19) made it clear that the best way to resist, overcome and adapt to health problems is to maintain a healthy and adequate diet. Various research has shown that an adequate and balanced diet is important to strengthen the immune system and prevent infections (Calder and Kew, 2002; Calder, 2020; Calder et al., 2020; Iddir et al., 2020). This was also the case to control the risk and persistence of COVID-19 (Villapol, 2020). That is, resisting and overcoming diseases and pandemics is directly related to the agri-food systems (Liaudat, 2020).

In general, modern chronic degenerative diseases such as diabetes mellitus, obesity, cancer, hypertension, cardiovascular and cerebrovascular diseases, to name just a few, are closely related to the foods we consume (Gallo et al., 2020; Grados et al., 2022). The above positions the agri-food sector as the highest priority and that we must revalue it to improve life and reduce environmental impacts (Vargas-Canales et al., 2023a). Currently, society faces very complex problems that increasingly affect us and are more frequent, and are mainly derived from the dominant economic development model (Vargas-Canales, 2022).

Recently a problem was identified that affects all aspects of our lives. The presence of microplastics has been detected in water, air and many of the products we consume. These are particles $<20\,\mu m$ in size that can penetrate cell membranes. This situation puts the feeding, metabolic processes, reproduction and behavior of organisms at risk (Hale et al., 2020). Multicolored microplastic fragments and fibers have been found in water trapped in the membranes of plant leaves (Fogašová et al., 2022). In humans, microplastics are able to cross cell membranes and trigger oxidative stress and inflammation, and have been linked to an increased risk of death from cardiovascular diseases and respiratory diseases or lung cancer (Vethaak and Legler, 2021).

The aforementioned events allow us to infer that global society has reached an unthinkable level of degradation, pollution and alteration of ecosystems. By extension, for the health and wellbeing of all ecosystems and the effects and implications are unknown. On the other hand, at a global level, the technologies proposed by agriculture 4.0, 5.0, and 6.0 present good expectations of satisfying the growing demand for food in a sustainable way, making rational and comprehensive use of resources and conserving the environment (Klerkx and Rose, 2020; Saiz-Rubio and Rovira-Más, 2020; da Silveira et al., 2023b; Neves, 2023; Vargas-Canales et al., 2023a). Of course, there are many regional asymmetries and many barriers to its massive implementation. However, emerging technologies in the field of life sciences, information and communication, data sciences, artificial intelligence and associated digital applications are significantly improving agri-food production and productivity (Hodson de Jaramillo et al., 2023).

The development of science, technology and innovation is essential to address the complex nature of agri-food systems, food security, health and wellbeing. In this sense, technological systems must be aimed at improving the health and wellbeing of society. However, the existing relationships between science, technology, agri-food systems, health and wellbeing are little known, studied and valued. The above leads us to question: what are the existing relationships between science, technology, agri-food systems, health and wellbeing? In this sense, the aim of this work was to carry out an analysis of the current logic and dynamics between science, technology, agri-food systems, health and wellbeing from the perspective of Social Studies of Science and Technology. The above with the purpose of generating information and evidence to develop new lines of research and impact agri-food policies for developed countries and especially developing countries that are affected by these dynamics.

## 2 Science and technology in the agri-food sector

In the global agri-food sector it is possible to identify the emergence, development and exhaustion or conclusion of certain scientific paradigms. Scientific paradigms are a shared organization of groups, ranging from preferred analogies and metaphors to shared examples, heuristics, ontological models, or accepted hypotheses of the laws of nature (Anand et al., 2020). It is a kind of methodological and conceptual universe that the scientist can use to reinforce existing theories or develop new (Guerra et al., 2011). These paradigms over time fill the gaps in knowledge that gave rise to them, which causes one paradigm to exhaust or end naturally, it is a kind of crisis, and therefore the beginning of another occurs naturally (Kuhn, 1971). The above gave rise to what is called the techno-economic paradigm (Pérez, 2001), which is a process that begins with the generation of new knowledge and continues with its application in the productive sector, its transformation into innovation and economic growth. It is a process that is occurring all the time on a recurring basis and is fundamental in the current economic dynamics (Vargas Canales, 2023).

The agri-food sector has experienced changes and transformations over time related to scientific and technological development. At least six stages or scientific paradigms that have revolutionized the sector can be identified (Kovács and Husti, 2018; Saiz-Rubio and Rovira-Más, 2020; Guzev et al., 2021). The first is identified as agriculture 1.0 (Cologne - 1940) which was characterized as labor-intensive agriculture, with low levels of productivity and a very low growth rate. Agriculture 2.0 (1920–2000) and was known as the Green Revolution. This stage was characterized by the use of improved seeds, fertilizers, agrochemicals and specialized machinery, which allowed an impressive increase in productivity, reduction of labor and high growth rates (Zhai et al., 2020; Vargas-Canales et al., 2022a).

Agriculture 3.0 (1990–2010) is identified as precision agriculture and was characterized by the use of Global Positioning System used for manual vehicle orientation, with the detection and control of some activities such as fertilization and with the telematics for vehicle monitoring (Kovács and Husti, 2018). Agriculture 4.0 (2000—present), also called digital agriculture, is based on the use of sensors, the Internet of Things, drones (unmanned aerial vehicles), the intelligent use of data and communications to use intelligent control devices and the automation of facilities (Kovács and Husti, 2018; Klerkx and Rose, 2020; Saiz-Rubio and Rovira-Más, 2020). Currently we are transitioning to agriculture 4.0. In this sense, it is worth mentioning that it will lead to a profound transformation in all agri-food systems and also great uncertainty around the political and social implications of its adoption (Fielke et al., 2019; Ingram et al., 2022). These technologies can benefit all stages and processes of the agri-food chain (da Silveira et al., 2023a).

Agriculture 5.0 (2010—to date) offers highly interconnected and data-intensive computing technologies and is oriented toward robotics and some form of artificial intelligence, autonomous decision-making systems in real time and focuses on protecting the environment (Ragazou et al., 2022; Vargas-Canales et al., 2022a; Juwono et al., 2023). It is worth mentioning that agriculture 5.0 requires the massive use of data and information and agriculture 4.0 technologies (Ragazou et al., 2022; Vargas-Canales et al., 2023a). Finally, agriculture 6.0 (2023 to date) that will provide specialized nature-based solutions to protect, manage and restore ecosystems in order to increase the response of productive environments and make agri-food systems healthier (Neves, 2023; Schattman et al., 2023). However, the benefits of these new technological revolutions will not be shared equitably due mainly to the technological, economic, political, social and environmental barriers of the different regions (da Silveira et al., 2023a,b). Therefore, it is important to design agri-food policies and strategically establish a political infrastructure that can address the sociotechnical problems that may arise (Fielke et al., 2019).

In the case of the agri-food sector, the changes, transformations and/or introduction of disruptive technologies that have occurred are very evident over time and are related to specific moments in the global economy (Pivoto et al., 2018; Vargas-Canales et al., 2022a). That is, 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. Furthermore, to the increase in the efficiency and complexity of tools and techniques that develop and evolve in human populations (Vitrano, 2017; Osiurak and Reynaud, 2019). The result of this recurring process is a gradual rejuvenation of the entire productive structure, so that mature and even updated industries can once again behave like new industries, in terms of dynamism, productivity and profitability (Pérez, 2001).

However, scientific and technological development is not completely objective, rational and innocuous, nor is it free of interests and intentions. Science and technology is developed from a social context and corresponds to a particular way of seeing and understanding the world, for this reason, the development and incorporation of technology depend on the social, political and economic bases of a society with specific characteristics and interests (Vargas Canales, 2023). Furthermore, it is developed in scientific fields and communities that respond to a logic and dynamic of organized creation (Kreimer, 2017), it is difficult to think that the neutrality of science and technology exists (Ward, 1989).

Technology contains the genetic code of the society in which it was developed, under the intentionality that was created and when favorable conditions exist for its growth and development, they tend to replicate the intentionality of the society that gave rise to it (Reddy, 1979). Likewise, given that the origin of technology is based on the principles and values of the society that generates it, when technologies are transferred; cultural forms, modes of human relationship, visions of life, etc. are transmitted (Herrera, 1978). In that sense, currently agri-food systems are subordinated to an economic and technological model in which only efficiency, productivity, profitability, and competitiveness matter (Vargas-Canales et al., 2023a).

That is, it is a technological system that is configured by neo-classical economic dynamics. Over time, agri-food systems were restructured, responding to the purely capitalist idea and logic. It is possible to perceive that in the agri-food sector, scientific and technological development presents a clear domination of the interests of certain sectors and global actors. With very clear objectives aimed at maximizing income, profitability and competitiveness of its capital. Even with a vision of the Green Revolution and with the predominance of excessive use of agrochemicals. In the current economic dynamics, the dominant economic elites gradually seek to guide all systems to meet their objectives, reproduce their capital and increase their wealth (Tello and Ibarra, 2020) without giving importance to the health and wellbeing of either society or the planet.

Scientific paradigms and scientific communities are completely imbued with the main premise of the dominant economic model, the maximization of economic profit (Camacho Vera, 2023). The development of science and technology seems to only be at the service of large transnational capitals. The ideas of neoclassical economics spread like a virus that was able to cross all borders and has shown an exponential capacity to infect not only living organisms and human beings but the economy, production, markets, politics, institutions (Cordera Campos, 2020). These interactions have caused a very strong distancing of science and technology from culture, nature and society, that is, it seems that there is a dissociation (Latour, 2007). Society is transforming its environment, its habits and its culture (especially food) very quickly and is moving further and further away from what is natural and biologically appropriate and its pace of evolution and adaptation is very slow.

## 3 Dynamics of agri-food systems

The agri-food sector is made up of all activities related to the production, collection, transformation, distribution and marketing of food for human consumption. Which come mainly from value chains related to agricultural, livestock, forestry, aquaculture activities, among others (Vargas-Canales et al., 2023a). The sector is complex and is made up of multiple national and international actors, such as farmers, input and service providers, manufacturers, importers, processors, packers, transporters, wholesalers, retailers, and consumers (Karwacka et al., 2020; Matthews, 2021). The importance of the agri-food sector for society goes far beyond the relevance for the economy of a nation given that it is the only economic sector that allows the reproduction of life. The food that society needs to live is produced in the agri-food sector (Vargas-Canales et al., 2023a).

