# Chapter 7: The role of innovative technologies for sustainability

Francesca Checchinato

Cinzia Colapinto

Vladi Finotto

Alena Myshko

**Abstract**

The agri-food sector has to cope with numerous issues to address its transition towards more sustainable practices.  such a transition might be enabled and sustained by digital technology. Indeed, the application of innovative technologies allows the implementation of sustainable practices and increases the economic and environmental sustainability of the sector. Smart agriculture and industry 4.0 are labels that also denote a policy-driven discourse aimed at triggering novel models of collaboration and coordination among firms, public actors, and research entities. Thus, their deployment brings about novel relational arrangements in territories and value chains.

The present chapter presents the results of a systematic literature review on the intersection between digital applications and sustainability in agri-food firms' strategies. The review was conducted using detailed criteria to identify academic articles, and specific keywords. The time frame considered included the years 2010s–2020s. To analyse the selected dataset, we adopted an extended analytical framework of the sustainability pillars (economic, environmental, and social), and also considered the institutional environment.  Sustainability in agriculture should be analysed as a complex system with interconnected subsystems. We find that a holistic approach to agriculture as a system is perceived to be the way of advancing its understanding. We point out the urge to consider the social impact of innovative technologies, which includes both intended and unintended consequences associated with them. Moreover, the recognition of the role of the institutional environment for technological advancement is crucial for advising the decision-making and creation of supportive policies and research.

## Introduction

The diffusion of new technologies entails finding a relationship between their potential and the schemata individuals use to make sense of the world (Garud & Karnoe, 2003; Hargadon & Douglas, 2001). Thus, regardless of the inherent revolutionary character of a novel solution, innovation needs to be framed and made intelligible via social-construction processes (Cornelissen & Werner, 2014).

Frames having to do with the improvement of the social and environmental contexts we inhabit have been frequent in history and have become increasingly more important in the past 20 years, at the same time inequality and pollution have reached unprecedented peaks. Policymakers welcome and use frames that combine narratives on the economic potential of new technologies – incentivizing profit-seeking organizations and entrepreneurs – with those focused on the social and environmental benefit technologies bring about. This framing is a matter of interaction and reciprocal influence between the discourses structured in different fields, most often the academic debate feeding the public discourse with data and analyses, and the policy-making one, taking stock of the former to set agendas and the allocation of resources.

Smart agriculture and industry 4.0 in the food sector are no exceptions. They are labels that denote an assortment of technologies and a policy-driven discourse aimed at triggering novel models of collaboration and coordination among firms, public actors, and research entities (Reischauer, 2018). Sophisticated sensors, limitless computational capacity, end-to-end integration of data, algorithms to optimize decisions, - all these and other features are usually mentioned in analyses on, and calls for, the adoption of industry 4.0 technologies (Coco et al., 2021). Smart and 4.0 technologies, on the one hand, could help firms increase their productivity and their competitiveness in general; on the other hand, they allow for sustaining profit-making with the improvement of workers' conditions, the reduction of emissions and environmental impacts on fields and production plants, reducing the overall footprint of the industry. Moreover, a combination of the new digital tools with the already integrated automated technologies, such as drones and smart tractors, is supposed to support farmers to 'be more precise with inputs (i.e. seeds, water, fertilizers and pesticides) while enhancing their knowledge of agro-ecological conditions (including weather and landscape interactions and soil and plant health)' (Rotz et al., 2019, p. 112). Industry 4.0, probably more than other technological trend, is both a label for a portfolio of technologies and applications and a policy-driven discourse aimed at inspiring novel models of collaboration and coordination among firms, public actors, research entities, and organizations (Reischauer, 2018).

At the same time, the agri-food sector has been facing serious pressure from global sustainability challenges. The sector is expected to increase food quality and quantity and thus resolve problems of food insecurity; in parallel, it is expected to decrease emissions and the environmental impact of its operations. The growing environmental, social and economic risks, as well as institutional conditions, have highlighted the need for integration of the environment and development, which is conceptualized as 'sustainable development'. In the last decade, sustainable development in general and sustainable development goals (SDGs) in particular have been central in the focus of a variety of supranational organizations, institutions, and in their initiatives. One of the most prominent initiatives is an action plan called Agenda 21, which was introduced at the Earth Summit in 1992. Agenda 21 presents an action plan for sustainable development, which is a response to the urgent need to integrate the environment and development issues more extensively.

The 2005 World Summit was a milestone in terms of developing the idea of sustainability and rebuilding concepts around it. At the summit, world leaders introduced three pillars of sustainability (or sustainable development), bringing together the environment, economic development, and human well-being. The agenda of the Summit and its final report was largely criticized by both researchers and policymakers. Firstly, for its misinterpretation of sustainable development as ‘a label for environmental issues’ (Wilkins, 2008, p. 171), which is partially responsible for ongoing limited understanding of sustainability as mostly an environmental agenda. Moreover, among other policy initiatives, it is frequently carried out with the concept of sustainable development as opposed to ‘sustainability’, thus shifting the emphasis on the development process.

While approaching sustainability by categorizing its issues and themes into three (or more) pillars can be perceived as ‘an inherently political act’ (Boyer, 2016, p. 3), this research utilizes the potential of a holistic and integrated understanding of such a complex and multi-layered phenomenon as sustainability. In other words, it appropriates the triple bottom line framework with the institutional dimension in order to analyse the variety of sustainability issues and, more importantly, the interconnections and interdependencies among them. The search for the most appropriate solution and its effective implementation requires a wide-ranging, complex overview of challenges related to sustainability in various industries, informing the decision-making process. In fact, one of the solutions to sustainability challenges involves introducing technological advancements and Industry 4.0 in different sectors. The benefits of innovative technologies have already been changing the agricultural and agri-food sector and its supply chains by optimizing processes and reducing the ecological impact.

This chapter aims to understand the role of innovative and digital technologies for sustainability in the agri-food sector through analysing technological applications and responses to various sustainability challenges and dimensions. Through the investigation of the application of innovative and Industry 4.0 technologies to implement sustainable practices and increase economic, environmental, social, and institutional sustainability, the chapter uncovers the pathways between technological development and sustainability in agri-food. Specifically, the chapter aims at shedding further light on the interaction between digital technologies and sustainability in the context of the agri-food industry. In particular, this research unpacks the application of digital technologies in the sector by analyzing the reasons for technological advancement, the part of the sector or supply chain and actors involved (or affected) in the application, and sustainability achievements through its dimensions.

The chapter utilizes the methodology of a systematic literature review to collect existing research, both theoretical and practical, on the connections between digitalization of the sector and its sustainability issues. In such a way, the review provides a range of technological implementations and their input in the sustainability of the sector, which should be useful to inform not only future research of sustainable agri-business but also policy initiatives. We assume, in fact, that policy-making and the scientific community are reciprocally influencing each other, thus a systematic analysis of the scientific literature might give us a representation of the determinants of public policy's focus on the sustainability potential of digital technologies.

The chapter is organized as follows: it begins with the introduction of the analytical framework of sustainability and its pillars, or dimensions, to investigate the existing research on innovative and digital technologies and their role for sustainability in agri-food. The second part is dedicated to the description of the methodology of this systematic literature review. In the third part, the results of the research are presented and discussed within the adopted analytical framework of sustainability. The chapter closes with conclusions and avenues for future research.

## Theoretical Framework

Sustainability is a largely complex phenomenon, which has been approached by policymakers, researchers and experts and conceptualised in a variety of ways. Being articulated in many discourses, often contradictory, has contributed to the concept's development, as well as to its broad ambiguity and fuzziness. One of the widespread approaches to sustainability, presented in both academic research and in the policy sphere, is the triple bottom line framework, which is based on the three pillars - environment, economy, and society, or planet, profit and people. Therefore, this framework encompasses three dimensions of sustainability - environmental, economic and social, which are interconnected and create the basis for sustainable communities and industries. An investigation into the conceptual origins of sustainability by Purvis et al. (2017) uses 'pillars' to address its complex nature, with sustainability at the intersections of society, economy, and environment. The authors mentioned a variety of notions used to present those pillars, such as dimensions, components, aspects etc., and stated their interchangeable use. We have not developed a specific preference for any of these terms, therefore, we use them as synonyms in our research. At the core is the perception of the complex nature of sustainability, which encompasses several dimensions and their interconnectedness.

