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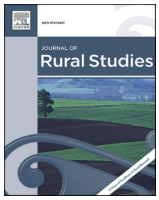

Farmers and their data: Evaluating the swiss conception of data sharing through the lens of digital farming

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A B S T R A C T

Digitalisation has changed agricultural production and will continue to do so. Although digital technology promises to increase the efficiency, productivity and environmental friendliness of agriculture while improving the work-life balance of farmers, new digital farming technologies come with potential negatives, such as privacy and security concerns. In recognition of that fact data is a fundamental part of digital adoption in the agricultural sector, this article analyses Swiss farmers perceptions of data sharing. We apply the Responsible Research on Innovation (RRI) approach to anticipate and discuss farmers' legal and political perspectives on agricultural data and data sharing. These form the foundation of and thus the key to digitalisation in agriculture. Based on a review of the literature and two exploratory interviews on the broader regulatory context of data sharing, Swiss data regulation and management were included as background to this work. This paper, further explores in detail the relationship between farmers' attitudes towards data sharing and their relatively low adoption of digital technologies. Such an analysis is valuable as it provides us with the farmers' perspective on data use and regulations in Switzerland which, though not an EU country, has its own high data-protection standards. More specifically, we assessed Swiss farmers' perceptions of agricultural data sharing with public and private entities and placed these perceptions within the broader Swiss framework for data regulation. This was accomplished by a survey of 939 randomly selected farmers in the German- and French-speaking parts of Switzerland. From the Swiss farming perspective, we discuss how innovation can respond to societal needs. We conclude that the concerns, risks and vulnerabilities that Swiss famers are currently experiencing with regard to their farm data need to be addressed through a broader regulatory reform of Swiss agricultural data protection if digital farming is to achieve its full potential in Switzerland.

1. Introduction

Over the past decade, the agricultural sector has undergone a digital transformation that has brought about a big data revolution (Lioutas and Charatsari, 2020). Innovative digital technologies can offer farmers a wide range of opportunities to optimise farm management, such as increasing yields, reducing input use and thus reducing the negative impact of production on the environment. Zscheischler et al. (2022) concludes that it also has the potential for a number of unintended side-effects and risks, which can increase the vulnerability of agricultural production and that have received little scientific or public attention of employing digitalisation and digital data in agriculture. However, to take advantage of the opportunities and reduce the risks associated with the new technologies, developing Agriculture 4.0 needs responsible socio-technical transitions (Rose et al., 2021). Different stakeholders have different perspectives about the role of digital technologies in the future (Regan, 2021). A review of the social science on digital agriculture, smart farming and agriculture 4.0. (Klerkx et al., 2019) shows that five thematic clusters can be identified in the social science literature on digitalisation in agriculture. Our research addresses the category «Power, ownership, privacy and ethics in digitalizing agricultural production systems and value chains» and applies critical social science perspectives on digitalisation in agriculture. In this thematic cluster Regan (2019) advocates for adopting a reflexive and transdisciplinary perspective to proactively address the risks associated with «Smart Farming» in Ireland, employing a responsible innovation approach (Klerkx et al., 2019, p. 7). Additionally, Bronson (2019) and Van der Burg et al. (2019), among other authors, also endorse the RRI approach. The framework serves to critically question and think about how innovations impact our society (Bronson, 2018; Fleming et al., 2018) and to anticipate potential risks or harm (Owen et al., 2013).

RRI is seen as having four main dimensions or principles (Eastwood et al., 2017): anticipating social, ethical, economic or environmental impacts; including the views of all actors in decision-making; reflecting

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on one's own assumptions and considering how they may differ from others; and responsiveness - taking meaningful action in response to concerns and needs raised. RRI is a values-based framework and these four principles are envisioned to act as a common set of objectives to guide decision-makers and governance actors (Bronson, 2018). The approach outlined by Klerkx et al. (2019) highlights the need to implement legal measures to regulate data control and power distribution in the context of interoperable data systems that are streamlined and standardised. Zscheischler et al. (2022) identified casual factors as side-effects of digital farming already data rights, the reshaping of the value chain through new market concentrations, alterations in power structures and dependencies, evolving knowledge demands for farmers (specifically, a lack of "digital competence"), and information asymmetries. While Wiseman et al. (2019b) conducted research in the same research cluster on ownership, portability, privacy, trust and liability in the commercial relationships governing digital agriculture and the perceptions of Australian farmers on this topic. Wiseman et al. (2019b) noted that farmers currently bear excessive risk and vulnerability. The authors stress the need to address broader legal and regulatory issues; particularly the 'take it or leave it' approach of current complex data licenses. The researchers argue for transparent and understandable terms in data licenses, specifying details such as data access, beneficiaries, and privacy safeguards.

There is a scarcity of empirical studies that address the uncertainties on farmers' side concerning agricultural data sharing (Fleming et al., 2018; Regan, 2019; Wiseman et al., 2019b; Zscheischler et al., 2022).

We have limited our research to the application of RRI on farmers, legal and policy perspectives of agricultural data and data sharing, as this is the foundation and the key to digitalisation in agriculture. Following the RRI framework, our research was structured as follows: (1) explore participants understanding of terms and conditions of data regulations (social) (2) identify concerns regarding challenges and opportunities facing data sharing of farmers (ethical and economic perspective) and (3) identify future actions required in the future use of agricultural data in Switzerland through exchange with policy makers and evaluation of industry standards. See methods to see how we have implemented each construct in our questionnaire.

Switzerland serves as a case study for data perception in digitalised agriculture. It is particularly suitable because the agricultural government is fully committed to the dissemination and use of digital technologies. In addition, the mandatory digital administration of direct payments (e-government) means that all Swiss farmers have already been confronted with the issue of sharing agricultural data, the absolute basis of digital farming. See methods section for details on Swiss context.

Agricultural digital technologies, encompassing diverse data types and sources, pose varying legal and regulatory considerations for collection, storage, and impact on stakeholders. Previous studies, such as Arnold et al. (2019), provide a comprehensive overview of the data landscape, including satellite-based systems, sensor technologies, robots, drones, farm management systems, and agricultural applications (Jouanjean et al., 2020; Kamilaris et al., 2017). Kritikos (2017) addressed the potential benefits and challenges associated with digital farming, highlighting how big agricultural data analysis can enhance productivity and, in some cases, reduce, environmental footprint (Kamilaris et al., 2017). Recognized for its the potential to enhance global agricultural production and nutrition, the value of agricultural data sharing is emphasized by organisations such as Global Open Data for Agriculture and Nutrition, aiming to address global food security (Vark, 2013). However, the advent of big data in agriculture introduces challenges, including privacy concerns, particularly when farm data are linked to geographic information (e.g. Coble et al. (2018); Wiseman et al., 2019a; Zhang et al., 2021). Geo-referenced data from farm management information systems, encompassing crop details, satellite images, and weather forecasts, can be traced back to individual locations, raising privacy issues. Some farmers express concerns not only about their data privacy, but also about third-party benefits without reciprocal sharing. Data sovereignty concepts suggest that farmers own data produced on the farm; however, modifications such as aggregation may transfer ownership of the data to the modifying party (Arnold et al. (2019). This underscores the necessity for robust data regulations to encourage sharing, fostering increased availability and utilization of agricultural data.

