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Smart Solutions in AgriTech: Research Trajectories in the Digital Transition

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Abstract. The following study investigates and identifies research trajectories pertaining to the digital transition of agriculture and food production. While a vast amount of research aims to discover new technologies, or to apply them in novel ways, their large-scale implications as regards data ownership and data governance are relatively overlooked. Regulatory interventions are demanded to steer data ownership and data governance towards the 'common good'. It is thus necessary to identify how research can contribute to the discussion on sensitive areas of policymaking that have been the object of environmental regulation, including the EU Green Deal and UN Sustainable Development Goals. In the light of this necessity, this paper identifies issues with ethical relevance emerging from the adoption of new technologies in agritech, including Artificial Intelligence techniques and Internet of Things applications. To do so, this study attempts to systematise and categorise existing research trends by clearly identifying their scope and understanding the relationships that exist among them. The results of this enquiry show that five interconnected research trajectories - namely, technical solutions, data governance, data ownership, ethics and law - can foster the discussion on agritech transition. The connections between these research areas can be understood in terms of a descriptive and a prescriptive perspective.

Keywords: Agritech · Smart farming · Green transition · Green deal · Data governance · Data ownership

1 Introduction

The European Union (EU) Green Deal[1] aims at fostering the transition towards eco-friendly and sustainable economic models of agriculture and food production.

[1] Communication From the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions "The European Green Deal" COM/2019/640 final.

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This intervention is aligned with the United Nations Sustainable Development Goals 2 ("Zero Hunger"), 8 ("Decent Work and Economic Growth"), and 12 ("Responsible Consumption and Production"). The 'great promise' of Big Data and Artificial Intelligence (AI) is to foster this transition by rationalising a wide set of operations. They range from public decision-making, to data availability for consumers, 'smart' solutions for food business operators, and so forth. Implementing policies seem urgent to implement the new political agendas set in the aftermath of COVID-19 pandemic, at national (e.g. the Italian National Plan Resistance and Resilience), regional and international level.

The digital transition of agriculture and food production is placed within the so-called Fourth Revolution [1] and raises interesting questions as regards the priorities to be set. Regulators should steer such "Green & Blue" [2] transition toward the 'common good' and their decisions should keep into account not only the economic growth, but also other factors such as food safety and long term sustainability. However, conflicting interests among the involved stakeholders - including consumers, the food industry, local farms, small-medium enterprises - might hamper the finding of shared solutions and policies.

Research could foster the discussion about such policy-making by identifying the goals and the means of agricultural policies aimed at digitalising farming. However, research areas focused on the adoption of agritech solutions seem quite fragmented. In particular, a gap can be observed between the discussion on 'smart' methods and the general policies set by the political agendas and supported by the legislation. Therefore, this paper aims to cast light on possible research trajectories in agritech with the goal of providing an overview of research topics and identifying their relationships.

The study adopts a cross-disciplinary method of enquiry, especially when establishing a connection between research areas with the goal of filling the aforementioned gap. Rather than a complete and systematic literature review, this paper identifies general trends across several research areas. The qualitative systematisations provided in this study are thus meant to identify common patterns in agritech that raise questions relevant to policymaking. Primary sources of investigations have been extensive reviews in agritech, identified by certain keywords[2]. Other sources have been selected from these reviews to investigate the use of established and newly-adopted technologies identified as such by the reviewers. In some of the extracted reviews, emerging trends have also been linked to existing issues in new technologies and discussions about their ethical and moral dimensions (e.g., AI ethics). From these premises, the overview of research trajectories has been developed by systematising these findings. The

[2] [["Big AND Data" OR "Artificial AND Intelligence"] AND ["Smart AND Farming" OR "Digital AND Agriculture" OR "Agritech"] AND "Review"] was the query used to identified papers that contain literature reviews on the topic under scrutiny. Research was performed on academic databases (namely, Scopus, Web of Science, Google Scholar) using title-based and topic-based queries and refined to avoid duplicates.

proposed categorisation consists of five intertwined research areas, namely technical solutions, data governance, data ownership, ethics and law.

The paper is divided in four sections following this Introduction. Section 2 briefly summarises the previous works in the area of agritech and data governance, whereas Sect. 3 contextualises these works within emerging trends in new technologies. Section 4 identifies the research avenues (or trajectories) for future studies in this area and briefly discusses their possible implications. Concluding remarks summarise the main findings of this work and illustrate the next steps for this research.

