OECD publishing

Please cite this paper as:

Jouanjean, M. *et al.* (2020-10-23), "Issues around data governance in the digital transformation of agriculture : The farmers' perspective", *OECD Food, Agriculture and Fisheries Papers*, No. 146, OECD Publishing, Paris.
http://dx.doi.org/10.1787/53ecf2ab-en

OECD Food, Agriculture and Fisheries Papers No. 146

Issues around data governance in the digital transformation of agriculture

THE FARMERS' PERSPECTIVE

Marie-Agnes Jouanjean,

Francesca Casalini,

Leanne Wiseman,

Emily Gray

OECD FOOD, AGRICULTURE AND FISHERIES PAPERS

The report was declassified by the OECD Working Party on Agricultural Policies and Markets in June 2020 and was prepared for publication by the OECD Secretariat.

Comments are welcome and can be sent to tad.contact@oecd.org.

Issues Around Data Governance in the Digital Transformation of Agriculture: The Farmers' Perspective

Marie-Agnès Jouanjean, OECD
Francesca Casalini, OECD
Leanne Wiseman, Griffith University, Australia
Emily Gray, OECD

Agricultural data and their use for better decision-making and innovation are at the core of the digital transformation of agriculture. But fragmented and unclear data governance arrangements may weaken farmers' willingness to adopt digital solutions. This, in turn, may reduce the availability and accessibility of agricultural data for policymaking, for the agricultural innovation system, and for developing services for farmers. A key challenge for policy makers lies in finding a balance between protecting the privacy and confidentiality of agricultural data, and farmers' economic interests in those data, while making it possible to leverage their potential for the sector's growth and innovation. This report focuses on farmers' concerns around access, sharing and use of agricultural data and explores whether and how existing policy frameworks and other sectoral initiatives can help to foster greater trust.

Keywords: Innovation policy, data cooperatives, data ownership

JEL codes: Q13, Q16, L14

Acknowledgements

The authors wish to thank OECD colleagues for their valuable comments and assistance in preparing this report. This report also benefited from comments by OECD delegations to the Working Party on Agricultural Policies and Markets.

Table of contents

Tables

Figures

Boxes

Executive Summary

Agricultural data and their use for better decision-making and innovation are at the core of the digital transformation of agriculture. But fragmented and unclear data governance arrangements have raised concerns in some farming communities about the regulatory environment governing the data collected on and about farms, potentially affecting farmers' willingness to adopt digital solutions. This, in turn, may reduce the availability and accessibility of agricultural data that are valuable for agricultural policymaking, for the agricultural innovation system, and for the development of services for the sector. Reflecting this, a key challenge for policy makers lies in finding a balance between protecting the privacy and confidentiality of agricultural data, and farmers' economic interests in that data, while making it possible to leverage their potential for the sector's growth and innovation.

This report focuses on farmers' concerns around access, sharing and use of agricultural data and explores whether and how existing policy frameworks and other sectoral initiatives help or could help to foster greater trust.

For farmers, key issues include who controls access to, and sharing of, data that are generated on and about farms, and how the value that is created from that data is re-distributed. An often-expressed view is that such concerns would be addressed if farmers 'owned their data'. However, this is a complex topic at the intersection of different regulatory frameworks, including: contract and competition law, intellectual property rights, personal data protection and privacy, which could all provide a way of ensuring that aspects of farmers' concerns are considered. Nevertheless, none of these instruments provides a satisfactory solution as yet, and many aspects of their application would, at a minimum, need to be clarified. In this context, emerging voluntary sectoral initiatives, such as codes of conduct and farmer data co-operatives, could help to increase awareness among competent authorities of the needs and priorities of farmers.

Moreover, some issues have been raised about how data governance may affect the supply of digital services for farmers. For example, there are concerns about how some clauses in technology contracts limit the ability of farmers to transfer historical data between technology providers, or restrict their ability to choose who services their machinery. Interoperability and data quality standards, as well as restrictions on cross-border data flows, may also reduce the availability of services and limit the choice of policies for farmers. All these aspects will also be key to developing trustworthy governance of agricultural data.

Many of these issues are not unique to agriculture, and a goal for data governance discussions should be to strengthen a common vision for the coherent implementation of existing data practices and policies across communities, sectors and countries. At the same time, policy makers could clarify how existing regulatory arrangements affect agriculture; ensure that broader data policies are applied in a way that responds to the sector's needs; and determine whether there are persistent gaps in existing data governance arrangements that may require a more tailored approach for agriculture. Governments can also improve communication around policy frameworks to build confidence in the use of digital solutions, especially among farmers.

This should also pave the way for whole-of-government and multi-stakeholder discussions about data governance, where the perspectives of all stakeholders and sectors are properly represented. Finally, discussions around data governance should also be facilitated at the international level, to ensure that efforts to establish standards and good practices around agricultural data governance advance coherently, and enable a greater flow of knowledge and services across borders.

1. Introduction

The digital transformation of agriculture, and of the economy more broadly, has significantly increased the amount of agricultural data that is generated and collected, and the rapidity and scale at which it can be accessed, shared and used. Agricultural data and their use for better decision-making and automation are at the core of the digital transformation of agriculture. When accessed, shared, and used, agricultural data – here considered to include farm administrative and production data, including agronomic, farmland, farm management and farm machinery data – can generate information and aid decision-making by stakeholders across agro-food sectors, potentially resulting in greater efficiency in the use of resources and in new sources of value addition.

However, the current policy environment governing the use of data, and agricultural data in particular, is complex. Data governance systems need to provide stakeholders with the institutional, regulatory and technical tools that they need to deliver value while maintaining trust in the use of digital technologies (OECD, 2019[1]). For this to happen, a key challenge lies in finding a balance between protecting the privacy of farmers, the security of agricultural data, and the economic interests of different stakeholders, while making it possible to leverage the potential for the sector's growth and innovation.

While a range of perspectives should be considered in the design of appropriate data governance arrangements, this report focuses on agricultural data governance from the viewpoint of farmers' concerns. Trust in the collection, use and storage of agricultural data is low among farmers, and this is seen to be hindering the uptake of digital tools on farm (FCC, 2018[2]; Jakku et al., 2019[3]).[1] This, in turn, may reduce the availability and accessibility of agricultural data that are valuable for agricultural policymaking, for the agricultural innovation system, and for the development of services for farmers.

Against this background, the report outlines trends in agricultural data practices and policies with the aim of providing some first insights to policy makers on how to conceive a data governance environment that takes account of farmers' concerns and expectations. While the report does not provide a systematic review of the laws and regulations of OECD countries, it highlights some country specific examples that are relevant to understanding the concepts discussed.

The report is structured as follows. Section 2 provides an overview of the potential advantages of data sharing for the agricultural sector, and sets the scene by presenting concerns in relation to data governance in the sector, with a focus on farmers' perspectives. These concerns are divided into two broad issues: i) the control of and access to data generated on farm (the 'data ownership' question); and ii) regulations around data access, sharing and use and how these can influence the availability of innovative digital services for farmers, including across borders. Policy considerations relating to these concerns are discussed in Sections 3 and 4 respectively. Section 5 provides some concluding observations.

2. The digital transformation of agriculture and the need for data governance

2.1. The core of the digital transformation of agriculture: accessing, sharing and using data

Digital agriculture can be broadly defined as the network of digital technologies and actors that support the development and delivery of information and services to farmers.[2] The digital transformation of agriculture covers a wide range of practices, ranging from low-tech solutions such as the use of mobile devices – for example, for farmers to access more precise weather forecasts – to high-tech 'digital farms' where

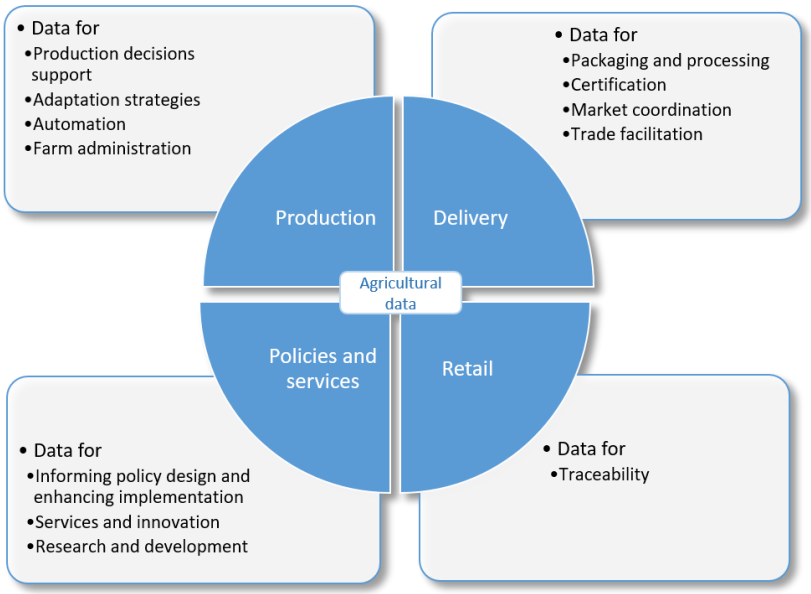
[1] While it is recognised that a wide range of other government regulations and policies will also affect innovation and the uptake of digital technologies in agriculture – for example, broadband infrastructure in rural areas – the scope of the analysis is limited to issues around agricultural data governance.

[2] This report does not engage with questions about the benefits from adoption of digital technologies. For a discussion of these issues, see McFadden and Schimmelpfennig (2019[56]); McFadden and Rosburg (2018[57]); Schimmelpfennig (2016[58]); and O'Keeffe (2019[59]).

integrated systems and big data analytics support decision making; through to drones, robotics, and artificial intelligence for the automation of processes.

The core of the digital transformation of the agro-food sector lies in the increasing capacity to produce, transfer and analyse data in ways that were previously not technically or financially feasible. Digital technologies make it possible to record and process a greater volume of agricultural data, while also expanding the collection of data to aspects of farm production for which data were previously unavailable. This includes raw data, obtained from remote systems such as satellites, and from *in situ* sensor systems such as those attached to farm machinery and precision agriculture equipment; as well as aggregated and processed data sourced from surveys and censuses, and financial and market data collection (OECD, 2019[4]). When accessed, shared and used among a range of stakeholders, these larger and more granular sets of agricultural data can enable benefits across many stages of the agro-food system (Figure 1).

Figure 1. The value of agricultural data for agro-food sectors



At the farm level, agricultural data can be analysed to generate information and actionable insights that support producers' decision-making and help them to better manage their operations. This includes using agricultural inputs more precisely; the ability to adapt to pest, weather and climate conditions; the automation of repetitive tasks; and more efficient record keeping and administration.

In the context of domestic and international agro-food value chains, the ability to access and share agricultural data can support more efficient transactions, improve trade facilitation and cross-border customs processes, and reduce traditional constraints to trade – allowing new actors, including smallholders, to participate in international trade. For example, sharing data from and through IoT solutions[3] may make it easier for suppliers to demonstrate compliance with regulations, such as SPS requirements, or support the rapid and efficient exchange of customs documentation. The increased capacity to share agricultural data can also enhance transparency and traceability of agricultural products. This can provide accountability about production conditions and processes, and, at the retail stage, allow farmers to differentiate their products and benefit from premium pricing (Jouanjean, 2019[5]).

[3] The Internet of things (IoT) refers to computing devices, and mechanical and digital machines, that have unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Rouse, 2020[62]).

More broadly, agricultural data have commercial significance, and the enhanced ability to access, share and use agricultural data among agri-food stakeholders is re-shaping competition in the sector. Agricultural data are a valuable resource for agricultural input and services providers, for the purpose of research and to develop new services (for example, pests alerts) (Greenville, Kawasaki and Jouanjean, 2019[6]). The increasing availability of data is also changing business models, fostering new types of vertical collaboration (for example, between machinery equipment and digital software providers), and providing increased opportunities to tailor products and services for farmers.

From a government perspective, the ability to access and process data generated and collected on farms can also enhance the design, implementation and monitoring of agricultural policies for farmers, and allow governments to overcome policy-related transaction costs that may have led to second-best policy choices in the past (OECD, 2019[7]). The availability of agricultural data can also be leveraged by governments to design demand-side policies that stimulate healthier and more environmentally sustainable food systems.

2.2. Emerging concerns around access, sharing and use of agricultural data

While the potential benefits of digitalisation for agriculture are generally recognised, there are increasing concerns among farmers that sharing agricultural data may not return the expected benefits for them, which is seen to be hindering some of the opportunities for agricultural data collection, sharing, and use in the sector. This section identifies farmers' concerns around agricultural data access, sharing and use, and sets out the policy issues that these generate, which are further explored in Sections 3 and 4.

Much agricultural data is collected on private farms but processed with private third-party software. This leads to the fundamental question of how that data should be governed – that is, who should control it and be able to extract value from it (Jakku et al., 2019[3]; Zhang et al., 2017[8]). In particular, farmers are calling for greater control over data generated on farms, and for action to redress power imbalances and information asymmetries in their dealings with digital service providers.