Food security and food safety are highlighting the importance of the agri-food sector worldwide (Mizik, 2021). In addition, raw materials for energy production, essential fibers, construction materials, biomaterials and many essential non-food consumables are increasingly being obtained to produce medicines, flavors and natural colors. In recent decades, advances in these areas have positioned the functions of the agri-food sector as essential to improve human health and quality of life (Vargas Canales, 2023). Currently, the agri-food system is experiencing widespread changes in business models and the use of technologies (Ancín et al., 2022). The change, transformation and renewal of the agri-food sector caused by the development and evolution of society is inevitable and in the coming years it will experience a strong reconfiguration driven by a greater demand for foods with very specific characteristics and by scientific and technological development (Vargas Canales, 2023).

For some years now, the global agri-food sector has shown growing specialization aimed at crops with greater commercial value in the national or international market (Vargas-Canales et al., 2020, 2022b). This intensification of specialization responds to the logic of the theory of comparative advantage and is the basis of the neoclassical theory of international trade (Costinot et al., 2015). Consequently, to continue in international markets and be competitive, a strong comparative advantage is necessary and a high degree of specialization increases competitive advantages (Kang, 2018). This process of agriculturization or intensification of agriculture began with greater dynamism in the seventies and radically modified the forms of production, land uses and the social subjects involved (Gárgano, 2022). This production model implies greater use of fossil fuels, agrochemicals, fertilizers, fresh water and drives a massive concentration of wealth (Gárgano, 2023).

The aforementioned changes gradually caused local agri-food systems to transform and respond to the interests and needs of other populations outside the territories where they are produced. For example, in Mexico the production of red fruits (González-Ramírez et al., 2020), the development of global value chains has subordinated traditional agri-food systems. In Brazil, the demand from global markets and the growth of the livestock value chain has important implications for sustainability (Guéneau, 2018). In Indonesia, supermarket demand is causing the abandonment of traditional food value chains (Vetter et al., 2019). The above is determined by the constant demand of societies in the global north to consume sumptuous foods (Vargas-Canales et al., 2023a). That is, a small part of the population that concentrates more than 60% of the net wealth maintains an extravagant demand and consumption of unsustainable luxury goods (Ramírez, 2016). In this economic dynamic, the production systems have been subordinated to the market and it does not matter if they generate a significant environmental burden or if they transform the territories without considering their characteristics and evolution (Vargas-Canales et al., 2020, 2022b).

It is worth mentioning that, in pre-Hispanic times, societies maintained a balanced diet and after the arrival of the Europeans, the diet increased in carbohydrates and decreased in proteins. In addition, there was a transformation of ecosystems due to the imposition of new agricultural and livestock production systems (Martínez Martín and Manrique Corredor, 2014). Diet was gradually modified and the great diversity of healthy foods and genetic diversity were lost. Ancestral communities around the world consume a greater variety of plant and animal species (Vega Mejía et al., 2018). It was not understood that the true treasure of the native peoples consisted of the advanced development and technology of their food systems, which supported a circular worldview of the world, where human beings lived in permanent symbiosis with their natural environment (Torres Sandoval et al., 2023).

Currently, the technological model of the agri-food sector is configured by the current economic dynamics of efficiency, productivity, profitability and competitiveness. Over time it was restructured, responding to the capitalist idea and logic. In the agri-food sector, scientific and technological development presents an evident domination of the interests of certain sectors and global actors. With very clear objectives aimed at maximizing income, profitability and the rapid reproduction of your capital (Vargas-Canales et al., 2023a). With an increasing use of agrochemicals, pollution and depletion of natural resources. The modern agri-food production system depends on the use of synthetic pesticides and generates strong negative externalities that affect health, the environment, ecosystem services and production systems (Elizondo, 2020; Alliot et al., 2022).

The monopolistic concentration of transnationals and the current market rules, with the complicity of the State, have resulted in a handful of powerful companies controlling food production and prices (García and Bermúdez, 2016). In the globalized agri-food system, competition shapes social and economic relations in the processes of production, transformation, distribution and consumption of food (Hernández Moreno and Villaseñor Medina, 2014). Companies reproduce objectives and interests oriented according to the formation of dominant groups in each place (Fracarolli, 2021). Furthermore, agri-food systems aimed at reproducing life, rather than profit, and with it the production of healthy, nutritious, safe and culturally appropriate foods have been marginalized and in some cases completely dismantled (Vargas-Canales et al., 2023a).

Changes in dietary regimes and the replacement of traditional production systems, harmonious with nature, with industrialized ways of growing and processing food that threaten environmental and human health have been promoted (Bermúdez and García, 2020). In that sense, it seems that science and technology are only at the service of transnational corporations (Liaudat, 2020) and that their approaches are the only valid ones. The problem with the above lies in the fact that the effects and impacts of the scientific and technological development that it generates on social, political, economic, cultural, environmental and, above all, health issues are not known (Vargas Canales, 2016). It is necessary to mention that we have everything to achieve healthy and adequate food production. It is pertinent to mention that the production of healthy, safe and culturally appropriate foods can be achieved without many complications. There is great agrobiodiversity, for example, Mexico is one of the most important centers of origin in domestication and continuous improvement of food species (Bermúdez and García, 2020).

Continuing with the previous example, Mexico has unique ecological, climatological, cultural, social and economic characteristics worldwide to implement sustainable, highly productive and diversified agri-food systems; with a production capacity 365 days a year (Vargas-Canales et al., 2023a). Derived from the above, it is important to increase scientific capacity, expand research collaborations between the public and private sectors, between farmers, emerging companies in value chains and scientific communities, share research infrastructure and data between the south and the north global (von Braun et al., 2023). To achieve this, it is essential to promote systemic interactions, formalize the flows and management of information and knowledge among interested parties, facilitate the generation and management of knowledge and innovation (Gardeazabal et al., 2023).

## 4 Food and health

Currently, more food is produced than what we as a population require to be well fed, however, hunger persists. Food loss and waste along distribution chains is estimated to be 31% [Food and Agriculture Organization of the United Nations (FAO, 2019); United Nations Environment Programme (UNEP, 2021)]. The FAO (Food Agriculture Organization of the United Nations, 2011) has reported for more than a decade that consumers in industrialized countries waste an amount of food equivalent to the total food production of sub-Saharan Africa. The above indicates that more food is produced than is required to feed the population and that it is a matter of distribution, not production. Without a doubt, the agri-food sector is essential to end poverty and guarantee food security in developing countries (Dhahri and Omri, 2020).

However, it is estimated that 821 million people in the world do not have enough food to live an active and healthy life. The vast majority of the world's hungry people live in developing countries. Furthermore, 12.9 percent of the world's population is undernourished (Kiliç, 2022). At the same time, there are worrying global trends in malnutrition, including the rapid rise in overweight and obesity (Wells et al., 2021; Vargas-Canales et al., 2023a). The new nutritional reality comprises a global double burden of malnutrition, where the challenges of food insecurity, nutritional deficiencies and malnutrition coexist and interact with obesity, sedentary behavior and unhealthy diets and environments that encourage unhealthy behaviors (Wells et al., 2021). For example, in Mexico it is estimated that 4.8% of children <5 years old were underweight, 14.2% short in height, and 1.4% wasted (Cuevas-Nasu et al., 2021). On the other hand, the combined prevalence of overweight (39.1%) and obesity (36.1%) affects about 8 out of 10 people aged 20 years or older (Kánter, 2021). It is important to mention that the above is one of the main threats to society today and has become a global challenge (Wells et al., 2021).

The origin of the above is largely due to the transformations of agri-food systems and the drastic change in the food regime, caused by the specific historical relationships of capitalism (Vargas-Canales et al., 2023a). The different food regimes are directly linked to the historical periods of capital accumulation and in this enormous historical expansion of the capitalist market the favorable context was given to influence taste, massify consumer trends and modify agri-food systems (Hiramatsu et al., 2023). Global economic cycles are what determine economic models, science and technology systems and therefore production systems, and to be more efficient in the reproduction of capital, low production costs and cheap food are required. Sustainable agri-food systems have higher production costs (He et al., 2023). It seems like there is no way to escape modern eating. Changes in agri-food systems transformed the eating, health and wellbeing habits of the population. The abandonment of traditional diets, the consumption of processed products and sugary drinks have increased caloric income per person per day in the last 50 years. This situation, together with the growing sedentary lifestyle, has led to the development of obesity and diseases associated with excess malnutrition, mainly those of cardiometabolic origin (González-Montero De Espinosa et al., 2017).

Globalization, the loss of biodiversity, the preference for industrialized foods instead of traditional foods and migration from the countryside to the city have led to a drastic change in lifestyle, such that currently there is a distancing important between the degree of evolution of the genome *Homo sapiens* and its ancestral environment (Román et al., 2013). All of this refers to the agri-food system, the production and consumption of ultra-processed food, with low nutritional levels, and the appropriation of agri-food chains by companies that are more concerned with maintaining a long life of food, rather than food quality (Liaudat, 2020). Recently, a clear relationship has been detected between the consumption of ultra-processed products and mortality (Brambila-Paz et al., 2023). Processed foods have a high environmental cost and require enormous amounts of water and agrochemicals (Vega Mejía et al., 2018).

Furthermore, the consumption of modern foods involves consuming sweeteners such as aspartame, especially in light and/or diet products, recently classified as potentially carcinogenic by the International Agency for Research on Cancer (IARC) [World Health Organization (WHO, 2023)]. Aspartame is one of the most widely used artificial sweeteners in the world and is an ingredient in more than 5,000 food products (Landrigan and Straif, 2021). Of course, there is great controversy about its effects and there is research that the consumption of aspartame is not carcinogenic in humans and that the inconsistent findings of the studies carried out can be explained by flaws in the design and conduct of the study (Haighton et al., 2019; Borghoff et al., 2023). However, others suggest that all national and international public health agencies urgently re-examine the health risk assessments of aspartame as it is considered a high priority for its carcinogenicity in humans (Landrigan and Straif, 2021).