2 Current Developments in Agritech

Reviewers (e.g. [3–5]) have identified several ongoing trends in agriculture 4.0, also known as precision agriculture (PA) or smart farming. These trends are not characterised by the use of a single technology, but they are made possible by the combination of multiple ICTs aimed at improving the profitability and sustainability of farming [6], e.g., by increasing the degree of automation in certain tasks or by improving decision systems [7]. Despite being dated back to 1980 s [8], digitalised agriculture is now scalable due to lower costs in microprocessors and new technologies such as cloud computing or mobile applications.

Geographic Information Systems (GISs) combine spatial data with soil information [9]. While this technology is not entirely new since it was originally proposed by FAO in the 1990s [10], its deployment has been recently proven to be successful in several case studies discussed by the literature in the fields of urban extension, deforestation and climate change [11]. Soil sensors aggregate these data with satellite images [12]. Recent data acquisition trends also relate to the use of Unmanned Arial and Ground Vehicles (UAVs and UGVs respectively) [13].

The deployment of Internet of Things (IoT) technologies - smart objects connected to each other through a wireless network infrastructure [14] - has been fruitful in crop and resource management and monitoring, with increases in quality and quantity of the crop yield [15]. Data acquisition is also related to environmental information, such as moisture, temperature, and light [12].

Furthermore, the proliferation of mobile applications for Agritech has been observed by reviewers [16], also in developing countries [17]. Mobile applications allow data access and visualisation, thus contributing to the decision-making processes regarding crop nutrition, fertilisation and irrigation. Smartphone cameras can be used for crop protection and diagnosis purposes.

Blockchain technologies are deemed to be game-changing for traceability across the whole food chain [18]. Use cases conducted by IBM and Walmart [19] and Carrefour [20] show the potential of this technology in food logistics. In smart farming, blockchain can be used in the early stages of the food chain by the seed provider and the producer [21]. Given the presence of several actors involved in the agricultural supply chain and the international nature of modern trades, blockchain can reduce the time required for manual checks and document processing [22], ultimately lowering production costs.

These technologies are, indeed, multifunctional. While they seem mainly oriented to support business activities of the food industry, they can also ease consumers' decision-making. The integration of these solutions goes under the names of "Traceability 4.0", "Smart Packaging" or "Smart Labelling". Recent studies [23] show that mobile applications equipped with augmented reality tools, including QR-codes, impact consumers' perception on product quality and origin, thus bringing consequences on the international food market. Traceability solutions are quite diverse and applicable to heterogeneous goods, including olive oil [24] and wine [25].

The integration of these technologies into interoperable models represent a noteworthy challenge. Different data sources should be integrated to extract meaningful information from them. Existing research has proposed an integration at the semantic level by means of Semantic Web Technologies [26], with possible benefits on data management and automated systems building [27]. However, these reviewers have identified a relative paucity of research in this area, which remains underutilised despite great potential.

The use of these technologies is also related to agricultural policymaking. Together with food producers, suppliers, and consumers, also policymakers can benefit from technologies such as remote sensing and data analytics to shape information-based governance models [28]. In particular, targeted policies for specific areas and real-time interventions become feasible when ICTs are spread throughout the food chain. Together with agricultural policies meant to support economic activities, deploying data-driven policies should also mean to foster sustainability [29].

To summarise, this section has highlighted how digital solutions are reshaping agriculture under several perspectives. The three main pillars of these developments consist in fostering agribusiness, empowering consumers, and sustaining decision-making processes. While existing research shows how each of these pillars can individually benefit from digital transition in agriculture, it is still unclear what direction the involved stakeholders should follow and, eventually, how to find a unified strategy for the 'common good' to be adopted by decision-makers. The next section illustrates some of the issues emerging from this transition to be investigated by academic research.

3 Agritech and Emerging Issues

The following section is aimed at identifying current and novel issues that emerge from the digital transformation of agriculture specifically related to data and information used for decision-making processes. As it will be discussed, the identified issues can be subsumed within two general categories, namely data ownership and data governance.

Reviewers in [5] observe that "[d]ata ownership, protection, and security are perceived as not sufficiently close to farmers' needs, thus becoming threats to be mitigated, if not completely avoided. In more words, nowadays, digital solutions for [smart farming, *ed.*] are under-utilised because practitioners fear data misuse and the loss of control over their business". Similarly, scholars have discussed data ownership in farming under the perspective of finding the entity entitled to exploit the economic value of information [30, 31] or in terms of the relation and the distribution of power between companies providing digital infrastructures *vis-a-vis* farmers [3, 32].