Due to the framework's roots in the policy dimension, it lacks an extensive theoretical basis but has been applied to numerous areas and investigations. The adoption of the framework for the analysis of the role of innovative technologies for sustainability in agri-food is based on the original ideas of developing sustainability as a complex phenomenon and agenda with interconnected dimensions and structures. According to Cluny and Zehnder (2020, p. 1001), the three-pillars approach is more practical and solutions-oriented by supporting 'the creation of new economic and political institutions that embed (from start to finish) the key inputs, stakeholders, and incentive structures necessary for sustainability planning and projects to be feasible, successful, and socially accepted'. This research recognises the 'extended' framework with the fourth pillar – the institutional one as a set of (particular) institutions and institutional conditions. In such a way, the sustainability framework provides an opportunity to analyse the impact of technology implementation for sustainability in the sector as a whole or as a segment, not only generally speaking, but also with social, ecological, economic, and institutional conditions. Furthermore, some research extends the framework by exploring culture as an independent aspect of sustainability (e.g., Birkeland, 2008; Soini and Birkeland, 2014) and presents it as a fourth pillar. Nevertheless, within this review, culture is not articulated as a distinct pillar or dimension.

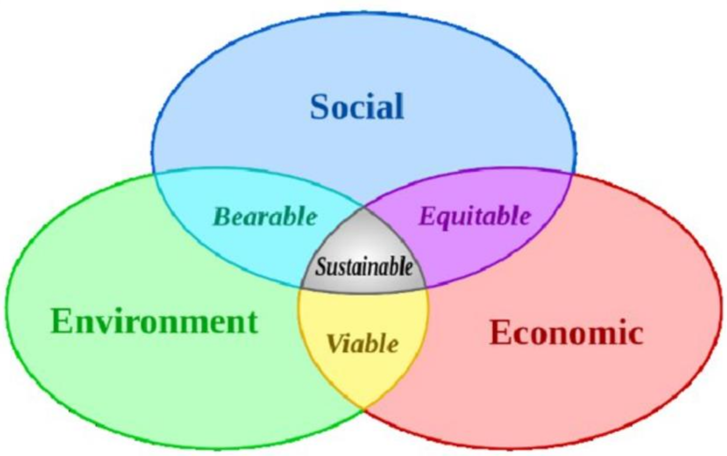
The economic understanding of sustainability is often associated with economic growth and, an increase in efficiency, which presupposes that resources are allocated to their highest valued use and, consequently, there is a rise in productivity and capital assets (Elliott, 2005). Then, environmental, or ecological, sustainability in agriculture focuses on the continued productivity and functioning of ecosystems, which includes a range of factors from resource base quality, the preservation of physical conditions and resources and of biological diversity to productive capacities and climate change mitigation (Yunlong and Smith, 1994).

While the meaning and, therefore, the practical application and measurement of two sustainability pillars - environmental and economic - are relatively clear and elaborated in research and policy, social sustainability is more challenging, having even being referred to as 'a missing pillar' (Bolstrom, 2012). The social sustainability pillar most definitely requires more clarification, especially as a dimension of sustainability as an analytical framework. The challenges of analysis and implementation, in projects and policies, of social sustainability are caused by, first of all, the roots of the sustainability agenda in 'specific forms of environmentalism based in models of global capitalism that thrive upon the exploitation of natural and human capital' (Boyer et al., 2016, p. 2). In such a way, historically the sustainability agenda has placed its focus upon green and nature-related issues instead of devoting more attention to social inequalities. Social issues, urban and rural complexities, in turn, are highly complex to be fully addressed and described by existing social science's methods, both qualitative and quantitative. Therefore, social issues and the corresponding sustainability dimension appear to be frustrating for researchers and policymakers to objectively measure, describe and integrate into policy decisions.

Social sustainability can be defined through the human appropriation of the environment and focuses on the availability of access to social resources by current and future generations, represented in intra- and inter-generational equity respectively (De Gennaro and Nardone, 2014, p. 25). Social, or societal, aspects of sustainability are largely based on broad stakeholder input and include, but are not limited to, animal welfare, values and responsibilities of consumers (as citizens), (un)documented labour conditions and issues, public engagement and others (von Keyserlingk et al., 2013). A review of the literature on the social pillar of sustainable development by Murphy (2012) resulted in a conceptual framework, which is based on the concepts and policy objectives outlined in the research, which identifies four comprehensive social concepts: public awareness, equity, participation, and social cohesion.

Moreover, a review by Boyer et al. (2016, p. 2) suggests that research into the social pillar provides it with a range of roles, from a stand-alone objective to a 'fully integrated, locally-rooted, and process-oriented approach to sustainability'. The authors conclude that the latter role is the most prospective not just for the development of the social pillar itself but for the whole of sustainability theoretical and practical research as well as policy-making. We second their call for efforts 'that recognise how environmental, social, and economic values overlap' and the need for a systematic, integrated and holistic approach to sustainability, which does not separate or prioritise its pillars (Ibid, p. 13). Figure 1 provides with a classical visual representation of interconnectedness of the three pillars with sustainability at the centre, which can be found in various academic and policy sources (e.g., Petrisor and Petrisor, 2014; Purvis at al., 2018; von Keyserlingk et al, 2013, to name just a few).

*Figure 1: Visualisation of the 'classical' three pillars of sustainability approach.*




Source: *Petrisor and Petrisor, 2014, p. 180*

Additionally, some research goes beyond the classical framework with three pillars by adding more dimensions to sustainability to emphasise its complex nature. While in the literature stream adopting the 'extended' framework, the fourth pillar is the cultural one (not least due to its explicit representation in Agenda 21), several researchers focus on the role of institutions and distinguish institutional sustainability pillar. Hosseini and Kaneko (2012) follow the approach by Hak et al. (2007) and present a dynamic concept of sustainability composed of four interlinked and integrated pillars. They identify causalities among those 'sustainabilities', which show, among other interlinks, that 'improvement in environmental conditions can strongly improve the social variables directly, and positively affect institutional development indirectly through the social pillar' (Ibid, p. 200).

To continue, Clune and Zehnder (2018) highlight the role of laws, governance, and regulations since sustainability depends on all levels, from local to international, 'upon matching the scope and scale of law and governance to social and ecological contexts' (p. 226). The authors highlight that, despite being a simplification of a complex system, the three pillars model does still provide 'an effective structure and analytic rigor related to key points of support and contribution', which is significant for the promotion of multidisciplinary projects (Ibid, p. 214). Though the institutional dimension is primarily characterized by consistency between norms and laws, on the one hand, and the levels of governance, it also has to be aligned with other sustainability dimensions.

Broadly speaking, institutional sustainability can be understood as 'the ability of institutions under particular conditions, to guide actors to reach desirable goals', for example, such as adaptation to and mitigation of climate change (Kajembe et al., 2016, p. 27). Within the context of governance for sustainable development, institutional sustainability consists of the institutions' capabilities and activities related to coordination and 'the facilitation of decision making and implementation of sustainability policies', often in order to achieve sustainability goals (Pfahl, 2005, pp. 83 - 84).