There are many components of food modernity, such as ultra-processed products, the use of agrochemicals to produce and preserve food, and monocultures, which greatly affect health and the environment. However, this analysis has a systemic approach and its object of study is agri-food systems and specifically an approach is made to the chemical substances used for agricultural and livestock production (agrochemicals, antibiotics and growth regulators). Currently, residues are being detected in practically all food chains of various products, such as bread, cereals, vegetable oil, fruit juices, fruits, beer, wine, honey, eggs and others (Khazaal et al., 2022; Rivas-Garcia et al., 2022; Ambrus et al., 2023). These types of substances are used massively in practically all agri-food production processes. It is worth mentioning that there has been evidence of their effects for several years; the problem is that they are analyzed in isolation and with little connection to the dynamics of agri-food systems and their implications for health and wellbeing. In this sense, a critical analysis of agri-food systems is developed with the purpose of encouraging the development of new research on these complex problems from different perspectives.

In the case of agrochemicals, it is true that they are contributing to the need to increase food production in current agriculture. More than 1,000 pesticides are used worldwide to ensure that pests do not damage or destroy food (WHO, 2022). Pesticide uses are not limited to agriculture, they are also used to control household pests, disease vector insects, and home gardening. But they are highly toxic by nature and pose serious risks to human health and the environment (Rani et al., 2021). It is estimated that around 385 million people get sick from the use of agrochemicals in the world and 11,000 deaths occur per year (Boedeker et al., 2020; Bär et al., 2022). People in Asia, Latin America and Africa are especially affected, it is where sales of agrochemicals are increasing and regulations are very lax (Bär et al., 2022). Additionally, about

44% of farmers and farm workers are poisoned by pesticides each year (Boedeker et al., 2020). Exposure to agrochemicals is extremely destructive to flora, fauna and the environment (Rani et al., 2021).

Since 1990, human poisoning by agrochemicals was seen as a serious public health problem (Boedeker et al., 2020). Thirty years later, there is no updated picture of agrochemical poisoning worldwide despite the increase in their use globally (Boedeker et al., 2020). The use of agrochemicals worldwide has transformed in the last two decades, but social science research has not kept pace. For example, a huge generic sector has emerged, changes in the geographies of agrochemical production and the dynamics of the agri-food sector have led to greater use of agrochemicals. Furthermore, decreased effectiveness due to resistance to agrochemicals and low institutional support for non-chemical alternatives have also driven the intensification of conventional systems (Mansfield et al., 2023).

The problem with the increased use of agrochemicals is the harmful effects they generate on health and the environment. The main long-term effects of agrotoxics can be grouped into those that directly affect the exposed individual, such as sterility, aplastic anemia, cancer and various disorders, and those that are observed in their offspring (teratogenesis, mutagenesis, alterations of the immune system and/or of the central nervous system) (Shah, 2020; Islam et al., 2021; Rani et al., 2021). People exposed to pesticides are at increased risk of developing several types of cancer, including non-Hodgkin lymphoma (NHL), leukemia, brain tumors, and cancers of the breast, prostate, lung, stomach, colorectal, liver, and urinary bladder (Shah, 2020). Evidence on exposure to agrochemicals indicates an increase in the occurrence of neurological syndromes or disorders. The most common diseases related to the neurotoxic impact of agrochemicals are Parkinson's and Alzheimer's (Islam et al., 2021; Rani et al., 2021). In addition, they are related to respiratory disorders that are expressed in lung diseases, such as asthma, bronchitis, hypersensitivity pneumonitis and neuromuscular respiratory failure among agricultural workers (Rani et al., 2021).

Diabetes mellitus is one of the main causes of death and projections agree on a growing trend of the disease and associate it with conditions of vulnerability (concentration of the population in urban areas, decrease in physical activity, among others) and genetics, related to changes in genes associated with human evolution (Vera-Cruz, 2021). However, several studies confirmed the correlation between exposure to agrochemicals and diabetes. Herbicides have been linked to an increased risk of developing diabetes (Jayaraman et al., 2023). That is, continuous contact with agrochemicals amplified the risk of suffering from diabetes (Rani et al., 2021). Glyphosate has been shown to negatively influence endocrine function and exposure to glyphosate has a deleterious effect causing skeletal muscle to become insulin resistant and eventually developing type 2 diabetes mellitus (Jayaraman et al., 2023).

Glyphosate has long been classified as a carcinogen. Epidemiological evidence supports strong correlations between glyphosate use in crops and a multitude of cancers that are reaching epidemic proportions (Samsel and Seneff, 2015). Likewise, maintaining prepubertal exposure to glyphosate alters testosterone levels and testicular morphology. It is a situation similar to what occurs in amphibians exposed to atrazine, processes of demasculinization and feminization of male gonads occur. Atrazine is one of the most used herbicides worldwide. The problem is that exposure to atrazine in adult amphibians has important reproductive consequences. Males exposed to atrazine are demasculinized (chemically castrated), are completely feminized, exhibit depressed testosterone, suppressed mating behavior, reduced spermatogenesis, and decreased fertility (Hayes et al., 2010).

Other illnesses related to food modernity are the increasingly frequent cases of psychological and/or psychiatric problems, which are also related to agrochemicals. There is an association between exposure to glyphosate and biomarkers indicative of neurological damage in adults (Yang et al., 2023). For example, maternal exposure of mice to low doses of glyphosate induced behaviors similar to depression, anxiety, and social deficits in the offspring (Buchenauer et al., 2023). Furthermore, exposure to pesticides leads to alterations in the profiles of the intestinal microbiota and problems with anxiety and depression (Matsuzaki et al., 2023). The gut microbiota is called the second human brain, as it plays a key role in regulating the central nervous system and has been correlated with alterations in major depressive disorder and other psychiatric disorders (Yang et al., 2020).

Likewise, the main malformations presented are related to the reproductive system, nervous system, musculoskeletal system, transverse limb deficiencies, digestive system and other malformations such as fetal growth restrictions, cleft palate and congenital heart diseases (Costa et al., 2021). These expressions of damage have been documented in different regions that use some agrochemicals massively and indiscriminately. However, it is true that methodologically it is very difficult to establish the causal relationship of any of these indicators with the effects of chronic exposure to these chemical agents (Rojas et al., 2000). For example, in Brazil the highest rates of congenital anomalies were found in the microregions of the states with the highest grain production and may be due to the population's exposure to agrochemicals (Dutra and Ferreira, 2019).

In the livestock sector, recent analyzes identify the consumption of commercial milk as a critical risk factor for breast cancer (Melnik et al., 2023). It is also associated with bladder and prostate cancer, although there is much controversy about the studiess (Dong et al., 2011; Larsson et al., 2020). Regarding the protein of animal origin that is consumed, the vast majority has high amounts of antibiotics. Consequently, enormous resistance of microorganisms to antibiotics is generated over time. Antibiotic resistance is a natural phenomenon, although misuse in humans and animals is accelerating the process. This problem is today one of the greatest threats to global health, food security and development. Antibiotic resistance prolongs hospital stays, increases medical costs and increases mortality (WHO, 2020).

Animal production uses chemicals called growth promoters such as steroid hormones, synthetic anabolics, growth hormone, antibiotics and the use of genetically modified foods to accelerate, alter or modify the animals' metabolism, growth processes and increase the production of meat. However, the impact of these foreign substances on the human body, including their pharmacokinetics and effects at the molecular level, requires investigation before establishing their apparent safety in humans (Fajardo-Zapata et al., 2011). The use of growth promoters always ends up causing the appearance of residues in foods of animal origin (Hirpessa et al., 2020). In the case of hormones, the World Health Organization suggests that very low values in relation to daily human production could generate unwanted physiological effects, and cause biological alterations, alter physiological effects, and create important changes not yet identified (Fajardo-Zapata et al., 2011).

An important aspect to consider is the permitted or suggested consumption so as not to put human health at risk, which is the mean lethal dose developed by John William Trevan since 1927. Which is defined as the amount of the dose of a substance, radiation or pathogen necessary to kill half of a set of test animals after a given time (Pillai et al., 2021). It is a general indicator of the acute toxicity of a substance that in some cases could be thought to be very high and it is difficult to reach that dose. However, living organisms do not completely discard what they consume, much less chemicals. Living organisms begin a process of bioaccumulation and biomagnification of these substances (Streit, 1992), that is, it is known that there is no complete elimination and what is known as bound waste that accumulates over time (Beek et al., 2005). The drawback is that it is not known when the average lethal dose could be reached and the effects of these processes on humans are not known. However, it can be inferred that consequences similar to those that occur in other long-term experimental species or in the offspring could occur. If we do not pay attention to these long-term processes in a short time, pandemic effects could occur.

Derived from the above, the agri-food modernity that is experienced today is an illusion that systematically sickens everything and gradually brings us closer to imminent annihilation. Under these conditions and only related to the diet and agri-food systems, it is practically impossible for Homo sapiens to express the maximum genetic potential. Society in general has a low perception of contamination risks from the use of agrochemicals, as well as risks to human health and the environment (Polanco Rodríguez et al., 2019; da Silva et al., 2020). Nor does it identify the risk associated with the consumption of animal protein, especially with respect to antibiotics and hormones. Furthermore, the long-term effects of changes in behavior or health are less visible and analyzed. On the other hand, it is true that as a species we are evolving and co-evolving and we would have to adapt to these problems. The drawback is that *Homo sapiens* does not have such a rapid capacity for evolution and adaptation. Adapting to these drastic changes and metabolizing agrochemicals requires thousands or millions of years of evolution.

## 5 Recommendations and alternatives on food and wellbeing

The lifespan of organisms can be extended through genetic, dietary, and pharmacological interventions, but these effects can be nullified by other factors (Podolskiy et al., 2020). In human beings, 120–150 years of age corresponds to a complete loss of resilience and is the fundamental or absolute limit of human life (Pyrkov et al., 2021). The above coincides with other analyzes that revealed that the limits of attainable longevity for humans are close to 138 years (Podolskiy et al., 2020). However, in order to express the maximum genetic potential, favorable economic, social and environmental conditions are required, which are not present today. In addition, life expectancy decreased with the pandemic (Schöley et al., 2022) and theoretically it should increase with all scientific and technological development.