At the same time, some producers have expressed concerns that data from farms, if improperly shared, could lead to anti-competitive practices and manipulation of market outcomes, such as price discrimination and commodity speculation.[4]

Wider access to agricultural data is also seen to increase the risk that personal or commercially sensitive information about farms will be revealed, which may even impact the value of a piece of land. In addition, farmers may be reluctant to share agricultural data to prevent it from being accessed by government agencies and used for regulatory purposes, for example, to verify compliance with environmental and animal welfare standards, or fiscal obligations.

Reflecting these broad concerns about control and access over agricultural data generated on and about farms, research and survey results indicate a certain wariness among farming communities about the regulatory environment governing the data collected on their farms (FCC, 2018[2]; Wiseman and Sanderson, 2017[9]; van Es, 2016[10]).[5] In policy terms, these concerns are also sometimes translated into advocacy for the principle that farmers should 'own' the data coming from their farms – although this may not be the most appropriate way to approach the issues at stake, as explained in Section 3.1.4.

Moreover, farmers also hold some concerns about data governance arrangements that may have specific implications for their relationship with service providers, in ways that they see as disadvantageous for themselves. In particular, from the perspective of farmers, one issue relates to clauses in technology contracts that prevent them from sharing data about their farms across different suppliers. This has led farmers to claim a right to data portability for agricultural data collected from their farms, in order to avoid being 'locked-in' to a given technology provider (Agronomic Crops Network, 2016[11]). Moreover, also in the context of technology contracts, farming communities are arguing for the 'right to repair' – that is, a

[4] For example, see the United States District Court for the Eastern District of Oklahoma class action complaint alleging data sharing and price fixing behaviour in *re Broiler Chicken Grower Litig.*, No. 6:17-CV-00033-RJS, 2017 U.S. Dist. LEXIS 142069 (E.D. Okla. Sep. 1, 2017). Case no.17-cv-033-sps; class action complaint jury trial demanded.

[5] For example, in November 2017, in his opening statement of the *US Senate Subcommittee on Consumer Protection, Product Safety, Insurance, and Data Security in their hearing*, *Technology in Agriculture: Data-Driven Farming*, United States Senator Moran highlighted '*the collection and use of [agriculture] data raises issues regarding control of the data [and] transparency of agreements between farmers and data firms.*'

right to access the data and software needed to repair their own machinery – rather than being contractually obliged to use licenced repairers (who may be costly and not readily available in remote areas), as it is currently often the case with digital equipment.

Finally, businesses – and governments also – could benefit from accessing a wide range of data in order to develop new and better digital services (and policies) for farmers. For this reason, less restrictive access arrangements for some types of data, including arrangements that allow stakeholders, such as researchers and agribusinesses, to discover certain public and private datasets within and across borders, may be important to ensure that businesses and governments are able to innovate. In this context, government agencies are exploring how to make the data that they hold more widely available, while also taking on a new role in supporting the networks necessary for both public and private data to be more easily discovered, accessed and used.

From a policy perspective, a key challenge in addressing these concerns relates to difficulties with characterising data. Data are multifaceted and a range of possible approaches for categorising the same data point emerge from the literature, depending on the perspective taken – see Annex A. As a result, different communities describe data and call for regulatory arrangements according to their own needs and concerns (such as privacy, equity, public goods, and innovation). Difficulties can arise when stakeholders in the same data user community disagree on the status of the data and the best data policy to apply. Reflecting this, a range of policies and practices need to be considered in thinking through a well-balanced governance system for agricultural data. At the same time, the use of digital technologies themselves may also facilitate the implementation of more contextual data governance solutions in the future (for preliminary discussion of technological approaches to data governance see Box 1).

Box 1. New digital technologies, data rights enforcement and distribution of incentives

One element that may be sometimes overlooked in policy discussions around the digital transformation of agriculture is that better governance could be ensured precisely thanks to digital technologies. In particular, new technologies can increase the capacity to enforce rights and ensure that incentives are correctly distributed. This is visible along a spectrum of solutions that can be used to strengthen the implementation of policies. For example, limiting data access to sub-groups of users is much easier through digital technologies. Similarly, machine learning techniques are being tested to automate reading and verify legal compliance of contracts and avoid unfair contractual terms.[1] Technological solutions that support protected data processing also include virtual data centres, remote analysis systems, or distributed computing, among many others. All these digitally-enabled solutions may contribute to increasing trust in data services and could be further explored to support adoption of digital technologies across the sector.

Work is ongoing in the OECD to review the opportunities and challenges of technological solutions for improving regulatory quality, including as it relates to data governance. For example, see (OECD, 2019[12]).

Note: 1. For example, see 'Automated CLAUse DETectEr' – CLAUDETTE, http://claudette.eui.eu/.

3. Legal frameworks and other emerging arrangements shaping access, sharing and use of agricultural data

To better understand the needs of farmers in relation to data governance, this section situates farmers' concerns within the legal frameworks that currently shape the access, sharing and use of agricultural data. It then provides an overview of arrangements that have emerged in relation to agricultural data, largely as a response to the limitations of existing frameworks in addressing those concerns. These arrangements and the principles that they uphold can help governments gain a better understanding of current trends in the sector, and of farmers' expectations and priorities around data governance.

3.1. Existing legal frameworks shaping access, sharing and use of agricultural data

Contracts and farm data licensing

The introduction of digital technologies on-farm has led to an increasing reliance on detailed and complex legal contracts to deal with data governance questions that may arise. Contracts regulate the relationship between farmers and machinery and service providers (for example, input suppliers, production advisors) all of which, once they enter into a business relationship with a farm, become potential stakeholders in the agricultural data generated on and about that farm.

While contracts vary from company to company, they usually include terms of use that establish what can and cannot be done with a technology and with the data collected by that technology. Terms of use in technology contracts tend to cover a broad range of matters such as: who 'owns' the data; who the data may be shared with; where the data may be stored (including in which country); the security and privacy parameters for the data; indemnities and liabilities in relation to the data; what may occur with the data when the contract comes to an end (legacy data); what happens with data when the business is sold or wound up; whether the data can be migrated or transferred from one vendor to another; and in which country a dispute under the contract may be heard. Contracts are also often linked to other policy documents, such as privacy policies. In some cases, it is the privacy policy rather than the terms of use of the contract that outlines who may have access to the data generated under the agreement (Wiseman et al., 2019[13]).

But today, there is little, if any, specific regulation that governs the fairness of terms of use in agricultural data contracts. For example, while the adoption of regulations such as the EU General Data Protection Regulation (GDPR) has empowered individuals in relation to personal data, agricultural data often falls outside the scope of 'personal data' and those protections may not be available (see the discussion on Personal data and privacy protection in Section 3.1.1). As a result, agricultural technology contracts may not always be seen as a sufficient safeguard for farmers.

In particular, there are issues relating to potential imbalances in the contractual relationship between farmers and service providers, due to information asymmetries, power imbalances and a lack of the requisite literacy among farmers (Wolfert et al., 2017[14]; Avelino and Wittmayer, 2015[15]). An unequal bargaining relationship may put them in a less favourable position relative to large technology providers, and reduce their capacity to negotiate the terms that govern agricultural data within broader technology and service contracts, especially when these are presented on a 'take it or leave it' basis. For example, where the terms of data licences allow for broad access rights to agricultural data for third parties, this can raise concerns among farmers about how they will maintain control over the data, and be able to benefit from the knowledge created and extracted from datasets about their farms. When these broad terms of access for third parties are not made transparent to the farmer prior to entering into the contract, this can lead to legal arguments about the fairness of the contract. Mergers between large agri-tech companies (Detrick, 2018[16]) are also seen as intensifying the power imbalance between agri-businesses and farmers in relation to contracting (Chauve, Parera and Renckens, 2014[17]).[6] At the same time, the terminology used in contracts can be highly technical and obscure for farmers, and especially for smaller producers who may not have the capacity or the support to understand complex legal contracts or negotiate their terms. This may be a particular issue if the terms that govern the security and safety protections afforded to the data are not clear to farmers. These dynamics exacerbate farmer scepticism of technology providers and reinforce the idea in some farming communities that there are more risks than advantages from sharing data and adopting digitally driven solutions on-farm.

The legal framework around the technology contracts that govern agricultural data is complex and fragmented (Leonard et al., 2017[18]). That said, imbalances in contractual relationships and mergers between agri-tech companies are issues falling within the remit of competition authorities. Therefore, contracts, if appropriately designed, and contract law, if appropriately enforced, could provide one important avenue for improving issues around data sharing in agriculture.

[6] The expanding power of global technology companies more broadly has been a matter of concern for regulators – see for example, (ACCC, 2019[63]) and (FTC, 2020[64]).

One option to address farmers' concerns and reinforce the role of contracts would be for governments to formulate guidelines or standard contractual provisions to be included (potentially mandatorily) in data sharing arrangements, whether specifically for agriculture or more broadly. Alternatively, governments could provide guidance via a "negative" approach; that is, by providing direction around contractual clauses that should be avoided for a contract to be deemed fair. Another option that could be explored would be to develop guidelines on how competition law should be applied specifically in respect to the relationship between farmers and digital service providers.[7] While some analysts have warned against the risk of limiting innovation, especially if these guidelines restrict data aggregation by machinery or service sellers (Atkinson, 2019[19]), the impact of such a policy approach would depend heavily on the nature of any guidance. Finally, codes of conduct (Section 3.2.1) are already being used to benchmark good practices around agricultural data contracting, although their impact is difficult to measure, given the voluntary nature of such arrangements.

Broader policy frameworks

With regard to data practices in technology contracts and data licenses in agriculture, some economy-wide policy frameworks may also already be shaping the governance of data, including agricultural data.

Personal data and privacy protection

In the digital economy, the protection of personal or personally identifiable information is an issue of primary importance for regulators. Personal data and privacy protection frameworks vary around the world, but they generally provide key principles in relation to data collection and processing practices, and establish a number of rights that allow the individual to exercise some degree of control over data that is about them (personal data). In the agricultural context, protection under personal data and privacy frameworks is often raised as a possibility, as farming activities can be closely linked to the private household of the farmer. Nevertheless, agricultural data may not always fall under the definition of personal data.[8] The control and other rights deriving from personal data protection frameworks may thus sometimes, but not always, be available for farmers in relation to data generated on or about their farms.

In particular, issues arise from a lack of clarity at the national and international level in relation to when agricultural data should be treated under personal data protection frameworks. For example, a common concern in farming communities is that farmers are not able to access the data (or copies of the data) that service providers and machinery sensors generate and collect on their farms for their own use beyond the service for which the data was collected (Atik, 2019[20]).[9] While a right to data access is widely recognised in relation to personal data, a right to access is not guaranteed for non-personal agricultural data. Therefore, the willingness of farmers to allow third parties to collect data on their farms may be reduced if they feel uncertain about whether their interests in that data will be sufficiently protected.

At the same time, in the absence of more specific rules, technology providers have, in some cases, resorted to personal data protection frameworks as a benchmark in order to define their agricultural data practices (for an example of a practice by an agri-digital business, see Box 2). However, while personal data and privacy protection regulations may sometimes be relevant in the agricultural context, other legal frameworks may be more appropriate to address the range of questions that arise around sharing and use of non-personal agricultural data.

[7] For instance, in 2017, the Japanese Fair Trade Commission released "Guidelines Concerning Abuse of a Superior Bargaining Position in Transactions between Digital Platform Operators and Consumers that Provide Personal Information, etc."

[8] For example, the EU Regulation on the Free Flow of Non-Personal Data 2018, which came into force in 2019, identifies 'machine generated agricultural data' as being non-personal data.

[9] This can be the case, for example, where yield data can be used by a service provider to produce irrigation advice, but not by the farmer for whom it could also be useful for administrative purposes.

Box 2. Data handling by agricultural digital services providers

The Climate Corporation is a digital agriculture company, a subsidiary of Bayer, based in the United States. Its core business relies on the analysis of weather, soil and field data to help farmers determine potential yield-limiting factors in their fields.

In the provision of its precision agriculture services, the Climate Corporation deals both with grower-customers' personal data, and with business-related agronomic field and production data that producers share with them.

According to declarations by the Company, these data are governed by data protection and privacy laws (e.g. EU General Data Protection Regulation), where appropriate, as well as by the Climate Corporation's Privacy Policy and the Climate FieldView service Privacy Notice and End User License Agreement ("EULA"). The Privacy Notice and EULA distinguish between individual grower agronomic data and "aggregated information." Aggregated information is data collected from multiple sources and/or multiple data points that have been combined and therefore cannot be traced back to a specific Climate FieldView user or account. Examples of aggregated information include summaries of pest and disease reports by region, the performance of a corn hybrid by soil type, or average yield by management practice in a state. While growers can access their data, public access to individual grower agronomic data and aggregated information is restricted.

