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Digitalising Agricultural and Food Systems: policy challenges and actions for the sustainable transition in the EU

by

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Abstract

The agricultural and food system faces significant challenges related to climate change, sustainable production, and food security. Digital innovation and the adoption of "enabling" technologies offer promising solutions for addressing these challenges. The European Commission's "From Farm to Fork" Strategy and the Common Agricultural Policy (CAP) place digital technology at the forefront of achieving sustainable agri-food systems. The paper aims to analyse the recent European Union policy agenda concerning digitalisation and the adoption of digital technologies in agriculture and food systems to promote sustainability and food security in Europe. It emphasises the significance of appropriate regulation to ensure that the transformative impact of new digital technologies effectively addresses social and environmental challenges while ensuring inclusivity for all stakeholders.

Key-words

digitalisation; sustainable agriculture; Farm to Fork strategy; common agricultural policy (CAP); distributed ledger technology; digital innovation; digital food systems; agricultural data

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1. Introduction

Addressing the impact of climate change and ensuring sustainable production in a context of growing climate vulnerability as well as improving food security and a better organising supply chain relationships are some of the challenges that the agricultural and food system is preparing to face. In this scenario, digital innovation and the development of applications based on the so-called "enabling" technologies can provide a tool to the actors in the agricultural and food systems to address the challenges in the near future (Basso 2020).

To drive the transition towards sustainable agricultural and food systems, the European Commission published the "From Farm to Fork" Strategy in May 2020, placing it at the heart of the European Green Deal.[II] The Strategy aims to comprehensively outline strategic directions for achieving sustainable agri-food systems that uphold the connection between healthy people, healthy societies, and a healthy planet. Within this strategy, the European Commission has identified innovation and digital technology as key factors to accelerate the sustainable transition. As part of the European data strategy, the European common space for agricultural data will strengthens sustainability, productivity, and competitiveness in the agricultural sector.[III] This will be achieved through the processing and the analysis of information related to production, land use, water usage, and environmental factors. These data-driven insights will enable precise and targeted actions at the individual farm level and facilitate broader monitoring from a systemic perspective (Carletto 2021).

The paper will investigate how the recent European Union policy agenda addresses the issue of digitalisation and the uptake of digital technologies in farming and food systems to ensure sustainability and food security in Europe. Proper regulation of the sector is of fundamental importance to ensure that the disruptive revolution of new digital technologies effectively addresses the social and environmental challenges and leaves no one behind.

2. The Agri-Food System Becomes Digital

According to the FAO, the next agricultural revolution will undoubtedly be digital (Trendov et al. 2019). Digital agriculture will impact the activities of farmers, upstream and downstream stakeholders in the agricultural and food systems, as well as wholesalers and retailers. The World Bank, in line with this perspective, notes that digital technologies have the potential to accelerate the transformation of food systems in ways never seen before (Lampietti et al. 2021).

By "digital agriculture" or "agriculture 4.0," we refer to the use of new integrated technologies in a system capable of enhancing field operations more productive, efficient, and sustainable, while supporting farmers in decision-making processes related to their activities and interactions with other actors in the supply chain (McFadden 2022). These enabling technologies include field sensors, drones, robotic machines, and advanced devices that can communicate with each other and provide a large amount of data and information (Colantoni et al. 2018). New technologies contribute to defining the paradigm of Agriculture 4.0, which marks the disruption of technologies in the agri-food system through four key factors: the increase in the volume of data currently available, in computational power, and in connectivity; the capacity for data analysis, also in terms of business intelligence, through the use of artificial intelligence and deep learning; the development of new forms of human-machine interaction; and the results achieved in transferring digital data to the physical world and vice versa (Pesce et al. 2019).