It is true that there is a gradual development of greater awareness about the constant crises caused by environmental, economic, social and health problems. That is to say, there is consensus in the scientific community that the current model can lead to an environmental and health catastrophe in the long term [Comisión Económica para América Latina y el Caribe (CEPAL, 2016)]. In that sense, it is convenient to think about sustainable production systems that improve the health conditions of the population. The above with the purpose of moving toward a state in which the ecosystems improve their health conditions and can carry out all their functions normally. It is also essential to think about a state of wellbeing that allows peace, tranquility, stability and social satisfaction to be achieved to achieve adequate physical, emotional, and intellectual development.

Improving food systems to make them more sustainable and resilient must be a priority more than ever (Boyacι-Gündüz et al., 2021). In this sense, in order to be able to propose alternatives for the future of the agri-food sector, it is convenient to think about some possible global scenarios. And do it with the vision of developing better production, nutrition, protecting the environment and improving life (FAO, 2021). Everything seems to indicate that the future will be determined by climate change, natural disasters, pandemics, armed conflicts and greater economic instability (Vargas-Canales et al., 2023a). Given this adverse scenario, the challenge for the future is to guarantee the level of wellbeing and consumption of the population and I believe that it could be achieved as mentioned above with scientific and technological development, but seeking a balance in two ways.

First, by offering appropriate technologies to address current problems. That is, technology designed in accordance with environmental, ethical, cultural, social, economic aspects and the needs of users (Schumacher, 1973). The second way is through the transformation of demands. In that sense, it is necessary to change our food culture. A food culture that in recent years has become one of the main sources of health problems and that has important implications for climate change (Vargas Canales, 2023). Given these scenarios, it is necessary to reorient agri-food markets and promote their transition toward sustainability from demand (Borsellino et al., 2020). That is, to heal, recover and improve agri-food systems, it is necessary to completely detoxify the current production dynamics and resume production systems that are based on ethics for life. Hence, a transformation of all the links that make up the agri-food sector is necessary, from production on the land to our mouths (Bermúdez and García, 2020).

Additionally, propose alternatives that have low costs (economic, social, and environmental) and that can be implemented massively in the short term. That is, they must be affordable so that the majority of the population can benefit. For example, currently scientific development has health alternatives such as organ reproduction in laboratories, artificial organ transplants, muscle-skeletal tissue transplants, novel and effective treatments to prevent, treat and eradicate cancer, however, they are very They are expensive and only a small part of the population can access them. The best way to attack current health epidemics is through prevention. That is, given the importance and relevance that agri-food systems have for life, health and wellbeing, it is essential that they adequately develop their functions of producing food. Foods that do not make the population sick, healthy foods free of agrochemicals, antibiotics, growth regulators, among others.

Derived from the above, the alternatives to start with the dynamics of healing, recovering and improving agri-food ecosystems and systems require resuming many of the technological systems that have existed, but that at some historical moment have been abandoned. Furthermore, it is essential to complement them with the most innovative technological developments. These are technological strategies that start from the same philosophical current. These are technological models and modes of production that can achieve an adequate symbiosis with the environment, with communities, with economies and with the planet. If they are disseminated, promoted and supported as part of a comprehensive agri-food policy, it is possible for production systems to be as productive, profitable and competitive as they are today.

The first technological system is *agroecology*, that which can be conceived as a possible epistemological core for a new food model; because, as a social and technical paradigm, it contemplates not only a technological proposal but also for the organization of production with a different configuration of actors, technology, marketing, participation of the State and communities and relations of can. Agroecology can be considered pluriepistemological since it does not rule out scientific knowledge, but does not give it priority over other types of knowledge (Ruiz-Rosado, 2006; Gavito et al., 2017; Borsellino et al., 2020). Agroecology is gaining more and more ground and has proven to contribute positively to food security, nutrition, organization and the economy (Bezner Kerr et al., 2021, 2022). The second is *family farming*, which is the central element of the proposals to achieve the food production that we as a society require. It is aimed at the production of foods of animal and plant origin in small production units with family labor, allowing the reproduction of the activity in the community and thereby safeguarding agri-food biodiversity and the sustainable use of natural resources. This type of agriculture encompasses more than 90% of agribusinesses around the world and has the capacity to produce more than 80% of the food calculated globally, as a requirement for society to live well (FAO, 2022). It also contributes to reducing food waste and losses, since consumers have easier access to quality products at affordable prices (Dal Moro et al., 2022).

The third is *organic agriculture* and its methods that involve considering harmony with the environment. Organic agriculture is a global production management system that encourages and facilitates the health of agroecosystems, biological diversity, biological cycles and soil biological activity. This is achieved by harmoniously applying agronomic, biological and mechanical methods (Céspedes, 2005). Organic agriculture in recent years has presented a constant growth trend with an annual rate of 10–15% with positive impacts on economic and ecological problems (Khodakivska et al., 2020). The fourth is the *social solidarity economy*, which has as its goal the conscious construction of an economic system. They are organized through social relations of production and exchange based on the non-exploitation of other people's labor, on fair exchange, reciprocity, cooperative competition, emulation, association, and recognition of the other as a peer, without renouncing rights and personal interests, that are legitimate (Coraggio, 1979, 2020). It is about generating well-being and sustainability (Belmont et al., 2022). It involves new forms of organization and business models that are capable of creating value but that are based on sustainable agri-food systems (Jonker and Faber, 2021).

Finally, component number five is *agriculture 4.0, 5.0 and 6.0*, these consist of including and integrating the latest developments based on digital technologies and the care and recovery of the environment. Agriculture 4.0 or digital agriculture is based on the use of sensors, the Internet of Things, drones, the intelligent use of data and communications to use intelligent control devices and the automation of facilities (Kovács and Husti, 2018; Klerkx and Rose, 2020; Saiz-Rubio and Rovira-Más, 2020; da Silveira et al., 2023a). Agriculture 5.0 is a second phase of domain or application and offers highly interconnected and data-intensive computer technologies and is oriented toward artificial intelligence, autonomous decision-making systems in real time and focuses on protecting the environment (Ragazou et al., 2022; Vargas-Canales et al., 2022a; Juwono et al., 2023). These technologies offer several benefits and positive impacts that are obtained from their implementation and are focused on sustainability and care for the environment (Rolandi et al., 2021; Bellon-Maurel et al., 2022).

Agriculture 6.0 is about offering specialized solutions based on the protection of nature, the management and restoration of ecosystems in order to increase the response of productive environments and make them healthier (Neves, 2023; Schattman et al., 2023). This version of the technology is the one that is most compatible with the previous alternatives. It generally includes regenerative agriculture, bioeconomy, circular economy, recovery and reuse of nutrients, the use of biofuels and bioenergy, some proposals for economic incentives and the cooperation and collaboration of all agents in innovation systems (Maroušek et al., 2023; Piscicelli, 2023; Vargas-Canales et al., 2023b; Zhu et al., 2023). The above is essential to improve global health, reduce regional disparities and improve protection against global health threats (Sekar et al., 2021).

Consequently, if governments invest in research and development to strengthen these technological alternatives and their components and if incentives and stimuli are developed for the population to adopt and adapt these technologies, in a not so long period of time important results could be obtained in the processes of healing, recovering and improving agri-food systems. To achieve this, it is necessary to design and implement national policies in which all actors related to health policies, agri-food production, and education and research policies participate. In addition, integrate large transdisciplinary work and research groups, which make it possible to address problems and propose alternatives from different perspectives. It is advisable to develop forms of collective work that include values and contribute to sustainable human development (Paoli Bolio, 2019). Subsequently define programs for the dissemination and dissemination of problems and/or controversies in relation to science, technology, agri-food systems, health and wellbeing with the aim of having a true impact on society and genuine social appropriation of knowledge.

## 6 Final considerations

The relationships between science, technology, agri-food systems, health and wellbeing are clear and very evident. That is, the economic model determines the type of scientific and technological development in the agri-food sector and this has important implications for health and wellbeing. There is research that has documented the harmful effects of technological models on health for decades. Which allows us to infer that scientific findings on these relationships are denied, minimized and/or marginalized because they go against the logic of the reproduction of capital. It is correct to doubt their veracity, objectivity, neutrality and harmlessness, however, there is a lack of dissemination, debates and academic and public discussions about it. Furthermore, in the face of controversies that could have a very strong impact on health, the precautionary principle should be adopted and it should be prohibited before there is conclusive scientific evidence of no risk.

Food today comes from an agri-food sector subordinated to an economic and technological model. The poison (agrochemicals and other molecules) ends up on everyone's plates despite regulations, accreditations, and certifications. Some effects have been identified exactly, others are not clear, but consequences similar to those that occur in other long-term experimental species or in offspring would be expected and effects in pandemic proportions would be expected. The most affected population is those with the lowest income and who are found in Latin America, Africa, and Asia. In these regions, it is urgent to improve regulations related to agrochemicals and implement training for users on their uses and possible consequences. In that sense, the alternatives proposed are ideal to begin with the logic of healing, recovering and improving agri-food systems to achieve the health and wellbeing of society and the planet.

Under current conditions, only related to the diet, it is not possible for the human genome to express its maximum potential and for us to be able to increase life expectancy and thereby achieve adequate physical, emotional and intellectual development. The above positions the agri-food sector as the most priority and as a society it must be valued or revalued with a vision of the future, of sustainability and based on ethics for life. Furthermore, it is imperative to begin with a total reconfiguration of technological models and economic relations.

The society in general has little access to information related to these issues and little knowledge of these problems and their origins. Consequently, there is practically no ability to influence scientific controversies of this type. Derived from the above, it is important to implement outreach programs and public discussions on these topics in order to achieve a true impact on society and genuine social appropriation of knowledge. It is essential to promote the integration and consolidation of broad work and research groups. Furthermore, design and implement national agri-food policies that stimulate the alternatives raised above and address these serious problems in which all actors in the innovation systems participate.

The potential benefits that could be expected from the promotion and implementation of the proposed alternatives are multiple and in general are the following: (1) improve and increase the diversity of foods of the population, (2) improve nutrition through culturally appropriate diets and of better quality, (3) maintain the community, improve social cohesion and self-organization, (4) increase species conservation and improve animal and plant genetic diversity, (5) increase financial autonomy and reduce dependence on external inputs and resources, (6) reduce the use of agrochemicals and other molecules used for food production, and (7) improve food security, health and wellbeing. With the correct planning and management, it could be achieved, in the long term and with sufficient investment in research, to satisfy the growing demand for healthy and innocuous foods.

