

Review

Transformation of the Three Pillars of Agri-Food Sustainability around the COVID-19 Crisis—A Literature Review

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Abstract: The COVID-19 crisis has disrupted economies and societies and the sustainability characteristics of agri-food due to a significant decline in turnover, difficulties in transportation, and changes in market and contact habits. An analysis was carried out using the PRISMA protocol and the Scopus, Web of Science, and Science Direct electronic databases. The aim of this research is to present the main research issues in agri-food sustainability (economic, environmental, and social issues) in the pre-COVID-19 period, to compare it with the research trends in the COVID-19 period, and to explore the influence of the epidemic. This research looks for research gaps and possible future research directions. Research before COVID-19 was primarily concerned with environmental and economic sustainability. The main focus areas were business development and environmental issues. During COVID-19, the focus shifted to economic sustainability. Survival was the primary issue. The main research areas were financial, inventory, waste management, and innovation issues. Food safety and digitalisation were highlighted. Precision agriculture, short food supply chains, and collaboration increased efficiency. The role of trust has increased. The COVID-19 experience is valuable for almost all disciplines. Policy, health, and economic decision-makers can apply better solutions to future crises.

Keywords: agri-food; sustainability; COVID-19; literature review



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1. Introduction

In 1972, the Club of Rome report marked the beginning of the sustainable development approach [1]. The approach to sustainable development involves meeting the needs of the present without compromising the ability of future residents to meet their own needs [2]. The topic has a broad social scope. Governments, NGOs, and academia are exploring solutions [3]. The approach to sustainability has focused primarily on environmental issues, but following the oil crisis, the issue of economic sustainability has also emerged [4]. The sustainability problem begins with basic human needs, including financial needs, environmental needs, and well-being [5]. Sustainability issues now touch every aspect of human life, with the main ones being economic, political, social and ecological aspects [6]. It seeks to address issues such as poverty, inequality, education, justice, or even wars and peace in the social category, along with environmental degradation, global warming, energy use, and climate change in the ecological category [7].

One possible definition of agriculture is the production of products that provide people with food, i.e., food security and quality of life [8]. Because agriculture involves both crop and livestock production, it also has characteristics such as soil type, the type and frequency of cultivation, and the main crops or animals involved in production. The process ranges from the procurement, production, cultivation, and domestication syndrome to the cultivation of domesticated crops and agricultural dispersal and intensification [9]. The impact of farming activity is a reduction in habitat area, soil erosion, pollution (air, soil, etc.), and increased carbon emissions [10]. These make it necessary to take steps towards sustainability [11], which will threaten the land and humanity [12] in the long term if no change is made [13].

Agriculture and agri-food contribute about 4% of the world's GDP globally. World Bank data show that the decline in percentage until 2018 has been reversed from 2019 and now stands at 4.6%. According to the latest available data, China, the US, Germany, France, Brazil, and Canada had higher agricultural output in terms of GDP in 2021 [14].

“Agri-food systems encompass primary agricultural production of food and non-food products (from crops, livestock, fisheries, forestry and aquaculture), the production of food of non-agricultural origin (e.g., synthetic meat), the food supply chain from producer to consumer and the final consumer of food.” Globally, these systems produce about 11 billion tons of food annually, forming the backbone of many economies [15].

Due to the strong linkages between different systems, food production and supply disruptions also affect household food security, which has repercussions on production and producers. The measures of COVID-19 have disrupted international and local supply chains, causing economic disruption in many countries in 2020. Purchasing power has fallen, threatening access to food for many people, especially among people experiencing poverty and in poor countries [15].

The WTO definition of agri-food is based on the WTO Agreement on Agriculture. In Annex 1, agri-food is defined as HS Chapters 1 to 24, less fish and fish products, plus products of animal and vegetable origin that are used but not necessarily consumed, e.g., hides and skins, wool and animal hairs, etc. [16,17].

2. Theoretical Background and Research Questions Development

Sustainable agriculture is defined as practices that provide food for the population while minimising environmental degradation and preserving natural resources [18–23]. In defining sustainable agriculture, people-centred elements come to the fore: human well-being, safe and long-term food supply, etc. Secondly, non-human factors such as the environment's state and products' value and sustainability come to the fore [20].

Despite the development of agriculture, at least 820 million people are food insecure and hungry. More people than this consume poor-quality food, resulting in deficiency diseases, obesity, a higher prevalence of infectious diseases due to poorer immune systems, and an increased risk of coronary heart disease, stroke, and diabetes. The development of agriculture should include reducing meat consumption, increasing plant nutrients, reducing crop losses, reducing wastage, and increasing production efficiency [24]. The main areas of sustainable agriculture are environmental issues, resource efficiency [25], and the technological developments that support it [26]. Most countries' food systems are heavily dependent on imported inputs, such as fossil fuels, fertilisers, and animal feed, which confirms that agriculture and food systems must be fundamentally transformed towards sustainability [27].

Significant milestones have appeared in the development of sustainable agriculture [28,29]. One of these is organic agriculture [30]. The others are integrated agriculture [31], ecological and sustainable intensification [32], measures to protect nature [33], precision agriculture [34], permaculture [35], and vertical agriculture [36].

Other problems include worker and nature exploitation and unfair distribution systems [37]. Within management and environmental sustainability, the focus is on energy efficiency and energy saving. This has made exploring and deploying renewable energy sources a priority [38,39].

The main objectives of sustainable agriculture include ensuring equality between different generations, stability of food production and farming, and environmental efficiency [40,41]. Initially, definitions of sustainability focused mainly on economic and ecological viability. Farming was thought to be sustainable if it conserved resources and was profitable. This was later supplemented because these approaches assumed that these two pillars automatically implied that it would be socially sustainable. Agriculture is sustainable in accordance with the needs if it includes social equity, that is, profitability, environmental protection, poverty, and hunger issues [42].

The purpose of this paper is not to present and analyse the effects of COVID-19 comprehensively, as this would not be sufficient, but to briefly describe the impact of COVID-19 on different areas of life and society because these forces and impacts have also affected agri-food systems directly or indirectly. The effect of COVID-19 was a reduction in economic output in the EU-27 by 11.1% in the second quarter of 2020 compared to the previous quarter. Private consumption expenditure in the EU-27 decreased by 12.2%. Exports declined at different rates in different countries. Population size and death rates also varied by country [43]. Globally, there was a 10% reduction in NO_x emissions in the 30 days following the introduction of the measures. This has a significant environmental impact but is equivalent to a 10% drop in industrial production [44]. One of the social impacts of COVID-19 is the increase in social inequalities [45]. The epidemic affected urban and rural societies at different time intervals and in slightly different ways [46]. The epidemic situation has also affected the labour market [47], caused changes in family relationships [48], and shaped the solidarity between people [49].

Because of the effects of COVID-19 mentioned above, it is possible to make assumptions before research. The economic viability of several actors may have been compromised, resulting in a shift in the company's objectives towards economic viability, efficiency, and effectiveness. For operators, the focus on environmental sustainability in the pre-COVID-19 period has shifted towards a financial focus. It was expected that the role of food safety would be significantly enhanced since public uncertainty and centralised regulation required the introduction and strengthening of procedures that would provide greater security. Given the problematic period for social actors, it was expected that the agri-food system would also have to cope with the adverse effects of the epidemic, and efforts were made to address these difficulties.

During the few years of the COVID-19 outbreak, several studies have been carried out in different areas of life, such as business [50], healthcare [51,52], education [53], supply chain [54–57], knowledge management [58], social media [59], environmental pollution [60,61], waste management [62], etc.

Most previous research on COVID-19 has typically focused on a single topic. It has also tended to focus on one dimension of sustainability [63], or it did not address the agri-food issue [64]. The primary body of research focused on the health impacts during the outbreak, as this was the most vital issue. No one has yet addressed the implications of COVID-19 for agri-food, which encompasses the economic, environmental, and social aspects of sustainability.

This review seeks to identify and synthesise the most relevant literature on the subject, comparing and contrasting results where appropriate. Therefore, the objective of this article is to provide the reader with a better understanding of agri-food sustainability during the COVID-19 period and provide directions for future research on agri-food sustainability.

This paper will provide a comprehensive overview of the issues and practices following the COVID-19 crisis. To this end, it analyses the potential impacts of the pandemic on the economic, social, and environmental pillars of sustainability through a review of the literature. This study aims to answer the following research questions:

RQ1. *What were the main research questions regarding agri-food sustainability (economic, environmental, and social issues) before COVID-19?*

RQ2. *What are the main issues and research directions for agri-food sustainability (economic, environmental, social issues) during and after COVID-19?*

RQ3. *How does COVID-19 affect the sustainability of agri-foods?*

RQ4. *What were the areas that were influenced by COVID-19 but under-researched? What are the research gaps? What are the possible future research directions?*

The rest of this paper is structured as follows: Section 3 describes the methodology used in the research. Section 4 presents a descriptive and thematic analysis of agri-food

sustainability and COVID-19 implications. Section 5 discusses the main findings. Finally, Section 6 presents the conclusions drawn from this study's research.

3. Materials and Methods

To provide a comprehensive review of the sustainability of COVID-19 agri-food products, an internet literature search has been conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol of Moher and colleagues, 2009 [65], using the Scopus, Web of Science, and Science Direct electronic database search engines. The first review examined the literature on agri-food sustainability before COVID-19 to identify sustainability issues in the pre-COVID-19 period. The aim is to research the state of agri-food sustainability issues before the pandemic to better understand the impact of COVID-19 measures on the issue under investigation and answer how COVID-19 has changed lives and what challenges it created. This will help to better define future research directions for agri-food research.