As the process of digitalisation impacts not only the agricultural production but the entire food system, it is necessary to consider how technologies such as robotics, artificial intelligence, automation, purchasing platforms, etc., are becoming increasingly widespread and utilised in sectors like processing, packaging, storage, transportation, and retail (Rotz et al. 2019). The creation of more sustainable and secure food systems is among the main objectives generally associated with the use of new enabling technologies in the agri-food sector within international and European Union policies and strategies (Ehlers 2021). Digital transformation holds the promise of ushering in substantial economic, social, and environmental advantages.

Digital agriculture is witnessing a conspicuous shift in trends, notably marked by the proliferation of various robots, most prominently designed for weed control through diverse methodologies (ITU and FAO 2020). The spectrum of robot designs ranges from compact modular units to substantial, specialized tools tailored for specific agricultural contexts such as viticulture and organic vegetable farming. In tandem with robot development, automation is making significant inroads across various domains, particularly in automated irrigation and the partial or complete automation of greenhouse systems. This encompasses technologies suited for vertical farming. These automated systems predominantly harness innovative sensor technology and data processing to forge novel systems. Additionally, tools aimed at enhancing the efficiency and automation of conventional equipment are also emerging. Another facet of automation is making its presence felt in livestock farming, offering functionalities such as round-the-clock livestock monitoring and automated cleaning.

Moreover, there is a discernible trend of integrating digital tools into everyday farming practices (FAO and ITU 2023). This integration is achieved through a diverse array of digital technologies at the farm level. These technologies encompass interconnected farm management systems that primarily amalgamate remote sensing, decision support systems, various sensors, cloud computing, farm management software tools, and frequently incorporate some form of artificial intelligence. Existing farm management systems are continually evolving in this direction, increasingly incorporating IoT technologies, and capitalizing on readily available open spatial data. Furthermore, a multitude of emerging startups is now offering analogous connected farm management systems, primarily catering to arable farming. These systems come bundled with a wide array of additional services derived from data, such as the calculation of management zones. Many of these systems also provide valuable data for yield monitoring and forecasting. These data-driven insights empower practitioners to boost production, streamline planning, and optimize various operational facets, including logistics, packaging, warehousing, and sales.

3. The Nexus Between Digital Agriculture, Food Systems, and Sustainability

According to the recent guidelines on food security and nutrition from the Committee on World Food Security (CFS), adopted in February 2021, food systems are sustainable when they ensure food safety, availability of supplies, and nutritional adequacy for present and future generations, within the three economic, social, and environmental dimensions of sustainable development.[IV] Sustainable food systems also need to be inclusive, equitable, and resilient (paragraph 21). Digitalisation, as mentioned, encompasses all phases and actors within the complex and multidimensional network of activities, resources, and stakeholders involved in the production and distribution of our food, representing food systems. Therefore, it is interesting to ask whether digitalisation can make a significant contribution to the sustainability of food systems and what challenges lawmakers and policymakers need to consider with a forward-looking perspective (Adornato 2015).

The initial conceptualisation of the notion of sustainable development dates back to 1987 and is contained in the Brundtland Report, also known as “Our Common Future”.[V] This report was named after the chairwoman of the World Commission on Environment and Development, established by the United Nations a few years earlier. The report emphasised the role of innovation and technology in enabling better and broader utilisation of natural resources. However, it also acknowledged that technological development could bring new challenges, such as "marginalising" large sections of the population. This concern aligns with the United Nations' 2030 Agenda, which highlighted the need for "leaving no one behind" and established the 17 Sustainable Development Goals (SDGs).

In the context of digitalisation of agri-food systems, the SDGs serve as a reference grid to understand the real scope of the phenomenon in relation to economic, social, and environmental sustainability goals. The use of new technologies, digitalisation, the Internet of Things (IoT), and various tools encompassed in "agriculture 4.0" or "digital agriculture" play a significant role in advancing all the Sustainable Development Goals. For instance, increased agricultural productivity positively impacts Goal 2 (Zero Hunger), reduced use of natural resources contributes to Goals 6 (Clean Water and Sanitation), 13, 14, and 15 (Climate Action and Life on Land and Below Water), more efficient post-harvest activities reduce waste (Goal 12), and the introduction of automation systems can improve working conditions in certain sectors (Goal 8).