The limitations of this work are that it lacks a deeper analysis of these issues and their relationships in more regions and countries. Furthermore, it is necessary to identify the dynamics and culture of the different agri-food systems and their advantages and disadvantages. For future research, it is important to continue documenting this problem and develop more research with solid evidence on the effects of agrochemicals on health. It is essential that the health dimension be integrated as a category of analysis in all research, evaluate the impact of the use of agrochemicals used in different agri-food systems on the environment and health, and monitor the content of agrochemicals in all agri-food product

## Author contributions

JV-C: Conceptualization, Investigation, Project administration, Writing – original draft, Writing – review & editing, Methodology, Supervision, Formal analysis, Validation. SO-C: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. SE: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. PC-O: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. JC-V: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. DL-C: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. NG-M: Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. BR-H: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. AV-C: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. YS-T: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. JF-R: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. MP-R: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. JO-L: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. OB-P: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. JP-P: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. PK: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review

& editing. JG-C: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. DR-B: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. JM-F: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. TB-L: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. EG-S: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. BH-H: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. VE-Q: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. CS-C: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. JB-P: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. SM-C: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. RG-R: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing.

## Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The APC was funded by Universidad de Guanajuato.

## Acknowledgments

We thank all the institutions participating in this work for promoting freedom, truth, and critical work in their teachers, researchers, and students, of course always thinking about the wellbeing of society.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

## References

Alliot, C., Mc Adams-Marin, D., Borniotto, D., and Baret, P. V. (2022). The social costs of pesticide use in France. *Front. Sustain. Food Syst.* 6:1027583. doi: 10.3389/fsufs.2022.1027583

Ambrus, Á., Vásárhelyi, A., Ripka, G., Szemánné-Dobrik, H., and Szenczi-Cseh, J. (2023). Evaluation of the results of pesticide residue analysis in food sampled between 2017 and 2021. *Agrochemicals* 2, 409–435. doi: 10.3390/agrochemicals2030023

Anand, G., Larson, E. C., and Mahoney, J. T. (2020). Thomas kuhn on paradigms. *Prod. Operat. Manag.* 29, 1650–1657. doi: 10.1111/poms.13188

Ancín, M., Pindado, E., and Sánchez, M. (2022). New trends in the global digital transformation process of the agri-food sector: an exploratory study based on Twitter. *Agric. Syst.* 203, 103520. doi: 10.1016/j.agsy.2022.103520

Bär, J., Bickel, U., Bollmohr, S., Bombardi, L. M., Bourgin, C., Bödeker, W., et al. (2022). *Pesticide Atlas 2022.* Heinrich-Böll-Stiftung. Available online at: https://www.arc2020.eu/wp-content/uploads/2022/10/PesticideAtlas2022_Web_20221010-1.pdf (accessed March 17, 2023).

Bardi, U. (2014). *Los l?mites del crecimiento retomados.* Madrid: Los Libros de la Catarata.

Beek, B. (ed.) (2005). "The assessment of bioaccumulation," in *in Bioaccumulation – New Aspects and Developments* (Berlin/Heidelberg: Springer-Verlag), 235–276.

Bellon-Maurel, V., Lutton, E., Bisquert, P., Brosard, L., Chambaron-Ginhac, S., Labarthe, P., et al. (2022). Digital revolution for the agroecological transition of food systems: a responsible research and innovation perspective. *Agric. Syst.* 203, 103524. doi: 10.1016/j.agsy.2022.103524

Belmont, C. E., Ribeiro-Palacios, M., and León-Salazar, C. (2022). Salir de la lógica dominante: contribuciones teóricas desde la Economía Social Solidaria. *Religación* 7, e210889. doi: 10.46652/rgn.v7i31.889

Bermúdez, G., and García, M. E. (2020). *Descolonizar de la tierra a la mesa... y hasta el paladar*. La Jornada del Campo. Available online at: https://www.jornada.com.mx/2020/10/17/delcampo/articulos/descolonizar-tierra.html (accessed September 2, 2023).

Bezner Kerr, R., Lieber, J., Kansanga, M., and Koienbaaren, D. (2022). Human and social values in agroecology. *Elementa* 10, 1–24. doi: 10.1525/elementa.2021.00090

Bezner Kerr, R., Madsen, S., Stuber, M., Liebert, J., Enloe, S., Borghino, N., et al. (2021). Can agroecology improve food security and nutrition? A review. *Global Food Sec.* 29, 100540. doi: 10.1016/j.gfs.2021.100540

Boedeker, W., Watts, M., Clausing, P., and Marquez, E. (2020). The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. *BMC Public Health* 20, 1875. doi: 10.1186/s12889-020-09939-0

Borghoff, S. J., Cohen, S. S., Jiang, X., Lea, I. A., Klaren, W. D., Chappell, G. A., et al. (2023). Updated systematic assessment of human, animal and mechanistic evidence demonstrates lack of human carcinogenicity with consumption of aspartame. *Food Chem. Toxicol.* 172, 113549. doi: 10.1016/j.fct.2022.113549

Borsellino, V., Schimmenti, E., and El Bilali, H. (2020). Agri-food markets towards sustainable patterns. *Sustainability* 12, 2193. doi: 10.3390/su12062193

Boyacı-Gündüz, C. P., Ibrahim, S. A., Wei, O. C., and Galanakis, C. M. (2021). Transformation of the food sector: security and resilience during the COVID-19 pandemic. *Foods* 10, 497. doi: 10.3390/foods10030497

Brambila-Paz, J. D. J., Rojas, M. M., Damian, M. M., and Cerecedo, V. P. (2023). Mortandad por enfermedades modernas en función del consumo de productos ultraprocesados: caso México. *Agric. Soc. Desarrollo* 20, 1–11. doi: 10.22231/asyd.v20i2.1481

Buchenauer, L., Haange, S.-B., Bauer, M., Rolle-Kampczyk, U. E., Wagner, M., Stucke, J., et al. (2023). Maternal exposure of mice to glyphosate induces depression- and anxiety-like behavior in the offspring via alterations of the gut-brain axis. *Sci. Total Environ.* 905, 167034. doi: 10.1016/j.scitotenv.2023.167034

Calder, P. C. (2020). Nutrition, immunity and COVID-19. *BMJ Nutr. Prev. Health* 3, 74–92. doi: 10.1136/bmjnph-2020-000085

Calder, P. C., Carr, A. C., Gombart, A. F., and Eggersdorfer, M. (2020). Reply to "comment on: optimal nutritional status for a well-functioning immune system is an important factor to protect against viral infections. *Nutrients* 12, 2326. doi: 10.3390/nu12082326

Calder, P. C., and Kew, S. (2002). The immune system: a target for functional foods? *Br. J. Nutr.* 88, S165–S176. doi: 10.1079/BJN2002682

Camacho Vera, J. H. (2023). Modernidad tecnológica en la producción de alimentos: ¿otro campo es posible? *Encrucijadas* 23, 1–24.

CEPAL (2016). *Ciencia, Tecnología e Innovación en la Economía Digital. La situación de América Latina y el Caribe.* Naciones Unidas, Impreso en Santiago, Comisión Económica para América Latina y el Caribe (Santiago), 96.

Céspedes, M. C. (2005). *Agricultura orgánica. Principios y prácticas de producción.* Boletín INIA-Instituto de Investigaciones Agropecuarias. Available online at: https://200.54.96.10/handle/123456789/7064

Coraggio, J. L. (1979). *Sobre la espacialidad social y el concepto de región*. Centro de Estudios Económicos y Demográficos, El Colegio de México. Available online at: http://www.coraggioeconomia.org/jlc/archivos-para-descargar/Espacialidad-social-y-el-conceptode$\sim$región.pdf (accessed March 26, 2022).

Coraggio, J. L. (2020). *Economía social y economía popular: Conceptos básicos*, 16. Available online at: https://www.coraggioeconomia.org/jlc/archivos/para/descargar/Economia/Social/y/Economia/Popular/Conceptos/Basicos.pdf (accessed March 26, 2022).

Cordera Campos, R. (2020). La "revolución de los ricos": Bajo la tormenta. *Trimest. Econ.* 87, 887–896. doi: 10.20430/ete.v87i347.1117

Costa, N. Z., Nora, C. R. D., Souto, L. H. D., Carlotto, F. D., Afonso, R. D. S., and Riquinho, D. L. (2021). Exposure to toxic agrochemicals and development of congenital malformations: a scoping review. *Texto Contexto Enfermagem* 30, 1–18. doi: 10.1590/1980-265x-tce-2020-0372

Costinot, A., Donaldson, D., Vogel, J., and Werning, I. (2015). Comparative advantage and optimal trade policy. *Q. J. Econ.* 130, 659–702. doi: 10.1093/qje/qjv007

Cuevas-Nasu, L., García-Guerra, A., González-Castell, L. D., Morales-Ruan, M. D. C., Humarán, I. M.-G., Gaona-Pineda, E. B., et al. (2021). Magnitud y tendencia de la desnutrición y factores asociados con baja talla en niños menores de cinco años en México, Ensanut 2018-19. *Salud Pública de México* 63, 339–349. doi: 10.21149/12193

da Silva, J. C. B., Dipe, F. L., Leite, C. S., Almeida, A. A., and Pires, O. C. (2020). Exposure to agricultural pesticides and use of personal protection equipment by small-scale farmers in a municipality of Minas Gerais, Brazil. *Ambiente e Agua* 15, 1. doi: 10.4136/ambi-agua.2542

da Silveira, F., Barbedo, J. G. A., da Silva, S. L. C., and Amaral, F. G. (2023a). Proposal for a framework to manage the barriers that hinder the development of agriculture 4.0 in the agricultural production chain. *Comp. Electron. Agric.* 214, 108281. doi: 10.1016/j.compag.2023.108281

da Silveira, F., da Silva, S. L. C., Machado, F. M., Barbedo, J. C. A., and Goncalves, F. (2023b). Farmers' perception of the barriers that hinder the implementation of agriculture 4.0. *Agric. Syst.* 208, 103656. doi: 10.1016/j.agsy.2023.103656

Dal Moro, L., Mazutti, J., Bradii, L. L., Casagranda, Y. G., and Mores, G. (2022). Overcoming the challenges of sustainable family agriculture in Southern Brazil: contributions to the 2030 agenda. *Sustainability* 14, 8680. doi: 10.3390/su14148680

Dhahri, S., and Omri, A. (2020). Foreign capital towards SDGs 1 & 2—Ending Poverty and hunger: the role of agricultural production. *Struct. Change Econ. Dyn.* 53, 208–221. doi: 10.1016/j.strueco.2020.02.004

Dong, J. Y., Zhang, L., He, K., and Qin, L. Q. (2011). Dairy consumption and risk of breast cancer: a meta-analysis of prospective cohort studies. *Breast Cancer Res. Treat.* 127, 23–31. doi: 10.1007/s10549-011-1467-5

Dutra, L. S., and Ferreira, A. P. (2019). Tendência de malformações congênitas e utilização de agrotóxicos em commodities: um estudo ecológico. *Saúde em Debate* 43, 390–405. doi: 10.1590/0103-1104201912108

Elizondo, C. (2020). *Rumbo al sistema agroalimentario que necesitamos: GISAMAC*. La Jornada del Campo. Available online at: https://www.jornada.com.mx/2020/10/17/delcampo/articulos/rumbo-agroalimentario.html (accessed July 23, 2023).