Since the COVID-19 pandemic has also attracted the attention of scientific thinkers, the action against the restrictions imposed by the crisis has had a significant impact, and some of the research on COVID-19 was already underway before the WHO announced the pandemic in March 2020. To ensure adequate coverage of the published articles and the collected publications' reliability, using the Web of Science (WoS), Science Direct, and Scopus research databases to collect the published articles, sustainability research before COVID-19 was examined in the following way. The first filtering round was performed for the search terms sustainability and agri-food in the databases listed above in articles published between 2016 and 2019. It was assumed that the researchers would give their work a title and an abstract, suggesting that their analysis would reflect actual research. Thus, if the issue of sustainability or one of its factors appears, they indicate it in the title, abstract, or keywords. For simplicity, there is a selection of materials written in English and a focus on the analysis of scientific journal articles only (book chapters or entire books were excluded from the database). After 355 hits, duplicates were filtered out, leaving 109 hits based on titles. In the second filtering stage, the content of the papers filtered in the previous stage was checked by reading the title, abstract, and conclusion and then reading the whole document to check the relevance of the papers. After reading these 109 documents, 47 relevant works in the literature remained that made a substantive contribution to the research of agri-food sustainability.

The leading search used a combination of the keywords COVID-19, sustainability, and agri-food, which had to appear in the title, abstract, conclusions, or keywords of the literature searched. The search engine also returns results that do not include one or all search terms in the title or abstract. To ensure accuracy, irrelevant documents were filtered out by carefully reviewing each article's title, abstract, and keywords. This means that only relevant literature was included in the review.

The literature searches, a crucial part of this review, took place in March 2024 and were limited to a database (journal publications only) with publications between 2020 and 2023 due to the topic. The first literature search yielded 230 papers, which included 69 duplicates, indicating that the number of articles on the subject is generally low after searching for irrelevant studies by title and removing duplicates, obtaining 66 studies. Of the 66 English-language journal articles, 9 did not address the impacts of COVID-19, and 4 did not include any sustainability topic. Finally, 53 relevant publications were identified for the topic (the relationship between agri-food, COVID-19, and sustainability). The source selection and exclusion process used in the literature review is illustrated in Figure 1.

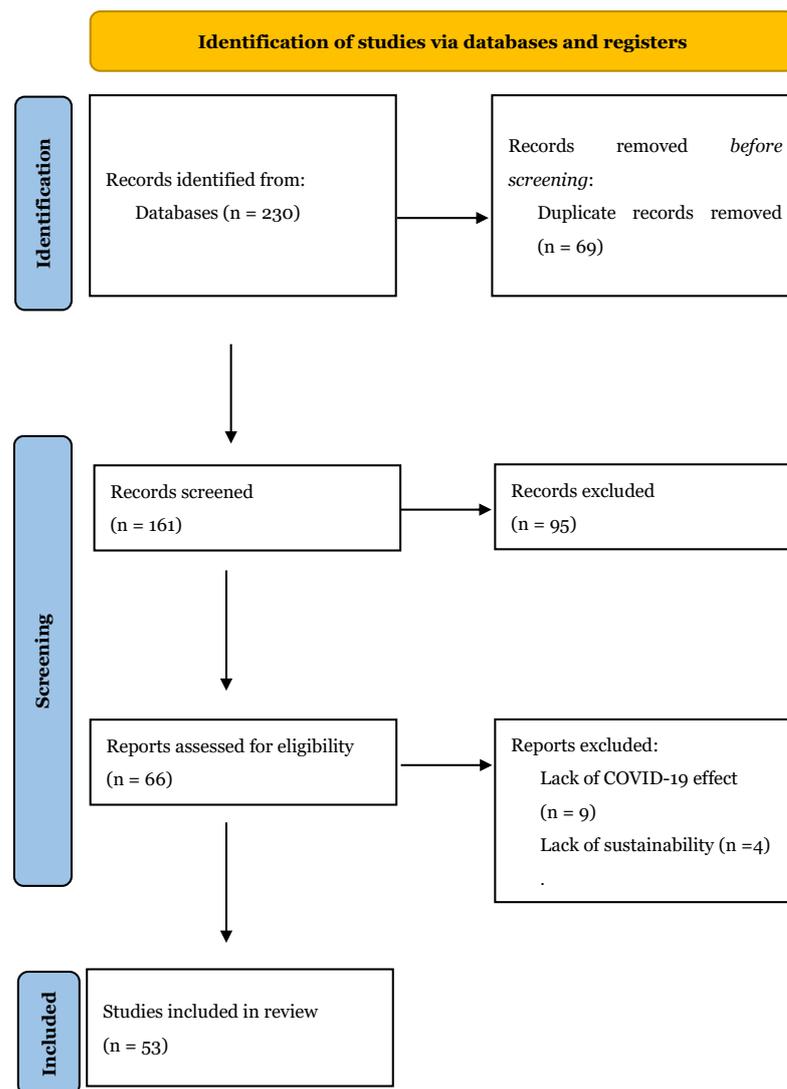


Figure 1. Milestones of the literature selection.

4. Results

4.1. Pre COVID-19 Sustainability

For economic sustainability, data-driven and adaptive management in agri-food production and distribution companies strongly impacts non-financial sustainability and supports financial sustainability [66]. Using cooperation and the sharing economy increases the financial sustainability of organic farming in developing countries [67,68]. Vertical coordination can help improve economic and environmental sustainability [69]. Better-managed organisational changes and strategies have supported the economic and social sustainability of the wine sector. [70]. Innovation has a positive impact on financial sustainability [71]. Economic sustainability can be improved by choosing the correct transport mode [72]. Resource use efficiency drives production's economic and environmental sustainability [73].

Reducing waste has a positive impact on environmental [74–76], economic [77,78], and social sustainability [79]. Using new technology and reducing production waste increases economic and environmental sustainability [80]. Certification increases environmental [81] and economic sustainability [82–86] but reduces social sustainability [87]. Building an adequate distribution network reduces the environmental burden but can also reduce economic results [88]. Precision agriculture can increase environmental and economic sustainability [89]. Poorer-quality land under production pressure means higher water demand and, thus, poorer economic sustainability [90].

Organic production improves environmental and health sustainability [91,92]. This advantage has not been seen in lettuce production, and further development is needed for better results [93]. Lack of confidence is the main obstacle to the broader uptake of organic food, which could reduce environmental pressures [94]. To mitigate greenhouse gas emissions in agriculture, combining crops that sequester these gases is possible, thereby reducing emissions [95]. Environmental pressures can be improved by reducing the amount produced, enhancing energy and fertiliser use efficiency, and increasing transport efficiency [96]. Cooperation between partners and suppliers and product innovation positively impact environmental sustainability [97,98]. Recycling tomato waste as compost can improve environmental sustainability [99]. A short food supply chain develops environmental sustainability [100]. A study on sheep found no significant difference in environmental impact between artisanal and industrial production [101]. Food production and consumption patterns influence environmental pressures [102]. A product affects the environmental footprint, so making the right choices increases environmental sustainability [103]. Proper water use can improve environmental protection [104]. There is a strong connection between sustainability and irrigation and water management [105–107]. Consumers are willing to pay even higher prices for products produced in a water-efficient way, so there is an economic benefit linked to environmental sustainability [108]. The product's qualitative (taste, packaging), financial (price, convenience, and so on) and safety (health, safety, environmental friendliness, and so on) characteristics have a positive impact on economic, environmental and social sustainability [109]. The growing demand for healthy food supports environmental protection [110]. A plant-heavy or plant-based diet reduces the global warming potential (GWP), while food waste increases it [111]. Environmental protection can be adequate with cleaner technology, effective enforcement and control over supply chains, protected brands, standards, and certifications [112]. The summary of the main topics is in Table 1.

Table 1. Main topics of pre-COVID-19 research. Source: The Scopus (<https://www.scopus.com>, accessed on 1 May 2024), Web of Science (<https://www.webofscience.com>, accessed on 1 May 2024), and Science Direct (<https://www.sciencedirect.com>, accessed on 1 May 2024) databases.

Resource Management	Innovation and Technology	Management, Cooperation,	Certification, Production	Education, Psychology
<p>transport method (Pérez-Mesa et al., 2019) [72]</p> <p>resource efficiency (Steyn et al., 2016; Tassielli et al., 2018) [73,96]</p> <p>waste reduction (Diaz-Ruiz et al., 2019; Garofalo et al., 2017; Kazancoglu et al., 2018; Sgarbossa et al., 2017; Singh et al., 2019; Gokarn and Kuthambalayan 2017; Woodhouse et al., 2018; Bonisoli et al., 2019; Boccia et al., 2019) [74–80,87,99]</p> <p>distribution network (Bortolini et al., 2016) [88]</p> <p>soil quality (Sartori et al., 2019) [90]</p> <p>use of plants that sequester carbon (Sulaiman et al., 2017) [95]</p> <p>water use (Ibidhi and Ben Salem 2018; Libutti et al., 2018; Miglietta et al., 2018; Yan et al., 2019; Pomarici et al., 2018) [104–108]</p>	<p>process innovation (Pérez Neira et al., 2018) [71]</p> <p>precision agriculture (Kendall et al., 2017) [89]</p> <p>organic farming (Annunziata and Vecchio 2016; Westphal et al., 2018; Tasca et al., 2017) [91–93]</p> <p>product innovation (Annunziata et al., 2018; Camanzi et al., 2017) [97,98]</p> <p>short food supply chain use (Canfora 2016) [100]</p> <p>large production (Vagnoni et al., 2017) [101]</p>	<p>data-based management (Akhtar et al., 2016) [66]</p> <p>well-managed change and strategy (Borsellino et al., 2019) [70]</p> <p>cooperation and sharing economy (Asian et al., 2019; Thorlakson et al., 2018; Singh et al., 2018; Rueda et al., 2017) [67–69,112]</p>	<p>certification use (Partzsch et al., 2019; Del Giudice et al., 2018; Rees et al., 2019; Silva et al., 2017; Tait et al. 2019; Tait et al., 2016; Bonisoli et al., 2019) [81–87]</p> <p>production characteristics (Rahnama 2017; Rijsberman 2017) [109,110]</p> <p>plant-based food (Veeramani et al., 2017) [111]</p>	<p>lack of trust (Vega-Zamora et al., 2019) [94]</p> <p>consumption choice (Ely et al., 2016; Mujkic et al., 2019) [102,103]</p>

4.2. Sustainability after COVID-19: Descriptive Analysis

The generalised worldwide effect (13) was the subject of most articles. It is followed by Italy, with eight studies. The next one is Bangladesh (3). Romania, Spain, and Canada are covered by 2-2 articles, and the remaining articles (23) deal with a single country or region.