Still, to date, there is limited research on data sharing attitudes and regulations in the Swiss context, which evaluates farmers' concerns and beliefs about agricultural data sharing. Although there is some literature on data governance and sharing in the EU (e.g. Jouanjean et al. (2020), there is none dealing with the Swiss context. Switzerland presents an interesting case study as it does have a detailed regulatory approach for agricultural data sharing with the government. However, like many other countries, it has yet to take steps to regulate agricultural data contracts with third party technology providers. In this study, we analyse Swiss farmers' attitudes towards the issues and challenges that arise when their agricultural data are collected, managed and shared. Our research findings contribute to the body of knowledge of how farmers in different countries are experiencing challenges and concerns after the adoption and uptake of digital farming technologies (Adrian et al., 2005; Brakenrig, 2014; Greiner et al., 2009; Hay and Pearce, 2014; Knierim et al., 2019; Rieple and Snijders, 2018; Shang et al., 2021). Our research is based on the framework of the RRI. To take advantage of the opportunities offered by agricultural data sharing, it is important to understand if there are protections in place for Swiss farmers' data sovereignty and data control. Furthermore, understanding Swiss farmers' attitudes, experiences and perceptions of agricultural data ownership and access will help to inform and stimulate the development of digitalisation strategies for a sustainable future of Swiss agriculture. Accordingly, we aim to understand the regulatory and situational context of data governance in Swiss agriculture and Swiss farmers' perspectives and concerns about agricultural data ownership and data sharing.

2. Background

2.1. Swiss context

The Swiss Confederation is promoting the adoption of digital technologies in the agricultural industry, encouraging farmers to modernise their farming practices. In fact, Switzerland has raised multiple initiatives such as the 'Charta Digitalisation' (El Benni et al., 2020) or 'Swiss open data' (opendata.swiss), a freely accessible platform that publicly offers Swiss federal data to promote digital development of the Swiss agricultural sector. Agricultural production in Switzerland is defined by small-scale family farms with an average size of 21 ha and few to no employees (Reissig et al., 2022). This business structure makes the farm manager, who usually owns the business, fully responsible for independent management decisions, and as such puts the farmer in the position to take the full responsibility for his or her actions. Hence, Swiss farmers usually have no staff to maintain technical or IT infrastructure or legal obligations in this domain. This would mean that the farmers themselves would need to have the requisite digital and data management skills, which is likely to present challenges to farmers who wish to uptake digital technologies on their farm.

Like in other European countries, Swiss agriculture is heavily subsidised, and Switzerland is one of the OECD countries with the highest government support (El Benni and Schmid, 2022). Switzerland defines its actions through the concept of 'Swissness', a model to promote the individuality and exclusivity of Swiss products (Haver and Middleton, 2015), by e.g. providing 'helvetised' digital technologies such as the farm management information system Barto. To receive direct payments, about 98% of Swiss farmers regularly provide data to the federal offices in a digital format (Federal Office for Agriculture (FOAG), 2021). Thus, e-government is the only digital technology that is obligatory in Swiss agriculture and therefore has been adopted comprehensively,

while this is not the case for other digital agriculture technologies, for which the adoption rate in Switzerland is rather low (Groher et al., 2020; Groher et al., 2020). In addition, farmers are required to enter relevant farm data into a federal controlling and monitoring system (called AGATE). Therefore, they are well accustomed to data sharing with the federal offices. As internet coverage across rural and urban regions in Switzerland is good, it does not present a challenge for digitalisation (Reissig et al., 2022).

2.2. Swiss regulation of agricultural data

To date, agricultural data sharing and privacy in Switzerland have only scarcely been the focus of any detailed analysis in academic scholarship or scientific literature. By way of contrast, the ownership of health data has recently been discussed among Swiss experts, who concluded that rules regarding data ownership, and what this involves, need to be clarified; without such clarification, 'health data cannot truly belong to anyone' (Martani et al., 2021, p. 1).

Although there appears to be a common belief that farm or agricultural data belong to the farmer who works or owns the land (European Farmers European Agri-Cooperatives, 2021), clarity on the topic of agricultural data ownership is far from resolved but it is increasingly important given agricultural data are increasingly an asset of value. Furthermore, there is a significant difference as to how agricultural data are protected in the public and private sector. For example, whereas the public sector must adhere closely to laws and regulations, the private sector does not and instead rely on contracts (i.e., data licences) to attach terms and conditions that govern the use and sharing of the agricultural data to not only protect the company but also allow further sharing and use of the agricultural data.

The Federal Act on Data Protection (FADP) regulates the use of data in Switzerland and 'aims to protect the privacy and the fundamental rights of persons when their data is processed' (235.1 Federal Act on Data Protection of 19 June 1992, p. 1). This FADP covers the 'processing of data pertaining to natural persons and legal persons by a. private persons [… and …] b. federal bodies' (p. 1) and thus includes data from the agricultural sector.

Although the international consensus tends to suggest that farmers own their agricultural data, to date there is no EU legislation that specifically regulates agricultural data ownership. This explains why determining some governance principles around the collection, management and sharing of agricultural data has become particularly important, as this allows defining 'the rights to use, transform and monetize the data' (Kritikos, 2017, p. 17). Kritikos (2017) has suggested that ownership should relate to the creation of value from raw agricultural data. Combining single farm data with those of other farms to evaluate performance across farms, and thus offering an aggregated dataset that can be analysed by third parties with a different intention, is what creates value to the data (Kritikos, 2017). This opportunity led to the development of agricultural decision support systems, which are offered to farmers, along with a waiver for data ownership rights, emphasising the development of unbalanced power between industry provider and farmer (Kritikos, 2017). In practice, this means that the farmers can purchase the product and waive their agricultural data rights or walk away and choose not to implement the innovative technology. Kritikos (2017) observes that companies often state that farmers are the owners of their data, even if that is not the case in practice. According to Kritikos (2017), the data ownership and who is profiting from the data needs to be clarified, with 'primary data' being seen as owned by the farmer whereas 'computed data' and 'data aggregated with other farmers' data' are considered as being owned by the one who performed the computing.

2.3. Potential concerns over future swiss governmental agricultural data sharing with third parties

It is common practice in Switzerland for Swiss farmers to be required to provide agricultural data to the government, but only in anonymised form regarding the specific dataset from the farm. In turn, this means that the data could then be passed on to another governmental or research department, without the farmers' name, but with the farm's specific location, making it possible to connect the farm with a different dataset. Within the Swiss Confederation, privacy standards for personal data are high; however, to date there are no regulatory standards for agricultural data. This is important to note given it is the interest of the Swiss Confederation to promote digitalisation within the agricultural context. However, whether farmers are motivated or not to share agricultural data highlights the dilemma with this current approach of the government sharing data. If, for example, in the future a certification scheme like organic farming or particularly animal-friendly husbandry want to access the data the farmer transmitted to the federal agricultural office in the future, the certification label's contract could be amended to include a passage in its terms of the contract to make federal agricultural data sharing a requirement to produce agricultural products for the certification label. The farmers then have to choose to either share their data or be excluded from the right to produce for the certification label, thus being in a position of the weaker party to the bargain, highlighting the power asymmetry in the data relationship. The opportunity to be part of the certification label with selective data sharing is not possible.