Fajardo-Zapata, Á. L., Méndez-Casallas, F. J., and Molina, L. H. (2011). Residuos de fármacos anabolizantes en carnes destinadas al consumo humano. *Univ. Sci.* 16, 77. doi: 10.11144/javeriana.SC16-1.road

FAO (2019). *The State of Food and Agriculture 2019. Moving Forward on Food Loss and Waste Reduction.* Rome: Food and Agriculture Organization of the United Nations. Available online at: https://www.fao.org/3/ca6030en/ca6030en.pdf (accessed May 9, 2023).

FAO (2021). *Strategic Framework 2022-31*. Food and Agriculture Organization of the United Nations, 1–39. Available online at: https://www.fao.org/about/strategy-programme-budget/strategic-framework/en/ (accessed May 9, 2023).

FAO (2022). *Introducción al Decenio de las Naciones Unidas de la Agricultura Familiar*. Rome: Food and Agriculture Organization of the United Nations.

Fielke, S. J., Garrard, R., Jakku, A., Fleming, A., Wiserman, L., and Taylor, B. M. (2019). Conceptualising the DAIS: implications of the "Digitalisation of Agricultural Innovation Systems" on technology and policy at multiple levels. *NJAS* 90–91, 1–11. doi: 10.1016/j.njas.2019.04.002

Fogašová, K., Manko, P., and Obona, J. (2022). The first evidence of microplastics in plant-formed fresh-water micro-ecosystems: dipsacus teasel phytotelmata in Slovakia contaminated with MPs. *BioRisk* 18, 133–143. doi: 10.3897/biorisk.18.87433

Food and Agriculture Organization of the United Nations (2011). *Global Food Losses and Food Waste–Extent, Causes and Prevention, SAVE FOOD: An Initiative on Food Loss and Waste Reduction*. Rome. Available online at: https://www.fao.org/3/i2697e/i2697e.pdf (accessed May 9, 2023).

Fracarolli, G. S. (2021). Global markets, local issues: the hegemonic process of agri-food construction to present challenges. *Land* 10, 1182. doi: 10.3390/land10111182

Gallo, M., Ferrara, L., Calogero, A., Montesano, D., and Naviglio, D. (2020). Relationships between food and diseases: what to know to ensure food safety. *Food Res. Int.* 137, 109414. doi: 10.1016/j.foodres.2020.109414

García, M. E., and Bermúdez, G. (2016). La neocolonización del paladar en las décadas recientes. *Razón y Palabra* 20, 105–117.

Gardeazabal, A., Lunt, T., Jahn, M. M., Verhulst, N., Hellin, J., and Govaerts, B. (2023). Knowledge management for innovation in agri-food systems: a conceptual framework. *Knowl. Manag. Res. Pract.* 21, 303–315. doi: 10.1080/14778238.2021.1884010

Gárgano, C. (2022). *El campo como alternativa infernal. Pasado y presente de una matriz productiva ?sin escapatoria?* Buenos Aires: Imago Mundi. Available online at: https://cl.boell.org/sites/default/files/2022-04/El/campo/como/alternativa/infernal/Cecilia/Gárgano_0.pdf (accessed August 29, 2023).

Gárgano, C. (2023). Agroextractivism in Argentina environmental health, scientific agendas, and socioecological crisis. *Front. Public Health* 11:1304514. doi: 10.3389/fpubh.2023.1304514

Gaspar, P. D., Fernandez, C. M., Soares, V. N. J., Caldeira, J. M. L. P., and Silve, H. (2021). Development of technological capabilities through the internet of things (IoT): survey of opportunities and barriers for IoT implementation in Portugal's agro-industry. *Appl. Sci.* 11, 3454. doi: 10.3390/app11083454

Gavito, M. E., Wal, H. V. D., Aldasoro, E. M., Ayala-Orozco, B., Bullén, A. A., Cach-Pérez, M., et al. (2017). Ecología, tecnología e innovación para la sustentabilidad: retos y perspectivas en México. *Rev. Mex. Biodivers.* 88, 150–160. doi: 10.1016/j.rmb.2017.09.001

González-Montero De Espinosa, M., Dolores, M., and Serrano, M. (2017). Obesidad y desnutrición en un mundo globalizado. *Anales Museo Nacional Antropol.* X. I. X., 117–126.

González-Ramírez, M. G., Santayo-Cortes, V. H., Arana-Coronado, J. J., and Munoz-Rodriguez, M. (2020). The insertion of Mexico into the global value chain of berries. *World Dev. Perspect.* 20, 100240. doi: 10.1016/j.wdp.2020.100240

Grados, L., Pérot, M., Barbezier, N., Delayre-Orthez, C., Bach, V., Fumery, M., et al. (2022). How advanced are we on the consequences of oral exposure to food contaminants on the occurrence of chronic non communicable diseases? *Chemosphere* 303, 135260. doi: 10.1016/j.chemosphere.2022.135260

Guéneau, S. (2018). Neoliberalism and the emergence of private sustainability initiatives: the case of the Brazilian cattle value chain. *Bus. Strat. Environ.* 27, 240–251. doi: 10.1002/bse.2013

Guerra, C., Capitelli, M., and Longo, S. (2011). "The role of paradigms in science: a historical perspective," in *Paradigms in Theory Construction*, ed L. L'Abate (New York, NY: Springer New York), 19–30.

Guzev, M. M., Ledeneva, M. V., Trukhlyaeva, A. A., and Mishura, N. A. (2021). "Smart technologies in agriculture," in *Lecture Notes in Networks and Systems*, eds E. G. Popkova, B. S. Sergi (Volgograd: Springer International Publishing), 1573–1584.

Haighton, L., Roberts, A., Walters, B., and Lynch, B. (2019). Systematic review and evaluation of aspartame carcinogenicity bioassays using quality criteria. *Regul. Toxicol. Pharmacol.* 103, 332–344. doi: 10.1016/j.yrtph.2018.01.009

Hale, R. C., Seeley, M. E., La Guardia, M. J., Mai, L., and Zeng, E. Y. (2020). A global perspective on microplastics. *J. Geophys. Res. Oceans* 125, 1–40. doi: 10.1029/2018JC014719

Hayes, T. B., Khoury, V., Narayan, A., Nazir, M., Park, A., Brown, T., et al. (2010). Atrazine induces complete feminization and chemical castration in male African clawed frogs (*Xenopus laevis*). *Proc. Nat. Acad. Sci. U. S. A.* 107, 4612–4617. doi: 10.1073/pnas.0909519107

He, Q., Sun, Y., and Yi, M. (2023). Evolutionary game of pesticide reduction management for sustainable agriculture: an analysis based on local governments, farmers, and consumers. *Sustainability* 15, 9173. doi: 10.3390/su15129173

Hernández Moreno, M. C., and Villaseñor Medina, A. (2014). La calidad en el sistema agroalimentario globalizado. *Rev. Mex. Sociol.* 76, 557–582.

Herrera, A. (1978). *Desarrollo, Tecnología y Medio Ambiente. Conferencia en el Primer Seminario Internacional sobre Tecnologías Adecuadas en Nutrición y Vivienda-PNUMA*. Santiago: México.

Hiramatsu, C., Alberto, O., and Ivars, J. D. (2023). Regímenes alimentarios y periodos de acumulación: recuperando el rol de la regulación política. *Millcayac* 10, 1–20.

Hirpessa, B. B., Ulusoy, B. H., and Hecer, C. (2020). Hormones and hormonal anabolics: residues in animal source food, potential public health impacts, and methods of analysis. *J. Food Qual.* 2020, 1–12. doi: 10.1155/2020/5065386

Hodson de Jaramillo, E., Trigo, E. J., and Campos, R. (2023). "The role of science, technology and innovation for transforming food systems in Latin America and the Caribbean," in *Science and Innovations for Food Systems Transformation*, eds J. von Braun, K., Afsana, L. O., Fresco, and M. H. A. Hassan (Cham: Springer International Publishing), 737–749.

Iddir, M., Brito, A., Dingeo, G., Campo, S. S. F. D., Samouda, H., Frano, M. R. L., et al. (2020). Strengthening the immune system and reducing inflammation and oxidative stress through diet and nutrition: considerations during the COVID-19 crisis. *Nutrients* 12, 1562. doi: 10.3390/nu12061562

Ingram, J., Maye, D., Bailye, C., Barnes, A., Bear, C., Bell, M., et al. (2022). What are the priority research questions for digital agriculture? *Land Use Policy* 114, 105962. doi: 10.1016/j.landusepol.2021.105962

Islam, M. S., Azim, F., Saju, H., Zargaran, A., Shirzad, M., Kamal, M., et al. (2021). Pesticides and Parkinson's disease: current and future perspective. *J. Chem. Neuroanat.* 115, 101966. doi: 10.1016/j.jchemneu.2021.101966

Jayaraman, S., Krishnamoorthy, K., Prasad, M., Veeraraghavan, V. P., Krishnamoorthy, R., Alshuniaber, M. A., et al. (2023). Glyphosate potentiates insulin resistance in skeletal muscle through the modulation of IRS-1/PI3K/Akt mediated mechanisms: an *in vivo* and *in silico* analysis. *Int. J. Biol. Macromol.* 242, 124917. doi: 10.1016/j.ijbiomac.2023.124917

Jonker, J., and Faber, N. (2021). *Organizing for Sustainability, Organizing for Sustainability*. Cham: Springer International Publishing.