Figure 2 illustrates that most of the papers (24 articles) focused on the agri-food system, a complex network involving multiple actors from production to consumption. Within this, farmers and entrepreneurs were the subject of 6-6 articles, while consumption and producer issues were covered in 5-5 articles. Two articles specifically addressed food traders, with others focusing on restaurants, meat producers, oil and wine producers, local food, fishermen, traders, or beekeepers.

The journals of the remaining 53 articles show a diversity. The Swiss journal *Sustainability* published 16 articles. The agriculture system has three articles, while *Socio-Economic Planning Sciences* and *Sustainable Production and Consumption* have 2-2 articles. The remaining articles were published in different journals.

The COVID-19 pandemic, a global crisis that significantly impacted various sectors, including the agri-food system, was a major catalyst for research in this area. Released at a larger scale in spring 2020, this was the year researchers began to investigate the issue. Seven selected articles were the result. The most common year for the research topic was 2021, with 21 articles written by the authors. This decreased in 2022, when 14 articles were selected. Eleven articles were selected in 2023, further underscoring the ongoing relevance of the topic.

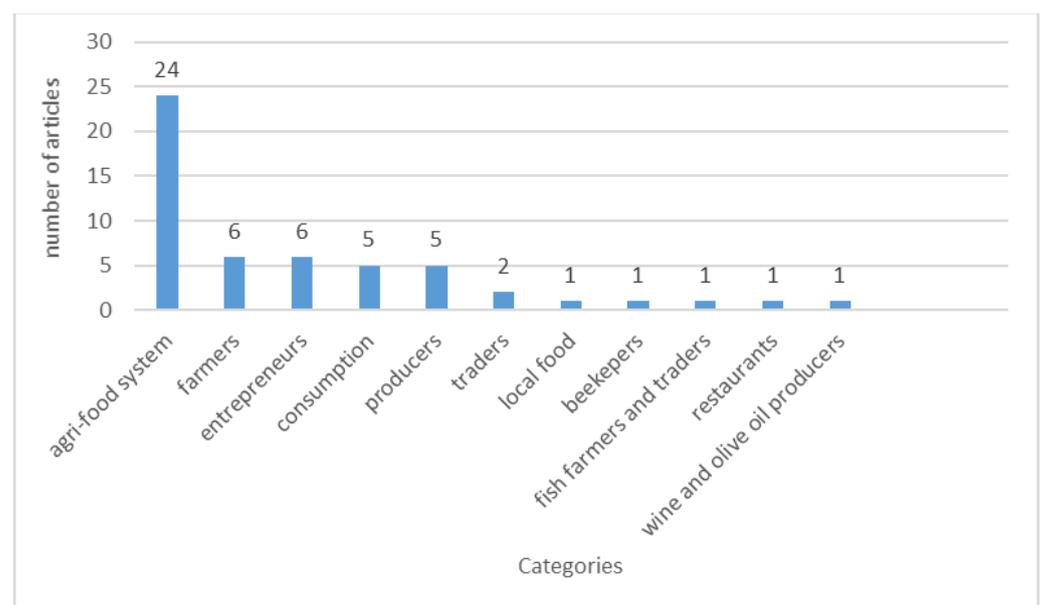


Figure 2. Research topics for agri-food sustainability. Source: The Scopus (<https://www.scopus.com>, accessed on 1 May 2024), Web of Science (<https://www.webofscience.com>, accessed on 1 May 2024), and Science Direct (<https://www.sciencedirect.com>, accessed on 1 May 2024) databases.

4.3. Sustainability after COVID-19: Thematic Analysis

A total of 15 papers deal with changes in consumer behaviour, 16 deal with trade, 29 deal with analysing production, and 9 deal with other topics such as supply chains. Economic sustainability appears in almost all articles, with 50 sources dealing with this topic. Environmental sustainability appears in 15, and the topic of social issues appears in 19.

Some articles discuss more than sustainability issues or one actor in the supply chain. Therefore, despite the efforts to classify all articles under a sub-theme, it is only possible for some of them (Figure 3). The structure of the Results section of this article is as follows: This paper first analyses the sources that deal with economic sustainability. The order is producers, traders, consumers, and systems. This is followed by articles dealing with environmental sustainability and then those dealing with social sustainability.

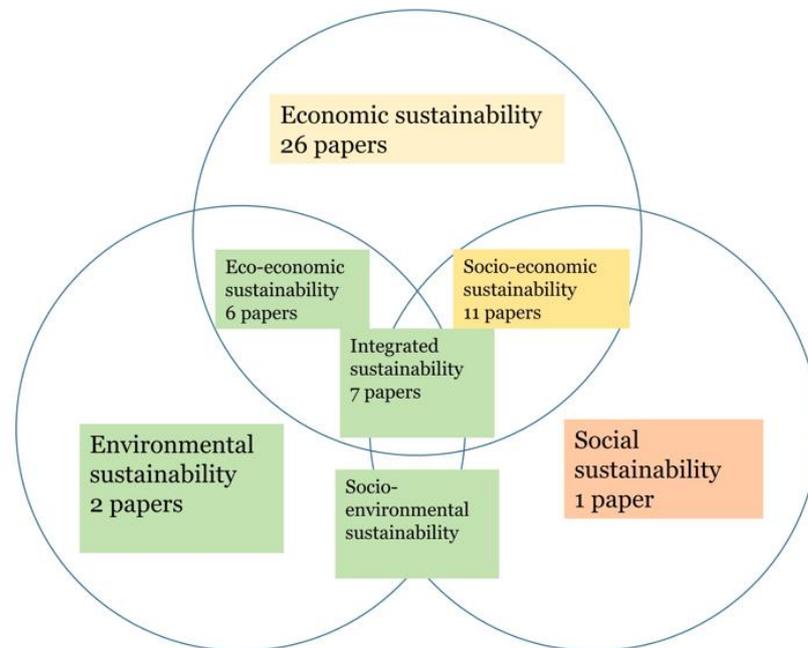


Figure 3. Primary sustainability analysis of COVID-19 research. Source: The Scopus (<https://www.scopus.com>, accessed on 1 May 2024), Web of Science (<https://www.webofscience.com>, accessed on 1 May 2024), and Science Direct (<https://www.sciencedirect.com>, accessed on 1 May 2024) databases.

4.3.1. Economic Sustainability

Spanish wine- and olive oil-producing companies have shown high resilience during COVID-19, which aligns with agri-food activities. Their sustainability can be increased by introducing digitalisation. According to the study, wine consumption has fallen. Demand for olive oil increased in the low and medium segments. Local market and online sales have become more critical. High-quality products were sold with new packaging. Grassroots initiatives were successful. Among the central measures, supporting the harvesting of grapevine and reducing stock production in the olive oil sector were typical [113]. According to Serbia's results, the most effective marketing channel for agricultural products is through processing plants (cold-drying plants, silos, and combine harvesters). Sales through advertising increased, and sales at farmers' markets were also significant but lagged behind processing plant turnover [114].

Based on the experience of the Konya province in Turkey, Ugur and Buruklar (2022) highlight that production costs increased, prices became unstable, labour recruitment became more complex, and the volume of markets decreased. This was very typical among producers of fruit and vegetables under irrigation. Difficulties in marketing and the supply of raw materials increased [115]. Wang et al. (2022) found that horticulture is a key export sector for Xinjiang's agricultural products. However, under COVID-19, development lagged behind other regions of the country. Highly processed products are a competitive advantage even in times of crisis [116]. Zielińska-Chmielewska et al. (2021) analysed proposals by country for the meat market. The solution for China is to promote rail transport and to subsidise rail transport. For Russia, the solution is to subsidise cold storage. In Russia, export restrictions have been imposed. The Russian government

provided significant support to producers and consumers. In the US, processors have introduced several innovative solutions and central measures to help the supply side. The sustainability of the food supply chain requires well-thought-out support for agri-food production [117].

In the countries of the Central American region, research has shown that firms and estates that are part of vertical integration have significant control in the supply chain or are self-sufficient, and self-consuming units were less affected by austerity. These units were more adaptable than medium- and small-scale farmers, whose primary income is agriculture [118].

Mastronaldi et al. (2022) studied 15 farms in central Italy using semi-structured interviews with text analysis. The results show that those diverse economies have a better chance of survival and are more economically sustainable. It helps economies become competitive if they have sustainable logistics and use e-commerce. There is a need to develop and exchange knowledge and innovation and to strengthen diversification. Farms with outsourced activities suffered more [119].

