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The Role of Privacy in Digitalization – Analyzing Perspectives of German Farmers

Abstract: Technological progress can disrupt domains and change the way we work and collaborate. This paper presents a qualitative study with 52 German farmers that investigates the impact of the ongoing digitalization process in agriculture and discusses the implications for privacy research. As in other domains, the introduction of digital tools and services leads to the data itself becoming a resource. Sharing this data with products along the supply chain is favored by retailers and consumers, who benefit from traceability through transparency. However, transparency can pose a privacy risk. Having insight into the business data of others along the supply chain provides an advantage in terms of market position. This is particularly true in agriculture, where there is already a significant imbalance of power between actors. A multitude of small and medium-sized farming businesses are opposed by large upstream and downstream players that drive technological innovation. Further weakening the market position of farmers could lead to severe consequences for the entire sector. We found that on the one hand, privacy behaviors are affected by adoption of digitalization, and on the other hand, privacy itself influences adoption of digital tools. Our study sheds light on the emerging challenges for farmers and the role of privacy in the process of digitalization in agriculture.

Keywords: digitalization, privacy, agriculture

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1 Introduction

Digitalization in agriculture is a process with very heterogeneous implementations by different actors. This makes this domain an interesting field of investigation in terms of the extent to which certain factors influence the adoption of digitalization. According to Gandorfer et al. [18], privacy is a factor that tends to slow the process of digitalization. The processing and exchange of data is a key element of digitalization, but not everyone is in favor of this development. Nevertheless, agriculture is an economic domain that relies heavily on the division of labor and collaboration [4]. Farmers usually cannot grow crops or breed cattle on their own. Multiple actors are involved in the whole process, from planning a season to delivering products to retailers. For these cooperations to function smoothly in times of digitalization, it is necessary to share data in order to be able to plan the individual production steps effectively.

Since data exchange is a major issue, privacy concerns are raised and trade-offs are necessary: High-tech machines can help to save resources and protect the environment, but they require comprehensive and processed data. This data is generated from a variety of information sources and is more useful the more information is available. However, at the same time, this availability can also be a problem: If farmers disclose too much information to their business partners, they run the risk of being put at a competitive disadvantage by individualized prices. Such fears paralyze enthusiasm for digitalization, especially if data flows and purposes are not clearly communicated and contractually secured. To find out how the heterogeneous adoption status and the long duration of the digitalization process in agriculture are influenced by data protection aspects and how digitalization affects the work processes of stakeholders, we conducted an empirical study to answer the following research question:

> **How does privacy affect the adoption of digital technology in agriculture?**

This paper is structured as follows: Section 2 presents the background and related work of digitalization and privacy in agriculture, as well as the research gap. Building on this, section 3 describes our methods, the participants involved in our study, the study design, and the data analysis. Section 4 presents the results of our empirical study, including the attitudes and concerns of the farmers. Based on our findings, section 5 discusses our results with reference to our research question. Sec-

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tion 6 concludes our study by recapitulating the main findings.

2 Background and Related Work

This section provides a brief overview of the context of our study: digitalization in agriculture. Although this paper focuses on privacy for and perceptions of farmers, background information on digitalization in general is helpful to understand the statements of the study participants in this context.

Even though the digitalization of agricultural processes is not a new idea, it is an ongoing development, especially in relation to the current introduction of modern concepts such as IoT or big data in this field [26, 43]. In this context, data privacy appears to be an important factor in the adoption of new digital technology [1, 12, 28]. However, studies conclude that digitalization in agriculture is lagging behind expectations [18]. Accordingly, other domains are more advanced in the integration of business models and processes. In the following section, we will summarize recent developments in the field of digitalization in agriculture (2.1), also called Smart Farming or Precision Agriculture, to provide context for the reader. We will then focus specifically on privacy and data ownership issues (2.2). Futhermore, we will discuss the role of user perceptions in relation to data privacy (2.3). The section concludes by identifying a research gap that our study addresses (2.4).

2.1 Background on Digitalization in Agriculture

Several benefits of digitalized agriculture are mentioned in previous research: First, it improves traceability. Retailers could offer their customers information about the origin of their crops. This could prevent or limit food scandals even more efficiently. One example from research Kamath [22] suggests that better traceability may simplify countermeasures during food contamination scandals. Here, the author refers to two food scandals, in 2006 in the U.S. and 2011 in China, where contaminated products from a single farm damaged the image of the entire sector due to a lack of traceability. In this context, a blockchain-based approach is presented to enable transparency and traceability in agriculture. Similar approaches to this objective exist in further research [2, 19].