Aggregated information is also used by the Climate Corporation and its affiliates to develop products and services, as well as to support the development, production, and deployment of innovative agriculture inputs, including seed and crop protection products. For example, aggregated information may be used to identify seed hybrids and varieties that will perform best for farmers and to produce that seed in the right quantity to meet farmer demand; to develop potential new seed or crop protection products that will be beneficial for farmers; or to inform agronomic models that the Climate Corporation delivers through its digital tools.

The Climate Corporation reports that there is an internal cross-functional group in charge of approving whether growers' agronomic data or aggregated data can be shared with affiliates (i.e. Bayer) or any third party. It reports that, whenever possible, only aggregated data is shared, and individual grower data is never shared with affiliates or third parties without the grower's permission or if this is required by law.

Climate Corporation, together with its parent company Bayer, have also adopted cyber-security policies and procedures, with practices identified in ISO/IEC standards 27001 and 27002.

Source: Authors' communication with Bayer, July 2019.

Intellectual property rights

Intellectual property rights can also play a role in agricultural data governance. Intellectual property rights provide exclusive rights for a limited time, to e.g. investors, brand owners, and creators of certain assets (inventions, source-identifying marks, creative works, and valuable secrets). They are designed, *inter alia*, to provide incentives to create and innovate, while ensuring that information and knowledge are available for society to enjoy the benefits of such innovations. In general, intellectual property rights are not meant to protect information on a general basis, but rather to cover assets that correspond to specific legal definitions. Hence, intellectual property can be said to cover a subset of agricultural data, but not necessarily all the infinite data points of information recorded by a sensor or a satellite.

The question of intellectual property rights in relation to agricultural data is further complicated by the fact that compilations of data are generally eligible to be copyrighted. In certain countries where *sui generis* database protection exists,[10] databases and the data that they contain may also be protected where their compilation may have required sufficient investment (OECD, 2019[21]). That said, challenges around the application of database protection have already arisen as an issue in other sectors, complicating guidance

[10] *Sui generis* database protection frameworks exist, for example, in the European Union, Japan and Korea.

that might be provided at this stage in terms of farmers' interests in data governance, including interests related to intellectual property.

The challenge of regulatory differences across countries for agricultural data governance

With the globalisation of agri-businesses and technology companies, an increasing difficulty also relates to regulatory differences across countries. The law of the country where the company is registered governs contracts entered into with farmers, in terms of that country's policies on privacy, intellectual property and competition. However, this can be a country other than where the company is delivering its services or doing its business.

As the legal principles that govern competition, privacy, and intellectual property in relation to data vary from country to country, this can create uncertainty about the level of protection afforded to farmers and the prospects for effective enforcement action, and further hinder the willingness of farmers to enter into such contracts (Wiseman et al., 2019[13]). These concerns can arise in particular in terms of the ability of farmers to access data generated on their farms, their right to data portability (see Section 4.1.1), as well as guarantees on the security of their data.

Greater international regulatory co-operation between governments on data governance, including agricultural data governance, could thus bring significant improvements to issues arising from regulatory fragmentation and jurisdictional differences. International regulatory co-operation is needed to avoid 'forum shopping' by digital companies; to protect consumer rights effectively; to promote interoperability across regulatory frameworks and enforcement; and to create a favourable environment for the digital economy to thrive (OECD, 2019[12]).

Although not focused on agricultural data specifically, dialogue about how to ensure that protections around data are ensured across borders are currently underway in a range of multilateral fora, including, for example, the World Intellectual Property Organization, and the World Trade Organization. The private sector is also actively engaged in initiatives to standardise data governance. Efforts include, for example, the ISO/IEC 27701 and ISO/IEC 27002 on privacy information management, and the ISO/IEC 18033s on IT security techniques. However, it can be difficult to generate uniform regulatory schemes for IT security certification internationally, and obtaining certification can be an expensive and lengthy process for businesses (OECD, 2019[12]).

Clarifying the "data ownership" discussion

In response to the concerns over agricultural data, 'ownership' is also often posited as a potential solution, under the reasoning that if ownership rights were properly allocated between farmers and machinery and service providers, many of the concerns would be settled. These discussions are referred to as the debate on "data ownership" (for an example of discussions on data ownership in data-driven agriculture see Box 4.7 in OECD (2019[21])).

While there appears to be a consensus among agricultural stakeholders (including farmers, governments, and agriculture machinery and service providers) that farmers "own" the data that is collected on their farms,[11] it is important to note that no explicit right or arrangement corresponding to ownership , in the sense of *property* over data, exist in the law.[12] In this sense, data ownership *per se* may not be the most useful policy lens from which to look at data governance issues and the concerns of farmers in relation to the use of data.

For example, contracts often provide a clause specifying the ownership of the data covered by the contract, while establishing the possibility that the other party can access and share the data under a form of licensing. Therefore, while contracts are legally binding, data ownership provisions in contracts are a relatively weak protection for farmers in terms of the rights that derive from it, and it will be the other terms and conditions specified in the contract that effectively determine the conditions of use of the data once it

[11] See Global Forum for Food and Agriculture (2019[55]); and as stated in various codes of conduct and charters such as Agridigital (2018[54]); Copa-Cogeca et al. (2018[53]); and American Farm Bureau Federation (2016[28]).

[12] Reflecting this, many codes of conduct analysed in Section 4.2.1 refer to the notion of 'ownership' in quotes.

is no longer in the exclusive possession of the farmer. In other words, ownership provisions in contracts do not necessarily confer the kind of control that farmers view as necessary to address their underlying concerns in relation to data sharing and use.

More fundamentally, given the particular nature of data, "ownership" of data may not be the best policy solution for addressing the issues at stake. Indeed, regulators have generally avoided using the notion of "ownership" as a way to address concerns relating to value derived from information and data, and have instead focused on the regulation and protection of access, control and treatment of data (Productivity Commission, 2017[22]). This stems in part from the difficulties associated with assessing the precise nature of data and its value (Box 3), both of which can be important in the concept of ownership. Indeed, from a policy perspective, a more practical way forward has been to focus directly on the policy issues that the concept of ownership is intended to address: that, is, questions relating to access, sharing and use of data. Rather than hard-to-resolve and often theoretical arguments about the nature of data, this would put the focus on striking a desirable balance in the conditions for sharing, controlling and using data, whether these are associated with ownership or not. In fact, as long as suitable institutions for access and use of data are provided, what matters is not necessarily who "owns" the data, but what rules govern the possibility of accessing and using data, under which conditions, and by whom.

In this respect, developing more solid guidance around data contracting, or developing legal rights that account for the specificities of use of agricultural data, or clarifying the scope of database protection under intellectual property, could be alternative avenues for enhancing the current governance of agricultural data to better reflect farmers' concerns.

Box 3. The nature of data and the difficulty of assessing its value

Data are a production asset that supports business innovation systems and can provide a competitive advantage. Data have also been said to be "the new oil". But while it is true that data fuel the digital economy, the comparison is not useful in understanding the complexity of the use of data throughout the economy. The comparison with oil in particular is misleading. Data is often non-rivalrous and is largely non-scarce. In addition, with some exceptions, a data point tends to have limited intrinsic value in isolation, in contrast to when it is combined with other data points and processed to generate information (Casalini and López González, 2019[23]; OECD, 2020[24]) (OECD, 2015[25]).

Data can be reproduced at nearly zero cost and therefore, in theory, its equilibrium price should be zero. But access to data alone does not generate value – rather, the value from data is derived in its use and after it has been collected, organised, and acted upon.

While it was previously relatively straightforward to establish the value added created by a researcher putting data into a database, automated processes whereby multiple data points are now captured by sensors and organised into databases make it more difficult to ascertain and define how much value is added and at which point in time. Moreover, the ease of collecting data means that it is not always being collected for a specific purpose, but because it may be useful in the future. Therefore, the value of data is difficult to quantify, as data that is not valuable today may become so tomorrow.

3.2. Sectoral initiatives for improving the governance of agricultural data

In response to the limitations of existing policy frameworks in addressing their concerns, farmers and farmer organisations are turning to their farming unions, representative associations, and other agricultural stakeholders to develop voluntary or self-regulating codes of conduct that encourage transparency and disclosure in agricultural data contracting. In addition, some are establishing data co-operatives as an alternative to database processing by third-party technology providers.

Voluntary codes of conduct

Voluntary codes of conduct, or codes of practice or charters, are a set of written, non-binding rules developed by the industry that describe how stakeholders in a particular sector or firm are advised to behave. In the agricultural sector, these codes have been developed in relation to the use of agricultural data to set voluntary rules and governance models beyond government legislation and encourage best practice in farm data management. They are seen as a means of improving transparency and fairness in agricultural data contracts, and, as such, they can be a viable option to support farmers in their relationship with technology providers and foster trust around digital technologies (CTA Working Paper, 2019[26]).

Voluntary agricultural data codes of conduct have been developed by farmers unions and associations, sometimes in collaboration with governments, and they are usually associated with a specific country. Several codes of conduct have a specific focus on the collection and sharing of agricultural data. These include the National Farmers' Federation Australian Farm Data Code, the EU Code of Conduct on Agricultural Data Sharing by Contractual Agreement; the French *Charte sur l'utilisation des données agricoles* (French Charter on the use of agricultural data); New Zealand's Farm Data Code of Practice; the Charter on the Digitalisation of Swiss Agriculture and Food Production; and the US Privacy and Security Principles for Farm Data (some of these are outlined in Annex B). A number of other developed and developing countries are also investigating the development of agricultural data codes of practice.

Although codes of conducts are voluntary and self-regulatory, they are sometimes also associated with accreditation or certification of practices. Certifications allow farmers to identify technology providers whose data management practices adhere to certain criteria set out by a standard setting or accreditation body. These standards are geared towards ensuring open and transparent data practices, particularly around data collection, processing and sharing, and data storage and security. Certifications can be a tool to foster trust in the system, while also providing an opportunity for product differentiation among technologies or services. Certifications are usually provided by an independent third party. In some cases, such as the New Zealand Farm Data Code, a trademark is used to signal compliance with the certification process. Data certification schemes can enhance trust as farmers are reassured by the fact that an independent and objective party has evaluated the provider's practices (for an example, see Box 4).

Indeed, all these codes aim to address the information asymmetry between agricultural technology service providers and farmers, and to help farmers decide if and when they should share their data. Nevertheless, these codes are not without challenges. While changing attitudes and behaviours around agricultural data use is an important aspect of agricultural data codes of practice, their voluntary nature remains a key challenge for evidence collection about their impact, as uptake may be minimal and enforcement either non-existent or ineffective (Sanderson, Wiseman and Poncini, 2018[27]). This issue is further exacerbated where confidentiality prevents contracts from being accessed by researchers to undertake analysis on the effects of data codes of practice on behaviour around data contracting in the sector. On the other hand, voluntary farm codes developed by and for farmers, potentially with government seed funding, can have broad buy-in if supported by producer groups.

Finally, a common feature of the agricultural data codes of conduct outlined above is that they tend to be principle-based and provide a benchmark of what industry regards as 'good' practice in agricultural data governance. The codes generally focus on transparency, disclosure, and consent as essential elements for building an environment of trust. In particular, they place importance on access and portability to data, for farmers on whose farm the data are generated (Sanderson, Wiseman and Poncini, 2018[27]; CTA Working Paper, 2019[26]). These principles and contents could provide useful guidance for governments when thinking through how to enable a data governance environment that reflect the needs of farmers, as well as of other stakeholders.

Box 4. Ag-Data Transparency Evaluator

The Ag-Data Transparency Evaluator was launched in 2016 to certify those agricultural technology providers (ATPs) whose contracts complied with the 13 Principles for Farm Data contained in the US Privacy and Security Principles for Farm Data. This tool, in which ATPs voluntarily submit their data contracts to a ten-question evaluation, was created by the American Farm Bureau Federation and is backed by a consortium of farm industry groups, commodity organisations and ATPs.

The Evaluator allows ATPs to assess themselves against the Principles for Farm Data as to whether or not they comply with the Privacy and Security Principles. The ten questions cover a range of agricultural data practices and include what categories of data are collected, whether consent is sought before data is shared with third parties, and how long data is retained. Answers to these questions, plus the ATP's contracts and policies, are submitted to, and reviewed by, an independent third-party administrator (the law firm of Janzen Agricultural).

Once reviewed, the results are posted on a website for farmers and other agricultural stakeholders to consult and review. If ATPs receive approval, they can use the "Ag-Data Transparent" seal. The use of the seal communicates to farmers that the ATP's approach to data management is in line with the Principles for Farm Data. That said, there is no mechanism to monitor and ensure compliance with the Principles.

The Ag Data Transparency Evaluator is provided free of charge to farmers to view so that they can make an informed decision about the data approaches taken by the businesses with which they choose to deal. The cost of the Ag Data Transparency Evaluator is borne by the ATPs who want to use the Ag Data Transparent Seal. The cost is based, first, on the age of the company, and then on its size and profits.