However, the introduction of disruptive technologies in the agri-food sector also brings various trade-offs. For instance, these technologies consume significant energy, which may offset their climate and environmental benefits (Schieffer et al. 2015). Automation may lead to job loss, especially for less-skilled workers. Furthermore, there is the challenge of digital access, particularly in some regions or for small farmers and economic operators with fewer economic and human resources (Jouanjean et al. 2020). This is known as the digital divide, which becomes more pronounced when considering women, who, according to the FAO, face a triple divide: digital, rural, and gender (Trendov et al. 2019).

In addition to the digital divide and the related inaccessibility, lacking digital literacy and skills needed to use specific devices or interpret and leverage the data collected can hinder harnessing knowledge from data (Tey 2012). Interoperability between various devices is another obstacle in effectively utilising data.

A recent study by the Panel for the Future of Science and Technology (STOA) of the European Parliament - published in March 2023 - has examined the impact of Artificial Intelligence (AI) in the agri-food systems.[VI] The study explores the main applications of AI and the associated risks, defining areas that may require specific legal and policy measures in the future to ensure that all stakeholders in the sector have fair access to the benefits that AI can bring to the agri-food system. Artificial intelligence is considered a key tool to support the sustainable transition of the agri-food system, enabling the development of new tools to improve supply chain processes and decision-making by economic actors (Lindblom 2017).

According to the study, effective management of agricultural data will create new opportunities to enhance the structure and competitiveness of agricultural businesses, streamlining costs and enabling better-informed decisions. However, the lack of data management skills and the adoption of digital tools in agriculture can limit the potential for digital transformation of the agri-food system. The study conducted by the European Parliament addresses key issues related to responsibility, risks, and ethical and social concerns regarding access and data management in the context of artificial intelligence development. The study proposes an ethical framework for designing and developing artificial intelligence technologies, based on six key pillars: equity, transparency, accountability, sustainability, privacy, and integrity (Dara et al. 2022). Among its policy recommendations, the study aims to define the responsibility of technology providers and envisions the possibility of legislative action to clarify the rights and legitimate expectations of agricultural businesses, technology providers, and society.

3.1 The case of distributed ledger technology in the EU

Among these technologies, distributed ledger technologies and blockchain play a prominent role. Exploring the opportunities, weaknesses, and prospects that blockchain technology can bring to the agri-food system involves dealing with a relatively young technology that needs to consolidate its use cases and address key aspects of agri-food systems (Attaran et al. 2019). Factors such as food safety, complex and structured supply chain relationships, difficulties in managing quality characteristics, and risk profiles related to production should be taken into consideration (Paunov 2019). At the European level, there is no clear legal framework that regulates the use of blockchain technology. To bridge this gap, the European Commission established the EU Blockchain Observatory and Forum, which released an initial assessment report in September 2019.[VII] The report acknowledges the need for clarity to further support the development of blockchain technology and its potential applications in economic sectors. It highlights several areas where European Union will need to intervene, including the legal recognition of distributed ledgers at the territorial level and issues related to responsibility and data protection.

This European initiative follows the European Parliament's Resolution of October 3, 2018, on distributed ledger technologies and blockchain, which emphasises the importance of technology in improving supply chains[VIII]. It notes that distributed ledger technologies can facilitate the traceability of goods and their ingredients or components, enhancing transparency, visibility, and control of compliance, including the effectiveness of customs checks. It also recognises the potential for ensuring sustainability protocols through a distributed ledger, reducing the risk of illegal goods entering the supply chain, and ensuring consumer protection. The potential uses of blockchain technology in the agri-food system can address both business-to-consumer and the business-to-business relationships (Spoto 2019).