A certain degree of lexical ambiguity can be found in this literature, possibly due to the diverse background of the scholars in this field. For instance, 'data privacy', 'data confidentiality', 'data protection', and similar expressions are used interchangeably. Most of them, however, regard different issues in the realm of personal data rather than other information that does not refer to an identified or identifiable individual[3]. While it is true that some data in this domain could potentially qualify as personal data for the purposes of data protection law - for instance, food consumption data [33] or farmers' location - the majority of the digital information produced in farms is constituted by the data on temperature, humidity, nitrogen levels, geographical information, water use, vehicle data, ecc. captured by sensors deployed in the fields.

When focusing on non-personal information from a data-centric perspective, the clashes between confidentiality and data re-use, the preservation of competition, and data sovereignty can be *prima facie* observed as the most relevant concerns emerging from digitalised agriculture. While these issues have been widely discussed in fields such as data protection, data security and international data transfer with regards to personal information, little discussion has been made over non-personal data, and even less about farm-related information.

Furthermore, the centrality of (big) data in the current debate shall not nudge researchers, practitioners and policy-makers into believing that algorithms should be relegated outside the discussion. In fact, while the crucial role of data-as-an-asset has been fruitfully captured by the contemporary debate in agritech information, the way we 'make sense' of data - i.e., algorithms - seems absent from the current literature.

However, scholars have progressively shifted from the data-centric to the algorithm-centric [34] level of abstraction [35]. Agritech is not different from other domains. With AI and automated decision systems made possible by the abundance of data provided by the applications discussed in Sect. 2, issues already identified by the technical and ethical literature [36] will eventually be detected in agritech. While AI systems can fruitfully enhance decision-making at every level (food business operators, consumers, policy makers), it might be the case that some risks outweigh the opportunities offered by such novel solutions. In particular, two possibilities can occur.

On the one hand, high-level and horizontal issues (i.e., pertaining to all AI applications meant to support decision-making) can be identified. *Inter alia*, algorithmic explainability can be seen a paramount requisite for AI systems meant to support public decision-making [37], whereas human oversight and accountability frameworks are necessary to attribute the responsibility for the

[3] That is the definition of 'personal data' under Article 4(1) of the EU General Data Protection Regulation (Reg. 2016/679).

actors involved, especially in the fields of product liability and in the business-to-business relationship between farmers and ICT suppliers.

On the other hand, applied and vertical issues (i.e., specifically pertaining to the context of agritech AI-powered solutions) raise attention. For instance, it might be the case that disparate access to 'smart' solutions amplify the diversity between different areas and regions, or that AI-suggested solutions prioritise profit over environmental concerns (e.g., in the case of fertilisation and the use of plant protection products vìs-á-vìs environmental concerns).

To summarise, two main areas of potential investigation have been identified in addition to technical advancements. On the one hand, the quasi-proprietary relationship between a legal entity and some information - identified as '*data ownership*' - has been detected as one of the key issues. As a research trend data ownership investigates the possibility to access, analyse, and store (i.e., 'use') data, both from technical and legal perspectives. In fact, the rules governing the usage of data by a qualified entity can be expressed in design requirements (e.g. via APIs, data portability instruments, etc.) as well as in legal terms (e.g. in 'hard laws', contracts, codes of conducts). On the other hand, data *governance* expresses the procedures that govern the creation of data-related rules, the regulatory instruments adopted to create, modify and to amend these rules, and the objectives that they are meant to fulfil.

Data ownership and data governance interplay significantly. Any entity qualified to use a given dataset is also entitled to determine the purposes of the such usage (e.g. business analysis) and the rules that govern it (e.g., restricting access to third parties). In other words, who owns the data usually decides how to use it. This faculty is subject to changes when a coercive regulatory intervention, such as 'hard law', determinates from the outside the behaviour of the data owner by restricting or enlarging its possibilities. Who shall determinate such behaviour, by what means, and for what purpose is the research trajectory that goes under the name of data governance.

4 Possible Research Trajectories and Their Connections

The previous section has identified data ownership and data governance as two central research areas. A combined discussion about these topics is necessary to understand digital transformations across the whole food chain. In particular, it has to be noted that, without regulatory interventions, a discrete margin of appreciation is left to the involved stakeholders in determining governance choices that have consequences on ownership (e.g., allowing or restricting data access to third parties).

Research has discussed how ethics play a significant role in determining governance and, consequently, ownership choices in new technologies. For instance, re-thinking data ownership in agriculture has been considered necessary, also on the basis of ethical considerations [38]. In the field of algorithmic governance, it has been observed that "[e]thics plays a key role in this process by ensuring that regulations of AI harness its potential while mitigating its risks" [39], when AI solutions are meant to promote a general interest and the social good [40], as with the case of agritech. In sum, the digital transition of farming and related activities require a careful balance of risks and opportunities.