As well as for the other sustainability dimensions, academia and policy-making saw various attempts to define, measure and access institutional sustainability. A number of policy actions and documents on sustainable development (and SDGs) included a set of sustainable indicators. Spangenberg (2002) outlines that sustainability indicators are supposed to be general, indicative, sensitive, and robust, and have different levels of details depending on the level of decision making; therefore, be organised in a hierarchy. Although, one of the major challenges for a comprehensive methodology has been a lack of (shared or common) understanding of institutions in the first place, as Pfahl (2005) points out, which are not equal to organizations or regimes. It should be noted that most of the research on measurement of institutional sustainability operates within the sustainable development paradigm.

Therefore, institutional sustainability provides actors with a framework to achieve other sustainability dimensions, on the one hand, and is influenced by the state of these dimensions, on the other hand. It is important to emphasize that institutions, both formal and informal, are not static but dynamic (if they are liveable), they constantly evolve and change over time and also act as an indicator of change. A lack of attention to the role of institutions is misleading 'since the concept of sustainable development attributes a central role to institutions as a tool for its implementation', especially as articulated in Agenda 21 (Pfahl, 2005, p. 80).

Despite several benefits and perspectives brought by the three-pillars framework, some authors point out its drawbacks. One such criticism is the very practical orientation of the framework without having developed a solid theoretical basis. While the approach has been shared as a 'common view' for at least two decades, it is difficult to trace its original urtext (Purvis et al., 2019, p. 685). Because it originated from policy-oriented research. that might explain, on the one hand, a widely practical application of the paradigm and, on the other hand, a shortage of theoretical background. The application of the framework to a specific sector such as agriculture and agri-food offers an overview of sustainability as a complex system with different dimensions and structures. At the same time, the research can benefit from breaking down the ambiguity of the sector's sustainability into more localised issues, which are interconnected within a system. In such a way, the framework provides opportunities to develop research and policy interventions, which, on the one hand, address localised issues and, on the other hand, can be incorporated into a holistic and comprehensive approach.

Broadly speaking, research on the three pillars of sustainability often either perceive them as distinctive perspectives, i.e. focus on one of them, or attempt a systematic approach by stressing their integration and interconnectivity. Within a system approach, 'there lacks a commonality in how interactions are treated, whether trade-offs occur or mutual reinforcements are made' (Purvis et al., 2019, p. 692). Despite the co-existence of the three pillars, and interlinks among them, the economy 'circle' and economic pillar come to the forefront, in both academic and policy-oriented research. One of the reasons is a blurring of the separation line between concepts of 'sustainability' and 'sustainable development', where the latter has often been associated with economic development ('such that economic development remained an implicit, but inadequately formulated, part of sustainability' (Purvis et al., 2019, p. 692)). We understand sustainability as both a process and an aim, but, at the same time, we should avoid direct correlations between 'sustainability' and 'development' in policy connotations.

In the agri-food sector, most research concentrates on economic and/or environmental sustainability, whilst the social dimension and its role in agriculture's development has been undeservedly underdeveloped. Some authors even point out that the focus of most of the studies on the topic have been on the ecological and environmental aspects of sustainability. For instance, Hubeau et al (2017, p. 52) specify that in the existing sustainability studies the ecological aspect of sustainability in agriculture is mainly presented through resource use efficiency and 'lack of embedding the agri-food system in the wider socio-ecological environment'. In that way, the problem of the existing imbalance among the sustainability pillars, which is present in research and policy, has been perpetuated in agriculture and agri-food. Yunlong and Smith (1995) promote sustainable agriculture, which combines the three dimensions, and warn against the focus on only one pillar. The concentration on one or two pillars without interlinking them with social conditions and institutional environment leads, in turn, to a narrow understanding of the sector's transformation under digitalization and the adoption of innovative technologies.

In such a way, to analyse the role of innovative and, in particular, digital technologies, our research was driven by these main research questions:

RQ1: Why is technology being introduced, or what is the aim of applying a specific technology to the agricultural and agri-food sector in general or to specific operations?

RQ2: Which operation(s), or stage in the sector or supply chain is the technology applied to?

RQ3: Which actors are involved in technology's application or are affected by its implementation?

RQ4: Which dimension of sustainability (one or more) do these technologies tackle?

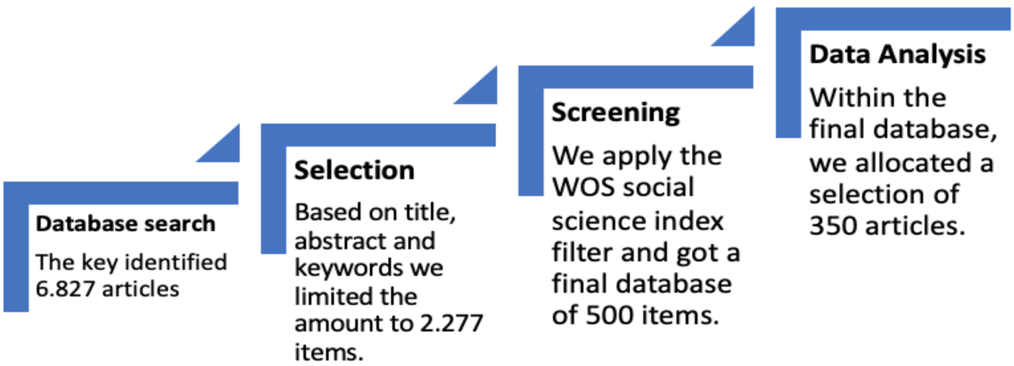
Our investigation is based on a holistic approach to sustainability as a complex phenomenon, which includes such dimensions as economic, social, and environmental (or ecological), as well as characteristics of the institutional environment. This systematic literature review attempts to describe and discuss not only each aspect of sustainability on its own how they are presented in the studied literature, but mainly to understand these dimensions as a whole system – in sustainable agriculture or the agri-food system.

## Methods

To investigate the outlined research questions and the general aim of this research, we have adopted the methodology of a systematic literature review. The research follows guidelines developed by Fink (2010) and Tranfield et al. (2003) for conducting an evidence-informed systematic literature review with a high level of transparency and reduced distortion. Following the steps in this review, the research questions and bibliographic database were selected, then at the conceptualization step research terms were defined. Web of Science (WOS) was selected as the main database to investigate the relevant literature for the analysis, with a parallel search carried out using the same keywords on Google Scholar. The methodology took advantage of some existing relevant literature reviews, for example, on the three pillars of sustainability during Covid-19 (Ranjbari et al., 2021), on the relationship between technology and sustainable development (Annosi et al., 2020), and digital transformation and environmental sustainability (Feroz et al., 2021), just to name a few. This investigation focused on terms related to, firstly, the agri-food sector, and, secondly, to smart technological development within the connection to sustainability (and sustainable development). We have also applied both practical and methodological quality screens (Fink, 2010).

The search and data download were performed on October 6, 2021. We used the following key search: (agri* OR agri-food OR agrifood OR food OR agribusiness OR agri-business) AND (industry 4 OR smart OR smart-agri* OR agri-tech OR agritech) AND (sustainab*). The search was limited by the topic parameter (title, abstract and keywords). Moreover, we analysed only the articles under the WOS social-science index (including management) as shown in figure 2.

*Figure 2: The research flow*




Within the database of 500 articles, we dismissed 62 articles, which did not focus on agriculture or agri-food sector; therefore, they were irrelevant for our review. Then, we selected 88 articles, which investigated sustainability issues but did not cover them in regard to smart or digital technologies. These articles were dismissed from the analysis but were still considered for the framing of sustainability and its pillars (for the theoretical framework). In such way, we allocated a final selection of 350 papers, which is at the heart of the analysis and discussion. The papers in the selection included all the search parameters, i.e. smart technological advancement and sustainability in agri-business.