Data sharing through the Swiss FOAG is regulated through the ordinance on Information Systems in the Field of Agriculture (ISLV SR919.117.71). In the 'Meine Agrardatenfreigabe' (MAF – 'My Agricultural Data Sharing programme'), farmers can give their informed consent for data sharing of federal data with third parties. These data are collected on three levels: agricultural data, farm control data and data from direct payments, which are anonymised by the federal offices for their use and statistics, but these can be also linked to the names of the farmers by the third party and then could be argued to identify the farmer by personal data. The relevant agricultural third parties can request these data at a moderate fee (between 3400 and 5800 CHF, depending on the size of the data package). Thus, third parties are indirectly given the opportunity to monetize the farmers' data with the farmers' informed consent. There are no guidelines regarding who can apply for these data, but there is a contractual agreement between cantonal government and third party. The contract is automatically renewed after one year for reasons of reduced administrative burden for the farmer, but it can be revoked at any time. However, it is also clear that the data supplied cannot be withdrawn.

Furthermore, Barto (www.barto.ch) – a helvetised farm management system – has been introduced with the intention to reduce administrative burdens in farming, increase digitalisation and promote productivity. This farm management system was implemented through a public–private partnership and aims to reduce the administrative workload of farmers by allowing them to share relevant farm data with federal offices and third parties directly. This highlights the complexity that can be introduced into data sharing arrangements when there are partnerships between governments and third parties. This is quite a delicate issue because public and private data sharing are regulated differently.

3. Material & methods

To prepare for the empirical studies, we reviewed literature about the regulatory approach to agricultural data sharing in Switzerland and conducted two interviews to describe the legal and political perspectives in digital farming. We conducted one interview with a legal representative, an expert from the agricultural research institute Agroscope (Bern, Switzerland), who is familiar with the legal situation and the

handling of agricultural data to get insights in the legal perspective of data sharing in digital agriculture. To get an inside view of the government's perspective on data sharing, a second interview was conducted with a government representative and project manager of an agricultural platform for sharing agricultural data given by farmers to the government with third parties. For the clarity and readability of the paper, we have presented these findings in the Background 2.2. and 2.3. sections. We will discuss the connection with the farmers' perspective in the discussion.

3.1. Agricultural data use RRI framework and operationalisation

The RRI framework guided our methodology. We have limited our research to the application of RRI on farmers, legal and political perspectives of data sharing in digital farming. Our research followed the structure, according to the RRI framework presented in Table 1. This paper combines insights from a survey of 939 Swiss farmers, across 12 agricultural farm types, and two interviews, with the background information (see chapter 2) of the legal and regulatory challenges related to current approaches to the collection and sharing of Swiss agricultural data.

We conducted a literature review about the regulatory approach to agricultural data sharing in Switzerland and conducted two interviews to cover the legal and political perspectives in digital farming. We conducted one interview with a legal representative, an expert from the agricultural research institute Agroscope (Bern, Switzerland), who is familiar with the legal situation and the handling of agricultural data to get insights in the legal perspective of data sharing in digital agriculture. To get an inside view of the government's perspective on data sharing, a second interview was conducted with a government representative and project manager of an agricultural platform for sharing agricultural data given by farmers to the government with third parties. Qualitative content analysis (Mayring, 2015) was used to analyse the interviews.

These interviews served to better understand the political and legal background of data sharing in Swiss agriculture. For the clarity and readability of the paper, we have presented these findings in the Background 2.2. and 2.3. sections. We will discuss the connection with the farmers' perspective in the discussion.

3.2. Survey about swiss farmers' perceptions on data sharing

3.2.1. Procedures and survey participants

The study was registered with the Ethics Commission of the ETH Zurich, Switzerland, EK 2021-N-17. A random sample of 3000 farms was selected by the Swiss Federal Office for Agriculture (FOAG), which maintains a database of all farm households that receive direct payments (98% of all Swiss farms). The written survey was conducted in April and May 2021. In a first step, we invited all farmers to participate in an online survey. Two weeks later, we sent the (paper-and-pencil) questionnaire by mail to non-respondents. This approach is proven to generate high response rates (Reissig et al., 2015). Kongsved et al. (2007) furthermore recommended this procedure to avoid selection bias. For the online survey, the www.unipark.com tool was used. For the two-step procedure, a personal coding of the questionnaires was necessary, and the data were anonymised. The respondents needed 50 min on average to complete the questionnaire. The survey was done in two of three language regions of Switzerland (German and French). The questionnaire was translated by a professional translation service and pre-tested by eight farmers. The paper-and-pencil questionnaires were entered by hand and merged with the online dataset. The dataset was checked manually for plausibility.

Table 1
Operationalisation of the RRI framework.

Structure RRI framework	Data from:
(1) explore participants understanding of terms and conditions of data regulations (social)	**Survey:** •*Terms and conditions of data regulations* •*Data access*
(2) identify concerns regarding challenges and opportunities facing data sharing of farmers (ethical and economic perspective)	**Survey:** •*Willingness to share agricultural data* •*Storage* •*Profit making* •*Data privacy* •*Third-party data sharing*
(3) identify future actions required in the future use of agricultural data in Switzerland through exchange with policy makers and evaluation of industry standards	**Background:** •This information has been gathered from the background (literature, 2 interviews governmental responsible and legal expert)

The response rate was 31.3% (939 utilisable questionnaires) from 12 farm types according to farm typology ZA2015 of the Central Evaluation of Accounting Data (Hoop and Schmid, 2020). In the survey, participants were asked whether they collected any on-farm data (e.g., pasture or vegetation mapping, yield mapping, soil mapping, and individual animal or herd feeding data). Further questions related to the willingness of data sharing, and the answers were compared between the farmers who do and those who do not collect data.

As our study was the first to look at how Swiss farmers perceive data sharing in the context of digital agriculture, farmers from all farm types and regions were surveyed. Our sample included a wide range of farm types (arable farming, livestock farming, horticulture, mixed farming) and 16.2% were organic farms. The average farm size was 28 ha, above the Swiss average, and ranged from 2 ha to 134 ha. Off-farm work was common (62%). The average number of employees was 2. The financial situation was mixed, with 50% reporting that their financial situation was very poor to just sufficient, and the other 50% reporting that it was rather good to very good. The educational level was rather high, about 9% had a "federal certificate of professional competence in agriculture", 55.3% had a "basic education in agriculture with federal certificate" and 32.9% had a "higher education in agriculture (master's degree, technician, engineer FH or ETH)". We did not ask any specific questions in relation to the gender of the farm manager, but we assumed the Swiss-wide share of 6% female farm managers (Federal Office for Agriculture (FOAG), 2021) in our sample. Table A1 in the supplementary material provides detailed demographic and farm information for all participants.

3.2.2. Instruments and measures

To measure the state of digitalisation of the farm we applied a phasemodel of technology adoption as already provided by Albrecht (1969). We applied this model to the agricultural context (see Table 2). The term digital technologies was defined in the survey as following: *"The term 'digital technologies' includes hardware, software, mobile apps, sensor technologies and big data applications, e.g., the use of information communication technologies for operational decision making and management, electronic measuring systems, the use of robots and the automation of work processes. Exception: Data collection in the TVD ("Tierverkehrsdatenbank" – Engl.: Livestock Traffic Database) and in cantonal systems for direct payments are not to be taken into account here. Digital technologies the farmers use via contractors are not part of this survey and research."*

Table 3 summarises the measures used to assess the participants' understanding of the arrangements they had with their service or technology providers about the agricultural data collected through their services and public administration, and the trust in them to maintain the privacy of the data.