Currently, the approved companies are filtered by the type of data they collect: agronomic, land, farm management, machine and weather data. From January 2020, the scope of Ag Data Transparent was expanded to include the farm financial sector. As agricultural lenders are increasingly collecting agricultural data, it was decided that extending the Seal to the farm financial sector provided some additional protection of farmers' privacy. Companies wishing to certify as "Ag Data Transparent" will have the option of identifying "farm financial and management data" as the category of information they are collecting.

As of January 2020, 23 companies and their products have been evaluated and granted approval to use the Ag Data Transparent Seal.

Source: Sanderson, Wiseman and Poncini (2018[27]); American Farm Bureau Federation (2016[28]); and Janzen Ag Law (2019[29]).

Farm data co-operatives

Traditionally, agricultural co-operatives are structures created and managed by their producer members to support collective action; to increase negotiating or purchasing power for the marketing and processing of farm products; for the purchase and production of farm inputs and machinery; and to organise the supply or provision of a range of services, from administrative support to agricultural advice. More recently, co-operatives have also emerged as an option to deal with farmers' concerns in relation to the use of digital technologies in agriculture, and data management in particular.

In some countries, farmer organisations and other agricultural stakeholders (for example, universities, research institutions) have investigated the development of data co-operatives (sometimes also referred to as 'data trusts') for farmers to store and pool their data, to empower co-operatives' individual members and involve them in decisions about the way in which their data is managed (Wiseman and Sanderson, 2017[30]). Moreover, from the perspective of service providers, by creating a platform for accessing farmers' data, data co-operatives can minimise the costs of development of digital services (applications). Indeed, in the absence of a data market, a business willing to develop an application that relies on farmers' data would have to negotiate access to data from each individual farmer, incurring important transaction costs and other potential barriers for the development and supply of services.

For farmers, participating in a data co-operative offers several advantages. First, agricultural data co-operatives are seen to address some of the concerns about value sharing in the digital transformation of the sector, ensuring more control for farmers over their farm data. For example, it is argued that the data co-operative model allows farmers to use their data for advice from experts of their choice, and not necessarily from those who provided the machinery for collecting the data. In addition, data co-operatives are argued to address power imbalances that may be present in contractual relationships governing farm data. Since data is an asset of value for other agriculture stakeholders along the value chain, pooling farm data at the co-operative level can create more leverage to negotiate contracts and data sharing arrangements between producers and digital agriculture service providers.

Beyond their role as an intermediary with third party service providers, agricultural data co-operatives can also directly serve as platforms to provide services to farmers, from which members can benefit in many ways. Platforms can be used, for example, to provide operational benchmarks and insights, advanced data analytics, curated software capabilities, or to allow members to compare data (including anonymously) and share knowledge and develop collaborations between themselves.

Data co-operatives can also address the issue of value distribution associated with the use of data, by ensuring a return to farmer members that support the development and provision of services by including their data in the co-operative digital platform. Moreover, because they are member-driven, data co-operatives can also facilitate the development of products and services that are grower-centric in their design and value creation.

Agricultural data co-operatives are organised around specific data governance decisions that include guiding principles and rules on how agricultural data are used and managed on behalf of the co-operative's members. This includes defining how the co-operative's data are managed and shared with third parties, whether in return for payment or other services. As a by-product, data co-operatives can also foster 'data literacy' and educate members about the data terms to consider when entering into contracts with parties who will be collecting and aggregating their personal and agricultural data, and making farmers more aware of the data they hold and how to protect these according to their preferences.

Moreover, data co-operatives remain an interesting model of database development that may be particularly useful for government and research actors. Where appropriate, governments may have an interest in ensuring that the right incentives and institutional environment exist in order to allow existing agricultural co-operatives, as trusted partners of farmers, to further develop data collection initiatives (see Section 4.2.3). For example, data co-operatives are considered by the CSIRO and Australian National Data Service (ANDS) *National Soil Data Project* as a tool to enable the sharing of farm data that contributes to government soil mapping activities, with a view to developing a sustainable operational environment for accessible, interoperable and well managed soil information.

Nevertheless, even within the co-operative constituency, confidentiality of farm data remains a concern, and farmers may not be willing to disclose all their data to other members. Even when aggregated, it might be easy for co-operative members to identify each other. While this is a potential constraint, new data co-operative platforms are in practice less bound to geographic location than the traditional input and output management co-operatives. As such, anonymisation may be easier and knowledge sharing potentially less compromised.

Data co-operatives are increasingly popular as a governance structure to enable data storage for mutual benefit. However, the creation of a data co-operative can also face barriers. In particular, data interoperability can be a key challenge, preventing members from transferring data into a co-operative platform or affecting the quality and usability of the data for farmers. Data generated by one type of software cannot always be viewed or aggregated into another software, making data pooling or sharing among individual farmers difficult, and ultimately reducing the insights and the value that can be created with the data. Given different constraints and objectives, the development of data co-operatives has taken many forms (for some examples, see Box 5).

Box 5. Examples of different data co-operative models

The United States has embraced open data platforms, allowing farmers to transfer data between systems with very little loss of functionality. Three US organisations have emerged with digital platforms that claim to operate as data co-operatives: Ag Data Coalition, Grower Information Services Cooperative, and the Farmers Business Network.

The *Ag Data Coalition (ADC)* is a partnership between a number of US universities, machinery companies and the American Farm Bureau. Its mission is focused on designing, creating and managing a central data repository where farmers can store their information and control how it can be accessed. The ADC does not provide an analytics platform, but instead a repository where farmers can store all their data and then decide with which platforms researchers or agencies they would like to share those data.

The *Grower Information Services Cooperative (GISC)* also provides a central repository for farm data, with the primary purpose of negotiating with customers, vendors and government agencies on behalf of the data originators for the control and use of the data. The GiSC also performs data analytics to provide data originators with management insights and negotiates opportunities to monetise the data on their behalf.

The *Farmers Business Network (FBN)* is a cooperative-like structure where members pay a subscription to be able to place their data on the FBN platform. In return for their participation, farmers get benchmarking of the accumulated data for management insights and analytics on matters such as price comparisons on agricultural inputs, hybrid performance, yield by soil type, and yield by fertiliser regime. FBN is similar to some commercial platforms such as Climate Fieldview. However, as with the ADC and GiSC, FBN's major selling point is that they are independent 'Farmer First' organisations not connected to any machinery, seed or fertiliser company.

There are many other organisations considering the development of open agricultural data exchange platforms that will, in effect, serve as data co-operatives. For example, JoinData is a Dutch data co-operative that started in the dairy and financial sectors in the Netherlands, and expanded its business to arable farming; Agrirouter is a primary data exchange platform for farmers and agricultural contractors with a focus on arable farming. The two joined forces in late 2019 to 'to stimulate the development of an international data exchange ecosystem with the farmer at heart.'

Source: http://agdatacoalition.org/; https://www.gisc.coop/; https://www.fbn.com/; https://www.join-data.nl/nieuws/agrirouter-and-joindata-join-forces-in-data-distribution-and-empowering-farmers/.

4. Maintaining a competitive and equitable environment for farmers as consumers of data services

This section looks at data-related policies that can impact the supply of digital services to farmers. Section 4.1 looks at 'lock-in' clauses that raise competition concerns in agricultural technology contracts. The clauses considered are the right to data portability and the 'right to repair', meaning the ability of farmers to choose providers for the servicing of their farm machinery. Section 4.2 explores the role that the government may have in enhancing the institutional arrangements for the collection, discoverability and usability of public and private agricultural data, including across borders, to support digital innovation of agro-food systems, and better inform agricultural policies and services for farmers.

4.1. Data and the issue of "lock-in" in agricultural technology contracts

The right to data portability

In the context of agricultural data contracts, there is often a lack of clarity on whether farmers are able to transmit data generated by a service provider on their farm to other service providers. Farmers often claim that they should be able to move agricultural data, expressing this as a right to data portability – a right which is defined, in the context of personal data, as the right of individuals to move, copy or transfer their personal data across different IT environments without affecting usability (Information Commissioner's Office, 2020[31]). In fact, the availability of historical series of agricultural data can be very important for farmers, as comparisons over relatively long spans of time on the same data point (e.g. a field or livestock unit) can be used to develop models and services that are better tailored to their needs and production conditions.

For farmers, not being able to transfer their historical data to a different provider can create several disadvantages. First, the loss of historical data when changing machinery brand or service supplier can reduce a farmer's choice of equipment and service provider and the possibility of switching provider, as choosing to switch without carrying along historical data may mean reduced accuracy in those services that require them as input. This dependency on the data held by the first provider can in turn weaken the farmer's position in renegotiating contractual arrangements with current providers and alternative ones. Finally, not being able to move data across systems can also prevent farmers from using a certain device or service in combination with other systems.

Today, some personal data protection frameworks recognise the right to data portability, enabling the movement of personal data across digital services in machine-readable format, and permitting their use by different technology providers.[13] The right to data portability for personal data has been developed, among other objectives, to allow users to overcome "stickiness" (lock-in effects) in markets where historical data can be used as a strategic point of control (OECD, 2019[21]). This, in turn, is also seen as a way to encourage competition among providers, potentially leading to more innovative products and services, and better pricing.

In this sense, farmers argue that the right to data portability should be ensured in relation to agricultural data as well, as this would protect them from potentially imbalanced market relationships with technology providers. It would also have the effect of enhancing competition among providers of digital services, leading to more and better services. Indeed, the concept of data portability has found favour with many farmers, and all agricultural Codes of Practice discussed above support the right to data portability within contracts, signalling this as an internationally recognised expectation of farmers in relation to agricultural data governance.

Choice in the servicing of farm machinery ('right to repair'[14])

A further issue is the ability of farmers to access the data and software needed to repair their digital farm equipment. Farm machinery and equipment now have sophisticated software programmes embedded, and the terms of use of the technology contracts that accompany the software often prevent farmers from being able to access the software for the purposes of repair (Solon, 2017[32]). Original Equipment Manufacturers (OEMs) also use digital locks (or technological protection measures) to protect their rights in software, including intellectual property rights, which can also make it difficult for farmers to access the software to undertake modifications or repairs (Gasser, 2016[33]).

[13] The objective is to make it possible for individuals to benefit from data generated about them, enabling them to take advantage of different applications and services that can use this data.

[14] The issue relating to "right to repair" are not unique to agriculture. While this document focuses on the agriculture sector dimension, the OECD Science and Technology and Innovation (STI) Directorate is addressing this issue within the drafting of a new *Consumer Product Safety Recommendation* which consolidates six previous instruments relating to product safety. This draft contains provisions relating to "Product recalls and other corrective actions".

Digital locks may create an asymmetry of access to repair information, as farmers are unable to gain access to diagnostic and repair information that is made available to the manufacturers' dealers and authorised repair facilities. OEMs also own intellectual property rights – such as copyright, designs and trade secrets – over repair instruction manuals and spare parts, which can inhibit a farmer's ability to repair digital technologies. An attempt to break the lock placed over the digital programmes can place farmers in breach of their technology contracts. In some cases, their equipment systems might shut down or become unusable as a result of an attempt to access the software or to change it.

Prohibitions or barriers to making repairs or accessing information necessary to make repairs is a particular issue for farmers, as this forces them to externalise the repair of their farming equipment, while, traditionally, they have modified and repaired their own farm equipment.[15] Farmers have expressed concern that the use of locks and the need to use external repair services can cause delays that impact harvesting, and undermine how efficiently they can use their machinery (Wiseman, 2019[34]; Mochan and Bennett, 2018[35]). Moreover, if access to authorised service technicians is limited, farmers' choice of agriculture machinery providers may be restricted to those offering repair services in their area.

Indeed, there are potentially also significant competition issues where OEMs tie farmers into service agreements with authorised service agents and prevent access to third party repair services (Keough, 2017[36]) – related, for example, to claims of abuse of dominant, or relatively dominant, position. The lack of choices in servicing of electronic equipment may also cause problems of enclosure of the data within markets, or "data oligopolies," due to the vertical structure of machinery and service providers.

Nevertheless, like many digital governance issues, restrictions on the ability to access repair information, services or spare parts is not specific to agriculture. Indeed, collectively, different stakeholder groups around the world (for example in Australia, Canada, the European Union, and the United States), including motorists, farmers, consumers, designers, repairers and environmentalists – have been claiming a 'right to repair' their own machinery and the equipment that they have purchased (Burt, 2018[37]). The right to repair movement aims to respond to the concerns of consumers about the choice of servicing for their digital equipment and to public policy concerns about the effects that this may have on the wider digital innovation system.