To analyse the selected articles, we applied the three sustainability pillars framework to the process of implementation of innovative and smart technologies in agri-food. To collect and analyse the data from the papers, we have developed an approach based on three general categories: smart technology; supply chain; and sustainability. In this way, in each article, we have identified, first of all, a type of digital and innovative technology, which has been applied in the agri-food sector. The category also included the rationale or justification behind a choice of an innovation in general and the particular technology. Along with the identification of a technology or digital tool, the use of a research framework, where applicable, was included in the analysis. Secondly, we looked at the sector or node of the supply chain, the phase of the extended production and activity system at which a technology is implemented. Then, we selected the actors, who are engaged in, or affected by, the technological implementation. Thirdly, we identified the so-called sustainability challenges. Finally, we considered the achieved results of technological application, or what impact technology has on increasing sustainability. These inputs were classified according to the four sustainability pillars, considering the interlinks among these dimensions. All these general categories and subcategories were the basis for grouping and coding the extracted data.

## Discussion

To discuss how digital technologies increase sustainability, the research applied the three-pillar analytical framework, which is extended with the institutional dimension. While there is a range of academic and policy work investigating sustainability and its pillars in agriculture, only a few of them link sustainability and digitalization. To demonstrate, the review by Annosi et al. (2020) investigated various challenges faced by agri-businesses to implement digital technologies, as well as challenges to sustainable development. Another systematic review by Feroz et al. (2021) identifies 'disruptions driven by digital transformation in the environmental domain' (p. 1). Furthermore, Annnosi and Brunetta (2020, pp. 2 - 6) investigated 'potential managerial factors affecting firms' reactions to digitalization waves', as well as 'the use of technology to meet the objectives of economic and environmental sustainability'. Considering a significant actual input and potential of digitalization for the sector, a better understanding is needed of the ways the smart technologies enhance sustainability and its various aspects. However, while most of the research focuses on environmental and economic sustainability, this chapter aims to embrace the existing research under the umbrella of an integrated and complex approach to the phenomenon. To be useful for research and practice, our analysis has to offer actionable insights and points of departure for further investigations. We thus look at sustainability in a detailed way through its dimensions and how it is connected to digitalization in the agri-food sector. We consider in particular the drivers and issues behind the application of innovative technologies to specific components of supply chains and which actors they involve.

### *Description of results*

Based on the results' analysis performed by WoS, all the articles in the final database of 500 items were published between 2010 and 2021. The popularity of the topics presented in our key has been steadily increasing year after year, especially since 2016. The largest publication input was in 2020 (135 items, 27%) and 2021 (123 papers, 25%). In this way, more than a half of the research has been published in the last two years. Although the topics in the focus of the current review have been clearly gaining unprecedented attention in the last few years, they are rooted in the earlier research of digitalization and, especially, the sustainability of the agricultural and agri-food sector.

The top three areas of published research are: Environmental Sciences Ecology (297 papers), Science Technology and other topics (181), and Agriculture (68)[1]. Therefore, the overwhelming majority of research lies within environmental and technological studies. Both environmental studies and science and technology studies (STS) are principally interdisciplinary fields, which emerged from the confluence of a variety of disciplines and disciplinary subfields and utilize their theoretical and methodological stands. The largest number of articles (115) comes from *Sustainability* journal; the second and third main sources are *Journal of Cleaner Production* (22) and *Land Use Policy* (19).

*Factors behind innovative technological implementations*

To start with, a significant number of papers in the array discussed smart technological transformation of the sector within a framework of climate-smart agriculture and climate change adaptation (in total, 156 from 338 papers). The understanding of it is helpful to analyse the digital transformations tackling sustainability challenges in the right light since it is the most spread framework[2] in the database. Climate-smart agriculture (CSA) can be understood as a transformative and sustainable agriculture "that tries to increase efficiency (productivity) in food security and production systems, using a combination of the pillars of climate change (adaptation, resilience, and mitigation) as well as smart and new technological knowledge, that do not only build capacity of farmers" in terms of farming techniques, but also increase profit, reduces vulnerability of the systems as well as their results (farm products/animals), through the reduction of GHG emissions' (Adesipo et al., 2020, p. 10-11). CSA rests on its three main pillars, such as agronomic and economic productivity, resilience and adaptive capacity, and climate change mitigation. This type of agriculture specifically highlights the necessity to address the challenges of both food security and climate change, which are interlinked. It is a type or an integrated approach in agriculture, which deals with managing the landscape (e.g., livestock, croplands, etc.). In such a way, it already has a restricted perspective of analysing the sector since it focuses on only one stage of it. Moreover, according to the Climate Change Action Plan 2016 by the World Bank, this agricultural approach has three main aims: a) increased productivity of food quantity

[1] Articles were assigned to one or more areas of research.

[2] Climate-smart agriculture can be understood as both a framework and an agriculture type.

and quality; b) enhanced resilience and reduced vulnerability to climate-related risks; and c) reduced emissions (in food production).

In such a way, a particular body of research focuses on two major challenges – climate change and food (in)security. Both challenges are very complex and do affect various spheres of life and industrial sectors, although climate change has traditionally been perceived primarily as an environmental threat. These papers embrace social conditions and institutions as well, although do focus largely on the environmental side of sustainability. In such a way, on the one hand, environmental sustainability comes to the forefront in this research, which can be also understood as a drawback of the framework. On the other hand, the application of the framework still allows researchers to investigate the role of social and institutional conditions, which provides more coherent research than those focused on only one sustainability pillar. Nevertheless, the risk is that the focus of this approach might overshadow the role of social and institutional factors for sustainability's expansion.

Another crucial challenge in agriculture is land use and degradation, which incorporates various factors such as soil quality, land management and others. Degradation of land has been intensified by 'problems related to the unsustainable use of land resources, rural–urban migration, farm marginalization and regional disparities' (Smiraglia et al., 2016, p. 598). Land use and land cover changes, which include soil erosion, malnutrition, desertification, have been identified as key drivers of global change. Likewise, the issues of water management and energy use (in particular, GHG emissions) require urgent development of more sustainable utilisation, which can be advanced by innovative technologies. Therefore, the main factors driving the implementation of digital technologies, as research identifies, lie primarily within the production stage, or farming. While some research considers challenges which occur at other nodes of a supply chain, farming conditions are at central stake for both researchers and policy makers.

A significant portion of research addresses, directly or indirectly, the differences of application of climate-smart agriculture (CSA) and climate change adaptation/ mitigation in developed and developing countries. Table 1 represents the distribution of research in general and the adaptation of CSA framework in particular by geographical area[3].

*Table 1. Distribution of research by geographical area*

[3] To clarify, it refers to the geographical location (continent's subregion, region, country, etc.) of investigations, not the researcher's or publication origin.

| Geographical location of research | Top countries (with number of articles) | Total amount of articles[4] | Amount of articles adopting CSA and climate change adaptation/ mitigation framework |
|---|---|---|---|
| **Africa** | Africa (9); Malawi (9); Southern Africa (9); Kenya (7); others (44) | 78 | 66 |
| **Asia** | China (14); India (8); Pakistan (6); others (23) | 51 | 17 |
| **South/ Latin America** | Brazil (6); rest (5) | 11 | 8 |
| **North America** | US (5) | 5 | 1 (along with cases from Sub-Saharan Africa) |
| **Middle East** | Turkey (3); Iran (2); others (2) | 7 | 4 |
| **Australia and New Zealand** | Australia (7); NZ (2) | 9 | 1 |
| **Europe** | Europe or several countries (20); Spain (5); others (37) | 63 | 10 |
| **Other or No specification** | Developing countries/ emerging economies (5); MENA region (1); Rep. of Moldova (1) others (122) | 129 | 49 |
| **TOTAL** | | **353** | **156** |

The analysis was conducted based on the set of articles including both sustainability and novel technologies in agriculture. The table shows that the largest proportion is represented by papers without specific geographical focus or which aim at cross-national investigation. The next largest set of articles focuses on Africa with the vast majority of it adopting the CSA framework. The second largest piece of research on CSA is based on Asian countries' cases. On the contrary, areas of developed countries, such as Europe, North America, Australia and New Zealand, have the smallest proportion of CSA research compared to their total numbers.