On the contrary, it might be argued that law is sufficient in addressing conflicting interests (e.g., between data confidentiality, openness and re-use). In the European legislation, data flows might even seem over-regulated: the contextual application of the General Data Protection Regulation[4], the Non-personal Data Regulation[5], the Data Act[6], the Data Governance Act[7], and the forthcoming Artificial Intelligence Act[8], jointly with sectoral food law legislation, e.g., in the field of food safety[9] suggests that EU decision-makers have already decided for a clear direction on how to solve ownership and governance issues.

Some clarifications on the role of ethics are then necessary. First, ethics is not necessarily meant to replace the normative role of existing laws. Following Floridi's interpretation of the role of ethics in this debate [41], it shall be deemed either as a challenge to the existing legislation to be used in a *de iure condendo* perspective ("hard ethics") or as what ought and ought not to be done over and above the existing regulations ("soft ethics", among which we can include 'data ethics' [35]). Furthermore, principles can be placed between law and design specifications [42].

As argued above, several pieces of legislation regulate the use of data in the European Union. Therefore, data ownership and data governance are (also) co-designed by such several provisions and, in turn, technical solutions are impacted by these rule-shaped ownership and governance models. While the law sets the "how" ownership and governance should be shaped, ethics contributes to identify the "what-for" certain choices are made. With new technologies and applications emerging and in a transition phase, ethics (as a discipline) has the capability to receive inputs emerging from the current status of ownership and governance and

[4] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC [2016] OJ L 119/1.

[5] Regulation (EU) 2018/1807 of the European Parliament and of the Council of 14 November 2018 on a framework for the free flow of non-personal data in the European Union [2018] OJ L 303/59.

[6] Proposal for a Regulation of the European Parliament and of the Council on harmonised rules on fair access to and use of data.

[7] Proposal for a Regulation of the European Parliament and of the Council on European data governance - COM/2020/767 final.

[8] Proposal for a Proposal for a regulation of the European Parliament and of the council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts - COM/2021/206 final.

[9] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety [2002] OJ L 31/1. This Regulation has been deeply amended by the 2021 Transparency Regulation to provide more public access to food safety information.

support legal operators (hence, not only lawmakers but also judges and scholars) in identifying the best option among the many possibilities offered by technical solutions.

This is the case of agriculture and food production. As a market sector, it constitutes a field of research dense with opportunities and risks. Their balance determines the quality of life of consumers and impacts the whole population of a given region, let alone economic consequences for food business operators. Moreover, data-centric regulations should match the goals of regional or international green transition programmes such as the EU Green Deal and UN Sustainable Development Goals. Ethics can contribute to the identification of a general trend, or solid pillars, to support the interplay between data-oriented provisions and digital transition programmes.

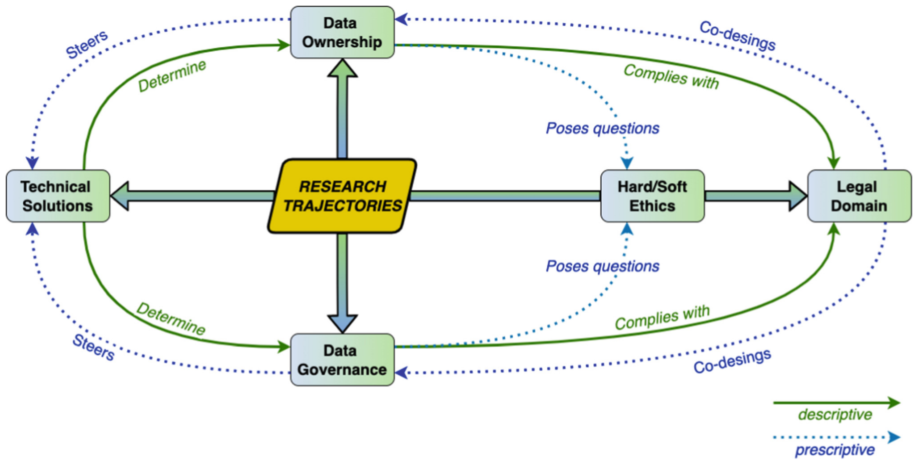

Fig. 1. Possible research trajectories: technical solutions, data ownership, data governance, ethics and law. Descriptive and prescriptive relationships are identified by the arrows

Figure 1 displays the research trajectories identified by this paper. They are not intended to be ranked or classified hierarchically and the order of presentation in this study is only for descriptive purposes. First, the domain of technical solutions is necessary to correctly understand what is (or can be) done with emerging technologies and applications in the realm of Big Data and AI. Such correct understanding is necessary also to prevent, in a later stage, that legal solutions impose excessive or impossible burdens on ICT providers or users.