While competition law represents the wider framework through which this issue could be addressed, the right to repair movement in particular has a two-pronged approach. One is to empower consumers with the right to repair their goods without requiring the service of an authorised agent, or the right to choose to have their own third party repair their goods. The second aspect relates to requiring that manufacturers of smart goods, cars and farm equipment make their diagnostic tools, manuals, and other repair-related resources available to all individuals and businesses, and not just to their dealerships and authorised agents (Keough, 2017[36]).

To date, countries have chosen different approaches for the integration of right to repair provisions in their regulatory settings. For example, Australia, Canada and the United States have chosen to approach the right to repair through the framework of consumer rights. Conversely, the European Union took an environmental sustainability approach to the right to repair – that is, focused on reducing electronic waste, placing the onus on manufacturers to facilitate repairs.

Against this trend, consumer goods and car manufacturers, as well as agricultural technology companies and manufacturers, have raised concerns in relation to the risk of dilution of their intellectual property rights in electronics (Weins, 2015[38]). Nevertheless, some have suggested that intellectual property rights in machines and technologies were never intended to extend into the 'aftermarket' of repair services and access to information (Chan Grinvald and Tur-Sinai, 2019[39]). Opponents also argue that untrained repairs can compromise safety, privacy and security, leading to liability concerns in relation for poor quality repairs (Povitch, 2019[40]). At the same time, in such cases, it is possible that contracts would shift liability to the repairer, releasing the OEMs from their product liability.

[15] Farmers continue to build and modify their machinery to suit their needs, and also share their hacking. See for example: https://farmhack.org/tools.

4.2. Fostering greater and better access to agricultural data among public and private actors in the sector

As the agricultural sector becomes more data-intensive, the arrangements that govern access, sharing and use of agricultural data will also become an important component of the enabling environment for innovation in agriculture, in terms of services and policies for the sector.

Broadly speaking, both the public and private sector recognise that data access and sharing are key for maximising the value of agricultural data, creating economic and social benefits, and opening up new business opportunities. Accordingly, agricultural data governance discussions are expanding to consider how to strengthen the networks of actors producing, sharing and consuming data and related services, such as analytics and applications. The following sections explore the opportunities and challenges associated with facilitating access to the agricultural data held by governments, businesses and individual producers, including to support the development of better and more innovative services for the sector.

Open access for agricultural data held by the government

Government agencies collect, curate, and hold significant amounts of agricultural data that are of interest to researchers and the private sector – including farmers. As a result, there is increasing interest in leveraging digital technologies to facilitate access to these data, in particular via "open data" arrangements.

The OECD has defined different types of data sharing arrangements, from *closed access* restricting the use of data to a data controller, to *controlled access*[16] that would entail sharing among one or more specific communities, through to *open access* (open data), the least restrictive and non-discriminatory arrangement (OECD, 2015[25]; 2019[21]). Definitions of open data access can vary. According to the OECD Council Recommendation on Principles and Guidelines for Access to Research Data from Public Funding, openness means i) access that should be granted on equal or non-discriminatory terms, and ii) access costs that should not exceed the marginal cost of dissemination (OECD, 2006[41]). Other sources refer to open data as "data that can be accessed and used by anyone without technical, legal or organisational restrictions" (OECD, 2019[21]). Open data can be desirable in some cases, but, as illustrated below, there may be legitimate reasons for restricting access in other cases.

Governments generally hold two types of agricultural data. First, governments collect data about farmers for administrative purposes, including census data or other farm data linked to the implementation of agricultural policies. These data hold significant value for research and services development, as they provide granular evidence about many aspects of primary production operations. However, open data access for this type of data remains controversial in several instances. In fact, many government agencies collect data from farmers under a legal pledge of confidentiality and non-disclosure.[17] In addition, open access for these data presents challenges relating to concerns around privacy, exposure of commercially sensitive information, and fear of compliance oversight by other government agencies. In fact, in all OECD countries, freedom of information laws presume a principle of maximum disclosure of information – that is, the information held by the state is in principle available to the public. However, they also provide a list of exemptions that may be applied to justify withholding certain information from disclosure. *Class tests* and *harm tests* are two common ways to exempt information. Under *class tests*, any information that falls within a certain category (such as national security or commercial confidentiality) can be denied. Under *harm test*s, the government can deny a request for information on the basis that disclosure would cause harm to commercial competitiveness or to an individual (OECD, 2011[42]).

[16] *Controlled access* is the sharing of data among members of a community which may or not comprise the public at large (when available to the public, it might be controlled by a form of licence which can be used to generate revenue to cover the upfront investment costs). Rationales for controlled access include confidential data associated with trade secrets, privacy, and organisational and national security. In a controlled access context, there is generally interest in sharing data within a certain defined community, but not externally.

[17] See for example the Confidential Information Protection and Statistical Efficiency Act (CIPSEA), that establishes uniform confidentiality protections for information collected for statistical purposes by United States statistical agencies. For example, among other things, CIPSEA prevents government agencies from using individual data for regulatory purposes.

Second, government agencies collect data on a range of variables that are relevant to agriculture, including weather, markets and natural resource conditions, which are used to provide information and other services to the sector. Such services include, for example, yield data for crop variety trials, climate and market data for forecasts, and data to support the provision of extension services. Digital technologies can lead to new efficiencies in the collection, and especially dissemination, of these agricultural data. In this sense, and where appropriate, open data access may be an approach for sharing this type of data.

Open data access allows any entity, including farmers, researchers and other stakeholders in the agro-food value chain, to have access to relevant data under equal and non-discriminatory terms. This could reduce the risk of a digital divide between agricultural service providers, where this is linked to the capacity of different actors to invest in widespread collection of data. Open data approaches may also lessen concerns related to data concentration and first-mover advantage effects that are common to the digital economy. As a result, open data access may allow businesses of all sizes to overcome market failures and develop more and better services for producers.

For example, the European Union Joint Research Centre (JRC) generates data that it shares in open access for crop monitoring and yield forecast based on weather, agriculture, and satellite data. The service is available since 1992, covering Europe and other strategic areas of production, and is widely used both by the public and private sector.[18]

Supporting businesses and government access to private agricultural data

Aggregating the often relatively small datasets of individual farmers can create significant opportunities for knowledge and value creation, and data obtained at the farm level, when assembled into databases, can have great value for research, evaluation, and marketing. Reflecting this, governments are starting to explore what role they may have in facilitating the exploitation of agricultural data collected by different actors in the sector. This could mean creating the data ecosystems needed to make publicly and privately collected agricultural data more widely discoverable and usable by businesses and researchers, as well as by governments themselves, to develop new and better services, and inform agricultural policy and services design.

First, data sharing via open access is not a concept limited to the public sector, and although business returns may not be easy to quantify, open data access is gaining ground in the private sector. For example, the private sector may benefit from providing access to their data via open access arrangements, to the extent that this increases external transparency, supports internal management, and facilitates automated reporting and greater data quality controls (Data Foundation, 2019[43]). Open data can also be a way to increase access to a company's other services, and a way to derive benefits though the network effect of services that can be built on top of the provided data. Open data arrangements may also be motivated by "data philanthropy", whereby the private sector shares data to enable societal benefits and support policy action for development (OECD, 2015[25]).

Data markets and platforms, whether privately or publicly owned, can also be important avenues to foster discovery, access and use of private agricultural data, favouring greater exploitation of data in the sector. The challenge for the creation of such data markets or platforms is to build a critical mass of data from individual data holders during the initial phase of market development, to make that digital space attractive. One role for the government could include developing institutions and incentives for data providers to support the pooling of a certain amount of data from a diversity of stakeholders at an early stage. Data co-operatives, as stewards of data collection and sharing in farming communities, could also provide a critical mass of agricultural data and be important partners for the creation of data markets or platforms.

An example of a publicly sponsored platform is the French AgGate, currently under development. AgGate aims to provide platform for stakeholders to search for and exchange agriculture data on a large scale. Through this platform, data could potentially be provided by the private and public sector alike, accessed upon acceptance of the terms of use, and also be exchanged for a payment.

[18] For more information, see: https://ec.europa.eu/jrc/en/research-topic/crop-yield-forecasting.

Data platforms for open innovation are also increasingly supported by the private sector. Often these platforms already provide public data, and farmers can add their data, over which they maintain control. An example is the John Deere Operations Center, an open cloud system for importing documentation data from different sources. Farmers can share their data bi-directionally with third party software tools to develop and provide services for them. Data can also be pulled out of the John Deere Operations Center organisation or pushed into the system using standard interfaces like the John Deere API or the industry standard ADAPT developed by AgGateway.

While open innovation arrangements supported by the government receive considerable support, to the extent that they favour synergies among actors and reduce the risk of data concentration in the hands of a few private actors, the rationale for public supply may nonetheless be limited. Historically, governments have stepped in to provide information and other services to the agricultural sector because of market failures that prevent the private sector from profitably supplying them. But digital technologies may overcome some of these market failures, reducing the need for government intervention in the first place. In these cases, there may be a fine line between the need for government intervention, and the risk that public services actually crowd out potential supply by the private sector.

Interoperability and data quality as preconditions for greater use of agricultural data in the sector

The usability, and hence the usefulness, of data generated by both the public and private sector essentially depends on their technical interoperability and quality. Interoperability in this context refers to the (technical) ability of two or more systems to exchange and use information,[19] allowing different digital structures that are domain-specific to be connected into a larger workflow. Towards this, pre-competitive collaboration around data standards to support technical interoperability should continue to be an important area of focus for policy makers.

A challenge for both the public and private sector is that different sources may be more or less reliable sources of information, and this has implications for the quality of the data and their use for innovation. This is especially true from the perspective of government agencies, for which issues relate to where the data came from and how it was acquired, i.e. whether it was freely provided, secretly sold, or hacked. It is often unclear when and how to consider data to be accurate and reliable. For example, county tax records are usually viewed as a trusted source, while a website that publishes salaries is viewed with uncertainty. To this end, more transparency and trust around data practices are needed, together with standards (for example ISO 8000s on data quality), systems and guidelines to verify the origin and accuracy of data.

In the context of agricultural data, demands and guidelines by regulatory bodies for the collection of certain data could be an important way to promote high-quality, widespread, and long-term monitoring of agricultural areas, and to develop reliable datasets that are valuable for research and policy activities. For example, today a lot more data is available where there are soil management guidelines for integrated fruit production (Della Chiesa et al., 2019[44]). Adopting similar guidelines for other information elements may promote better quality and usability of agricultural data, and again, data co-operatives could be important partners as intermediaries in this process.

[19] At the technical level there are two types of interoperability: syntactic interoperability, where two or more systems are able to exchange data, allowing different software components to co-operate, even if the interface and the programming language are different. And semantic interoperability, where systems exchange data with unambiguous, shared meaning. This can be achieved by adding data about the data (metadata) and linking each data element to a shared vocabulary, and its related ontology.

Cross-border aspects of data governance affecting the availability of digital services to farmers

Increasingly, public and private services for agriculture, such as extension services, certifications, logistics and support services, and traded advisory services, can be provided remotely – that is, digitally delivered – or provided more efficiently thanks to digital solutions. However, data regulations may affect the supply of digital services across borders or increase the cost of supplying them across borders.[20] In particular, some key concerns relate to regulatory differences in data policy across countries, and a growing number of limitations on cross-border data flows (Casalini and López González, 2019[23]).

First, differences in data policy can represent a source of cost when engaging in international trade in agriculture-related services, as foreign suppliers need to differentiate their data management processes to comply with different regulations when operating in different markets.

Second, cross-border services can only be provided if farmers and service providers are able to share their data with the agriculture service provider of their choice, including across borders. Digital companies often choose to locate their data centres in countries other than the one where their services are delivered for a variety of business reasons, including economies of scale and a lack of data storage capacity in certain countries. Therefore, many data-driven services might depend on access to data from abroad.

However, various measures are emerging that condition the cross-border flow of data, or mandate that certain data be stored locally. Countries currently regulate the transfer of data abroad for several reasons, ranging from privacy protection to regulatory reach, and from security to digital industrial policies (Box 6). For example, agricultural data that are characterised as personal data and government data must meet some of the most restrictive conditions for storage and transfer. Specifically, government data are sometimes subject to full data localisation measures under rationales of regulatory reach, national security, or the notion of data sovereignty.[21]

While countries have legitimate cultural and social differences underpinning the different type of policy approach that they take, and it is important for trust in digital technologies that data be afforded protection when it crosses borders, these restrictions may affect the availability of digital services for farmers from abroad.

In particular, the agricultural sector is characterised by a high level of diversity of production systems around the world, as a consequence of different heritages, landscapes and climate. This means that it is essential that researchers and innovators have access to local data if they are to develop suitable and customised models that inform services and advice for farmers. Frictions in access to and use of agricultural data across borders create a risk that some regions in the world may be disadvantaged by biased datasets, or suffer from a data divide.

In light of the costs for international trade created by regulatory heterogeneity, and of measures restricting cross-border data flows, a whole-of-government approach and international co-operation efforts are required to support the interoperability of regulatory systems and ensure the seamless transmission of data across borders can take place, *with trust* – that is, ensuring adequate protection is maintained. This will avoid the emergence of restrictive conditions that affect the supply of innovative digital services for farmers and for the sector.