This dispersion should be considered when discussing the context and conditions of technological applications. Some research assumes that 'the way that climate change challenges are addressed, either through mitigation (mostly for the developed countries) or adaptation and productivity-increase lenses' are strongly dependent on the national economic development ratio (Totin et al., 2018, p. 12). Moreover, the research from low-income countries addresses also the crucial challenges of poverty

[4] Some papers included cases from more than one area, therefore, this total number exceeds the total amount of analysed papers.

and land inequality, which are reinforced by climate change conditions (Rampa et al, 2020). Last but not the least, the issues of energy use and energy poverty differ in developed and developing countries, particularly in energy availability and accessibility.

Thus, the major body of the analysed research, both theoretical and empirical, focuses on climate change, food (in)security, productivity growth and land use as the main factors behind the application of digital technologies. These grounds are partly rooted in the CSA framework and its application, which, in turn, derives from policy institutions, initiatives and documents. In fact, these conditions are discussed as global challenges, not only for agriculture but for humanity in general, and digital technologies are one of the ways to tackle them.

*Mapping the sector: nodes of the agri-food supply chain*

This research is interested in the input of different smart technologies in terms of the enhancement of sustainability and sustainable agriculture. In the papers, a great deal of attention is paid to the use of smart technologies in farming, or the production stage. Some research specifically highlights optimization of agricultural production processes as one of the major challenges in the sector, as well as the reason behind application of novel technologies. The enhancement of farms is particularly important since they 'are the engine to support rural employment and to make a considerable contribution to territorial development' (Lezoche, 2020). The implementation of smart technologies at the production stage can be united under the umbrella of smart farming, which 'connects farm equipment to software platforms that track on-farm data and enable analyses of soil and climate conditions in specific locations' (Clapp and Ruder, 2020, p. 49). Smart farming technologies, in turn, can be divided into three main categories: 'farm management information systems, precision agriculture systems, and agricultural automation and robotics' (Balafoutis et al., 2020).

Crop operations and management can be largely supported by a variety of digital technologies, such as big data, internet of things (IoT), robotics, sensors (or remote sensing), 3D printing, system integration, artificial intelligence, digital twins, blockchain, and others. Their uses for specific operations related to minimizing emissions, water management, energy consumption, waste collection, and more are mainly discussed in relation to farming. Moreover, the analysis of the technological contribution to social issues and labour relations (part of social sustainability) is significant for farmers, but is not limited to them. Whereas the contributions brought by these technologies are complex and various, one of the main transformations is the integration of operations and aspects into smart connected systems. These innovations link operations with a farm as a unit into a system and then can include it into a larger data-driven system of units, or system of systems.

One of the most widely spread innovations is the application of robotics for production and crop management. While the majority of the papers analyse its use during the farming stage, some research suggests the technology's capabilities to be applied at other nodes of the supply chain. Robotics is one of the technologies, that has a wider impact on sustainability, the research implies, since it affects its three dimensions. The use of robots reduces material costs and human labour, and it also tackles harsh working conditions and difficult work in farming. Another popular technology used at the production stage is remote sensing, which has been largely applied to water management (reduction of water losses, estimation of crop water requirements and more) and to estimate soil erosion (Adamides, 2020). This technology's use has an impact on environmental and economic sustainability, especially through control of resources, but its effect related to social conditions is not widely discussed.

The concept of smart farming should not be confused with the idea of smart agriculture or Agri-food 4.0. While smart farming, as shown above, transforms farm operations, smart agriculture 'offers the opportunity to farmers, technology and service providers, governance agencies and other impacted stakeholders (financial organization, investors, traders, etc.) to share their experiences and preoccupations in the optimization in the farming supply chain with the close respect of production sustainability' (Lezoche et al., 2020). Therefore, smart agriculture also includes both traditional suppliers of farm inputs (packing, machinery, chemicals and else) and digital services providers. Nevertheless, the farming supply stage, as well as distribution, as wide fields for technological advancement are out of focus in the analysed research. Moreover, the role of distribution, both wholesale and retail, is crucial for the integrity and continuity of agri-food supply chains. It provides a large room for technological improvement and sustainability development, ranging from labour operations to tracking and transport services. The integration of smart technologies in agri-food logistics can reduce food losses along production and supply chains (Vernier at al., 2021). Other investigations in the literature on sustainability and logistic processes and strategies in food chains define it as limited and incomplete (e.g., Seccia, in De Gennaro and Nardone, 2014). They add value to the topic of production and are included in sustainable supply chain management, but are not part of the focus of digital technology applications for sustainability. Evidence from research shows that 'supply chain performance will improve when chain transparency and customer-oriented supply chains are created with associated operational coordination mechanisms' (Ibid, p. 45).

In a nutshell, the review of technological applications in agri-food supply chains shed light on disproportional research and policy interest in the production stage, or farming. While the incorporation of innovative technologies on farms and for crops is crucial for both increasing productivity and decreasing the ecological impacts, the other components of supply chains similarly require input from research and policy fields. One of the most under investigated processes in agri-food chains are logistics and distribution. This gap is crucial to address since distributors are an integral part of the supply chain and operation of the sector as a whole, and they also have an observable potential for technological refinement and sustainability input (for example, reverse logistics). In such a way, the use of many technologies is not limited to the covered applications and they have a larger potential to boost not only effectiveness but also sustainability in agri-business as a whole.

*Mapping the sector: the role of actors*

As it has been demonstrated above, the analysed research largely focuses on farming and farms as units within supply chains and networks. Nevertheless, various investigations in farming and increase in its sustainability does not necessarily lead to adopting a complex approach to farmers as subjects or actors in supply chains. In other words, the research pays more attention to farming as a supply chain’s node than farmers as actors and their role in the sector's operations. However, among other groups of actors within the supply chain, farmers and smallholder farmers are the most investigated group, with a few exceptions. For instance, the analysis of barriers to the adoption of CSA in Europe by Long et al. (2016) considers, among others, the challenges for technological innovation providers and technology users. However, its focus is limited by innovation providers and does not reflect on the links between other providers (e.g., of machinery) and sustainability.

One of the main reasons behind this disproportion is the framework of climate-smart agriculture, which identifies the main issues and threats to climate change as located at the production stage. As was shown previously, this framework focuses on technological advancement and improvement at the production stage, which is based on the producers – farmers. To specify, Collins (2017) addresses the three core pillars for CSA (as articulated by the World Bank): ‘sustainably improve agricultural productivity and enhance food security, increase farmers’ resilience and adaptation to climate change, and reduce and/or remove greenhouse gas (GHG) emissions where possible’ (p. 5). In such a way, the policy-oriented framework has a specific target group, which receives wide recognition and certain resources through various plans and projects. This highlight of farmers is consistent within the framework since it focuses on challenges of climate change and food security, which, in turn, rely primarily on crop production and management. At the same time, food losses and waste contribute to food insecurity, which, in turn, can be improved by technological advancement of logistics and distribution.

Within the body of research in sustainable and smart farming, some works examine farmers’ motivations, as well as drivers and existing barriers to adopt novel technologies. These papers highlight the need to investigate deeper these conditions in order to develop a more complex understanding of farmers' knowledge and attitudes to digitalization. The farmers' relationship with technologies, knowledge and trust in them, as well as the competencies to use them, are at heart of success and effectiveness of smart farming and its contribution to sustainable development.

Selected articles demonstrate that often policy makers and institutions encourage farmers to adopt smart technologies, especially in developing countries. In such a way, it is rather a top-down than bottom-up approach, which contributes to the challenges that farmers experience with the digitalization of the sector. These challenges and barriers also include (lack of) knowledge of particular technologies, of their application and maintenance, and the following transformations of operations. Accordingly, based on their assessment of correlations among smart agriculture (SA) related knowledge, attitude, and adoption among farmers, Chuang et al. (2020) suggest that 'agricultural R&D institutes should concentrate on improving market access for established and valuable SA technologies'.