The majority of experiences focus on the business-to-consumer relationship, where agri-food companies have utilised blockchain-certified data to demonstrate product origin, the adoption of sustainable agricultural practices, or actions taken to measure their ecological footprint, meeting consumer expectations (Lattanzi et al 2020; Saba 2020). Blockchain technology finds its application in developing a distributed data registry system for agri-food products, by integrating digital and immutable traceability. However, the opportunities for its use in the business-to-business relationships between actors in the agri-food system, where it could facilitate vertical integration and better coordinate contractual relationships between farmers and processing and distribution companies, are still largely unexplored (Saba 2020).

In this scenario, digitalisation combined with the adoption of blockchain technology and protocols based on smart contracts can facilitate and improve commercial relationships among actors in the agri-food system. This can lead to reduced transaction costs, decreased complexity, and the introduction of a fully transparent and traceable verification system at every stage of the commercial relationship (Commandré et al. 2021). Blockchain technology presents opportunities and potential uses, especially when used in synergy with other enabling technologies, such as Artificial Intelligence, Internet of Things, and Big Data. Together, they can create a digital ecosystem capable of managing the transition to a sustainable agri-food system that recognises the link between healthy individuals, healthy societies, and a healthy planet. However, innovation and new enabling technologies, evaluated for their ability to contribute to the intended goals, need to continue their development and experimentation to fully adapt to the specificities and complexities of the agri-food system (Lattanzi 2017).

4. Toward the ambitious pathways of EU Policies for the Digital Transition of the Agricultural and Food Systems

During the 2019 Global Forum for Food and Agriculture, 74 Ministers of agriculture addressed the topic of digital agriculture by adopting resolutions aimed at promoting environmentally and animal-friendly, high-quality, and safe agricultural production[IX]. These resolutions were intended to reduce costs, improve information availability and traceability throughout the food system, and facilitate trade (Jouanjean 2019). In this context, the Ministers committed to achieving four main objectives: 1) identifying and harnessing the potential of digitalisation to make agriculture more efficient, sustainable, and to improve rural living conditions; 2) expanding and ensuring farmers' access to digital technologies through training programs that impart the necessary skills; 3) improving farmers' use of digital data and ensuring its security and "sovereignty" in terms of protecting and respecting data ownership by the generating entity; 4) managing structural changes through the use of digital technologies in agriculture and rural areas to ensure their vitality and counter depopulation. This is an ambitious strategy that, if consistently implemented at the national or EU level, can lead the digital *revolution* of agri-food systems, while minimising the associated risks - especially the social risks related to excluding workers with limited digital skills and smaller farmers or data governance (FAO 2020).

For several years, the European Union has been exploring the possibilities of leveraging digital innovations in the agricultural and food sector to enhance agriculture and rural development.[X] The 2016 final paper titled "A strategic approach to EU agricultural research and innovation," marks the culmination of this process, which commenced during Expo Milano in June 2015. Recognising the potential of "smart" applications, the 2016 final paper lays the groundwork for integrating digital innovations in the agricultural sector. An important step in this direction comes from the 2019 Declaration titled "A smart and sustainable digital future for European agriculture and rural areas", wherein almost all EU Member States commit to collaborating on the development of agricultural digitalisation. This commitment is viewed as a crucial and timely means to address economic, social, climatic, and environmental challenges. From this standpoint, the Common Agricultural Policy (CAP) is regarded as a suitable framework for establishing connections between farmers and digital innovation.[XI]

Furthermore, the European Green Deal, which envisages a more central role for agriculture in climate change mitigation, places significant emphasis on digitalisation.[XII] The Farm to Fork Strategy adopts a systemic approach, recognising the complexity of food chains and setting the ambitious goal of "food sustainability" that encompasses economic, social, and environmental aspects (Lattanzi 2021). As part of the strategy, the digital and technological transition of agriculture is prioritised to achieve better climate and environmental outcomes and enhance resilience to climate change. This entails encouraging farmers to adopt technology-based solutions, digital tools, and space-based resources such as remote sensing and open-access data from the EU Copernicus Earth Observation program. These innovative solutions present fascinating opportunities, but their successful implementation requires a skilled workforce and substantial financial investments.