[20] The OECD has also developed a Digital Services Trade Restrictiveness Index that measures horizontal barriers to key services for digital trade, see (Ferencz and Gonzales, 2019[65]).

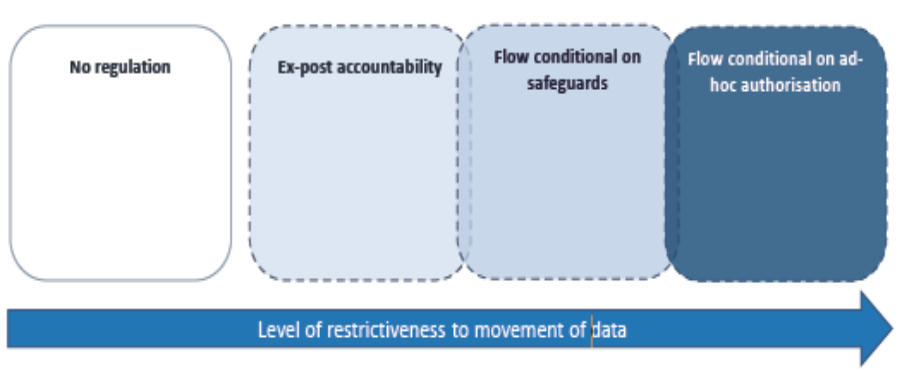
[21] In OECD countries, data sovereignty is generally discussed as the idea that data is subject to the laws and governance structures of the country where it is collected, despite the impact that this may have on cloud computing processes. Nevertheless, caution is warranted, as in some other countries, data sovereignty may be used as a more far-reaching term, to assert the absolute prerogative of governments to control the digital activities within their borders, including preventing access to an open internet for their citizens.

Box 6. Trade and cross-border data flows

Data is central to trade in the digital era. However, the growing exchange of data has led many governments to update their data-related regulations, leading, among other things, to a growing number of conditions on the transfer of data across borders or to requirements that data be stored locally. These regulations can create an additional layer of complexity to the sharing of data across borders, potentially altering the conditions of competition for the cross-border provision of value adding services in the agro-food chain.

Four broad approaches to the regulation of cross-border data flows are emerging (Figure 2).

Figure 2. Approaches to cross-border data flows



These are not mutually exclusive; different approaches can apply to different types of data even within the same jurisdiction (health data or government-held data, for instance, might be subject to more stringent approaches than data related to product maintenance), and the boundaries between each approach can overlap.

1. At one extreme, there is no regulation of cross-border data flows, usually because there is no data legislation at all. While this implies no restrictions on the movement of data, the absence of regulation might affect the willingness of others to send data. Many LDCs are in this situation.
2. The second type of approach, ex-post accountability, does not prohibit the cross-border transfer of data nor does it require any specific conditions to be fulfilled ex ante, but provides for ex-post accountability of the data exporter if data sent abroad is misused (e.g. firms can transfer data abroad, but if something goes wrong they are legally accountable).
3. A third approach, flows conditional on safeguards, includes approaches relying on the determination of adequacy or equivalence as ex-ante condition for data transfers. These determinations can be made by a public authority or by private companies, depending on different regulations, and can include more or less explicit requirements about how data are to be treated once transferred abroad. Where an adequacy determination has not yet been made, firms can move data abroad under other options such as contractual clauses, binding corporate rules or consent.
4. The last broad type of approach, flow conditional on ad-hoc authorisation, relates to systems that only allow data to be transferred on a case-by-case basis, subject to review and approval by relevant authorities. This approach can relate to personal data for privacy reasons, but also to the more sweeping category of “important data”, including in the context of national security.

Digital infrastructures such as the Internet were born global, but they raise challenges for domestic and international policy in a world where borders and regulatory differences between countries remain. Reaping the benefits of digitalisation for trade will increasingly require international dialogue on approaches that ensure the interoperability of differing regulatory regimes, notably on data transfers.

Source: Casalini and López-González (2019[23]).

5. Conclusions

The digital era and the insights that can be generated from greater access, sharing and use of agricultural data are an opportunity to increase the productivity, sustainability and resilience of the agricultural sector, and enable improved access to markets (OECD, 2018[45]). But governance arrangements – or the lack thereof – for agricultural data may affect the trust of farmers in digital technologies, in turn hindering farmers' willingness to adopt digital solutions on farm and enter into data sharing arrangements with other stakeholders.

In particular, key issues reflect concerns about who controls access to and sharing of data that is generated on and about farms, and how the value that is created from that data is distributed. Concerns have also been raised about how agricultural data governance may affect the supply of digital services to farmers, with issues that may arise from lock-in effects, difficulties in discovering and using agricultural data, or cross-border restrictions of data flows. While many of these issues are not unique to agriculture, it is important that agricultural policy Makers understand how existing regulations work, ensure that their community's stakeholders understand the protections available for them, and identify whether and what gaps exist for agriculture.

A key challenge for policymakers is that different stakeholders – including farmers, technology providers and researchers – have an interest in the same agricultural dataset, along with competing and/or complementary views on access, use and extracting value from it. Therefore, it is difficult to identify a way forward that would address all stakeholders' concerns with agricultural data governance. The perspectives not only of farmers, but of a range of stakeholders, will also need to be carefully understood in developing an effective data governance system for the sector. As a starting point, the International Digital Council for Food and Agriculture[22] may provide a multi-stakeholder forum for discussing good practices. Similarly, the principles contained in the OECD report on Enhancing Access to and Sharing of Data offers a framework for assessing positions and conceiving solutions that would allow the benefits from accessing and sharing of data to be maximised, while taking into account potential risks (OECD, 2019[21])

This report mainly focused on identifying the concerns of farmers, and discussed the policy issues that these generate. Previous OECD analysis has explored the needs and concerns of governments in relation to data sharing (OECD, 2019[7]), and this has been further developed in Section 4 of this report. Further work will be needed to ensure that the perspective of other stakeholders, such as researchers and agricultural technology and service providers, are also better understood. Moreover, since digital technologies tend to develop faster than the regulation or social structures governing them, regulatory solutions will require periodic adaptations and constant government monitoring (OECD, 2019[12]), and should, where possible, be technology neutral.

Nevertheless, several insights emerge from the analysis conducted in this report. In particular, it appears that several innovative policy approaches and voluntary and institutional arrangements are being leveraged to address farmers' concerns relating to agricultural data governance. However, some issues have yet to be resolved and it will be key that data governance discussions focus on strengthening a common vision and coherent implementation of existing data practices and policies, across communities, sectors and countries (OECD, 2019[1]).

More specifically, some preliminary observations that may be of guidance to policy makers in thinking through a system of agricultural data governance that reflect farmers' concerns and expectations include:

- Agricultural policy-makers need to clearly identify the concerns and priorities of their communities. At the same time, they need to improve their understanding of how economy-wide regulatory frameworks on data might affect the agricultural sector. This should lay the foundations for whole-of-government and multi-stakeholder discussions about data governance, where the perspectives of all sectors, including agriculture, are properly represented. This should ensure that, at a minimum, broader data policies and their implementation respond to specific needs of the agricultural sector, even as further work is needed to determine whether a more tailored approach for agricultural data may be necessary.

[22] http://www.fao.org/e-agriculture/international-digital-council-food-and-agriculture.

- At the same time, an ongoing discussion of the current regulatory framework is needed to foster awareness among farmers about the opportunities of digitalisation for agriculture, and the protections available for farmers and for data generated on farms. Indeed, there still seems to be uncertainty about how the current regulatory environment and existing data policies, such as, for example, personal data protection or competition policy, apply in relation to agricultural data, particularly among farmers. Therefore, governments may need to consider how communication around existing regulatory frameworks could be improved to build greater confidence in the use of digital solutions in the sector.
- Discussions around data governance should also be facilitated at the international level. An internationally shared understanding of the challenges and good practices is important for achieving international regulatory co-operation in this field. This could avoid additional issues relating to regulatory differences across countries, including in relation to laws governing technology contracts and restrictions to data flows, and facilitate the flow of knowledge and services across borders.

Annex A. Characterising data, a literature review

This Annex is a high level discussion of the type of data discussed in this paper, to better highlight some of the complexities that surround data governance in agriculture, and hence the importance of the debate for farmers and for innovation in the sector.

The classification of agricultural data is complex, and a variety of approaches to defining the scope and characteristics of different types of data emerge from the literature. Until now, different ways to approach data characteristics have allowed communities in different jurisdictions to call for regulatory arrangements to address their needs and concerns (privacy, equity, public good, innovation, etc.). But these different approaches have created parallel streams of discussions across communities (farmers, agribusinesses, public and research communities, and between agricultural stakeholders and technology providers), making it difficult for stakeholders to converge towards a common understanding of how to govern data along the agro-food value chain.

To better understand the issue, this Annex considers what is meant by "agricultural data," outlining three ways of characterising agricultural data that are being used as a basis for regulatory considerations. The first characterisation differentiates agricultural data according to *where* they are collected and used. The second focuses on *how* data is generated and structured. Finally, the third characterisation looks at the data for *different objectives*. The analysis of these characterisations highlights their usefulness for certain purposes. However, it also shows that data are multidimensional and that no one characterisation is always better than another to support regulatory conclusions. On the contrary, from a policy perspective, instead of choosing one characterisation over another, a better starting point may be to understand risks and concerns on the basis of specific use-cases, to understand what different policy arrangements may be suitable in different contexts.

Three agricultural data characterisations

In this Annex the analysis is structured around three broad types of data (Table A A.2): farm business operations and management data; farm production process tracking data (applied processes data); and data collected to provide general services to agriculture. These latter data are particularly important in agriculture and have traditionally been collected and provided by public institutions and include data on pest status, weather forecasts, or market prices.

Defining data on the basis of their practical use can be helpful when describing the digital transformation of agriculture. From a data governance perspective, however, these different uses can involve a range of regulatory issues such as personal data protection, information security, intellectual property, and consumer protection. A key challenge for regulators is to ensure that core public policy principles (such as equity, innovation, social protection) continue to be upheld in the new digital environment. Models that attempt to describe the characteristics of data can adopt different angles, each leading to different, but only partial, regulatory outlooks.

For example, agricultural data could be classified according to where data is generated and used. Maru et al. (2018[46]) define four types of data (Table A A.1): localised, imported, exported, and ancillary (the latter defined as data used to assist in analysis and classification, or to populate metadata):

- *Localised data* are collected on-farm directly by farmers and their staff or by third parties (service or machine provider), manually or in an automatically by sensors (IoT). This same data can then be processed for insights to support processes on-farm by either the farm staff, the service provider, or the machine.
- That same data collected on-farm can be
  - *exported* off-farm (exported) for the use of other stakeholders
  - or complied with other databases to create *ancillary data*, in which case on-farm data can be used to inform a service provider's innovation systems and therefore be used on- and off-farm.

- Conversely, data used to support on-farm decisions can also be *imported* from data collection activities off-farm conducted by research institutions, governments and agribusinesses services.

Table A A.1. Type of farm data streams

	Data generated and collated		Data used	
	On-farm	Off-farm	On-farm	Off-farm
Localised	X		X	
Imported		X	X	
Exported	X			X
Ancillary	X	X		X

Source: (Maru et al., 2018[46])

While this approach can be helpful to highlight how the on-farm, off-farm interaction of data can enable benefits for the sector, it is unclear to what extent the location of data collection – that is, on- or off-farm – points to an applicable regulation. For example, intuitively, localised data (i.e. created and used on-farm) should not carry any form of access constraints for the farm operator. But if the data were collected on-farm through a third party (e.g. via proprietary software), this could lead to barriers that prevent access for farmers (Section 3).

In this sense, the issue of *by whom or through what processes,* rather than just where, the data is collected is an important feature of the debate over agricultural data governance. A question often discussed is whether the data collected by a sensor on a tractor during farm operations belong to the owner of the farm, the owner of the tractor (when these are different, for example, in the case of a co-operative or when the tractor is rented), or the technology provider collecting the data through the IoT of its tractor. In particular, this question becomes more complex when the identity of the driver is associated with the data collected by the IoT. In this case, the data collected can become personally identifiable and fall under personal data protection regulation. Hence, to fully comprehend the regulatory challenges surrounding farm data, another dimension to add to the characterisation of data is the aspect of *whom or through what processes* data has been generated, as this can also affect access the use rights of different stakeholders.

In their literature review, Wolfert et al. (2017[14]) argue there are three broad categories of data generation (Devlin, 2012[47]; UNECE, 2013[48]): *process-mediated, machine-generated* and *human-sourced*. The *process-mediated* type of data covers traditional business data, resulting from processes that record and monitor business events of interest, such as the purchase of inputs, feeding, seeding, the application of fertiliser, or taking an order.