Juwono, F. H., Wong, W. K., Verma, S., Shekhawat, N., Lease, B. A., and Apriono, C. (2023). Machine learning for weed–plant discrimination in agriculture 5.0: an in-depth review. *Artif. Intell. Agric.* 10, 13–25. doi: 10.1016/j.aiia.2023.09.002

Kamboj, R., Kamboj, S., Kamboj, S., Kriplani, P., Dutt, R., Guarve, K., et al. (2023). "Climate uncertainties and biodiversity: an overview," in *Visualization Techniques for Climate Change with Machine Learning and Artificial Intelligence*, eds A. L. Srivastav, A. K. Dubey, A. Kumar, S. K. Narang, and M. A. Khan (New Delhi: Elsevier), 1–14.

Kang, M. (2018). Comparative advantage and strategic specialization. *Rev. Int. Econ.* 26, 1–19. doi: 10.1111/roie.12300

Kánter, C. I. (2021). Magnitud del sobrepeso y obesidad en México: Un cambio de estrategia para su erradicación. *Serie Mirada Legislativa*, 1–24. Available online at: http://bibliodigitalibd.senado.gob.mx/handle/123456789/5127 (accessed February 10, 2023).

Karwacka, M., Ciurzynska, A., Lenart, A., and Janowicz, M. (2020). Sustainable development in the agri-food sector in terms of the carbon footprint: a review. *Sustainability* 12, 6463. doi: 10.3390/su12166463

Khazaal, S., Darra, N., Kobeissi, A., Jammoul, R., and Jammoul, A. (2022). Risk assessment of pesticide residues from foods of plant origin in Lebanon. *Food Chem.* 374, 131676. doi: 10.1016/j.foodchem.2021.131676

Khodakivska, O., Pugachov, M., Hermaniuk, N., Mohylnyi, O., Tomashuk, O., and Gryshchenko, O. (2020). The organic agriculture: world trends and opportunities. *Int. J. Adv. Sci. Technol.* 29, 5308–5317.

Kiliç, R. (2022). The problem of hunger in the world and a new model proposal to solve this problem. *Balkan Sosyal Bilimler Dergisi* 11, 63–68. doi: 10.55589/bsbd.1107538

Klerkx, L., and Rose, D. (2020). Dealing with the game-changing technologies of Agriculture 4.0: how do we manage diversity and responsibility in food system transition pathways? *Global Food Sec.* 24, 100347. doi: 10.1016/j.gfs.2019.100347

Kovács, I., and Husti, I. (2018). The role of digitalization in the agricultural 4.0 – how to connect the industry 4.0 to agriculture?. *Hung. Agric. Eng.* 7410, 38–42. doi: 10.17676/HAE.2018.33.38

Kreimer, P. (2017). Los estudios sociales de la ciencia y la tecnología: ¿son parte de las ciencias sociales? *Teknokultura* 14, 143–162. doi: 10.5209/TEKN.55727

Kuhn, T. S. (1971). *La estructura de las revoluciones científicas*. México: Fondo de Cultura Econ?mica.

Landrigan, P. J., and Straif, K. (2021). Aspartame and cancer – new evidence for causation. *Environ. Health.* 20, 42. doi: 10.1186/s12940-021-00725-y

Larsson, S. C., Mason, A. M., Kar, S., Vithayathil, M., Carter, P., Baron, J. A., et al. (2020). Genetically proxied milk consumption and risk of colorectal, bladder, breast, and prostate cancer: a two-sample Mendelian randomization study. *BMC Med.* 18, 370. doi: 10.1186/s12916-020-01839-9

Latour, B. (2007). *Nunca fuimos modernos: Ensayo de antropología simétrica.* Buenos Aires: Siglo, X. X. I.

Liaudat, S. (2020). La pandemia está directamente relacionada al sistema alimentario agroindustrial. *Ciencia Tecnol. Polít.* 3, 041. doi: 10.24215/26183188e041

Mansfield, B., Werner, M., Berndt, C., Shattuck, A., Galt, R., Williams, B. (2023). A new critical social science research agenda on pesticides. *Agric. Hum. Values.* doi: 10.1007/s10460-023-10492-w

Maroušek, J., Minofar, B., Maroušková, A., Strunecký, O., and Gavurová, B. (2023). Environmental and economic advantages of production and application of digestate biochar. *Environ. Technol. Innovat.* 30:103109. doi: 10.1016/j.eti.2023.103109

Martínez Martín, A., and Manrique Corredor, E. (2014). Alimentación prehispánica y transformaciones tras la conquista europea del altiplano cundiboyacense, Colombia. *Rev. Virt. Univ. Católica Norte* 41, 96–111.

Matsuzaki, R., Gunnigle, E., Geissen, V., Clarke, G., Nagpal, J., and Cryan, J. F. (2023). Pesticide exposure and the microbiota-gut-brain axis. *ISME J.* 17, 1153–1166. doi: 10.1038/s41396-023-01450-9

Matthews, A. (2021). "Agri-food sector," in *The Economy of Ireland: Policy Making in a Global*. London: Bloomsbury Publishing, 276–299. Available online at: https://books.google.es/books?hl=es&lr=&id=e6ZEEAAAQBAJ&oi=fnd&pg=PT288&ots=XeDeJlEEZ4&sig=wtgU2dMDLMdB_ys6xXL1MimP4gY#v=onepage&q&f=false (accessed October 11, 2023).

McLennan, M. (2022). *The Global Risks Report 2022*. Available online at: https://www.weforum.org/reports/global-risks-report-2022 (accessed May 24, 2022).

Melnik, B. C., John, S. M., Carrera-Bastos, P., Cordain, L., Leitzmann, C., Weiskirchen, R., et al. (2023). The role of cow's milk consumption in breast cancer initiation and progression. *Curr. Nutr. Rep.* 12, 122–140. doi: 10.1007/s13668-023-00457-0

Mizik, T. (2021). The performance of the agri-food sector in the recent economic crisis and during Covid-19 pandemic. *HighTech Innovat. J.* 2, 168–178. doi: 10.28991/HIJ-2021-02-03-02

Neves, M. F., et al. (2023). Agriculture 6.0: a new proposal for the future of agribusiness. *Rev. Gestão Soc. Ambiental* 17, e04004. doi: 10.24857/rgsa.v17n9-021

Osiurak, F., and Reynaud, E. (2019). Behavioral and brain sciences (forthcoming) the elephant in the room : what matters cognitively in cumulative technological culture. *Behav. Brain Sci.* 97, 1–57. doi: 10.1017/S0140525X19003236

Paoli Bolio, F. J. (2019). Multi, inter y transdisciplinariedad. *Problema Anuario de Filosofía y Teoría del Derecho* 13, 347–357. doi: 10.22201/iij.24487937e.2019.13.13725

Pérez, C. (2001). Cambio tecnológico y oportunidades de desarrollo como blanco móvil. *Rev. CEPAL* 75, 115–136. doi: 10.18356/761d3578-es

Pillai, S., Koboyashi, K., Michael, M., Mathai, T., Sivakumar, B., and Sadasivan, P. (2021). John William Trevan's concept of Median Lethal Dose (LD50/LC50) – more misused than used. *J. Preclin. Clin. Res.* 15, 137–141. doi: 10.26444/jpccr/139588

Piscicelli, L. (2023). The sustainability impact of a digital circular economy. *Curr. Opin. Environ. Sustain.* 61, 101251. doi: 10.1016/j.cosust.2022.101251

Pivoto, D., Waquil, P. D., Talamini, E., Finocchio, C. P., Corte, V. F., and Mores, G. V. (2018). Scientific development of smart farming technologies and their application in Brazil. *Inf. Process. Agric.* 5, 21–32. doi: 10.1016/j.inpa.2017.12.002

Podolskiy, D. I. Avanesov, A., Tyshkovskiy, A., Porter, E., Petrascheck, M., Kaeberlein, M., et al. (2020). The landscape of longevity across phylogeny. *bioRxiv*. doi: 10.1101/2020.03.17.995993

Polanco Rodríguez, A. G., Magana Castro, T. V., Cetz Luit, J., and Quintal Lopez, R. (2019). Uso de agroquímicos cancerígenos en la región agrícola de Yucatán, México. *Centro Agrícola* 46, 72–83.

Pyrkov, T. V., Avchaciov, K., Tarkhov, A. E., Menshikov, L. I., Gudkov, A. V., and Fedichev, P. O. (2021). Longitudinal analysis of blood markers reveals progressive loss of resilience and predicts human lifespan limit. *Nat. Commun.* 12, 2765. doi: 10.1038/s41467-021-23014-1

Ragazou, K., Garefalakis, A., Zafeiriou, E., and Passas, I. (2022). Agriculture 5.0: a new strategic management mode for a cut cost and an energy efficient agriculture sector. *Energies* 15, 3113. doi: 10.3390/en15093113

Ramírez, G. S. E. (2016). Los súper ricos y la élite global. *Boletin* 2, 16–31.

Rani, L., Thapa, K., Kanojia, N., Sharma, N., Singh, S., and Grewal, A. S. (2021). An extensive review on the consequences of chemical pesticides on human health and environment. *J. Clean. Prod.* 283, 124657. doi: 10.1016/j.jclepro.2020.124657

Reddy, A. K. N. (1979). *National and Regional Technology Groups and Institutions: An Assessment. Towards Global Action for Appropriate Technology.* Oxford: Pergamon.