These measures were applied to all farmers because Swiss farmers are compelled to share data with the public government to receive direct payments. The data were analysed with SPSS statistical software version 26.0..1 (IBM, Chicago, IL).

Table 2
Phases of adoption of digital farming and explanation as applied in the survey.

Unknown phase	Perception phase	Interest phase	Evaluation phase	Trial phase	Adoption phase
The term "digital technologies in agriculture" means nothing to me.	I have already learnt about the existence of digital technologies in agriculture. However, I do not yet know any details and do not feel the need for more detailed information.	I have become aware of the existence of digital technologies and am already endeavouring to obtain information.	I am already familiar with the technologies and have assessed their advantages and disadvantages for myself and have decided whether or not to use a technology.	I use digital technologies to a limited extent and am looking for more information about them.	I use digital technologies regularly.

4. Results

4.1. Univariate statistics

Of the evaluated 939 responding farmers, 35.7% (335 respondents) collected digital production data via apps or software to manage their farms. We identified slight differences between farm types on the specific questions. The relationship between concerns and willingness to share agricultural data is also presented in the appendix in Table A1.

4.1.1. State of digitalisation – basis for data use and provision

Most Swiss farmers are aware of the digital technologies available,[1] as 93.1% responded that they were at least in the perception phase of digitalisation, while only 12.8% responded to be in the adoption phase (Fig. 1). This applies to digital technologies from private providers.

The results are shown in Table 4 if no other reference is available. The results presented in the table are explained in the following sections.

The table shows the measures used, including their scales. In addition to frequencies, the percentages are also shown, as well as the results of the statistical comparison of the statements between data collectors and non-data collectors.

4.1.2. Swiss farmers' knowledge of terms and conditions

Of the participants collecting digital operating data, 38.2% of the respondents did not know much about the terms of the contracts related to data collection that they had with their service or technology providers, while 35.5% felt well informed about their agreements with third parties on data collection. By contrast, of those farmers that do not collect digital operating data, 63.2% did not feel well informed about terms and conditions that would apply if they were to use a new digital technology. We found a significant difference between the groups (Table 3), except in producers' willingness to share their on-farm input and production data with service providers and government.

4.1.3. Direct access to agricultural data by service providers

Most respondents disagreed with third-party service providers being able to access their data directly. However, among those already collecting digital agricultural data, the response rate for 'not comfortable at all' was considerably lower (24.3%) than that of participants who do not collect on-farm data (41.8%). Only 15.1% of those collecting data, vs. 6.2% of those who do not, felt comfortable or extremely comfortable with service or technology providers having direct access to their farm data.

4.1.4. Attitude towards profit making from producers' agricultural data by service or technology providers

Only a minority of respondents (4.6% of those collecting data and 1.7% of those not collecting data) were comfortable or extremely comfortable with service or technology providers using client data to gain profit for themselves. Half of the respondents who collect data on their farm would choose to pay more for a technology to maintain the rights over their data, while this was also the case for 35.7% of those who currently do not collect data on their farm. More than half of the respondents who collect data on their farm are not comfortable with reduced costs for products by allowing data access.

4.1.5. Willingness to share data with third parties vs. federal government

Over 50% of the surveyed producers were not comfortable in sharing their farm input data (such as fertiliser and pesticide applications) with service or technology providers or federal institutions. A similar response was found on farm production data. However, the producers were more comfortable in sharing their data with federal institutions than with service or technology providers. The group differences are not significant. The attitude towards data sharing is independent of the actual data collection.

4.1.6. Willingness to accept that service or technology providers maintain farmers' data privacy

Only 14.5% of data-collecting respondents and 7.5% of non-collecting ones had willingness to trust or total willingness to trust in service or technology providers maintaining the privacy of their data. Of the data-collecting respondents, 20.1% stated they had no willingness to trust at all. Of the respondents not collecting data, 32.7% had no trust at all in service or technology providers maintaining their data privacy. Additionally, most respondents had little or no trust at all that service or technology providers with direct access to their data would not share these data with third parties.

4.1.7. Data storage

Only 21.7% of those farmers collecting agricultural data were at least comfortable with sharing their data on central servers, while this was the case for only 11.5% of non-collecting respondents.

4.2. Bivariate correlations

Bivariate correlations are presented to support the relationship between concerns and willingness to share agricultural data. Table 5 shows the correlations between the state of digitalisation and the different measures according to data sharing.

State of digitalisation correlates, like expected high medium with 'knowledge about terms and conditions' ($r = .31$), the data sharing measures show only week correlations. The relationship between 'knowledge about terms and conditions' and data sharing measures has weak correlations. For 'Data access' and 'Profit making of service/technology providers by farmers data' we found medium ($.30 < r \leq .50$) correlation coefficients for all data sharing measures except for 'pay more for service to retain rights over data' ($r = .08$). 'Pay more for service to retain rights over data' on the other side is low correlated with data sharing measures. For 'Use of farmers data by service/technology providers followed by service cost reduction for farmers' we found either medium ($.30 < r \leq .50$) or large ($r > .50$) correlation coefficients for all data sharing measures, expect "pay more for service to retain rights over data'. The same also applies 'third-party data sharing',

[1] The term 'digital technologies' includes hardware, software, mobile apps, sensor technologies and big data applications, e.g., the use of information communication technologies for operational decision making and management, electronic measuring systems, the use of robots and the automation of work processes. Exception: Data collection in the TVD ("Tierverkehrsdatenbank" – Engl.: Livestock Traffic Database) and in cantonal systems for direct payments are not to be taken into account here. Digital technologies the farmers use via contractors are not part of this survey and research.

Table 3
Measures to assess participants' understanding of data arrangements based on Wiseman et al. (2019a).

Measure	Description	Question	Scale
Terms and conditions	To examine producers' understanding of the terms and conditions with service providers in relation to farm data collection.	'For tools (such as machines and apps) used to collect on-farm data, how much do you know about the terms and conditions relating to data collection in your agreement with the service or technology providers?'	1 = Don't know at all 5 = Know very well
Data access	To examine producers' attitude towards farm data access by service providers.	'For any of the on-farm data collected, how comfortable are you if the service or technology providers (such as John Deere or a weather station provider) have direct access to your data through the services they provide to you?'	1 = Not comfortable at all 5 = Extremely comfortable
Profit making	To examine producers' attitude towards the making of profit from their farm data by service providers.	'If the service or technology providers had direct access to their client's data including yours, how comfortable are you if they use the data to make profit for themselves?' 'I agree to pay more for the service or technology in exchange for retaining the rights over my operational data.' 'I agree that the service or technology providers use my operational data and in return I have less costs for the service or technology.'	1 = Not comfortable at all 5 = Extremely comfortable
Data privacy	To examine producers' trust in service providers in maintaining the privacy of their farm data.	'If the service or technology providers had direct access to your data, how much do you trust them to maintain the privacy of your farm data?'	1 = No trust at all 5 = Total trust
Third-party data sharing	To examine producers' trust in service providers not sharing their farm data.	'If the service or technology providers had direct access to your data, how much do you trust them not to share the data with third parties?'	1 = No trust at all 5 = Total trust
Willingness to share agricultural data	To examine producers' willingness to share their on-farm input and production data with service providers.	'Please indicate how comfortable you are to share farm input data such as fertiliser and pesticide applications with service or technology providers.' 'Please indicate how comfortable you are to share farm input data such as fertiliser and pesticide applications with the public sector (FOAG, cantonal administration).' 'Please indicate how comfortable you are to share production data with service or technology providers.' 'Please indicate how comfortable you are to share production data with the public sector (FOAG, cantonal administration).'	1 = Not comfortable at all 5 = Extremely comfortable
Storage	To examine producers' attitude towards central data storage.	'To what extent do you agree to your data being stored centrally on a server?'	1 = Not agree at all 5 = Extremely agree