Second, digitalized agricultural machinery and equipment could also bring monetary benefits. So-called smart farming approaches promise to increase efficiency and effectiveness [44, 45] through precise maneuvering and application of seeds, fertilizer, and other resources. Taking advantage of these benefits can save time and financial resources. Elijah et al. [10] also see the benefits of IoT in reducing needed resources while feeding a growing population. Rosskopf and Wagner [37] conducted annual studies from 2002 to 2005 to investigate the usage of computers and electronic devices in German agriculture. Main challenges were lack of understanding of computers and time spent without perceived benefits. In 2017 Gandorfer et al. [18] confirmed these findings and stated that privacy is a particularly relevant issue.

Third, the precise application of agents and better calculation based on sensor data could reduce pesticide contamination and thus environmental pollution. As early as 2007, Pinaki and Tewari [34] show in their review of trends in precision farming that there is enormous potential for environmentally sustainable agriculture, an argument which Finger et al. [13] also provide. A meta-study of energy use in precision farming is provided by Pelletier et al. [32]. The authors compare different approaches and sub-domains, such as livestock or crop production.

2.2 Privacy in Digitalized Agriculture

The adoption of digital tools is closely linked to the handling of data, which makes privacy an important factor. Shepherd et al. [39] approach the topic of digitalized agriculture from a socio-ethical perspective: They point out that digitalization in agriculture could help feed the growing population, but success depends on business models that can ensure data privacy and security. The desired increase in agricultural efficiency depends on the establishment of new technologies such as IoT and data analytics in agriculture. The need for security and privacy as well as data ownership is also emphasized by Elijah et al. [10]. In addition to general security issues in the IoT world, agricultural IoT devices are also vulnerable to physical tampering, such as theft or animals attacks. Looking at the cloud-based backend infrastructure, successful attacks can lead to unauthorized data access. The problem of data privacy is not exclusive to agriculture. Privacy and secure data processing are also important in other areas where IoT is used to prevent de-anonymization or re-identification of individuals [30].

The increasing impact of aggregated and processed data on agriculture is highlighted by Sykuta [42]. The author proclaims principles of big data for agriculture and mentions privacy as an issue. Nery et al. [31] name knowledge engineering as a proposed solution. The authors point out challenges such as the semantic gap, dealing with spatial and temporal information, and correlation issues. Fleming et al. [14] present perspectives of the industry with a focus on big data. The authors note the need to address issues such as trust, equity, distribution of benefits, or access.

Research also focuses on different countries and their attitudes toward digitalization: Specific drivers for digitalization in Australian agriculture are presented by Zhang et al. [46]. The authors interviewed 1,000 Australian farmers from 17 subsectors about their expectations and needs regarding digital agriculture. One striking finding was that the majority of farmers were highly critical of various data assets and wanted more privacy, but were still keen to share data with other stakeholders in agriculture, such as big companies. Fountas et al. [15] asked 198 farmers in the U.S. and Denmark about their attitude towards precision agriculture. They found that the main problem was too time-consuming data handling and that 80% of farmers wanted to store their data themselves. Carbonell [5] sees power asymmetry between farmers and agribusinesses as a problem. The author calls for open source tools and open data for a fairer use of big data. An overview of the adoption of digital tools in agriculture in different EU countries is provided by the study of Kernecker et al. [23]. A total of 287 participants from seven countries participated in this study. It revealed that farmers wanted more instructions and security. It also became clear that most farmers with more than 500 ha land run fully digitalized businesses. Especially the smaller farms still lack digitalization.

The fact that small enterprises in particular lack digitalization has also been concluded by Regan et al. [35]. As an example, the authors refer to agriculture in Ireland, which consists mostly of family-run farms. They present an interesting view on data ownership and maintaining privacy for farmers. The researchers found a general distrust towards companies, but a very open attitude towards actors with whom the farmers had longstanding partnerships. The authors assume that the reason for this is the family-owned business model. This theory is supported by the work of Cravotta and Grottke [8]. They conducted a study that highlights the tendency of family-run enterprises to favor old-fashioned over innovative solutions. In Germany the demographic situation is similar, as shown by federal statistics [41]: The majority of farmers cultivate less than 200 ha of land. This circumstance makes it worth investigating whether small and medium-sized enterprises (SMEs) in particular are lagging behind in digitalization and whether the lack of viable privacy solutions is a reason for this. For the purpose of this paper, we use the definition of the European Union when referring to SMEs[1].