Calculations of material, energy, and economic costs associated with beef, pork, and poultry meat in Italy have been presented in a paper. The study's results highlight the importance of waste management, the cost-increasing impact of generation, and the cost of disposal. It has been estimated that more than 0.45–0.50 million tonnes of fresh meat was lost during COVID-19 throughout the Italian agri-food chain. This corresponds to approximately €242–268 million, to which additional energy and water losses should be added (€435–481 million). There are two main barriers to sustainable food supplies. First, entrepreneurs are distrustful of both government and sustainability measures. The other fact is that not everyone can access safe food [120].

In Macedonia, 91 farmers were asked how the outbreak affected their farms. Characteristics included the disconnection between farmers and traders/processors, the need for more technical support on the ground, and uncertainty. The volume of production decreased, and the quality of agricultural products became uncertain. Seasonal workers were not available, and costs increased. The typical structure of small farmland and lack of cohesion made survival and effective responses to the crisis difficult. A breakdown in communication between buyers and producers became a feature. Low awareness was accompanied by a decline in sales in the HoReCa channel [121].

Ignat and Constantin (2020) examined the resilience of entrepreneurs in all regions of Romania during COVID-19. The results show that entrepreneurial resilience is generally stronger in poorer, less developed regions, both qualitatively and quantitatively. This is due to entrepreneurial initiatives. Entrepreneurs with higher quality and capital strength proved more stable during the crisis in the wealthiest Romanian countries. Business development activities increase the flexibility of enterprises [122].

The study analysed data collected in May 2020 from 367 agri-food SMEs in 17 countries to explore how COVID-19 measures have impacted this segment. Most respondents (94.3%) experienced a decline in turnover, had insufficient reserves, and had difficulty finding suitable employees. Additionally, 13% had stopped production, 82% had reduced production, and 54% had changed their sales prices. If a firm's turnover was less than USD 50,000 per year, it was more likely to have been negatively affected by the crisis. Young firms that have been around for a short time and have few employees have been the least affected by the crisis. A total of 80% of firms have taken action in response to the COVID-19 measures. For example, 44% looked for new business opportunities [123].

The Egyptian example shows that SMEs in developing countries need more financial resources to manage risk and develop a strategy. Due to resource constraints, they have yet to be able to take advantage of the favourable opportunities under COVID-19. A mindset change is needed to prepare these enterprises for crises [124].

Jámbor et al. (2020) found that the main impacts of the pandemic most likely affect the following aspects: supply, demand, labour, food security, food safety, trade, and other effects. The impacts show variations. Some were positively affected, others negatively [125]. Liu et al., 2022, argue that significant waste exists in the agri-food supply chain (AFSC), with export earnings falling short under COVID-19, because of a lack of cold storage capacity, inadequate handling, and poor product packaging on sales. If the supply chain strategy is well planned, the presence of network planning and a well-functioning information system will reduce the risk of turnover losses. This requires minimising transport damage. Recycled packaging and protective packaging are seen as good practices [126].

According to the researchers' study, the COVID-19 crisis has hardened long food supply chains. The system's sustainability requires solidarity, cooperation and collective action to maintain a resilient food system. The crisis has affected all activities of the food system (from production to consumption) and all pillars of food security (availability, access, utilisation, stability). The crisis has most affected the extended supply chain as it has the most vulnerable, complex systems [127].

Sama-Berrocal and Martínez-Azúa (2022) studied agri-food companies in Extremadura (Spain). Their question was which activities were most hampered by the COVID-19 austerity measures. The companies' finances (decrease in turnover and decrease in product demand) and operations (difficulties in marketing activities and stop/decrease in the financial year) were the most important characteristics of economic sustainability. Most companies have introduced new marketing strategies, stricter hygiene standards, and reorganisation. They changed either their product or their service. They have improved relations with customers and suppliers and tried to offer discounts. Their responses included digitalisation, a new marketing strategy, and stricter health protocols [128].

The outbreak has shown that Malaysian care is not stable. Typically, food was hard to come by, and people panicked, and in many cases, prices rose. Output in the economy and emissions fell back. There were labour shortages and high exposure to imported fertilisers, feed, and migrant workers. Movement restrictions have had a significant negative impact on the entire supply chain, including logistics. The government supported the development of digitalisation and stimulated the economy. Precision technology would increase efficiency in production, while blockchain distribution in the supply chain would help manage disruptions [129].

According to Xue et al. (2021), food insecurity, information flow stagnation, and transport stagnation were all problems during the epidemic. The symptoms caused by the crisis include distorted food demand due to panic buying. On the supply side, food transport and production could be improved, which could be a solution, thus increasing local food consumption and local supply [130].

The advantage of intelligent packaging with the correct information is that it informs consumers about the freshness of the product. This promoted sustainability during the epidemic, with the main aim of preventing food waste. Optimal inventory capacity, freshness indicator, duration of freshness period, and product quantity were the main factors influencing the grocery supply chain performance during the epidemic [131].

Millard et al. (2022) examined local (subnational) differences in the behaviour of household food consumption before and during the first wave of COVID-19 in 2020. They found that low-income households were highly affected by the epidemic, but small towns made them more resilient. Households in large cities were hit harder by the crisis. Health characteristics were most affected by how household income changed under the restrictions. Where it decreased, health characteristics worsened. The use of convenience foods, in particular, has fallen as a result of income losses in households. Households not characterised by income loss used more raw materials during COVID-19 and reduced their use of processed food. Households with income loss have been forced to make more changes (essential provision, austerity, saving, new recipes, more food choices, and so on) [132].

The outbreak meant a collapse of the logistics network, uncertainty of demand, and sustainability problems. The authors' study concludes that various IoT technologies, namely blockchain, robotics, big data analytics, and cloud computing, are increasing global competitiveness. Blockchain technology in agri-food supply chains increases sustainability by improving safety, quality, traceability, and transparency [133].

Research in six African countries shows that smaller, mainly women-owned agri-business SMEs have been more affected by the epidemic. Marketing, labour supply, and job security were disadvantageous, and as a result, these enterprises experienced a financial loss at the time. The larger agri-SMEs were better able to adapt, redeploy resources, manage crises, and increase job security. Credit-constrained agri-SMEs operating further away from urban centres and those producing agricultural inputs were also more likely to suffer losses [134].

In urban and metropolitan areas around the Mediterranean, closer cooperation between agriculture, the cultural dimension of food, logistics, research and innovation, and tourism marketing has become a necessity and an opportunity during and after COVID-19 [135].

A survey in Tunisia asked how consumers waste food [136]. Two hundred eighty-four respondents took part in the survey. A total of 89% of the respondents knew that they had wasted food. A total of 93% of respondents said the COVID-19 closure would encourage them to reduce waste. A total of 85% of respondents had significantly reduced their wastage after introducing the restrictions. The behaviour change was driven more by economic and social reasons (i.e., food availability, mobility constraints, loss of income) than by a desire to protect the environment. Food waste prevention would be supported by education.

Waltnoefler and Riefler (2022) aim to determine whether perceptions of local food consumption changed during the COVID-19 outbreak [137]. A sample of 351 items from Austria was analysed. Perceptions of local food consumption remained stable. Thus, one of the reasons for Austrian flexibility is the local food supply and its relationship with consumers.

In North America, the almost complete temporary failure of the food distribution channel in the early stages of the COVID-19 pandemic revealed significant vulnerability. With the growth of online shopping, the increase in demand for local products was typical. It can be concluded that the crisis affected low-priced, mass-produced firms more. More significant consolidation and diversification of supply chains could solve these issues and make them more resilient to crises [138]. Table 2 summarises economically sustainable publications in terms of subject areas (themes), research focuses and objectives, the scale of the studies, geographical scopes, and key results and findings.

Table 2. Summary of the research conducted separately on the economic pillar of sustainability and COVID-19.

Reference	Sustainability Dimension	Subject Area/Theme	Research Focus and Objective(s)	Geographical Scope	Findings
Rodriguez-Cohard et al., (2021) [113]	economic	Wine and olive production	Studying the implications of COVID-19 for producers	Spain	High-quality products were sold with new packaging. Grassroots initiatives were successful. Producers' sustainability can be increased by introducing digitalisation.
Tosovic-Stevanovic et al., (2020) [114]	economic	Agriculture production and sales	Examining the implications of COVID-19 for producers and sales	Serbia	The most effective marketing channel for agricultural products is through processing plants (cold-drying plants, silos, and combine harvesters).
Ugur et al., (2022) [115]	economic	Agriculture production and sales	Analysing the implications of COVID-19 for producers and sales	Turkey	Production costs increased, prices became unstable, labour recruitment became more complex, and the volume of markets decreased.
Wang et al., (2022) [116]	economic	Horticulture production and sales	Studying the implications of COVID-19 for horticulture producers and sales	China, Xinjiang	Highly processed products are a competitive advantage even in times of crisis.
Zielińska-Chmielewska et al., (2021) [117]	economic	Meat market	Examining the implications of COVID-19 for meat market	Russia, China, the US	Government agri-food support is useful for food supply chains.
Lopez-Ridaaura et al., (2021) [118]	economic	Agriculture production and sales	Studying the implications of COVID-19 for producers and sales	Central American region	Firms and estates that are part of vertical integration have significant control in the supply chain or are self-sufficient; self-consuming units were less affected by austerity.
Mastronardi et al., (2022) [119]	economic	Agri-food farms	Analysing the implications of COVID-19 for farms	Central Italy	It helps economies become competitive if they have sustainable logistics and use e-commerce. There is a need to develop and exchange knowledge and innovation and to strengthen diversification. Farms with outsourced activities suffered more.
Stojcheska et al., (2021) [121]	economic	Agri-food farmers	Examining the implications of COVID-19 for farmers	North Macedonia	The disconnection between farmers and traders/processors, the need for more technical support on the ground, and uncertainty were typical. Seasonal workers were not available, and costs increased.
Bux and Amicarelli (2022) [120]	economic	Beef, pork, and poultry meat producers	Studying the implications of COVID-19 for meat producers	Italy	The study's results highlight the importance of waste management, the cost-increasing impact of generation, and the cost of disposal. Distrust and lack of access to safe foods are the main barriers to sustainable food supply.
Ignat et al., (2020) [122]	economic	Resilience of entrepreneurs	Studying the resilience of entrepreneurs	Romania	The entrepreneurial resilience is generally stronger in poorer, less developed regions, both qualitatively and quantitatively.