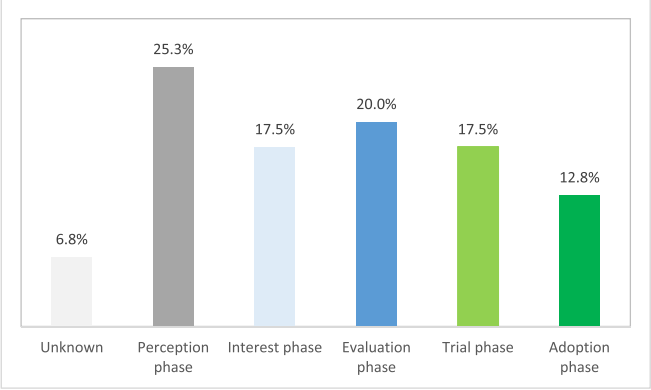

Fig. 1. State of digitalisation with technologies from private providers among Swiss producers (N = 896).

'willingness to share agricultural data' and 'data storage'.

5. Discussion

The presented research provides a unique perspective of data sharing by Swiss farmers and the legal and political context in Switzerland. Our work is based on the RRI framework as set out in the background chapter, and the discussion follows this structure. The research specifically focusses on farmers' perception of digitalisation and discusses its implications.

5.1. State of digitalisation and data usage in swiss agriculture

The current state of digitalisation in Swiss agriculture serves as a basis for understanding the broader issues around data collection, aggregation and sharing in Switzerland. Our findings show a considerable interest of Swiss farmers in digitalisation. Despite this general interest, only 35.7% of Swiss farmers in our sample collected digital operating data. This is in line with the findings of previous studies, which reported low adoption rates of digital technologies among Swiss farmers (Ammann et al., 2022; Groher et al., 2020; Groher et al., 2020). At European level, Sweden remains the EU innovation leader, followed by Lithuania, the Netherlands, Malta, the UK, Latvia and France as the fastest growing innovators in farming (Maloku, 2020). In Germany, 79% of the farmers use at least one digital technology (Rohleder and Meinel, 2022). The low adoption rate among Swiss farmers could be due to a number of issues such as a more traditional perception of farming, concerns about data sharing and general mistrust of information provided (Walter et al., 2017). However, this causality was not analysed in the current study. Our analysis focussed on data sharing with third

Table 4
Results of the used measures to assess participants' understanding of data arrangements, including the scales, frequencies, the percentages are also shown, as well as the results of the statistical comparison of the statements between data collectors and non-data collectors. The second column shows the percentage of each response, with data collectors in the top row and non-data collectors in the bottom row. Missing values have been omitted to improve readability. The table also includes a static comparison of information between data collectors and non-data collectors. The mean values and a comparison of the mean values were statistically calculated and presented. The Cohen's d, is used as the measure of effect size for unpaired t-tests.

Description	Question	Scale	percentage collecting data/percentage not collecting data					collecting data		not collecting data				
			1	2	3	4	5	N	mean	N	mean	t-value	p-value	effect size Cohen's d
To examine producers' understanding of the terms and conditions with service providers in relation to farm data collection.	'For tools (such as machines and apps) used to collect on-farm data, how much do you know about the terms and conditions relating to data collection in your agreement with the service or technology providers?'	1 = Don't know at all 5 = Know very well	8.6/ 28.5	29.6/ 34.7	26.0/ 23.4	31.9/ 10.2	3.6./ 1.3	303	2.92	537	2.20	9.87	.00	.70
To examine producers' attitude towards farm data access by service providers.	'For any of the on-farm data collected, how comfortable are you if the service or technology providers (such as John Deere or a weather station provider) have direct access to your data through the services they provide to you?'	1 = Not comfortable at all 5 = Extremely comfortable	24.3/ 41.8	37.2/ 31.2.	22.7/ 19.3	13.8/ 5.7	1.3/ .5	302	2.30	540	1.90	5.67	.00	.41
To examine producers' attitude towards the making of profit from their farm data by service providers.	'If the service or technology providers had direct access to their client's data including yours, how comfortable are you if they use the data to make profit for themselves?'	1 = Not comfortable at all 5 = Extremely comfortable	43.3/ 57.8	36.2/ 24.8	14.8/ 14.2	3.3/ 1.5	1.3/ .2	301	1.82	540	1.59	3.73	.00	.27
	'I agree to pay more for the service or technology in exchange for retaining the rights over my operational data.'		12.8/ 19.3	15.5/ 17.2	21.7/ 26.3	36.5/ 26.6	12.5/ 9.1	301	3.21	540	2.89	3.53	.00	.26
	'I agree that the service or technology providers use my operational data and in return I have less costs for the service or technology.'		20.1/ 29.4	34.5/ 30.3	24.0/ 24.5	19.1/ 13.1	1.3/ 1.1	301	2.47	539	2.25	2.82	.00	.21
To examine producers' trust in service providers in maintaining the privacy of their farm data.	'If the service or technology providers had direct access to your data, how much do you trust them to maintain the privacy of your farm data?'	1 = No trust at all 5 = Total trust	20.1/ 32.7	34.9/ 35.0	29.9/ 23.4	13.5/ 6.8	1.0/ .7	302	2.40	540	2.06	4.84	.00	.33
To examine producers' trust in service providers not sharing their farm data.	'If the service or technology providers had direct access to your data, how much do you trust them not to share the data with third parties?'	1 = No trust at all 5 = Total trust	22.7/ 35.0	37.5/ 37.4	26.3/ 20.4	11.8/ 5.1	1.0/ .7	302	2.30	541	1.98	4.84	.00	.34
To examine producers' willingness to share their on-farm input and production data	'Please indicate how comfortable you are to share farm input data such as fertiliser and pesticide applications with service or technology providers.'	1 = Not comfortable at all 5 = Extremely comfortable	25.0/ 29.4	33.9/ 27.2	22.4/ 28.3	15.1/ 11.3	2.6/ 2.0	301	2.36	538	2.28	1.00	.32	.07

(*continued on next page*)

Table 4 (*continued*)

Description	Question	Scale	percentage collecting data/percentage not collecting data					collecting data		not collecting data				
			1	2	3	4	5	N	mean	N	mean	t-value	p-value	effect size Cohen's d
with service providers.														
	'Please indicate how comfortable you are to share farm input data such as fertiliser and pesticide applications with the public sector (FOAG, cantonal administration).'		29.6/ 26.8	22.7/ 22.6	26.0/ 29.0	16.4/ 13.9	4.6/ 6.2	302	2.43	540	2.49	−.68	.50	−.05
	'Please indicate how comfortable you are to share production data with service or technology providers.'		21.4/ 28.6	30.3/ 28.6	27.6/ 28.3	18.8/ 11.3	1.3/ 1.6	302	2.48	540	2.28	2.68	.01	.19
	'Please indicate how comfortable you are to share production data with the public sector (FOAG, cantonal administration).'		24.7/ 26.6	26.6/ 22.4	25.3/ 30.5	20.1/ 14.2	3.0/ 4.4	303	2.50	538	2.46	.43	.67	.04
To examine producers' attitude towards central data storage.	'To what extent do you agree to your data being stored centrally on a server?'	1 = Not agree at all 5 = Extremely agree	20.7/ 34.5	24.0/ 23.4	32.9/ 29.0	16.8/ 8.9	4.9/ 2.6	302	2.61	539	2.20	5.07	.00	.37

parties, as data sharing with the federal government (e-government) is mandatory for receiving direct payments and is therefore already adopted by almost all farmers (Reissig et al., 2022).