Furthermore, previous work has outlined that access to corporate data is an existential problem for farmers, as noted by Fraser [16]. Increasing "data grab" can lead to "land grab". Once companies have access to the business data, they can easily overtake the farm. By acquiring many smaller farms, companies can manage large scaled agricultural businesses with the data they obtained from former owners. With less effort, the companies are able to gain much more profit from the land than many small farms before. Ferris [12] sees opportunities in precision agriculture, but also dangers arising from the massive collection of data: Exposure of personal data, income, or yield of the fields. The author states that farmers fear disadvantages if this data is accessible for their competitors. Therefore, the author calls for the need for governmental regulation.

2.3 The Influence of Users' Perception on Privacy Preferences

The previous section has shown that privacy is an important issue that requires specialized techniques to protect end-user data. However, when developing privacy-enhancing solutions for specific use cases, it is necessary to investigate the behavior and preferences of the target audience. Not only privacy and security behavior [3], but also user perception and reality often differ, as research in other domains shows:

Malkin et al. [27] investigated the perception of users with regard to smart speakers and found serious misconceptions. About half of the participants were unaware that smart speaker recordings are permanently stored. Furthermore, most users were not familiar with the available privacy functions. 23,8% plan to use them in the future. Users' perceptions of smart home technology were studied by Zimmermann et al. [47]. The

1 https://ec.europa.eu/growth/smes/sme-definition_en, based on headcount (micro $<$ 10, small $<$ 50, medium $<$ 250) and turnover (micro $\leq$ 2 million €, small $\leq$ 10 million €, medium $\leq$ 50 million €) of the enterprises

researchers conducted 42 semi-structured qualitative interviews with inexperienced users of smart home technology and found that users not only fear attacks, but also feel they are losing control. Another example of differences between the mental model of users and real-world technology was found by Han et al. [20]. Their study examined the differences between free apps and their paid versions. After assessing which mental model the users had regarding these apps, the researchers found that only 3,7% of the 5877 pairs of apps had significant differences in their use of permissions and data usage. This contradicted most users' impression that paid apps were more privacy protective than free versions. Reasons for specific perceptions regarding privacy and digital tools were investigated by Smullen et al. [40], who found that users' preferences are related to a specific purpose. Coopamootoo and Groß [6] found that privacy preferences and willingness to share data are based on a person's personality. The researchers identified specific personality traits and their influence on attitude towards privacy. However, these approaches focus on the private individual and their use of technology in their everyday lives. Considering that digitalization affects the business aspects of peoples' lives, it has to be expected that factors other than personality are key to understanding the motivation to adopt or not to adopt. Career implications must also be considered. An approach that considers these perceived negative consequences of online tracking was conducted by Melicher et al. [28]. The qualitative interviews showed that users are distrustful of tools in the context of tracking and fear risks such as price discrimination. Although this addressed a monetary factor that influences privacy attitudes, the impact of tracking on individuals is less severe than in a business context.