Moreover, the analytical review by Lajoie-O'Malley et al. (2020) finds out that 'many of the texts also mention the importance of farmers' trust in the technologies themselves', where 'trust in one technology can … also generate trust in others'. The research suggests that digital tools can be, on the one hand, technologies themselves and, on the one hand, means to engage farmers to define their needs and concerns (for example, ICTs). At the same time, several researchers emphasize the growing concerns related to unequal access to technology and its reproduction, specifically among farmers, in particular if adopted 'within existing knowledge power structures' (Ibid). To paraphrase, an increase in technological advancement in agri-food can widen the so-called digital divide by expanding the existing access and not providing with sufficient new opportunities.

To add, due to the lack of research on other groups of actors within a supply chain, it is difficult to debate about the barriers and drivers they experience. Although, based on the extensive interdisciplinary research beyond this database, the assumption is that technological knowledge and competencies, attitude and trust are also crucial for other actors to implement smart technologies effectively. Moreover, actors' cross engagement and exchange of knowledge and experiences in technological advancement can influence its acceptance and distribution.

In general, the analysed research investigates different components of a supply chain with a particular focus on farming, especially within the framework of climate-smart agriculture and challenges of climate change and food (in)security. At the same time, it tends to under-investigate the role of actors for the supply chains' operations in general and their input in the increase in sustainability and spread of technological applications. Innovative technologies can definitely transform operations along the whole supply chain, contribute to improving the resources conditions and use, labour performance and analysis of information and data. However, their establishment, provision and implementation is vastly dependent on the actors. To specify, crucial is not simply a particular group of actors, such as farmers, but all the variety of actors, including institutional actors, distributors, service and machinery providers, consumers and others. Hence, an analysis of technological advancement of the agri-food sector requires a comprehensive approach, which includes all supply chain nodes and all groups of actors.

*Sustainability: towards a comprehensive approach*

The analysed research highlights the significant contribution of innovative technologies to sustainability development in agriculture, notably within the discourse of climate change and food insecurity global challenges. Despite the fact that only a few papers conceptualize sustainability through the application of the triple bottom line framework, the existing research tends to investigate more than one dimension. In other words, most of the papers do address more than one pillar, even without referring to the set of conditions as such.

The main focus of the research is on the environmental set of issues in agri-food, although it has been considered with relation to other conditions, in particular economic and social. Such attention to the ecological dimension was predicted because, firstly, of the roots of the sustainability concept, and, secondly, the utilization of the climate-smart agriculture framework. One of the major achievements brought about by smart technologies is control of resources and their more effective use, which is, at the same time, linked to economic sustainability. Although, in a number of countries (often developing countries), the concern also refers to primary unequal access to resources and land in particular. A large share of papers refer to adaptation and mitigation of climate change (156 in total) brought about by innovative technologies, for example, through the reduction of greenhouse gas emissions (mainly considered in farming). The energy use, which includes energy efficiency and renewable energy, lies at the overlapping of economic and environmental sustainability.

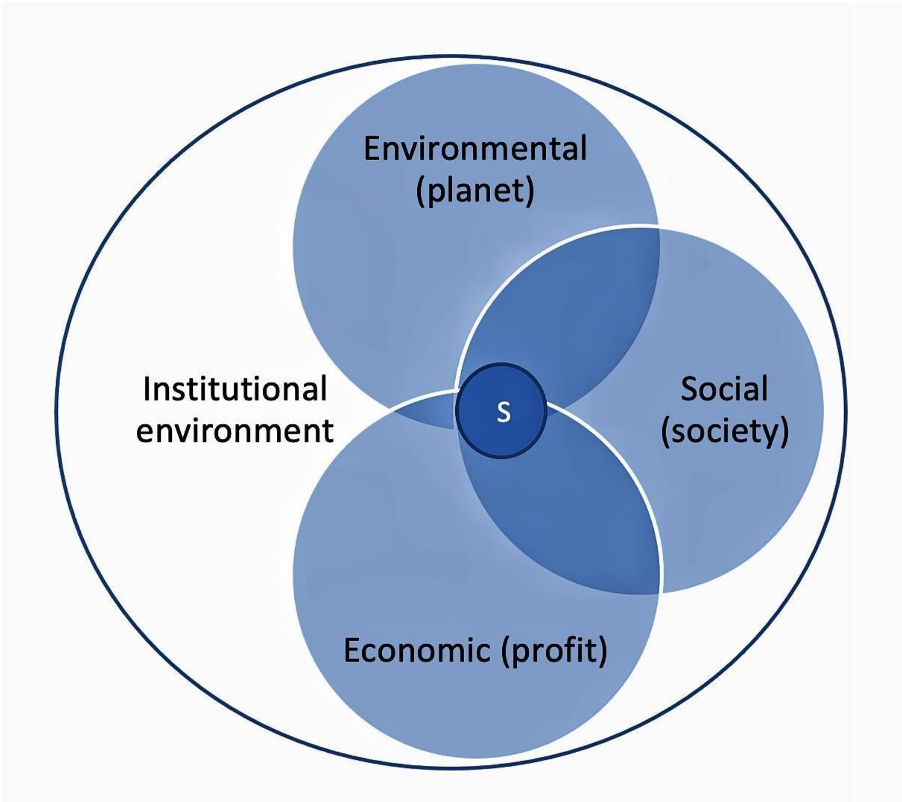
Economic sustainability is enhanced through, first of all, the optimization of operations, resource management and an increase in productivity (in particular, crop productivity). Precision or smart farming can not only boost productivity but also decrease the damages and waste. Agricultural data analytics contributes to more effective planning of operations through data-based decision-making. Moreover, particular technologies such as robotics are said to transform labour operations and costs. The research points out the input of blockchain technology into traceability and transparency of transactions and processes, which raises the economic return. Overall, the technologies affect the rise of productivity and capital assets through resources allocation to their highest valued use, but under the conditions of global challenges and environmental crisis. In such a way, the economic profit is linked to the sector's engagement with environmental conditions. Moreover, implementation of smart technologies throughout the supply chain can ensure the continuity of economic sustainability.

Social sustainability is an essential part of agricultural sustainability, which, first of all, refers to food safety and control to ensure both its quantity and quality and production of healthy food (Hrustek, 2020). Also, it embraces social equity, which can be conceptualized, firstly, through labour conditions and relations. The review shows that one of the most notable roles in increasing social sustainability is performed by robots. Robots are capable of undertaking dangerous and difficult tasks, performing under harsh working (and weather) conditions, and reducing medical hazards. Moreover, they can tackle the high costs of production that derive from increased labour costs, the aging of rural populations, and the observed shortages of laborers (Adamides, 2020). An important social threat to the sector is rural population aging, which affects not only social but also economic conditions. Another challenge is shared with other industries and is the sector's gender inequality(ies) and imbalances that might arise through the application of new technologies (Collins, 2017). While the risks have to do with the increase in technological advancement itself (such as potential access imbalances), the way corporate actors utilise the language and framework of CSA can lead to the reinforced perpetuation of gender inequality in agriculture as a whole.

Last but not least, the institutional dimension of sustainability is addressed in the papers mostly through the institutions, which are often presented through their policies and policy-making, or political institutions. Some papers stress the need for policy and institutional strategies 'to be locally context specific in order to ensure success and sustainability of scaling processes' in agriculture through a regulatory and policy support framework (Makate, 2019, p. 46). Rampa et al. (2020) argue that 'communities/groups should also be a subject of tenure security recognised by other sources (such as local, regional, central governmental and legislative institutions)' to ensure their stability. The ecosystem-based approach to climate-smart agriculture includes the analysis of institutional requirements, which are important for its application and effectiveness (e.g., Akamani, 2021). While the selected research highlights the importance of policies and regulatory frameworks for technological spread and implementation, it does not provide a clear image of its enablers and constraints or barriers and how they act towards digitalization in agri-food. For example, knowledge gaps and institutional barriers, as shown by Dougill et al. (2017, p. 25), 'influence land management decision-making and constrain conservation agriculture uptake'. The knowledge of such context, as demonstrated by Totin et al. (2018), contributes to the research design and supportive policy (for technological sustainability-oriented implications).