Table 2. Cont.

Reference	Sustainability Dimension	Subject Area/Theme	Research Focus and Objective(s)	Geographical Scope	Findings
Nordhagen et al., (2021) [123]	economic	Agri-food SMEs	Examining the implications of COVID-19 for SMEs	Global	Most respondents (94.3%) experienced a decline in turnover, had insufficient reserves, and had difficulty finding suitable employees; 13% had stopped production, 82% had reduced production, and 54% had changed their sales prices.
Hatab et al., (2023) [124]	economic	SMEs	Studying the implications of COVID-19 for SMEs	Egypt	SMEs in developing countries need more financial resources to manage risk and develop a strategy. A mindset change is needed to prepare these enterprises for crises.
Jámbor et al., (2020) [125]	economic	Agri-food firms	Studying the implications of COVID-19	NA	The main impacts of the pandemic most likely affect the following aspects: supply, demand, labour, food security, food safety, trade, and other effects.
Liu et al., (2022) [126]	economic	Agri-food supply chain (AFSC)	Examining the implications of COVID-19 for AFSC	Global	If the supply chain strategy is well planned, the presence of network planning and a well-functioning information system will reduce the risk of turnover losses. This requires minimising transport damage.
Rivera-Ferre et al., (2021) [127]	economic	Food supply chains	Studying the implications of COVID-19 for food supply chains	Global	The system's sustainability requires solidarity, cooperation and collective action to maintain a resilient food system. The crisis has most affected the extended supply chain as it has the most vulnerable, complex systems.
Sama-Berrocal and Martínez-Azúa (2022) [128]	economic	Agri-food companies	Examining the implications of COVID-19 for food firms	Spain, Extremadura	The companies' finances (decrease in turnover and decrease/decrease in product demand) and operations (difficulties in marketing activities and stop/decrease in the financial year) were the most important characteristics of economic sustainability.
Tan et al., (2023) [129]	economic	Agri-food supply	Studying the implications of COVID-19	Malaysia	There were labour shortages and high exposure to imported fertilisers, feed, and migrant workers.
Xu et al., (2021) [130]	economic	Agri-food supply	Examining the implications of COVID-19 for food supply	NA	On the supply side, food transport and production could be improved, which could be a solution, thus increasing local food consumption and local supply.
Kabadurmus et al., (2023) [131]	economic	Agri-food supply	Analysing the positive strategies during COVID-19	NA	Optimal inventory capacity, freshness indicator, duration of freshness period, and product quantity were the main factors influencing the grocery supply chain performance during the epidemic.

Table 2. Cont.

Reference	Sustainability Dimension	Subject Area/Theme	Research Focus and Objective(s)	Geographical Scope	Findings
Millard et al., (2022) [132]	economic	Food consumption	Examining local (subnational) differences in the behaviour of household food consumption	Global	Low-income households were highly affected by the epidemic, but small towns made them more resilient. Households with income loss have been forced to make more changes (essential provision, austerity, saving, new recipes, more food choices, and so on).
Cruz et al., (2023) [133]	economic	Logistics network	Studying the implications of COVID-19	Global	Blockchain technology in agri-food supply chains increases sustainability by improving safety, quality, traceability, and transparency.
Kadzamira et al., (2023) [134]	economic	Agri-business SMEs	Studying the implications of COVID-19 for SMEs	African countries	The larger agri-SMEs were better able to adapt, redeploy resources, manage crises, and increase job security.
Cavallo and Oliveri (2022) [135]	economic	Food logistics	Studying the implications of COVID-19	Studying the implications of COVID-19	Closer cooperation between agriculture, the cultural dimension of food, logistics, research and innovation, and tourism marketing has become a necessity and an opportunity.
Jribi et al., (2020) [136]	economic	Food waste	Analysing food waste during COVID-19	Tunisia	The behaviour change was driven more by economic and social reasons (i.e., food availability, mobility constraints, loss of income) than by a desire to protect the environment.
Wallnoefer et al., (2022) [137]	economic	Local food consumption	Analysing local food consumption during COVID-19	Austria	Perceptions of local food consumption remained stable because of the flexibility of local food supply and its relationship with consumers.
Weersink et al., (2022) [138]	economic	Agri-food supply chain	Studying the implications of COVID-19 for SMEs	North America	The crisis affected low-priced, mass-produced firms more. More significant consolidation and diversification of supply chains could solve these issues and make them more resilient to crises.

4.3.2. Environmental Sustainability

According to a study on environmental sustainability, during the first part of the pandemic, CO₂ emissions in the agri-food system in 23 European countries fell by 0.3 million tonnes. Implementing a circular economy supports the achievement of sustainability goals [63].

Consumers sensitive to sustainability tend to turn to local producers because they associate quality with the producer. They are more inclined to separate their waste and are more environmentally sensitive. They rediscovered the importance of local food, the healthy existence of food, environmental sustainability, and packaging. Individual sensitivity to sustainability, change in purchasing behaviour, expectations related to the agri-food system, knowledge of agri-food policy, and the system of businesses operating in farmers' markets have increased [139].

4.3.3. Social Sustainability

Priyadarshini and Abhilash's (2021) experiences in India show that digitally connecting rural actors (producers, traders) during COVID-19 improved the sustainability of the food supply. Providing adequate nutrition improves the health of society, especially among people experiencing poverty. There is a need to improve food and nutritional security, which helps sustainability on both the demand and supply sides. During the crisis, possible remedial actions help to handle social problems—linking cities and the countryside for trade or supply, the digitalisation of retail processes, efficient distribution of food aid, nutritional supplements for the deprived, the promotion and practice of healthy eating, and environmental education [140].

4.3.4. Eco-Economic Sustainability

In the months since COVID-19 was launched, many governments restricted agri-food exports. They did not allow the export of these staple foods, which increased food insecurity. Food security has been negatively affected by freshwater shortages, poor farmland conditions, armed attacks, political disagreements, and rising temperatures [141].

The COVID-19 pandemic has brought digital technology to the fore. Based on data from a sample of 574 green food entrepreneur firms, the authors argue that local, eco-friendly products sold online make them more sustainable [142].

The Greek experience under COVID-19 shows that 134 green agri-food supply chain company managers say that information sharing, logistics networking, and transport are the most influential factors affecting sustainable business and supply chain performance. Green and environmentally sustainable warehousing and logistics emissions have not improved business results or increased economic sustainability [143].

Castellini et al. (2021) studied data from 1004 Italian respondents. Italian GDP fell by 11.3% in the first wave of COVID-19, which caused uncertainty in the economy and changed consumer habits. The COVID-19 emergency has changed consumer attitudes. A total of 30% of respondents frequently consumed certified sustainable foods, and 20% intended to increase their consumption in the next six months. Consumer interest in animal and environmental issues and human health has improved [144].

Feeding the population requires greater efficiency in production. This results in increased yields, fertiliser, and chemical use, which leads to higher environmental pressures and health risks. IoT systems can help address the issue but at a higher cost. Still, we can expect their greater uptake in the future, increased efficiency in their use, better-quality food produced through their use, and more significant economic benefits in the longer term [145].

Food production and processing in the EU-27 are moderately sustainable. As they increase their GDP sustainability, they decrease their environmental impact. Using production techniques based on a circular economy can increase productivity while increasing ecological sustainability, which is needed for the future [146].

4.3.5. Socio-Economic Sustainability

This analysis explores the impact of the COVID-19 pandemic on agri-food systems in Bangladesh, including increased hunger, reduced access to food, and reduced access to basic food. During the crisis, possible remedial actions help to handle social problems—linking cities and the countryside for trade or supply, the digitalisation of shops, distribution of food aid, nutritional supplements to the impoverished, promotion of healthy eating, and environmental education [147].

Alam et al. (2023) found that as many growers have been impoverished during the crisis, the government's role is to provide financial assistance to fish farmers in the short term and to help them produce and market their products. Two hundred and fifty intensive fish farmers and traders from Bangladesh responded to the researchers. As a result of COVID-19, farm gate prices of different fish decreased by 22–40%, and fish feed prices increased significantly. Income from fish farming declined in the cases studied. Consequently, capital is also reduced. Food insecurity was general. The COVID-19 outbreak hampered market access for fish farmers and reduced production, resulting in lower incomes and increased vulnerability to food insecurity. The purchase of basic foodstuffs has decreased, with an increase in the proportion of cheaper foodstuffs purchased, purchases on credit and the sale of assets. COVID-19 has led to the use of Facebook, the Internet, or the selling of fish directly to the buyer (16%) [148].

The COVID-19 pandemic disrupted food systems, and food prices increased due to restrictive measures in Kenya. The traders interviewed spoke of a rise in commodity prices and a drop in sales. Except for a few products (cabbage, potatoes), prices rose by 13% over the period. The trader (97%) experienced a decrease in delivery volumes. Consumption at home fell (52%), there was a reduced choice of food (44%), and missing meals also occurred (32%) [149].