Rivas-Garcia, T., Espinosa-Calderon, A., Hernandez-Vazquez, B. H., and Schwentesius-Rindermann, R. (2022). Overview of environmental and health effects related to glyphosate usage. *Sustainability* 14, 6868. doi: 10.3390/su14116868

Rojas, R. A., Ojeda, B. M. E., and Barraza, O. X. (2000). Malformaciones congénitas y exposición a pesticidas. *Rev Méd Chile* 128, 399–404. doi: 10.4067/S0034-98872000000400006

Rolandi, S., Brunori, G., Bacco, M., and Scotti, I. (2021). The digitalization of agriculture and rural areas: towards a taxonomy of the impacts. *Sustainability* 13, 5172. doi: 10.3390/su13095172

Román, S., Ojeda-Granados, C., and Panduro, A. (2013). Genética y evolución de la alimentación de la población en México. *Rev. Endocrinol. Nutr.* 21, 42–51.

Ruiz-Rosado, O. (2006). Agroecología: una disciplina que tiende a la transdisciplina. *Interciencia* 31, 140–145.

Saiz-Rubio, V., and Rovira-Más, F. (2020). From smart farming towards agriculture 5.0: a review on crop data management. *Agronomy* 10:207. doi: 10.3390/agronomy10020207

Samsel, A., and Seneff, S. (2015). Glyphosate, pathways to modern diseases IV: cancer and related pathologies. *J. Biol. Phys. Chem.* 15, 121–159. doi: 10.4024/11SA15R.jbpc.15.03

Schattman, R. E., Rowland, D. L., and Kelemen, S. C. (2023). Sustainable and regenerative agriculture: tools to address food insecurity and climate change. *J. Soil Water Conserv.* 78, 33A—38A. doi: 10.2489/jswc.2023.1202A

Schöley, J., Aburto, J. M., Kashnitsky, I., Kniffka, M. S., Zhang, L., and Jaadla, H. (2022). Life expectancy changes since COVID-19. *Nat. Hum. Behav.* 6, 1649–1659. doi: 10.1038/s41562-022-01450-3

Schumacher, E. F. (1973). *Small is Beautiful: Economics as if Poeple Mattered*. London: Blond & Briggs. Available online at: https://www.daastol.com/books/ (accessed February 23, 2023).

Sekar, M., Kumar, T. P., Kumar, M. S. G., Vaníčková, R., and Maroušek, J. (2021). Techno-economic review on short-term anthropogenic emissions of air pollutants and particulate matter. *Fuel* 305, 121544. doi: 10.1016/j.fuel.2021.121544

Shah, R. (2020). "Pesticides and human health," in *Emerging Contaminants*, ed A. Nuro (Rijeka: IntechOpen).

Streit, B. (1992). Fachbereich Biologie, University of Frankfurt, Siesmayerstrasse 70 , D-6000 Frankfurt am Main (Federal Republic of Germany). *Experientia* 48, 955–970. doi: 10.1007/BF01919142

Tello, C., and Ibarra, J. (2020). *La revolución de los ricos*. México: Fondo de Cultura Econ?mica.

Torres Sandoval, I., Gómez González, G., and Guzmán López, F. (2023). Cuestión agraria y pueblos originarios huastecos veracruzanos durante la colonización española. *Alegatos* 111–112, 385–406.

UNEP (2021). *Food Waste Index Report 2021*. Nairobi: United Nations Environment Programme. Available at: https://www.unep.org/resources/report/unep-food-waste-index-report-2021 (accessed October 25, 2023).

United Nations (2019). *World Population Prospects 2019*. Department of Economic and Social Affairs. World Population Prospects 2019: Highlights (ST/ESA/SER.A/423), (141). Available online at: http://www.ncbi.nlm.nih.gov/pubmed/12283219 (accessed October 12, 2023).

Vargas Canales, J. M. (2016). *Cambio tecnológico e innovación en agricultura protegida en Hidalgo*. México: Universidad Autónonoma Chapingo. Available online at: http://ciestaam.edu.mx/cambio-tecnologico-e-innovacion-en-agricultura-protegida-en-hidalgo-mexico/ (accessed February 03, 2022).

Vargas Canales, J. M. (2023). *Tendencias de la ciencia, la tecnología y la innovación en el sector agroalimentario y los agronegocios en México*. Colegio de Postgraduados. Available online at: http://colposdigital.colpos.mx:8080/xmlui/handle/10521/5051 (accessed August 02, 2023).

Vargas-Canales, J. M. (2022). El sector agroalimentario mexicano y las nuevas tecnologías. *Revista eAgron.* 8, 89–113. doi: 10.18845/ea.v8i2.6156

Vargas-Canales, J. M. (2023). Technological capabilities for the adoption of new technologies in the agri-food sector of Mexico. *Agriculture* 13, 1177. doi: 10.3390/agriculture13061177

Vargas-Canales, J. M., Brambila-Paz, J. D. J., Pérez-Cerecedo, V., Rojas-Rojas, M. M., López-Reyna, M. D. C., and Omaña-Silvestre, J. M. et al. (2022a). Trends in science, technology, and innovation in the agri-food sector. *Tapuya* 5, 2115829. doi: 10.1080/25729861.2022.2115829

Vargas-Canales, J. M., Bustamante-Lara, T. I., and Rodríguez-Haros, B. (2022b). Especialización y competitividad del sector agrícola en México. *Braz. J. Bus.* 4, 1890–1905. doi: 10.34140/bjbv4n4-020

Vargas-Canales, J. M., Carbajal-Flores, G., Bustamante-Lara, T. I., Camacho-Vera, J. H., Fresnedo-Ramírez, J., Palacios-Rangel, M. et al. (2020). Impact of the market on the specialization and competitiveness of Avocado Production in Mexico. *Int. J. Fruit Sci.* 20, S1942–S1958. doi: 10.1080/15538362.2020.1837711

Vargas-Canales, J. M., García-Melchor, N., Orozco-Cirilo, S., and Camacho-Vera, J. H. (2023a). Los siete pecados capitales del sector agroalimentario en México y cómo revertirlos. *Agric. Soc. Desarrollo* 20, 516–532. doi: 10.22231/asyd.v20i4.1578

Vargas-Canales, J. M., Orozco-Cirilo, S., Medina-Cuéllar, S. E., Vera, J. H. C., and García-Melchor, N. (2023b). Tendencias de la bioeconomía en la búsqueda de un modelo económico sustentable. *Acta Univ.* 33, 1–19. doi: 10.15174/au.2023.3920

Vega Mejía, N., Ponce Reyes, R., Martinez, Y., Carrasco, O., and Cerritos, R. (2018). Implications of the western diet for agricultural production, health and climate change. *Front. Sustain. Food Syst.* 2, 1–5. doi: 10.3389/fsufs.2018.00088

Vera-Cruz, A. O. (2021). *Generación, movilización y uso del conocimiento en diabetes mellitus 2 en México*. México: Universidad Autónoma Metropolitana.

Vethaak, A. D., and Legler, J. (2021). Microplastics and human health. *Science* 371, 672–674. doi: 10.1126/science.abe5041

Vetter, T., Nylandsted Larsen, M., and Bech Bruun, T. (2019). Supermarket-led development and the neglect of traditional food value chains: reflections on Indonesia's agri-food system transformation. *Sustainability* 11, 498. doi: 10.3390/su11020498

Villapol, S. (2020). Gastrointestinal symptoms associated with COVID-19: impact on the gut microbiome. *Transl. Res.* 226, 57–69. doi: 10.1016/j.trsl.2020.08.004

Vitrano, R. M. (2017). Il ruolo della cultura tecnologica nella dicotomia teorica tra tecnica e forma. *Techne* 13, 204–211. doi: 10.13128/Techne-19754

von Braun, J., Afsana, K., Fresco, L., and Hassan, M. (2023). *Science and Innovations for Food Systems Transformation*. Cham: Springer International Publishing.

Ward, H. (1989). "The neutrality of science and technology," in *Liberal Neutrality*, eds R. E. Goodin, and A. Reeve (London: Routledge), 157–192.

Wells, J. C. K., Marphatia, A. A., Amable, G., Siervo, M., Friis, H., Miranda, J. J., et al. (2021). The future of human malnutrition: rebalancing agency for better nutritional health. *Global. Health* 17, 119. doi: 10.1186/s12992-021-00767-4

Werndl, C. (2016). On defining climate and climate change. *Br. J. Philos. Sci.* 67, 337–364. doi: 10.1093/bjps/axu048

WHO (2020). *Resistencia a los antibióticos*. World Health Organization. Available online at: https://www.who.int/es/news-room/fact-sheets/detail/resistencia-a-los-antibióticos (accessed August 8, 2023).

WHO (2022). *Residuos de plaguicidas en los alimentos*. World Health Organization. Available online at: https://www.who.int/es/news-room/fact-sheets/detail/pesticide-residues-in-food (accessed August 08, 2023).

WHO (2023). *Se publican los resultados de la evaluación del riesgo y la peligrosidad del aspartamo. Comunicado de prensa conjunto.* Ginebra: World Health Organization. Available online at: https://www.who.int/es/news/item/14-07-2023-aspartame-hazard-and-risk-assessment-results-released#:$\sim$:text=El-CIIC-ha-clasificado-el,mg%2Fkg-de-peso-corporal (accessed July 14, 2023).

Yang, A.-M., Chu, P.-L., Wang, C., and Lin, C.-Y. (2023). Association between urinary glyphosate levels and serum neurofilament light chain in a representative sample of US adults: NHANES 2013–2014. *J. Exp. Sci. Environ. Epidemiol.* 1–7. doi: 10.1038/s41370-023-00594-2

Yang, Z., Li, J., Gui, X., Shi, X., Bao, Z., Han, H., et al. (2020). Updated review of research on the gut microbiota and their relation to depression in animals and human beings. *Molecular Psychiatry* 25, 2759–2772. doi: 10.1038/s41380-020-0729-1

Zhai, Z., Martínez, J. F., Beltran, V., and Martínez, N. L. (2020). Decision support systems for agriculture 4.0: survey and challenges. *Comp. Electron. Agric.* 170, 105256. doi: 10.1016/j.compag.2020.105256

Zhu, F., Cakmak, E. K., and Cetecioglu, Z. (2023). Phosphorus recovery for circular economy: application potential of feasible resources and engineering processes in Europe. *Chem. Eng. J.* 454, 140153. doi: 10.1016/j.cej.2022.140153