This research suggests that the blurred and scattered incorporation of institutional framework into smart and sustainable agriculture can be rooted in limited utilization of the concept of institutional sustainability (or a pillar). As it was presented in the framework, several authors assembled institutional factors within a so-called the fourth sustainability pillar. On the contrary, we suggest distinguishing institutional environment and institutional sustainability. The latter can be understood as a characteristic of the institutional environment, which ensures its stability and creates opportunities for accomplishment of other sustainability dimensions. In such a way, we propose conceptualizing the institutional factors not as another pillar but as a determining environment for sustainability enhancement, as shown in Figure 2. The institutional factors affect technological implementations at all stages of the supply chain, as well as transactions and interactions among actors and stakeholders, which, in turn, predeterminate development of particular sustainability dimensions.

*Figure 2: Proposal for the extended sustainability framework:*




Overall, the existing research on the innovative technological development and sustainability in agriculture and agri-food in particular is relatively imbalanced. It represents extensive technological implementation based on digital and precise innovations within the focus on farmers as actors and farming or production as the phase in the supply chain. Certainly, the potential for transformations at the production stage is immense, yet the other actors and nodes of supply chains could benefit from technological interventions. Moreover, the role of technologies in increasing the environmental sustainability has been in the spotlight of analysed research, with attention also paid to their input in terms of economic sustainability. One of the factors behind this limited approach is the employment of climate-smart agriculture framework by corporate actors and firms, policy makers, and researchers. This review highlights the importance of social and institutional factors for development of sustainability in agri-food by addressing their presence in the analysed literature. Nevertheless, those factors are mostly not conceptualised as sustainability dimensions or aspects and mostly conceptualised through economic and environmental sustainability.

## Conclusion

This chapter researched the existing literature on topics of sustainability and digitalization, or smart technology implementation, in the agricultural and agri-food sector. To analyse the selected dataset, the research adopted an analytical framework of three sustainability pillars (economic, environmental, and social), which was extended by the institutional environment. The utilization of the framework allowed us to analyse inputs brought by innovative technologies to enhance agricultural and agri-food sustainability through its dimensions. However, these dimensions were reviewed not separately but as interconnected pillars within a complexity of sustainability as a phenomenon.

The interconnections between sustainability dimensions can be seen, for example, in the analysis of transformations in labour relations and conditions. The application of innovative technologies in agri-food, for example, can shift the performance of dangerous tasks and address unequal power relations and entrenched inequalities (social aspect), as well as tackle the high cost of production (economic aspect). Also, technologies can encourage and support farmers' ability to adapt to climate change (environmental dimension). Wherein, all these aspects are in close interrelation and when carried out together, it increases the sector's sustainability as a whole.

Sustainability in agriculture can (and should) reasonably be analysed and treated as a complex system with interconnected subsystems. In other words, while the ecological and environmental sustainability of the agricultural sector is clearly important, it will not be understood without its connections to economics, social sustainability, and the institutional environment. Thus, a holistic approach to agriculture as a system is perceived to be the way of advancing its understanding. Moreover, it requires more investigations into the social impact of innovative technologies, which includes both intended and unintended consequences associated with them. This so-called double-edged nature of technology affects the distribution of power as well, for example, increasing the risk of suppressing environmental side effects and 'further concentrate power in the hands of corporate actors in ways that undermine farmer autonomy' (Clapp and Ruder, 2020, p. 64). Moreover, spread of innovative technologies in agriculture risks intensifying the existing so-called digital divide by reproducing the power relations and access (to resources, information, technology).

This research highlights the importance of examining the factors and conditions behind the choice and application of particular innovations and digital strategies. The identification of issues and aims for each case in agri-business is supposed to assist the choice and implementation of innovation, the node of supply chain and actors involved. Although, to achieve a pervasive transformation in agri-food, which will lead to a turning point in fighting the global sustainability challenges, the existing efforts might not be enough. The application of innovative technologies requires a more strategic, or systematic, and comprehensive approach, which focuses on all supply chain nodes and actors (or sector as a whole), on the one hand, and on tackling different sustainability dimensions, on the other hand.

Moreover, the recognition of the role of the institutional environment for technological advancement is crucial for advising the decision-making and creation of supportive policies and research. A set of particular institutions constitutes an environment, where a variety of relations, including those regarding technological development, are executed. While a (smart) technology has a particular set of common features and implementations, its performance and outputs will vary from context to context depending on the existing enablers and constraints and the way they impact that implementation. In such a way, the technology's utilization and the following contribution to sustainability and its dimensions will change in different contexts. Hence, the extension of the three pillars framework with the institutional dimension (but not as an extra pillar) provides a more comprehensive approach to sustainability. Furthermore, the analysis of the institutional environment can also contribute to understanding of the factors behind innovative technological implementations.

This chapter has identified some gaps for future research avenues. First of all, the sector requires more research to understand the role of novel technologies in different components of supply chains. The analysed research covered various technologies and their input in terms of sustainability in the sector, paying special attention to technological advancement at the production stage, or digital and precision farming. Without downplaying the contribution of farming into fighting global challenges, the input of the other nodes of the supply chain is valuable. To specify, logistics' role to support supply chains and its continuity is crucial, also there is a plenty of potential for smart technological advancement to enhance its sustainability, for example, through reverse logistics. Last but not least, the institutional framework and its role in the development of agricultural sustainability through digitalization requires more investigations.

References:

Adamides, G. (2020). A Review of Climate-Smart Agriculture Applications in Cyprus/ Atmosphere, Vol. 11, Issue 9

Adesipo, A. et al. (2020). Smart and Climate-Smart Agricultural Trends as Core Aspects of Smart Village Functions/ Sensors, Vol. 20, Issue 21, https://doi.org/10.3390/s20215977

Akanami, K. (2021). An Ecosystem-Based Approach to Climate-Smart Agriculture with Some Considerations for Social Equity/ agronomy, Vol. 11, No. 8, https://doi.org/10.3390/agronomy11081564

Annosi, M.C., Brunetta, F. (2020). How is Digitalization Affecting Agri-food? New Business Models, Strategies and Organizational Forms. Taylor & Francis, Routledge

Annosi, M.C., Brunetta, F., Capo, F. & Heidelved, L. (2020b). Digitalization in the agri-food industry: The relationship between technology and sustainable development/ Management Decision, Vol. 58, Issue 8, pp.1737-1757

Birkeland, I. (2008). Cultural sustainability: industrialism, placelessness and the reanimation of place/ Ethics, Place and Environment, Vol. 11, Issue 3, pp. 283 - 297

Boström, M. (2012). SSPP: A missing pillar? Challenges in theorizing and practicing social sustainability: Introduction to the special issue. Sustainability: Science, Practice and Policy, Vol. 8, N. 1, pp. 3 - 14

Boyer, R.H.W., et al. (2016). Five approaches to social sustainability and the integrated way forward/ Sustainability, Vol. 8, Issue 9, pp. 1 - 18

Chuang, J.-H., Wang, J.-H., Liou, Y.-C. (2020). Farmers' Knowledge, Attitude, and Adoption of Smart Agriculture Technology in Taiwan/ International Journal of Environmental Research and Public Health, Vol. 17, No. 19. DOI: 10.3390/ijerph17197236

Clapp, J., Ruder, S.-L. (2020). Precision Technologies for Agriculture: Digital Farming, gene-edited crops, and the politics of sustainability/ Global Environmental Politics, Vol 20, Issue 3, pp. 49 - 69

Clune, W.H., Zehnder, A.J.B. (2018). The three pillars of sustainability framers: approaches for laws and governance/ Journal of Environmental Protection, Vol. 9, No. 3, pp. 211 - 240

Clune, W.H., Zehnder, A.J.B. (2020). The evolution of sustainability models, from descriptive, to strategic, to the three pillars framework for applied solutions/ Sustainability Science, No. 15, pp. 1001 - 1006

Coco, N., Colapinto, C., & Finotto, V. (2021). Supporting Pervasive Digitization in Italian SMEs Through an Open Innovation Process In A. Hinterhuber, T. Vescovi, & F. Checchinato (Eds.), Managing Digital Transformation. Understanding the Strategic Process (pp. 259-269). Routledge.