Machine-generated *data* is automatically generated without the active intervention of a human, by sensors, computer process and applications. This data range from simple sensor records to complex computer logs, and is typically well-structured for computer processing. An important difference with the *process-mediated* type of data is that the scale, scope and speed of data generation is vastly increased. Moreover, they do not appear only in lists or tables, but also as images or sounds (Sonka, 2015[49]). As a consequence, these type of data are often directly stored on cloud-based platforms. In addition, their format and computation can be specific to a software, making them difficult to transfer to other systems, thereby creating issues of interoperability. This is particularly important in agriculture given the increasing use of sensors, IoT, and other connected devices that are now used to automatically measure and record farming information, which is then stored and processed to provide insights for farmers' decision making (sometimes automatised).

Human-sourced data are the record of human experiences recorded in books, photographs, audio and video, all of which can now be digitised and more easily shared. This type of data is usually loosely structured and, as a consequence, considered to be difficult to integrate for use in a big data context (Bennett, 2015[50]). However, new AI technologies, such as machine vision, are likely to change this. For example using photos of plant diseases, sometimes gathered through crowd funding, can support AI systems for the identification of pests.[23] Nevertheless, these type of data have always been important in agriculture, and although they do not have the scale and scope of machine-generated data, the impact of the digital transformation of the economy and society should not be underestimated. The rise of social media plays an important role in sharing human-sourced data, including in agriculture. Crowd-sourcing platforms are becoming more common for farmers to share their experience in using or even "hacking" new and old technologies to better serve their needs.[24]

A final way to characterise data is according to the *objective of their use and their state*. Whilst this paper takes a farmer-centric approach, flows of agricultural data also matter to other stakeholders. In terms of objectives, farmers use agricultural data for their decision process; businesses use agricultural data to produce customised services for farmers and to support their own innovation activities; and the public sector produces public goods and uses agricultural data to inform their innovation activities and policies.

There are many ways to describe the *state of data*, but in essence the most important are raw, processed, aggregated and anonymised (Dodds, 2015[51]). For example, when *raw data* collected on-farm by a service provider can be anonymised and aggregated within the broader service provider database.

Of particular interest are specific types of processed data called *derivative data*, which is data generated by the analysis of data or by mixing different sources of different data (Dodds, 2015[51]). The issue of derivative data is important when reusing and mixing data that might be accessed under different types of data governance. For example, an important question is what happens to the information created when mixing open data with controlled accessed data (Korne, Oppenheim and Duncan, 2007[52]). This issue applies in agriculture when farmers' data are used by agribusiness services (anonymised and aggregated), associated with their own data and potentially open public data to create new knowledge and services to be sold to farmers. This issue is therefore attached to a complex set of regulations as each database used might have to comply with different sets of regulations. Some might be personal data. But once data are anonymised and derived data are created, the question is whether the farmer continues to have any control over the way it is used. This issue is discussed in Section 3.

The discussion in this Annex highlights that how data is characterised points to different regulatory perspectives, and hence different regulatory outcomes in terms of how to balance the interests of different stakeholders along the value chain by instituting appropriate data governance arrangements. While no characterisation is incorrect, none of them alone captures the complexities that underlie the creation of value through data in the era of digitised agriculture, nor provides for ready-made regulatory applications.

No matter how complex, setting out the appropriate data governance arrangements remains a key function for supporting a fair transition of the sector. As alluded to in this Annex, a number of concerns are emerging in the digital agriculture space, as in other sectors, due to data regulation (Table A A.2).

[23] See, for example, Ferentinos (2018[60]) and Mohanty, Hughes and Salathe (2016[61]). Examples at: https://plantvillage.psu.edu/; https://www.gomicro.co/application/agriculture/.

[24] See https://farmhack.org/tools.

Table A A.2. Three types of farm data

	Description of the type of data	Where the data used is generated	Type data stream from a farmer perspective	Potential type of regulations applying
Farm business operations and management data	Financial Tax Human resource Contracts Supply chain (partnerships, customer and supplier information) Rolling and fixed asset data Machine operations data (fuel consumption, equipment function, reference) Reporting and compliance data (government policies, certification schemes)	On-farm	Localised, Exported	Intellectual property; Personal data protection; Data retention requirements; Consumer protection
Farm production process tracking data (applied processes data)	Crop seed Dates of operations Water management Disease and pest management (type of herbicides, insecticide, fungicide used and dates and location applied) Yield data Land data (Soil and fertility data, watershed, drainage, tillage practice) GIS, GPS and field boundary data Livestock data (breed, genetics, feed, production)	On-farm	Localised, Exported	Intellectual property; Personal data protection; Consumer protection; National security laws
Data collected to provide general services to agriculture	Climate and weather data Environmental and ecological data Commodity prices and market information	Off-farm	Imported, Ancillary data	Intellectual property; Personal data protection

Source: Authors, inspired by www.agGateway.org and Maru et al. (2018[46]).

Annex B. Industry Codes of Conduct

The United States' Privacy and Security Principles for Farm Data and Ag Data Transparency Evaluator

Established in 2014, the American Farm Bureau's *Privacy and Security Principles for Farm Data* ('Principles for Farm Data') set out core principles around the agreement and disclosure (such as 'access and use of farm data should be granted only with the affirmative and explicit consent of the farmer'), and aim to ensure that the ag-data is not misused. The voluntary Principles for Farm Data also provide companies that collect and analyse ag-data guidelines when constructing their contracts and technologies related to ag-data.

The Principles for Farm Data set out thirteen key areas: (i) education; (ii) ownership; (iii) collection, access and control; (iv) notice; (v) transparency and consistency; (vi) choice; (vii) portability; (viii) terms and definitions; (ix) disclosure, use and sale limitation; (x) data retention and availability; (xi) contract termination; (xii) unlawful or anti-competitive activities; and (xiii) liability and security safeguards. A guide called *Ponder These 9 Before You Sign* was also developed in conjunction with the Privacy and Security Principles.

Based on the Principles for Farm Data, in 2016, the *Ag Data Transparency Evaluator* was launched. The Ag Data Transparency Evaluator is a tool designed to help US farmers understand how their data will be used when they adopt precision agriculture technologies. The tool was created by the American Farm Bureau Federation and backed by a consortium of farm industry groups, commodity organisations and agriculture technology providers to bring transparency, simplicity and trust into the contracts that govern precision agricultural technologies.

The Ag Data Transparency Evaluator is a process by which agriculture technology providers voluntarily submit their data contracts to a simple 10-question evaluation. These questions are directed at discovering the approach taken by the technology providers to data management. Answers are reviewed by an independent third-party administrator, the law firm of Janzen Agricultural Law LLC. Once reviewed, the results are posted on the website for farmers and other agricultural professionals to consult and review. Only companies receiving approval can use the *'Ag Data Transparent'* seal. This seal then serves to inform farmers whether the approach taken by the technology provider is in line with the American Farm Bureau's Data Principles. The ability to use the seal indicating that the business is Ag Data Transparent provides an incentive for the agricultural technology providers to review and improve their contractual terms in light of the Data Principles.

The Ag Data Transparency Evaluator is provided free of charge to farmers to view, so they can make an informed decision about the data approaches taken by the businesses with which they choose to deal. The cost of the Ag Data Transparency Evaluator is borne by the technology providers who want to use the Ag Data Transparent Seal. The cost is based first on the age of the company, and then on the size and profit that they make. For example:

- Start-up provider (a participant operating for less than four years): USD 2 000.
- Regular provider (a participant that is not a start-up provider or large provider): USD 4 000.
- Large provider (a participant with annual sales greater than USD 100 million): USD 6 000.

Currently, the approved companies are filtered by the type of data they collect: agronomic, land, farm management, machine and weather data. From January 2020, the scope of the Ag Data Transparent was expanded to include the farm financial sector. As agricultural lenders are increasingly collecting agricultural data, it was decided that by extending the Seal to the farm financial sector provided some protection of farmers' privacy. Companies wishing to certify as "Ag Data Transparent" will have the option of identifying "farm financial and management data" as the category of information they are collecting. As at January 2020, there are 23 companies and their products that have been evaluated and granted approval to use the Ag Data Transparent Seal.

New Zealand Farm Data Code of Practice, Standards and Accreditation

Another example of an agricultural data certification scheme is the *New Zealand Farm Data Code of Practice* ('NZ Farm Data Code'), with complimentary standards and accreditation. The NZ Farm Data Code was established in 2014 to 'set of guidelines enabling effective sharing of data within the New Zealand agriculture industry.' Organisations must agree to disclose their practices and policies around data rights, data processing and sharing, and data storage and security. In return, these organisations can display the Code of Practice trademark on their websites and documents. The NZ Farm Data Code targets providers that manage farm data for agri-businesses in New Zealand, and focuses on disclosure with compliant organisations agreeing to:

- make disclosures to primary producers and other end users about the rights that the parties have in the data, rules and processes for data sharing, about data security and the legal jurisdiction in which data is kept, and
- implement a set of practices that provide primary producers with confidence that data pertaining to their farming operations is secure, managed according to agreed terms and for agreed purposes, and accessible under appropriate terms and conditions.

In June 2014, when the NZ Farm Data Code was launched, six industry organisations provided the mandate for its establishment (Beef + Lamb New Zealand; Dairy New Zealand; Dairy Companies Association of New Zealand; Federated Farmers New Zealand; Te Tumu Paeroa: The New Maori Trustee; and the New Zealand Veterinary Association).

The NZ Farm Data Code targets providers that manage farm data for agri-businesses in New Zealand. The NZ Farm Data Code requires organisations to outline the steps they take to safeguard farmer data. Under the NZ Farm Data Code, organisations agree to disclose their practices and policies around data rights, data processing and sharing, and data storage and security. By so doing, it is felt that farmers will have more trust and confidence that farm data is safe and is managed fairly. It is important to note that the scope of the NZ Farm Data Code extends to all farm data, which is recognised under the scheme to include non-personal information as well as personal information.

An ag-provider that complies with the Code's standards is authorised to display the Code of Practice mark on its website and documents. One of the ways in which compliance with these standards is communicated to consumers is by registering a word, words or image as a trade mark. For example, the NZ Farm Data Code seal is registered with the NZ Intellectual Property Office as a trade mark. Accreditation of the NZ Farm Data Code is essential a form of self-regulation in which companies conduct a 'self-audit' and statutory declaration to confirm that they comply with the NZ Farm Data Code. Once companies have done this, their application is assessed and, if approved, they will receive an annual licence and certificate as well as the Farm Data Code of Practice trade mark to use. Then, if approved the companies receive an annual licence and certificate. A number of ag-providers (i.e. Gateway Data 45 Services, Farmax, Farm IQ, Greenlea and apps on farm) have been accredited, and thus can display the Code's mark.

In addition to the NZ Farm Data Code, a set of technical NZ Farm Data Standards have been developed with the hope of assisting data sharing across the dairy sector. These standards provide 'a set of common data vocabularies that assist the business and industry organisations that serve NZ farmers to develop efficient technology applications and integrations'. So far, there are standards for animal data; land application data; financial data; irrigation and effluent data; stock reconciliation data; farm features and attributes data; pasture, grazing and feed data; farm and model data; and health and safety data. New standards will be developed depending on industry need.

The European Union Code of Conduct on Agricultural Data Sharing by Contractual Agreement ("EU Code of Conduct")

On the 23 April 2018, a coalition of associations from the EU agri-food chain launched a joint EU Code of Conduct on agricultural data sharing: the *EU Code of Conduct on Agricultural Data Sharing by Contractual Agreement.* In launching the Code, it was highlighted by the parties that 'the Code promotes the benefits of sharing data and enables agri-business models, including agri-cooperatives and other agri-businesses, to swiftly move into an era of digitally enhanced farming'.

The EU Code of Conduct attempts to define key concepts and sets out general principles for sharing agricultural data including that "[t]he collection, storage and usage of the collected agricultural data can only occur once the data originator has granted their explicit, express and informed permission via contractual arrangement".

The Code of Conduct explains contractual relations and provides guidance on the use of agricultural data, particularly on the rights of access and use of the data. It is important to note that the Code was a collaborative effort between farmer's co-operatives in the European Union allied to Copa-Cogeca and CEJA (that focusses on young farmers up to 40 years of age), as well as representatives of animal breeding companies and large organisations representing various industries producing animal feed, fertilisers, seeds, or farm machinery (like CEMA, Fertilizers Europe, CEETTAR, ECPA, EFFAB, FEFAC and ESA). Unlike the US and NZ models, there is no certification or accreditation aspect of the EU Code of Conduct.