To support this digital transformation, the European Commission's commitment to achieving 100% access to fast broadband internet in rural areas by 2025 is highly positive. Broadband internet access can facilitate the adoption of precision agriculture, artificial intelligence, and harness the EU's leading position in satellite technology, ultimately leading to improved land management, reduced fertiliser use, and greenhouse gas emissions. The main objective in this area is to promote private investments, including from the financial sector, and encourage the participation of SMEs and medium-sized enterprises. While private investments are crucial for driving technological transformation, there is a concern that they might primarily benefit larger, more established economic entities, potentially leaving smaller and marginalised entities behind (Alabrese 2020).

Consequently, it will be crucial to assess how the Common Agricultural Policy 2023-2027 will influence these aspects and, more importantly, how the national strategy for implementing the CAP will promote the digitalisation of agriculture and actively involve the diverse array of small to medium-sized farmers that characterise the agricultural economic landscape in Europe. In this regard, the renewed support for building Agricultural Knowledge and Information Systems (AKIS) under the CAP 2023-2027 will play a pivotal role in disseminating skills and knowledge and facilitating a bottom-up adoption of digital technologies by actors in the agricultural and food systems.

5. Concluding remarks

In the face of the complex challenges posed by climate change, sustainable production, and food security, the agri-food system stands at the threshold of a profound transformation. The fusion of digital innovation and "enabling" technologies offers a potent arsenal for surmounting these challenges. Europe's farsighted "From Farm to Fork" Strategy, aligned with the Common Agricultural Policy (CAP), positions digital technology as the vanguard of sustainable agri-food systems within the broader canvas of the European Green Deal.

This study has navigated the contours of the European Union's agri-food policy paradigm, dissecting its approach to digitalization and the assimilation of digital technologies into agriculture and food systems to bolster sustainability and food security. Unmistakably, the fulcrum for translating the promise of emerging digital technologies into impactful solutions resides in adept regulatory frameworks: crafting a visionary regulatory framework to harness the transformative potential of digital technologies while safeguarding sustainability and inclusivity is a task of paramount significance.

Moreover, the regulatory framework should evolve as a living organism, adapting to the dynamism of technology and its impact. A proactive approach that anticipates emerging trends, embraces experimentation, and calibrates swiftly to societal needs is essential. Continuous dialogue among stakeholders – from tech pioneers to rural custodians – forms the bedrock of a responsive architecture in this field. Central to the framework is the principle of inclusivity. It should dismantle digital divides and ensure equitable access to technologies, leveling the playing field for smallholders and rural communities. Digital literacy programs, targeted investments, and tailored incentives should infuse innovation, bridging gaps and amplifying voices often unheard. Regulations should strike a harmonious balance between rapid adoption and sustainable scaling. While encouraging disruptive technologies, the framework should embed checks against ecological imbalances and resource depletion. The symbiotic relationship between innovation and environmental stewardship should be fostered through incentivizing eco-friendly practices and circular economy models. Finally, the guardianship of data privacy and ownership should be guaranteed. The regulatory framework should cultivate a culture of data trust, promoting transparent data-sharing mechanisms while safeguarding individual privacy rights. Sovereignty over data should empower farmers, ensuring they control the narrative of their own agricultural journey.

As the landscape of digitalization unfurls, it becomes resoundingly clear that the governance mechanisms put in place hold the key to unlocking the transformative potential of novel technologies. The veritable synergy between technological innovation and incisive regulation will define the course of addressing societal and environmental quandaries, ensuring an inclusive trajectory that leaves no stakeholder behind.

The trajectory of European agri-food systems toward resilience and sustainability hinges upon the harmonious interplay of digital ingenuity and robust regulatory scaffolding. The convergence of these elements promises a future where challenges are not only met but surpassed, and where stakeholders collectively thrive amidst the digital renaissance of agriculture.

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