Based on a research study in Latvia, the authors state that arable crop farmers were less affected by the COVID-19 crisis than other agricultural workers [150]. The situation in Latvia affected crop processors more than other actors. This was due to decreased demand and dependence on imported raw materials. Producers who also exported were also more vulnerable. According to the research results, field plant growers were less exposed to the adverse effects. However, the negative effect was more robust in the plant processing industry than in other sectors. What caused the most significant impact was the change in demand, the industry's dependence on imported raw materials, and the uncertainty of export markets. Long-term effects of a crisis can be higher unemployment, a decrease in purchasing power, an increase in the proportion of food spent within the household, an increase in food prices, a deterioration in the quality of food for individuals, unhealthy eating, and the spread of automated production processes.

The restrictions caused by the epidemic have changed the supply side of the labour market, which has also brought changes in the social sphere. Bixby et al. (2021) found that the lack of temporary foreign workers and the use of local workers decreased work effectiveness [151]. Based on a survey of 200 Canadian beekeepers, there are two main issues they will have to address under COVID-19: uncertain livestock replacement and the availability of temporary foreign labour. Productivity was reduced as they had to employ local workers. Beekeepers have found that the productivity gap exists because local workers are less skilled and that local workers tend to quit before the end of the contract. Hiring local labour, lacking foreign workers, and lacking bee colonies could reduce profits by 55–75%.

A Canadian study claims [152] that the use of off-site food services (takeaway/transportation) increased in Canada during the COVID-19 pandemic. Consumers significantly reduced their use of restaurant food services. Meal service use varied by sociodemographic groups: age, education and educational attainment, household income, distance from home, number of children, and marital status. Older people ate more often away from home. Participants with lower levels of education perceived food eaten locally to be more expensive than those with higher levels of education, so the latter is the leading

market segment for restaurants. On the other hand, those with lower educational attainment perceived food eaten locally to be less convenient than those with higher educational attainment. Participants with high household income perceived food eaten locally to be less expensive and of good quality, while those with lower income perceived food eaten locally to be costly and of poor quality. Consumers in small towns or rural areas perceived food eaten locally as less convenient than those in suburban areas.

Experience in Romania shows consumers turned to healthier food during COVID-19 [153]. Preference was given to local food sourced through short supply chains. The use of digital technology has come to the fore. Producers who had this had a competitive advantage. Consumers favoured local products. Production needed to be improved by logistical constraints and the unavailability of seasonal labour. Poverty increased, and diversification was an advantage. The producer and the consumer were separated.

Based on studies of alternative and local food systems in 13 countries, researchers have found that social and technological innovation, greater citizen participation, and greater interest from policymakers and retailers increase the sustainability of food systems [154]. In alternative local food systems, food is considered safer, less polluting, better quality, and healthier. Producers have responded to the restrictions, selling online and adapting to the situation. Labour shortages were also a big problem. Regional initiatives and municipal and government support were supportive.

In the COVID-19 survey, the researchers collected the experiences of organic and agroecological farmers and alternative grassroots food networks (AFNs) in Rome [155]. The results highlight the importance of local grassroots action in food access, supply, and distribution. COVID-19 has increased the share and role of online sales. The volume of trade through the HoReCa channel has decreased. The role of local direct sales is significant, and it performed 40% better in closures than before. Further, food prices have increased to varying degrees, and the role of social cohesion and solidarity cohesion has increased. Food poverty has increased, i.e., a part of the population does not have access to sufficient quality and quantity of food, which is accompanied by health risks.

A study in Qatar found that consumers adopted healthier eating practices during COVID-19 [156]. Local and domestic food consumption increased due to safer food. They increased online purchasing. Panic buying and food hoarding were rare in Qatar. Healthy eating and lifestyles came to the fore during the pandemic, as demonstrated by an increased consumption of fresh fruits and vegetables. In parallel, respondents consumed more water. Consumption of fast food and other unhealthy foods decreased.

In a study in Kuwait, a total of 841 responses were processed [157]. The results showed changes in consumer behaviour. Online food purchasing has become more common (42.8%). Long-shelf-life foods are the leading food purchased (76%). Eating at home has become more common, with a decrease in eating away from home (76%) and typically following government regulations (98%). The possibility and frequency of men meeting regularly decreased during this period. This had an impact on men's lives, habits, social relationships, and loneliness. Table 3 summarises these publications in terms of subject areas (themes), research focuses and objectives, the scale of the studies, geographical scopes, and key results and findings.

Table 3. Summary of the research conducted separately on the main pillars of sustainability and COVID-19.

Reference	Sustainability Dimension	Subject Area/Theme	Research Focus and Objective(s)	Geographical Scope	Findings
Adelodun et al., (2021) [63]	environment	Circular economy	Studying the implications of COVID-19 for environment	European countries	CO2 emissions in the agri-food system in 23 European countries fell by 0.3 million tonnes. Implementing a circular economy supports the achievement of sustainability goals.
Foti and Timpanaro (2021) [139]	environment	Agri-food consumers	Examining the implications of COVID-19 for consumers	Global	Individual sensitivity to sustainability, change in purchasing behaviour, expectations related to the agri-food system, knowledge of agri-food policy, and the system of businesses operating in farmers' markets have increased.
Priyadarshini and Abhilash, (2021) [140]	social	Agri-food consumers	Analysing the implications of COVID-19 for society	India	There is a need to improve food and nutritional security, which helps sustainability on both the demand and supply sides.
Manikas et al., (2022) [141]	eco-economic	Agri-food security	Studying the implications of COVID-19 for food security	Global	Food security has been negatively affected by freshwater shortages, poor farmland conditions, armed attacks, political disagreements, and rising temperatures.
Wang and Fan (2021) [142]	eco-economic	Agri-food sales	Examining the implications of COVID-19 for markets	Global	Based on data from a sample of 574 green food entrepreneur firms, the authors argue that local, eco-friendly products sold online make them more sustainable.
Trivellas et al., (2020) [143]	eco-economic	Agri-food supply chain	Studying the implications of COVID-19 for supply chain	Greece	Information sharing, logistics networking, and transport are the most influential factors that affect sustainable business and supply chain performance.
Castellini et al., (2021) [144]	eco-economic	Agri-food consumption	Studying the implications of COVID-19 for consumption	Italy	The COVID-19 emergency has changed consumer attitudes. Consumer interest in animal and environmental issues and human health has improved.
Senturk et al., (2023) [145]	eco-economic	Industry technology	Examining the implications of COVID-19 for technology	Global	IoT systems can help address the issue but at a higher cost. Still, we can expect their greater uptake in the future and increased efficiency in their use.
Castillo-Díaz et al., (2023) [146]	eco-economic	Food production and processing	Studying the implications of COVID-19 for food production	EU-27	Using production techniques based on a circular economy can increase productivity while increasing ecological sustainability, which is needed for the future.
Talukder et al., (2021) [147]	socio-economic	Agri-food system	Studying impact of the COVID-19 pandemic on agri-food systems	Bangladesh	During the crisis, possible remedial actions help to handle social problems, such as linking cities and the countryside for trade or supply, digitalisation, and distribution of food aid.

Table 3. Cont.

Reference	Sustainability Dimension	Subject Area/Theme	Research Focus and Objective(s)	Geographical Scope	Findings
Alam et al., (2023) [148]	socio-economic	Smallholder aquaculture farmers	Examining the implications of COVID-19 for SMEs	Bangladesh	The COVID-19 outbreak hampered market access for fish farmers and reduced production, resulting in lower incomes and increased vulnerability to food insecurity.
Kunyanga et al., (2023) [149]	socio-economic	Agri-food traders	Studying the implications of COVID-19 for traders	Kenya	The trader (97%) experienced a decrease in delivery volumes. Consumption at home fell (52%), there was a reduced choice of food (44%), and missing meals also occurred (32%).
Upite et al., (2022) [150]	socio-economic	Agri-food workers	Studying the implications of COVID-19 for workers	Latvia	According to the research results, field plant growers were less exposed to the adverse effects. However, the negative effect was more robust in the plant processing industry than in other sectors.
Bixby et al., (2021) [151]	socio-economic	Labour market—beekeepers	Examining the implications of COVID-19 for beekeepers	Canada	Hiring local labour, lacking foreign workers, and lacking bee colonies could reduce profits by 55–75%.
Abebe et al., (2022) [152]	socio-economic	Off-site food services	Studying the implications of COVID-19 for food services	Canada	Consumers significantly reduced their use of restaurant food services. Meal service use varied by sociodemographic groups: age, education, attainment, household income, distance from home, number of children, and marital status.
Tanasa et al., (2022) [153]	socio-economic	Agri-food consumers	Examining the implications of COVID-19 for food consumers.	Romania	Consumers turned to healthier food during COVID-19. Preference was given to local food sourced through short supply chains and important characteristics of economic sustainability.
Nemes et al., (2021) [154]	socio-economic	Local food systems	Studying the implications of COVID-19.	13 countries	Social and technological innovation, greater citizen participation, and greater interest from policymakers and retailers increase the sustainability of food systems.
Zollet et al., (2021) [155]	socio-economic	Agri-food networks	Examining the implications of COVID-19 for food supply	Rome, Italy	The results highlight the importance of local grassroots action in food access, supply, and distribution. COVID-19 has increased the share and role of online sales.
Ben Hassen et al., (2020) [156]	socio-economic	Agri-food consumption	Analysing the impact of COVID-19 on consumption	Qatar	Local and domestic food consumption increased due to safer food. They increased online purchasing. Healthy eating and lifestyles came to the fore.