Collins, A. (2017). Saying all the right things? Gendered discourse in climate-smart agriculture/ The Journal of Peasant Studies, Vol. 45, Issue 4, pp. 1 - 17

Cornelissen, J. P., & Werner, M. D. (2014). Putting Framing in Perspective: A Review of Framing and Frame Analysis across the Management and Organizational Literature. Academy of Management Annals, 8(1), 181-235. https://doi.org/10.1080/19416520.2014.875669

DE Gennaro, B.C., Nardone, G. (eds.) (2014). Sustainability of the agri-food system: Strategies and Performances/ Proceedings of the 50th SIDEA Conference Lecce, Chiostro dei Domenicani, 26-28 September 2013**,** Universitas Studiorum S.r.**l**

Dougill, a. J. et al. (2017). Mainstreaming conservation agriculture in Malawi: Knowledge gaps and institutional barriers/ Journal of Environmental Management, Vol. 195, pp. 25 - 34

Duic, N., Urbaniec, K., Huisingh, D. (2015). Components and structures of the pillars of sustainability/ Journal of Cleaner Production, Vol. 88, pp. 1 - 12

Elliott, S.R. (2005). Sustainability: an economic perspecive/ Resources, Conservation and Recycling, Vol. 44, pp. 263 - 277

Fink, A. (2010). Conducting resaerch literature reviews. From the Internet to Paper. 3rd ed. California: Sage Publications.

Garud, R., & Karnoe, P. (2003). Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. Research Policy, 32(2), 277-300. https://doi.org/Pii

Gaviglio, A., et al. (2016). The social pillar of sustainability: a quantitative approach at the farm level/ Agricultural and Food Economics, Vol 4, N. 15

Giddings, B., Hopwood, B., O'Brien, G. (2002). Environment, economy and society: fitting them together into sustainable development/ Sustainable Development, Vol. 10, pp. 187 - 196

Goel, R.K. et al. (2021). Smart agriculture – Urgent need of the day in developing countries/ Sustainable Computing: Informatics and Systems 30 (2021) 100512

Hak, T., Moldan, B., Dahl, A.L. (2007). Sustainability indicators : a scientific assessment. SCOPE Project. Washington, DC : Island Press

Hargadon, A. B., & Douglas, Y. (2001). When Innovations Meet Institutions: Edison and the Design of the Electric Light. Administrative Science Quarterly, 46(3), 476-501. https://doi.org/10.2307/3094872

Hosseini, H.M., Kaneko, S. (2012). Causality between pillars of sustainable development: Global stylized facts or regional phenomena?/ Ecological Indicators, Vol. 14, pp. 197–201

Hrustek, L. (2020). Sustainability driven by agriculture through digital transformation/ Sustainability, Vol. 12, 8596

Kajembe, G.C. et al. (2016). Institutional Sustainability in the Face of Climate Change: Empirical Insights from Irrigation Institutions in the Iringa Rural District, Tanzania, in Lal, R. et al (eds.). Climate Change and Multi-Dimensional Sustainability in African Agriculture Climate Change and Sustainability in Agriculture. Springer

Lajoie-O'Malley, A. et al. (2020). The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents/ Ecosystem Services, Vol. 45: 101183

Lezoche, M. et al. (2020). Agri-food 4.0: a survey of the supply chains and technologies for the future agriculture/ Computers in Industry, 117:103187

Lioutas, E. D., Charatsaric, C., De Rosae, M. (2021). Digitalization of agriculture: A way to solve the food problem or a trolley dilemma?/ Technology in Society, No. 67, 101744

Long, T.B., Blok, V., Coninx, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy/ Journal of Cleaner Production, Vol. 112, pp. 9 - 21

Makate, C. (2019). Effective scaling of climate smart agriculture innovations in African smallholder agriculture: A review of approaches, policy and institutional strategy needs/ Environmental Science and Policy, Vol. 96, pp. 37 - 51

Moldan, B., Janouskova, S., Hak., T. (2012). How to understand and measure environmental sustainability: indicators and targets/ Ecological Indicators, Vol. 17, pp. 4-13

Murphy, K. (2012). The social pillar of sustainable development: a literature review and framework for policy analysis/ Sustainability: Science, Practice and Policy, Vol. 8, N. 1, pp. 15-29

Petrisor, A.-I. and Petrisor, L. (2014). 25 years of sustainability: a critical assessment/ Present Environment and Sustainable Development, Vol.  8, No. 1, pp. 175 – 190

Pfahl, S. (2005). Institutional sustainability/ International Journal of sustainable Development, Vo;. 8, Nos. ½., pp. 80 - 96

Purvis, B., Mao, Y., Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins/ Sustainability Science, Vol. 14, pp. 681 - 695

Ranjbari, M. et al. (2021). The three pillars of sustainability in the wake of Covid-19: a systematic review and future research agenda for sustainable development/ Journal of Cleaner Production, Vol. 297, 126660

Rampa, A., (2020). Land Reform in the Era of Global Warming—Can Land Reforms Help Agriculture Be Climate-Smart?/ Land, No. 9, Vol. 12: 471

Reischauer, G. (2018). Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing/ Technological Forecasting and Social Change, Vol. 132, pp. 26-33. https://doi.org/10.1016/j.techfore.2018.02.012

Rotz, S., et al. (2019). Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities/ Journal of Rural Studies, Vol. 68, pp. 112 - 122

Smiraglia, D. et al. (2016). Linking trajectories of land change, land degradation processes and ecosystem services/ Environmental Research, Vol. 147, pp. 590-600

Soini, K., Birkeland, I. (2014). Exploring the scientific discourse on cultural sustainability/ Geoforum, Vol. 51, pp. 213 - 223

Spangenberg, J.H. (2002). Institutional sustainability indicators: an analysis of the institutions in Agenda 21 and a draft set of indicators for monitoring their effectivity/ Sustainable Development, Vol., 10, pp. 103 - 115

Spangenberg, J.H., Pfahl, S., Deller, K. (2002). Towards indicators for institutional sustainability: lessons from an analysis of Agenda 21/ Ecological Indicators, Vol. 2, pp. 61 – 77

Totin, E. et al. (2018). Institutional perspectives of climate-smart agriculture: a systematic literature review/ Sustainability, Vol. 10, Issue 6

Tranfield, D., Denyer, D., Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review/ British Journal of Management, Vol. 14, No. 3, pp. 207 – 222

Vernier, C. et al. (2021). Adoption of ICTs in Agri-Food Logistics: Potential and Limitations for Supply Chain Sustainability/ Sustainability, 13, 6702. https://doi.org/10.3390/su13126702

Von Keyserlingk, M.A.G. et al. (2013). Invited review: Sustainability of the US dairy industry/ Journal of Dairy Science, Vol. 96, pp. 5405 - 5425

Wilkins, H. (2008). The Integration of the Pillars of Sustainable Development: A Work in Progress/ McGill International Journal of Sustainable Development Law & Policy, Vol. 4, No. 2. Available at SSRN: https://ssrn.com/abstract=2623221

Yunlong, C., Smit, B. (1995). Sustainability in agriculture: a general review/ Agriculture, Ecosystems and Environment, Vol. 49, pp. 299 - 307