Then, data ownership and data governance are *prima facie* determined by technical solutions previously discovered. As a research trajectory, data ownership poses the question "Who owns the data?" and investigates the quasi-proprietary relationship between stakeholders and personal or non-personal information, access conditions, data transfers, data processing, data warehousing, and so forth.

Instead, data governance seeks answers to the question "How is data managed?". In particular, it focuses on the allocation of decision-making powers in data-related questions, what regulatory instruments are adopted in the definition of these rules, how they are enforced, what are the general goals of these rules, etc.

Then, data ownership and data governance have to comply with legal requirements, in particular the complex legislative scheme described above. Therefore, a scrutiny on their level of fitness to the current regulation is required. This first set of questions regards any scenario at any given time and a *descriptive* goal.

While being compliant with legal requirements, ownership and governance models pose questions that have an ethical relevance, as they demand morally-relevant choices. As argued above, technologies can be used to prioritise food production, lower costs for consumers, increase access to food, perhaps at the expense of increased land usage and environmental concerns. Ethical dilemmas are not new to agriculture and food production, especially in bioethical research [43].

Today, these trajectories require the inclusion of approaches capable of casting light on novel technologies. After all, and on a positive note, a certain degree of consistency on high-level bioethical principles and AI principles has already been identified by qualified working groups [44], thus paving the way for a progressive integration at applied levels such as agritech. Moreover, this method has been proved to be correct elsewhere, when applied to food safety [33,45]. Furthermore, ethical contributions might be necessary to foster the current debate on forthcoming pieces of legislation in the EU (Data Act and Artificial Intelligence Act).

Therefore, it might be necessary to identify, alongside the legal domain, an ethical research trajectory capable of capturing instances of 'what for' discussions emerging from the debate on data ownership and data governance. Therefore, differently from the other relationships, the one between ownership and governance trajectories is not descriptive, but it aims at discovering "hard ethics" or "soft ethics" approaches to the existing regulation, hence being *prescriptive* or ought-oriented.

Such prescriptive relationship between research trajectories is not isolated. Besides setting general principles and constituting powers [46], law is also inherently *prescriptive*, thus mandating certain behaviours that shall be followed when implementing data ownership and data governance models. Therefore, legal provisions co-design these models, together with other factors such as economic considerations, global policies, power relationships, and so forth.

In turn, ownership and governance models steer the development and the design of the technical solutions deployed in a given environment and, ultimately, are a contributing factor to their adoption. By means of this prescriptive relationship, technical solutions eventually mirror the regulations and contribute to achieve policy-makers goals.

Let us briefly discuss the main implications of the proposed classification. First, the interdependences of the identified research trajectories entail that their integration is necessary to solve the complexities of agricultural transition. In other words, decision-makers should rely and be informed on these five areas to identify the pros and cons of digital transition policies that are relevant to agritech. Secondly, ethics play a key role in mediating different positions and being, either as a 'hard' or a 'soft' ethics, the pivot of the research trajectories. In this regard, agritech is consistent with other research domain, including bioethics and AI ethics. Finally, the circularity of the proposed model implies that, while no research area is more important than the others, new advances in each area have implications for the others. This map can contribute to identify the nature of such consequences from a theoretical point of view.

5 Concluding Remarks

This study has contributed to identify possible research trajectories in agritech data-related issues. A systematisation of the existing research trends and methodologies was necessary to identify a common ground for further discussion. In summary, the paper has identified five main research tracks in agritech data-related issues: technical solutions, data ownership, data governance, ethics and law. The existence of descriptive and prescriptive relationships among them has also been detected. In this sense, this study in an original contribution to an ongoing, yet highly fragmented, discussion.

However, this study is also limited because it only provides a short description of each research trajectory, without specifying specific methodologies to tackle the peculiar issues of each research area. While each of them remains independent, it is necessary to contextualise them within a broader framework to verify the technical feasibility, the connections with data ownership and data governance, the ethical implications, and the compliance to legal requirements of every newly-developed research product that can contribute to the 'common good' in the digital transition of the agrifood sector. The next steps seem likely to put the research trajectories into practice. Naturally, it might the case that research products do not cover all the aforementioned issues in detail. However, a generic assessment of their implications or, vice versa, their check under a different perspective seems ultimately beneficial for the interplay between research community and to policy-makers.

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