5.2. Understanding of terms and conditions of data regulations (social perspective) and data access

As we are dealing with the issue of data sharing of agricultural data in this thesis, we explore participants' understanding of the terms and conditions of data regulations. Of the participants collecting digital agricultural data in the current study, almost 40% did not know much about the terms and conditions of the data contracts they enter with digital farming, while about 60% of those not collecting operating data responded in the same way (Table 3). This finding indicates that farmers may choose not to collect data because they feel poorly informed about the terms and conditions, or they only read the terms and conditions if they agree to collect data. Furthermore, Swiss farmers who do not collect data may be unaware of the rights they have in terms of data ownership, which could contribute to their reluctance in using digital farm technologies and potential data sharing. However, of those who collect data, 35.6% felt well informed about their agreements with third parties, showing that dealing with digital technologies, or information through technology providers, led to a better dispute with the terms and conditions of the agricultural data contracts, thus suggesting that information could potentially help to build trust in this concern (Table 3). The low rates of trust in data sharing with service or technology providers reported in our findings were not surprising and are in line with the results of Castle et al. (2016).

5.3. Concerns regarding challenges and opportunities facing data sharing of farmers (ethical and economic perspective)

Having established where farmers in Switzerland stand in terms of digitization and data use, and knowing more about their knowledge of the conditions for data sharing, we now take a look at the challenges and opportunities of data sharing in line with the RRI framework used. We found that although farmers are reluctant in the transformation towards a digital farming environment, generally they do not appear restrained by a lack of interest. Poor information on the terms and conditions can partly explain the concerns that farmers have about data sharing. Currently, technology providers need the farmers' consent to use and process their agricultural data. This consent, which is usually well hidden in the terms and conditions of a contract and not negotiable, is easy to get. The problem is that this consent does nothing to protect the farmer, but it protects the company from potential legal issues (Albrechts, 2014).

Our results also show that Swiss farmers are reluctant to share their agricultural data, which manifests itself also in their willingness to pay more for agricultural equipment that allows them to retain ownership over their agricultural data in 50% of the surveyed farmers; furthermore, only 20% agree with the idea of paying less for the technology and making their data available in return, i.e. paying with the data. An awareness about the value of the data also becomes visible here. With the realisation of the value of their agricultural data, farmers have the knowledge to claim the monetary advantage of the data for themselves, as in general considerations of digitalisation, data are described pictorially as 'data is the new oil' and 'who has no data has no oil' (Bernet, 2017). The majority of our survey respondents weighted the value of their data higher than the value they generate through price reductions on technological products. This is in contrast to results of the digital industry association's survey of German farmers (Rohleder and Meinel, 2022), in which the authors showed that farmers are willing to share their data when there is a tangible not only monetary benefit, such as easing the administrative burden.

It is also interesting to note that almost half of these farmers would share their data in return for financial compensation (Rohleder and Meinel, 2022), contrary to Swiss farmers. Sharing data is also sharing knowledge and gives others an advantage that previously was perhaps held in confidence. This is in line with the findings of Brown et al. (2022), who discussed that sharing data could put farmers at risk of

Table 5
Correlations between concerns and willingness to share agricultural data and phase of digitalisation on the farm ($N = 938$), with asterisks indicating the level of significance (*: $p \leq 0.05$; **: $p \leq 0.01$).

Measure	Question	1	2	3	4	5	6	7	8	9	10	11	12
Phase of digitalisation on the farm	**1.** Phase of Digitalisation	–											
Terms and conditions	**2.** "For tools (such as machines and apps) used to collect on-farm data, how much do you know about the terms and conditions relating to data collection in your agreement with the service providers?"	.314**	–										
Data access	**3.** "For any of on-farm data collected, how comfortable are you if the service/technology providers (such as John Deere or a weather station provider) have direct access to your data through the services they provide you?"	.174**	.232**	–									
Profit making	**4.** "If the service/technology providers had direct access to their client's data including yours, how comfortable are you if they use the data to make profit for themselves?"	.104**	.151**	.699**	–								
	5. "I agree to pay more for the service or technology in exchange for retaining the rights over my operational data myself."	.138**	.175**	.084*	.02	–							
	6. "I agree that the service providers/technology providers use my operational data and in return I have less costs for the service or technology."	.126**	.102**	.469**	.457**	.128**	–						
Data privacy	**7.** "If the service/technology providers have direct access to your data, how much do you trust them to maintain the privacy of your farm data?"	.194**	.141**	.488**	.430**	.141**	.422**	–					
Third-party data sharing	**8.** "If the service/technology providers have direct access to your data, how much do you trust them not to share the data with third parties?"	.165**	.160**	.487**	.458**	.125**	.397**	.883**	–				
Willingness to share agricultural data	**9.** "Please indicate how comfortable you are to share farm input data such as fertilizers and pesticides application with technology and service providers?"	.06	.102**	.514**	.456**	.097**	.521**	.425**	.426**	–			
	10. "Please indicate how comfortable you are to share farm input data such as fertilizers and pesticides application with public sector (OLAG, cantonal administration)?"	.096**	.135**	.320**	.291**	.142**	.292**	.310**	.316**	.583**	–		
	11. "Please indicate how comfortable you are to share production data with technology and service providers?"	.129**	.120**	.553**	.489**	.133**	.527**	.501**	.509**	.711**	.585**	–	
	12. "Please indicate how comfortable you are to share production data with with public sector (OLAG, cantonal administration)?"	.105**	.122**	.359**	.317**	.169**	.328**	.358**	.358**	.533**	.824**	.625**	–
Storage	**13.** "To what extent do they agree to their data being stored centrally on a server?"	.201**	.186**	.460**	.397**	.166**	.414**	.537**	.518**	.468**	.538**	.546**	.592**

losing their competitive advantage if others were to use their innovative methods or trade secrets. This might explain the reluctance of farmers to share their data. In the end, the question addressed by Zhang et al. (2021) is: Who benefits from the data? If the farmers do not consider themselves a beneficiary, they are less willing to share their data, as Zhang et al.'s (2021) results show.