References

ACCC (2019), *Digital Platforms Inquiry - final report*, https://www.accc.gov.au/publications/digital-platforms-inquiry-final-report. [63]

Agridigital (2018), *Charter on the Digitalitsation of Swiss Agriculture and Food*, https://agridigital.ch/wp-content/uploads/2019/01/Charta-Digitalisierung_e.pdf. [54]

Agronomic Crops Network (2016), *Portability - The Big Data Confusion: Part 8*, https://agcrops.osu.edu/newsletter/corn-newsletter/portability-big-data-confusion-part-8 (accessed on 3 April 2020). [11]

American Farm Bureau Federation (2016), *US Privacy and Security Principles for Farm Data*, https://www.fb.org/issues/technology/data-privacy/privacy-and-security-principles-for-farm-data. [28]

Atik, C. (2019), "Data ownership and data portability in the digital agriculture sector: a proposal to address novel challenges", *Florence School of Regulation Conference*, https://fsr.eui.eu/atik-c-how-big-data-affects-competition-law-analysis-in-online-platforms-and-agriculture-does-one-size-fit-all/. [20]

Atkinson, R. (2019), *IP Protection in the Data Economy: Getting the Balance Right on 13 Critical Issues*, http://www2.itif.org/2019-ip-protection-data-economy.pdf?_ga=2.50635887.758392791.1556791907-569744070.1556791907 (accessed on 2 May 2019). [19]

Avelino, F. and J. Wittmayer (2015), "Shifting power relations in sustainability transitions: a multi-actor perspective.", *J. Environ. Policy Plan 18*, pp. 628-649. [15]

Bennett, J. (2015), "Agricultural Big Data: Utilisation to Discover the Unknown and Instigate Practice Change", *Farm Policy Journal, 12*, pp. 43-50, https://www.researchgate.net/publication/274253896_Agricultural_Big_Data_Utilisation_to_Discover_the_Unknown_and_Instigate_Practice_Change. [50]

Burt, J. (2018), *Tractor hacking farmers fight for the Right to Repair under equality laws*, https://www.abc.net.au/news/rural/2018-02-22/tractor-hacking-farmers-in-the-us-fight-for-right-to-repair/9470658. [37]

Casalini, F. and J. López González (2019), "Trade and Cross-Border Data Flows", *OECD Trade Policy Papers*, No. 220, OECD Publishing, Paris, https://dx.doi.org/10.1787/b2023a47-en. [23]

Chan Grinvald, L. and O. Tur-Sinai (2019), "Intellectual Property Law and the Right to Repair", *Fordham Law Review 63*, Vol. 88:1. [39]

Chauve, P., A. Parera and A. Renckens (2014), "Agriculture, Food and Competition Law: Moving the Borders", *Journal of European Competition Law & Practice*, Vol. 5:4, pp. 304-313, https://doi.org/10.1093/jeclap/lpu020. [17]

Copa-Cogeca et al. (2018), *EU Code of conduct on agricultural data sharing by contractual agreement*, https://copa-cogeca.eu/img/user/files/EU%20CODE/EU_Code_2018_web_version.pdf (accessed on 2 May 2019). [53]

CTA Working Paper (2019), "Review of codes of conduct, voluntary guidelines and principles relevant for farm data sharing", *CTA, GODAN*. [26]

Data Foundation (2019), *The State of the Union of Open Data*, https://www.datafoundation.org/the-state-of-the-union-of-open-data-ed-3. [43]

Della Chiesa, S. et al. (2019), "Farmers as data sources: Cooperative framework for mapping soil properties for permanent crops in South Tyrol (Northern Italy)", *Geoderma*, Vol. 342, pp. 93-105, http://dx.doi.org/10.1016/j.geoderma.2019.02.010. [44]

Detrick, H. (2018), *The Justice Department Is Going to Let Bayer Buy Monsanto. Here's Why It Matters*. [16]

Devlin, B. (2012), *The Big Data Zoo - Taming the Beasts*, http://9sight.com/pdfs/Big_Data_Zoo.pdf. [47]

Dodds, L. (2015), *What is derived data?*, https://blog.ldodds.com/2015/09/05/what-is-derived-data/. [51]

FCC (2018), *Farm Data Study: Decoding trust in data management in Canada*. [2]

Ferencz, J. and F. Gonzales (2019), "Barriers to trade in digitally enabled services in the G20", *OECD Trade Policy Papers*, No. 232, OECD Publishing, Paris, https://dx.doi.org/10.1787/264c4c02-en. [65]

Ferentinos, K. (2018), "Deep learning models for plant disease detection and diagnosis", *Computer and Electronics in Agriculture*, Vol. 145, http://dx.doi.org/10.1016/j.compag.2018.01.009. [60]

FTC (2020), *FTC to Examine Past Acquisitions by Large Technology Companies*, https://www.ftc.gov/news-events/press-releases/2020/02/ftc-examine-past-acquisitions-large-technology-companies. [64]

Gasser, U. (2016), "Legal Frameworks and Technological Protection of Digital Content: Moving Forward towards a Best Practice Model", *17 Fordham Intell. Prop. Media & Ent. L.J. 39*, https://ir.lawnet.fordham.edu/iplj/vol17/iss1/2. [33]

Global Forum for Food and Agriculture (2019), *Communiqué, Agriculture Goes Digital – Smart Solutions for Future Farming*. [55]

Greenville, J., K. Kawasaki and M. Jouanjean (2019), "Dynamic Changes and Effects of Agro-Food GVCS", *OECD Food, Agriculture and Fisheries Papers*, No. 119, OECD Publishing, Paris, https://dx.doi.org/10.1787/43b7bcec-en. [6]

Information Commissioner's Office (2020), *Right to Data Portabilty*, https://ico.org.uk/for-organisations/guide-to-data-protection/guide-to-the-general-data-protection-regulation-gdpr/individual-rights/right-to-data-portability/ (accessed on March 2020). [31]

Jakku, E. et al. (2019), "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharinf in smart farming", *NJAS - Wageningen Journal of Life Sciences*, Vol. Volumes 90-91, https://doi.org/10.1016/j.njas.2018.11.002. [3]

Janzen Ag Law (2019), *Ag Data Transparent*. [29]

Jouanjean, M. (2019), "Digital Opportunities for Trade in the Agriculture and Food Sectors", *OECD Food, Agriculture and Fisheries Papers*, No. 122, OECD Publishing, Paris, https://doi.org/10.1787/91c40e07-en. [5]

Keough, M. (2017), *Right to Repair Debate highlights critical issue of data rights*, http://www.farminstitute.org.au/ag-forum/right-to-repair-debate-highlights-critical-issue-of-data-rights. [36]

Korne, N., C. Oppenheim and C. Duncan (2007), *IPR and Licensing Issues in Derived Data*, https://www.yumpu.com/en/document/read/23669953/ipr-and-licensing-issues-in-derived-data-jisc. [52]

Leonard, E. et al. (2017), *Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia*, https://www.crdc.com.au/precision-to-decision. [18]

Maru, A. et al. (2018), *Digital and data-driven agriculture: Harnessing the power of data for smallholders*, https://cgspace.cgiar.org/handle/10568/92477. [46]

McFadden, J. and A. Rosburg (2018), *Yield Maps, Soil Maps, and Technical Efficiency: Evidence from U.S. Corn Fields*. [57]

McFadden, J. and D. Schimmelpfennig (2019), *The Emerging Structure of the U.S. Precision Agriculture Industry*, Proceedings of the 12th European Conference on Precision Agriculture (ECPA). [56]

Mochan, K. and M. Bennett (2018), *Farmers driving 'right to repair' issue as legislative battle unfolds in US*, https://www.abc.net.au/news/rural/2018-03-11/farmers-spearhead-right-to-repair-fight/9535730). [35]

Mohanty, P., D. Hughes and M. Salathe (2016), "Using Deep Learning for Image-Based Plant Disease Detection", *Computer Vision and Pattern Recognition*, https://arxiv.org/abs/1604.03169. [61]

OECD (2020), *Mapping Approaches to Data and Data Flows. Report for the G20 Digital Economy Task Force*, OECD Publishing, http://www.oecd.org/trade/documents/mapping-approaches-to-data-and-data-flows.pdf. [24]

OECD (2019), *Digital Innovation: Seizing Policy Opportunities*, OECD Publishing, Paris, https://dx.doi.org/10.1787/a298dc87-en. [4]

OECD (2019), *Digital Opportunities for Better Agricultural Policies*, OECD Publishing, Paris, https://doi.org/10.1787/571a0812-en. [7]

OECD (2019), *Enhancing Access to and Sharing of Data: Reconciling Risks and Benefits for Data Use across Societies*, OECD Publishing, Paris, https://doi.org/10.1787/276aaca8-en. [21]

OECD (2019), *Regulatory effectiveness in the era of digitalisation*, https://www.oecd.org/gov/regulatory-policy/Regulatory-effectiveness-in-the-era-of-digitalisation.pdf. [12]

OECD (2019), *The Path to Becoming a Data-Driven Public Sector*, OECD Digital Government Studies, OECD Publishing, Paris, https://dx.doi.org/10.1787/059814a7-en. [1]

OECD (2018), *Summary Record: OECD Global Forum on Agriculture, 2018. Digital technologies in food and agriculture: Reaping the benefits*, OECD, http://www.oecd.org/tad/events/gfa-18-summary-record.pdf (accessed on 21 September 2018). [45]

OECD (2015), *Data-Driven Innovation: Big Data for Growth and Well-Being*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264229358-en. [25]

OECD (2011), *Government at a Glance 2011*, OECD Publishing, Paris, https://doi.org/10.1787/gov_glance-2011-en. [42]

OECD (2006), *Recommendation of the Council concerning Access to Research Data from Public Funding*, https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0347. [41]

O'Keeffe, S. (2019), "Unlocking innovation through new technologies", *Farmonline National*, https://www.farmonline.com.au/story/6412016/bridging-the-agtech-disconnect/ (accessed on 30 October 2019). [59]

Povitch, E. (2019), *Tech Giants Fight Digital Right-to-Repair Bills*, https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2019/10/16/tech-giants-fight-digital-right-to-repair-bills. [40]

Productivity Commission (2017), *Productivity Commission Inquiry Report: Data Availability and Use, Report No. 82*, https://www.pc.gov.au/inquiries/completed/data-access/report/data-access.pdf (accessed on 19 September 2018). [22]

Rouse, M. (2020), *Internet of things (IoT)*, https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT. [62]

Sanderson, J., L. Wiseman and S. Poncini (2018), "What's behind the ag-datalogo? An examination of voluntary agricultural-data codes of practice", *International Journal of Rural Law and Policy*, Vol. Vol 1, https://doi.org/10.5130/ijrlp.1.2018.6043. [27]

Schimmelpfennig, D. (2016), *Farm Profits and Adoption of Precision Agriculture*. [58]

Solon, O. (2017), *A right to repair: Why Nebraska farmers are taking on John Deere and Apple*, https://www.theguardian.com/environment/2017/mar/06/nebraska-farmers-right-to-repair-john-deere-apple. [32]

Sonka, S. (2015), "Big Data: from Hype to Agricultural Tool", *Farm Policy Journal*, https://www.researchgate.net/publication/279771638_Big_Data_From_Hype_to_Agricultural_Tool. [49]

UNECE (2013), *Classification of types of big data*. [48]

van Es, H. (2016), *Digital Agriculture in New York State: Report and Recommendations*, Cornell University, Ithaca, NY. [10]

Weins, K. (2015), *We can't let John Deere destroy the very idea of ownership*, https://www.wired.com/2015/04/dmca-ownership-john-deere/. [38]

Wiseman, L. (2019), "Do Australian Farmers Need a Right to Repair?", *Griffith News, Griffith University*, https://news.griffith.edu.au/2018/11/23/do-australian-farmers-need-a-right-to-repair/. [34]

Wiseman, L. and J. Sanderson (2017), *Accelerating Precision Agriculture to Decision Agriculture - Enablign Digital Agriculture in Australia*, https://www.crdc.com.au/precision-to-decision. [30]

Wiseman, L. and J. Sanderson (2017), *The legal dimensions of digital agriculture in Australia: An examination of the current and future state of data rules dealing with ownership, access, privacy and trus*, http://www.acipa.edu.au/pdfs/GU_USC_Legal_Dimensions_Report.pdf (accessed on 27 April 2018). [9]

Wiseman, L. et al. (2019), "Farmers and their data: An examination of farmers' reluctance to share their data through the lens of the laws impacting smart farming", *NJAS - Wageningen Journal of Life Sciences*, Vol. 90-91/December, https://doi.org/10.1016/j.njas.2019.04.007. [13]

Wolfert, S. et al. (2017), "Big Data in Smart Farming – A review", *Agricultural Systems*, Vol. 153/May, pp. 69-80, https://doi.org/10.1016/j.agsy.2017.01.023. [14]

Zhang, A. et al. (2017), *Accelerating precision agriculture to decision agriculture: The needs and drivers for the present and future of digital agriculture in Australia. A cross industries producer survey for the Rural R&D for Profit*, https://www.crdc.com.au/sites/default/files/P2D%20producer%20survey%20-%20CSIRO%20Final%20Report.pdf. [8]