Table 3. Cont.

Reference	Sustainability Dimension	Subject Area/Theme	Research Focus and Objective(s)	Geographical Scope	Findings
Altarrah et al., (2021) [157]	socio-economic	Food consumption	Examining local (subnational) differences in the behaviour of household food consumption	Kuwait	Low-income households were highly affected by the epidemic, but small towns made them more resilient. Households with income loss have been forced to make more changes (essential provision, austerity, saving, new recipes, more food choices, and so on).
Dewick et al., (2020) [158]	integrated	Circular economy	Studying the implications of COVID-19 for circular economy	Global	The pandemic has placed farmers in a precarious position, hindering their growth and participation in larger markets.
Barrett et al., (2021) [159]	integrated	Agri-food system innovation	Studying the implications of COVID-19 for innovation	Global	The social challenge is strengthening the supply chain's resilience and building social trust. Increasing the strength of the supply chain is necessary. Diversity, flexibility, modularity, and redundancy can help optimise global, regional, and local sourcing opportunities.
Di Giacomo and De Felice, (2022) [160]	integrated	Agri-food system	Studying the implications of COVID-19	Europe	The positive impact of COVID-19 is that people are turning away from traditional values and becoming more aware of themselves and their environment to prioritise local producers' production of quality food and reduce the supply chain length.
Galanakis et al., (2021) [161]	integrated	Innovation and technology	Analysing food waste during COVID-19	Global	Intense, sustainable food production systems (e.g., digitalisation, artificial intelligence and automation in smart agriculture) and safety risk management could be promoted.
Ardekani et al., (2023) [162]	integrated	Food supply chain	Analysing local food consumption during COVID-19	Brazil	Supply management, transport, and logistics management positively and significantly changed food supply chains' sustainable performance; relationship management and supply chain impact management negatively affected sustainable performance, and the effects of demand and production management were not significant.
Alam et al., (2023) [163]	integrated	Agri-food supply chain	Studying the implications of COVID-19 for food security	Global	Food supply chain disruptions can be solved by using sustainable food supply chains and precision farming practices.
Righi and Viganò, (2023) [164]	integrated	Organic farm	Examining COVID-19's effect on organic farming	Italy	Consumers are more attracted to local and organic foods to ensure food safety. The professionalism of farmers can be achieved through organisational innovation, knowledge dissemination, and integration.

4.3.6. Integrated Sustainability

The research by Dewick et al. (2020) underscores a crucial lesson from the COVID-19 pandemic: adopting circular principles can significantly mitigate smallholder farmers' social and economic vulnerability while enhancing environmental sustainability [158]. The pandemic has placed farmers in a precarious position, hindering their growth and participation in larger markets. The lower profits will make it challenging for them to invest in and enhance their operations. The widespread use of MBOs, increased government involvement, improved access to infrastructure and technology, and the availability of support services are imperative to address this.

Barrett et al. (2021) highlighted the areas where progress is needed under COVID-19 to ensure the crisis is well managed [159]. The social challenge is strengthening the supply chain's resilience and building social trust. Increasing the strength of the supply chain is necessary. Diversity, flexibility, modularity, and redundancy can help optimise global, regional, and local sourcing opportunities. Local supply provides security. The right technology and innovation level would help overcome difficulties and address problems. Pandemics could be a consequence of excessive human disturbance of natural ecosystems. Uniform food safety regulations, environmental safety, and health management are needed. High-frequency monitoring, remote sensing, appropriate use of data science, proper management of digital records, and monitoring disease biomarkers can all help adaptation. One lesson of the epidemic highlights the need for a social safety net. The impact of the epidemic has increased inequalities.

The experience of COVID-19 has made us realise the importance of bringing producers and consumers closer together to ensure food safety, food security, and sustainability. Two important lessons are to expand trade flows and help migrant labour farm the land. The other is to prioritise the production of quality food by local producers and reduce the supply chain length. The positive impact of COVID-19 is that people are turning away from traditional values and becoming more aware of themselves and their environment [160].

Under COVID-19, changes in the food industry (e.g., lab-grown meat, plant-based alternatives to meat, and the appreciation of natural sources), as well as the development of nutrition and immune-boosting products, may become widespread. The workforce is being educated and trained to use these technologies. Food safety has become a priority at the global level as one of the elements of managing epidemics. Intense, sustainable food production systems (e.g., digitalisation, artificial intelligence and automation in smart agriculture) and safety risk management could be promoted [161].

Ardekani et al. (2023) assessed the impact of the COVID-19 pandemic on the sustainable (environmental, social and economic) performance of agri-food supply chains [162]. They surveyed 349 different Brazilian agri-food companies, which were medium and large. It was found that (1) supply management, transport, and logistics management positively and significantly changed food supply chains' sustainable performance; (2) relationship management and supply chain impact management negatively affected sustainable performance; and (3) the effects of demand and production management on sustainable performance were not significant. The impact of the COVID-19 pandemic has shown the vulnerability of supply chains.

COVID-19 has caused food supply disruptions, mostly in developing countries. Thus, the food supply needs to be improved. This can be solved by using sustainable food supply chains and precision farming practices, which are addressed by Agriculture 4.0 [163].

Due to the disruption caused by COVID-19, economic survival has become the main problem for farmers, specifically production costs, changes in product prices, and volatility. Consumers are more attracted to local and organic foods to ensure food safety. The professionalism of farmers needs to be increased. This can be achieved through organisational innovation, knowledge dissemination, and integration. The use of advisory services, the development of knowledge chains, and the enhancement of education and skills can help achieve these goals and increase sustainability [164]. Tables 4 and 5. summarise the main topics of COVID-19 research.

Table 4. Main topics of COVID-19 research I. Source: The Scopus (<https://www.scopus.com>, accessed on 1 May 2024), Web of Science (<https://www.webofscience.com>, accessed on 1 May 2024), and Science Direct (<https://www.sciencedirect.com>, accessed on 1 May 2024) databases.

Sales	Handling Social Problems	Change in Consumption	Crisis Effects
<p>sales through processing plants (Tosovic-Stevanovic et al., 2020) [114]</p> <p>online sales (Alam et al., 2023; Mujkic et al., 2019; Zollet et al., 2021) [103,148,155]</p> <p>local supply (Xue et al., 2021; Zollet et al., 2021) [130,155]</p> <p>supply management (Ardekani et al., 2023) [162]</p>	<p>support rural population (Priyadarshini, and Abhilash 2021; Talukder et al., 2021) [140,147]</p> <p>inequalities (Barrett et al., 2021) [159]</p> <p>loneliness (Altarrah et al., 2021) [157]</p>	<p>income and health (Millard et al., 2022) [132]</p> <p>sustainable products (Castellini et al., 2021) [144]</p> <p>mindful consumption (Foti and Timpanaro 2021; Tanasa, et al., 2022; Ben Hassen et al., 2020) [139,153,156]</p> <p>food customs (Abebe et al., 2022) [152]</p> <p>reducing waste (Jrib et al., 2020) [136]</p>	<p>fish farmers and traders (Alam et al., 2023) [148]</p> <p>agriculture workers (Upite et al., 2022; Bixby et al., 2021) [150,151]</p> <p>trust in producers and the food system (Walnnoefer and Riefler 2022) [137]</p> <p>resilience (Ignat and Constantin 2020; Nordhagen et al., 2021) [122,123]</p> <p>export restrictions (Manikas et al., 2022) [141]</p> <p>supply, demand, labour, food security, food safety, and trade (Jámbor et al., 2020; Kunyanga et al., 2023; Barrett et al., 2020) [125,149,159]</p> <p>finance and operations (Sama-Berrocal and Martínez-Azúa 2022) [128]</p>

Table 5. Main topics of COVID-19 research II. Source: The Scopus (<https://www.scopus.com>, accessed on 1 May 2024), Web of Science (<https://www.webofscience.com>, accessed on 1 May 2024), and Science Direct (<https://www.sciencedirect.com>, accessed on 1 May 2024) databases.

Resource Management	Innovation and Technology	Management, Cooperation	Certification, Production
<p>state subsidy (Zielińska-Chmielewska et al., 2021) [117]</p> <p>stock (Hatab et al., 2023) [124]</p> <p>waste management (Bux, and Amicarelli 2022; Liu et al., 2022) [120,126]</p> <p>financial characteristics (Kadzamira et al., 2023) [134]</p> <p>circular economy and carbon (Adelodun et al., 2021; Castillo-Díaz et al., 2023; Dewick et al., 2020) [63,146,158]</p> <p>centralised protection (Ugur and Buruklar 2022) [115]</p> <p>consolidation and diversification (Weersink et al., 2021) [138]</p>	<p>highly processed products (Wang et al., 2022) [116]</p> <p>social and technological innovation (Nemes et al., 2021) [154]</p> <p>use of IoT technologies (Adelodun et al., 2021; Cruz and de Arruda Ignacio 2023; Senturk et al., 2023; Galanakis et al., 2021) [63,133,145]</p> <p>short food supply chain (Walnnoefer and Riefler 2022; Di Giacomo and De Felice 2022) [137,160]</p> <p>precision agriculture (Alam et al., 2023) [163]</p> <p>innovation and knowledge (Righi and Viganò 2023) [164]</p>	<p>digitalisation (Rodriguez-Cohard et al., 2021; Wang and Fan 2021) [113,142]</p> <p>vertical integration (Lopez-Ridaura et al., 2021) [118]</p> <p>cooperation (Rivera-Ferre et al., 2021; Tan et al., 2023; Cavallo and Olivieri 2022) [127,129,135]</p> <p>disconnection of members (Stojcheska et al., 2021) [121]</p>	<p>intelligence package (Kabadurmus et al., 2023) [131]</p> <p>sustainable production (Castellini et al., 2021) [144]</p>

5. Discussion

In this section, several studies have addressed the issue of agri-food sustainability at economic, environmental, and even social levels in the four years before and during the COVID-19 epidemic. The research questions are presented in detail below.