Our research has already shown that Swiss farmers are partially aware that the data they collect are of value. In contrast, when it comes to contracting with private companies for agricultural technologies, their perception of the value of the data does not seem to matter, and farmers sign the terms and conditions. We can conclude that the existing knowledge is not being applied, because they are in a stalemate as adoption and use of the new technologies is not possible without acceptance of the terms and conditions. In order to retain data sovereignty, the only option currently available is to refrain from using the technology. The willingness to share data therefore determines the farmers' possibility to adopt new digital farming technologies. This is consistent with the findings of Zhang et al. (2021), who concluded from their study on Australian farmers, that success of big data applications in agriculture depends on farmers' willingness to share their farm data. Our data also show that Swiss farmers currently have little trust in service or technology providers, and the majority did not trust companies in not sharing their data with third parties. McFadden et al. (2022) addressed further issues concerning the lack of trust that included problems of data privacy, security, and confidence in data sharing. The authors hypothesised that mistrust can be a barrier for adoption of innovative technologies and proposed strategies to help governments bridge this trust issue. Similar conclusions have been drawn in relation to Australian producers and growers. Wiseman et al. (2019b) described this lack of trust as 'hardly surprising', while addressing the legal relationships in digital farming. Unfortunately, this lack of trust increases the reluctance of farmers to share their data and even more noticeably may explain the low adoption rate of digital technologies in Switzerland (Ammann et al., 2022; Groher et al., 2020; Groher et al., 2020) see also section 4.1, state of digitalisation). Farmers are at risk of any errors in their work becoming visible and traceable in their data, implying that checking on their work becomes easier, which can pose a risk to the farmer. This point also explains the reluctance of farmers to share data with governmental organisations, even though they usually share their data with them in order to receive direct payments.

This could indicate that farmers are concerned their agricultural data can be used against them, e.g., for control mechanisms; moreover, the farmer cannot anticipate the future consequences of data sharing with industry partners. Against the backdrop of the research of Forney and Epiney (2022), this is not surprising. The authors discuss the growing agri-environmental monitoring through the development of digital tools and conclude that '[t]he digitization of agri-environmental governance is guided by interests other than those of the farmers.' Our results refer to the awareness of Swiss farmers of this transformation in the system of governance through data, pointed out by Forney and Epiney (2022).

At the intersection of government data and private enterprise, there is one notable project. The Swiss Confederation has implemented a scheme which allows federal data sharing with third parties, under the condition of the farmers' informed consent (MAF programme). The first experience with this system is in line with our findings, as on average about 20% of farmers would agree to federal data sharing in the MAF programme (personal communication, B. Gade, FOAG, Switzerland). We conclude that the level of communication had a strong influence on the farmers' willingness to take part in the MAF programme (no communication: 1% agreement to data sharing, moderate communication: 15% agreement to data sharing, persuasive communication: 28% agreement to data sharing; personal communication, B. Gade, FOAG, Switzerland). It is therefore important to consider how Swiss farmers' willingness in data sharing can be increased. On the other hand, theoretically, this tool can also be used in the future to pass on high-quality governmental data, currently demanded by many private companies through separate tools.

It is interesting to know that despite a commitment to Swissness, i.e. keeping data on Swiss servers, a public–private Swiss farm management system provides data to Germany under the protection of German data privacy laws (Barto, 2021). In addition, limitations are placed on performance of the platform, loss of functionality or loss of data (Barto, 2021). This emphasises that the terms and conditions have the exclusive function to waive rights from the producer and protect the company from any responsibility. Barto attained a voluntary privacy certification for their software through a third party (SQS Switzerland, 2018), which emphasises that data privacy is a recognized issue, but also that its regulation is unclear and that shifting responsibilities to external parties may present a way to deal with the issue. The digital technologies in agriculture consequently raise the question of data storage and accessibility, mentioned previously by Jakku et al. (2018) as technical risks of digital farming. The farmers in our sample were mainly not comfortable with central data storage. This raises the question of the technical need for central storage of farming data by the agricultural industry enterprises or distributed solutions. A conflict of interest emerges where farmers wish to have this very convenient solution but simultaneously prefer to maintain the autonomy to their data.

Significant concerns have been identified about agricultural data security as more and more digital farming technologies have been adopted across farming communities (Mutschler, 2018). To address any potential concerns raised by possible data breaches, Swiss farmers are therefore recommended to ensure that agricultural data are stored on Swiss, or at least on EU-based servers (personal communication, S. Eberle, Agroscope, Switzerland), so that they are covered by national law.

While privacy laws currently focus their protection on personal information and personal data, it remains unresolved whether agricultural data, even when linked via GPS to an individual farm, will ever be considered the subject of personal data or information eligible to be protected under privacy regimes. Placing the burden on Swiss farmers to pursue a remedy against agricultural technology providers under privacy regimes would impose not only a time burden but also a heavy financial liability on farmers, with potentially little chance of success. Data privacy is not widely discussed among the agricultural industry, despite being extremely relevant. On the other hand, our results show that farmers indeed think about privacy concerns.

This willingness to share agricultural data is compromised twofold: on the one hand in the individual farmer, including his or her personality and experiences of farmers with privacy elapse, and on the other hand in the external situation, including practices of technology enterprises, missing legal and regulatory protections and the one-sided terms and conditions of data contracts.

Direct access of farm data by technology providers makes 24.5% of those farmers using the technology uncomfortable, while 42.4% of those not collecting data did not appreciate this idea at all. The response reflects the mistrust toward technology providers and shows that although Swiss farmers are open to the idea of digitalisation in general, they are not comfortable with the idea of sharing their data with companies (see previous section).

5.4. Actions required with regard to usage of agricultural data in Switzerland through exchange with policy makers and evaluation of industry standards

Looking through the lens of responsible research and innovation and considering the impacts, transparency about the terms and conditions that regulate agricultural data sharing could be achieved by a more open approach to entering contractual agreements. Such transparency would be particularly important in relationships of unequal power, discussed by (Zscheischler et al., 2022) as exemplified by the vastly different contracting positions of farmers and agricultural technology providers.

However, van der Burg et al. (2021) recently pointed out that such contracts can only foster trust if they consider the aspects that leverage

the party of lower power in a position, where the farmer is fully informed while entering into the contract by mainly clicking agree or turning on machinery. As such, the information needs to be comprehensive, understandable and adequately tailored to the needs of the contracting parties. This gained knowledge creates power, and accordingly, missing information presents one of the main barriers for technology adoption and innovation. Farmers are therefore in need of education about the range of issues raised by data collection, management and sharing. We suggest that agricultural technology providers and companies as well as government bodies that engage with Swiss farmers regarding data sharing should pay close attention to the need to address these issues when contracting with farmers. It is only then that farmers may develop more understanding and confidence in the adoption and uptake of digital technologies on their farms.

Zhang et al. (2021) referred to the missing discourse on the value proposition of agricultural big data from the farmers' perspective, and how this affects farmers' willingness to share on-farm input and output data. What is needed is discourse on the value, the owner, the regulation of agricultural data from the perspective of and roles of the various stakeholders.

Even though our survey suggests that Swiss farmers already understand the value of their data, it's important to remember that, the objective value of agricultural data in Switzerland remains unclear, as they will have different value according to the purchasing party and its purpose. Research with Irish farmers referred to the data sharing for the common good (Brown et al., 2022). The fact that agricultural data can be a common good and not a private good must be taken into account when regulating the handling of data.

Further actions required in the future are addressed in the conclusion.

5.5. Limitations and future research

Although the current study gives new and valuable insights, we would like to address limitations of the study. Some questions of the questionnaire could have been more precise. We asked few questions on the data shared with governmental institutions via digital tools and focussed on data shared with private companies in our survey, protected via contractual terms and conditions. After we have seen in this analysis that data perception by farmers is a huge issue and that the results indicate that the evaluation of data also influences the decision to use digital technologies or not, it is advisable in a next step to survey this by means of a questionnaire that specifically collects the other variables influencing this decision.

However, our research highlighted the structural and legal difference between data sharing with governmental institutions and private companies. We propose that future research should assess if the farmers know about these differences and whether this awareness is reflected in their trust in data security but also in their willingness to share their data or use new digital technologies.

Further research is needed to address how agricultural data in Switzerland are valued, given that it would be possible, in certain circumstances, to ascertain the value of a farm from these data, which would in turn potentially reveal sensitive information about the farm such as farm value and income. Furthermore, detailed knowledge about contractual terms and conditions and the server infrastructure is needed to understand the complex regulation of agricultural data (Klerkx et al., 2019). Additionally, we propose using a socio-cyber-physical framework introduced by Rijswijk et al. (2021) to better understand who is responsible or accountable for the identified impacts (positive or negative), like in this paper, i.e. accountability in the adoption of digital technologies in agriculture.

6. Conclusion

The increasing availability and usability of data in agriculture leads to new potentials in economical, ecological, labour, social and regulatory perspectives, yet there are also very good reasons not to share agricultural data. This paper highlights the Swiss small-scale farmers' perceptions of agricultural data and links them to the regulations and frameworks around digital farming and digital technology. Establishing trust with regard to agricultural data is the foundation for the application of any digital farming technology. While industry partners (including certified label organisations) are interested in selling their products, and federal institutions have a controlling interest in relation to agricultural data, farmers tend to be reluctant to share data with these parties, which has been confirmed in our results. Data transport information that was previously solely in the purview of farmers, and many treat this as their confidential information, whereas this information and thus values are now shared. Farmers share mandatory data with the government. This sharing works and is strictly regulated. Currently, farmers feel that they bear too much of the risk and vulnerability and do not benefit from the rewards that digital farming brings. As data are described as the new oil in today's world, it is also necessary to enable farmers to use the data, to have control over them and to profit from them. As the results of our study show, the legal regulation for agricultural data has not clearly been stipulated so far, and there is insufficient knowledge about it among farmers.

Until the legal and regulatory dimensions of the socio-technical big data discussion taking place in digital farming are addressed, Swiss farmers will continue to be reluctant with sharing data and implementing digital technologies. The lack of clear regulation and EU harmonisation regarding agricultural data tends to promote legal uncertainty, but maybe even more importantly, it puts third parties in a position of power with respect to their contractual negotiations with farmers. Laws are mostly national whereas companies operate internationally and globally and thus also the paths of the data. Furthermore, the power asymmetry is highlighted even more when all technology providers have access to lawyers and legal advice, whereas farmers have little or no legal support. Swiss farmers have no advocate for their rights, and no one feels responsible to take on this role. We believe it is urgently required to address the problematic fact that there is a gap between the extensive data protection rules for public institutions such as governments on the one hand and, on the other hand, far less stringent data protection rules for private-sector companies. To this end, considering the current complex data licences presented to farmers on the governmental and private side on a 'take it or leave it' basis, we recommend the following to stakeholders:

If data are to be shared, it is essential to ensure that the terms of data licences are understandable, transparent and accessible to farmers. To do this, it is necessary for regulators to turn their attention to the complex and lengthy data licences that are presented to farmers who adopt smart farming technologies. By recognising the power asymmetry that exists between private-sector companies involved in smart farming technologies, regulators could require that a simple one-page, clearly written summary of the key terms that address and regulate data access, data sharing, beneficiaries and privacy concerns be made available by the service providers. This could be available on their websites or data products so that farmers could see and read their data terms well before entering into data contracts with that service provider. Requiring this type of mandatory disclosure around data sharing approaches, would not only require service providers to articulate clearly with whom and when farmers' data would be shared but this would also serve to provide a source of disclosure which would educate farmers about different data sharing approaches being taken by different service providers prior to entry into contracts. This mandatory disclosure requirement would help to build a better culture around farm data management and governance, which in turn would build knowledge, through education and raising awareness, within Swiss agricultural stakeholder communities. The issues arising through the collection, control, sharing and usage of agricultural data can then become part of a broader dialogue around the values and challenges of data, which are fundamentally important to

ensure better data management practices. Furthermore, concerning the obligatory data exchange with the government, transparency would amplify trust of farmers. As Wiseman et al. (2019b) recommended, these concerns are best addressed through open and transparent governance frameworks that are implemented without exception through the agricultural industries and governments.

Not least because '[t]echnology innovates faster than the regulatory system can adapt' (Charo, 2015, p. 384), we should do everything possible to ensure that farmers can make informed decisions. Requiring better disclosure by service providers around their data sharing terms is an important first step, which can then be supported by accessible resources around best practice in agricultural data sharing. In addition, independent advisors could also offer to educate farmers about their data rights and, more importantly, present how sharing their agricultural data with third parties could help their productivity. To date, such frameworks have not been developed in Switzerland. This is partly due to the expertise required to advise farmers in such a novel, uncertain and constantly developing environment.

Mandatory codes of conduct laying out guidance about best practice in relation to the collection and management of agricultural data would assist both the data aggregator and the farmers to develop a better understanding of how the agricultural data will be managed. However, given these agricultural codes of conduct are voluntary, they have been somewhat limited in their effectiveness in achieving more transparency about the terms governing data sharing (Wiseman and Sanderson, 2017).

By opening the discussion, technology providers, stakeholders and researchers can bring forward their intentions and develop the best way to increase benefit and reduce risks. The different actors (farmers, advisors, policy makers, researchers) need to be supported in their reflexivity about the implications, as pointed out by Klerkx et al. (2019). One way to proceed would be to adopt the approach introduced by Ehlers et al. (2021), namely by adapting the Swiss direct payment system to directly using digital farming data for result-based subsidies, thus promoting a more rewarding direct payment system and giving the farmer greater incentives for both data sharing and highly regarded agricultural production.

When thinking about data in Swiss agriculture and the perceptions by farmers and legal regulators, power imbalances inevitably become visible. An imbalance of power exists between farmers and industry and between farmers and the government because of the requirement of sharing agricultural data in order to use digital farming technology and to receive direct payments via e-government tools (Reissig et al., 2022). However, these data are used for matters serving the common good, such as soil protection and animal welfare. Sustainable agriculture that can fulfil its various roles, such as food security, landscape conservation, environmental preservation and rural revitalisation, needs to develop a strategy to deal with power imbalances exacerbated by data use.

The governmental attitude is that technological innovation in agriculture should not be hindered by regulation, including the area of data protection. Since this clearly leads to an imbalance of power, as shown in this research, and consequently hinders the use of technological innovations in agriculture, we are clearly in favour of regulating the exchange of agricultural data with technology companies as strictly as the exchange with government institutions. In addition, technology providers should be required to disclose what data is used and how it is used, and this data should be stored on servers at least within the European Union. Even if the question of whether agricultural data is personal data is an unregulated area that needs to be regulated, this data is data of general interest, even if it is not personal, and therefore needs special protection.

Finally, the sense of responsibility of different stakeholders in the establishment of digitalisation in agriculture remains to be emphasized. This study provides ideas on responsible data sharing and data regulation in agriculture.

CRediT authorship contribution statement

Linda Reissig: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Leanne Wiseman:** Writing – review & editing, Writing – original draft, Conceptualization. **Marianne Cockburn:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of Competing interest

The authors declare no conflict of interest.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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