RQ1. *What were the main research questions on agri-food sustainability (economic, environmental, and social issues) before COVID-19?*

Before COVID-19, two major research areas on agri-food sustainability were economic and environmental sustainability. In economic sustainability, micro-economic issues came to the fore. Increasing efficiency became a priority. Data-driven management [66], a form of management that relies on data analysis for decision-making, managed change management (a process of planning and implementing change in an organisation) [70], and innovation [71] were possible ways of doing this. Efficiency was a key issue [73].

Cooperation and vertical coordination were economically beneficial at the macroeconomic level [69]. The weight and role of environmental sustainability were substantial at this time. Recovering and reducing waste was important, as it was an environmental and economic issue [74–76]. By increasing production efficiency [89] or even by choosing an environmentally friendly way of production, steps towards environmental sustainability could be taken [91,92]. Selecting the right way of transport [97,98], the ecological negative effect could be reduced. Positive actions towards consumers, such as packaging and safe transport, also increase sustainability [108].

RQ2. *What are the main issues and research directions for agri-food sustainability (economic, environmental, social issues), considering the implications of COVID-19?*

The period of COVID-19 created a significant burden for economies and economic operators. Many countries reported a significant economic downturn.

Tables 2 and 3 show that research topics expanded during COVID-19. Research has highlighted the epidemic's impact on the economy, making it significantly more challenging to achieve agri-food sustainability. There has been a macroeconomic downturn on both the supply and demand side [125]. The performance of individual actors, especially SMEs, has declined significantly [123]. Confidence in each other and in supply has declined significantly [94]. Resilience has developed in many operators [122] who have not gone bankrupt. Countries have imposed export restrictions in an effort to ensure food security [117]. As financial difficulties increased, solvency problems emerged for many operators [128]. The crisis has had an impact on both the sales side and the consumption side. The role of local sales has improved [15]. Online sales have increased [113]. Cost reduction became a central issue [164]. Mindful buying has emerged and increased [139], and purchasing has also changed due to changes in income. Public responsibilities have been strengthened to support the socially disadvantaged and to shore up economies. At the same time, areas that were already research areas before the epidemic have been retained. Resource management, innovation [71], management and cooperation, and certification are all areas already present before COVID-19. These articles have increased compared to the previous period because the topic has become very topical.

The focus has shifted from environmental sustainability to economic sustainability. Researchers were looking at how businesses and economies could survive, and these measures also had a positive environmental impact. Efficiency in resource management has remained. Issues of finance, inventory, and waste management emerge as the basis for efficiency.

The role of innovation has increased significantly in research during the pandemic. Processed products are easier to sell, suggesting greater safety. IoT systems are an advantage and a survival advantage. Precision agriculture means efficiency and lower costs. A short food supply chain is also an advantage. Collaboration can also mean survival and increased efficiency as digitalisation becomes more widespread in sales and production. The use of certification increases security when shopping.

RQ3. *How does COVID-19 affect the sustainability of agri-foods?*

COVID-19 had a mixed impact on the sustainability pillars. On the one hand, the constraints have changed the way of life and economic functioning. There was a significant economic downturn. The sustainability of the agri-food systems was not achieved; it was reduced. Production [9], sales [148], exports [117], and turnover in restaurants have declined [152]. Many businesses faced financial difficulty, and many went bankrupt and became financially vulnerable [152]. Some of the states intervened and gave subsidies [117]. Creative human solutions have come forward to help businesses stay afloat. The result, in turn, was precisely the efficiency-enhancing management solutions that became so successful after the first waves of COVID-19. Safe food and food supply security became priority themes, and direct sales were strengthened along these lines [125]. Cooperation between producers became a priority [127]. Logistical solutions have improved, reducing

costs and emissions [153]. Alliances between people, rural and urban areas, producers, and consumers have emerged because rising prices and falling sales have made this necessary. Digitalisation has made sales and transport safer. Vulnerability to imports has been a challenge, with a decline in international trade and a shortage or even lack of supply of raw materials [129].

The goal was to achieve smaller inputs for producing and using the same output during production and use. In the process, they envisioned these with better transportation results [152], waste reduction [62], reduction of water use [120], and other resource efficiency. In addition, better financial processes resulting in primary economic results played a role.

The apparent reason for this was that during this period, due to the restrictions introduced for health reasons, safety and the safety of the food supply came to the fore. As a result of the crisis, there was a drop in sales and consumption, as a result of which the way of sales became one of the research topics for sustainability. In connection with this, the change in consumption habits has also become a related topic. The crisis and its impact received a separate research direction. At the same time, the research areas of resource use, management, innovation, and cooperation, as well as the research of its changes during the crisis, remained. However, building trust between the players and general confidence in the people could have been more successful.

RQ4. *What were the areas that were influenced by COVID-19 but under-researched? What are the research gaps? What are the possible future research directions?*

It is striking that, with one or two exceptions, social sustainability issues are not featured in agri-food research. This is undoubtedly a research gap that could be filled in the future. Most of the SDG targets do not appear here. There was no poverty, zero hunger, and good health and well-being. Researchers should explore what steps are needed to make agri-food systems contribute to this goal. The themes of quality education and gender equality are not necessarily the most closely linked to agri-food, but it is also possible to examine whether and what role agri-food systems can play. The themes of clean water and sanitation, affordable and clean energy, reducing inequalities, and sustainable cities and communities may have a more significant link to the system and its sustainability. Peace, justice, and strong institutions for agri-food system actors could be options.

Partnership for the SDGs is an area worth researching from an agri-food perspective. Research on this could be an opportunity for the future.

An important research topic could be trust and lack of confidence among actors in agri-food systems. It would also be worth exploring what is needed to develop greater cooperation between actors and what could be done to support this process.

It has not yet been possible to cover all the areas relevant to this topic. For example, it was impossible to cover an important topic such as the presentation, analysis, and comparison of agricultural characteristics in different countries. Strengthening the crisis resilience of SMEs could also be a new area of research. Research on this could be a possible direction for the future.

For more profound research, it is recommended to include interdisciplinary character because, for example, social research and results are hardly represented in the literature reviewed. More in-depth research is needed on the three pillars, including the social, economic, and environmental pillars. This would better prepare us for the future impacts of different crises, such as COVID-19.

This study has limitations: The search was limited to the literature published in the WoS, Scopus, and Science Direct databases. The research could include journals that do not appear in these databases. It could be complemented with research published by national research, governmental materials, and policy research.

6. Conclusions

This study aimed to analyse changes in agri-food sustainability before (2016–2019), during, and after (2020–2023) the COVID-19 outbreak with a literature review.

Before COVID-19, business development, efficiency, and innovation were the main focus areas. The researchers focused on increasing environmental sustainability without compromising or improving economic sustainability, which was feasible for the actors involved.

The research prominently analysed the effects of the crisis on various actors and areas of life, including the employee and consumer sides. One significant change was the introduction of restrictive measures, which also appeared in the research because it impacted both social and economic sustainability.

The focus on environmental sustainability has shifted towards economic sustainability under COVID-19. The main characteristics of economic sustainability during the COVID-19 pandemic were related to food security, so food safety and security became a priority. Several countries have imposed export restrictions as a result. Survival became the keyword in the producer and service sector. The crisis hit firms short on capital harder, with many going bankrupt. State support became a priority for companies. IT developments, including IoT, blockchain, etc., and cooperation between actors increased the chances of survival.

High unemployment hindered social sustainability. People separated, which brought mental difficulties. The crisis increased social inequalities. In several countries, the unskilled rural population lost their jobs. Social cohesion and social networks were a necessity. For this reason, training and central support can be necessary. Due to the restrictions, the crisis positively affected environmental sustainability.

It should be stressed that in the case of actors having difficulty due to the crisis, e.g., SMEs, the underlying causes of the crisis must be addressed. Therefore, a business is unlikely to be economically sustainable if the entrepreneur does not have the minimum economic and commercial skills. Competitiveness is only possible if there is enough capital and money to run the business, and the economic and technical conditions for digitalisation, online sales, and secure support still need to be implemented. Positive examples are in vain if consumers are so poor that they cannot afford basic foodstuffs or are starving. These examples cannot be implemented in all places and societies. Public intervention and support would only be worthwhile if resources and distribution were based on the principle of need. Vertical coordination will only be valuable if the level of trust is so low that the actors are unwilling to work together and do not even trust their government. The circular economy is only effective if the technical and economic conditions are fully in place.

The impact of COVID-19 and the lessons learned from the response to this period provided valuable findings for almost all disciplines. This research can also help decision-makers (governments, authorities, practitioners) to guide their efforts and actions to mitigate the adverse effects of the epidemic on agri-food sustainability in the event of a similar outbreak in the future and can help researchers to identify areas of research. At the same time, this study's practical significance is that it is an opportunity for agri-food businesses and their stakeholders to prepare themselves for the efficiency and economic decisions they must make and stick to in the next crisis, without which they cannot survive. The economic, environmental, and social sustainability of the company may be compromised. For business operators, it identifies areas where it is essential to carry out due diligence and, where necessary, improve efficiency. Costs need to be reduced, and current practices need to be changed.

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