2.4 Research Gap

In the previous sections, we presented the state of research on digitalization in agriculture and the role of privacy. Agriculture relies on the division of labor and therefore the sharing of operational data [4]. Additionally, farmers have reporting obligations to authorities and retailers strive for transparency to provide traceability to their customers. While most of the privacy research mentioned focuses on the issue of privacy in consumer applications, the implications of digitalized tools and data collection in a commercial context need to be considered as well. In a context where the disclosure of proprietary or sensitive data can lead to financial damage or competitive disadvantages for a business, privacy considerations take on great importance. One industry that is particularly vulnerable to these risks is agriculture. This results from multi-actor supply chains and high demands for transparency and traceability from both commercial and governmental sides. While many studies exist on the establishment of digital tools for transparency [2, 19, 22], few examine farmers' perception and their roles in the transforming domain of agriculture. While the aforementioned study by Zhang et al. [46] provides some insight into the situation in Australia, it also raises new questions: Why are farmers willing to share their data with third parties when they actually consider it critical in principle? Is this related to the specific economic circumstances in Australia, or does it result from a misconception of privacy, as studies in other areas suggest (see [20, 27])? In terms of structural reasons, Kernecker et al. [23] show for Europe that digital tools are less adopted by smaller enterprises. However, their sample for Germany consists mostly of larger farms, while the agricultural sector in Germany is predominantly characterized by small farm structures. Hassan et al. [21] demonstrate that the decisions of German SMEs to adopt cloud computing are influenced not only by their perceptions of usefulness, security aspects, and the implementation costs, but also by the internal capabilities of an SME. Moreover, the main drivers of technological innovation are larger companies upstream and downstream in the supply chain. Therefore, the incentives for new technologies come from actors with a significantly stronger market position than SME farmers. This creates an imbalance of power and leaves the perspectives of farmers underrepresented. Considering this situation, where SMEs predominate in the middle of the agricultural supply chain, the perceptions of farmers could provide valuable insights into the challenges and barriers to digitalization adoption, and thus privacy attitudes across this sector.

To conclude: To our knowledge, a study with German SMEs in agriculture with a focus on perceived privacy and their experiences with digitalization is currently both entirely lacking and urgently needed. The contribution of this paper is to provide information about farmers' views on the issues of digitalization and privacy. Further, we elaborate how these aspects correspond to the adoption of new technologies. This provides a broad information basis for future studies and allows to address these topics appropriately, taking into account the subjective perspective of farmers.

3 Method

Our study aims to find privacy-related issues and obstacles in the adoption of digitalization in agriculture. In the context of this paper, the notion of privacy is not limited to the field of private data, but is extended to the usage for operational data owned by individuals. In this section, we present our overall methodology to address our research question, as mentioned in section 1, as well as the design and conduction of the actual study.

3.1 Participants

We conducted a qualitative study with 52 participants from agricultural businesses. The study took place at the machinery ring[2] "Maschinen und Betriebshilfsring Rheinhessen-Nahe-Donnersberg", "John Deere European Technology Innovation Center (ETIC)" and "Hofgut Neumühle", a training and research farm. In preparation for the actual study, we consulted stakeholders from agriculture, such as farmers, machinery manufacturers, and representatives of farmers' associations, in regular meetings every 2 weeks for more than 8 months, and discussed typical work routines and technological innovations, as well as the challenges of data sharing in agriculture, the parties involved, and regulations. This helped in the preparation of the interview guidelines by pointing out relevant topics and potential conflicts in advance.

We are working in a publicly funded research project called HyServ with partners from the private sector, federal institutions, and associations for farmers, such as machinery rings. Their clients and members were invited to participate in our focus groups. Everyone participated voluntarily and no compensation was paid. Each participant was informed about the objectives and topics of the study via a informed consent form, which was signed by each person. On the advice of our project partners, we launched events for farmers to meet and exchange ideas and expertise or learn about new products and services offered by one of our project partners. In this way, we planned events that were conducted over five days. The first event was a collaboration with the machinery ring, the second with John Deere ETIC. With Hofgut Neumühle we held events on three days due to the high number of participants. During the events, the farmers had the opportunity to attend different program points. One was the focus group interview presented in this study, the second was an agronomy workshop, and the third was a presentation of a NIER-sensor for the analysis of liquid manure. Offering multiple program points increased the motivation to participate by providing a better cost-benefit ratio of travel and offered content. We interviewed the participants in focus groups of 3 to 6 people [24, 29] with a duration of 25 to 30 minutes. These focus groups were conducted by two of our researchers and explored the participants' experiences regarding digitalization and privacy in their systems. I this way, we were able to recruit 52 participants, who own family-run farms in south-western Germany, which can be considered as SMEs. This region is quite rural and has a long history of agriculture. Furthermore, the climate and soil in this region is suitable for viticulture, which allowed us to investigate this particular branch of agriculture.

Our aim was to involve participants at the decision-making levels. Therefore, each participant in our study owns or manages an agricultural business. Most of them run farms, but some also provide services to other farmers. Additionally to farmers, we interviewed one service provider who runs a soil laboratory for farmers and two representatives of the administration, including the head of the local machinery ring and a counselor from a federal administration. For further studies it would be interesting to approach stakeholders downstream or upstream the supply chain in order to broaden the perspective.

Seven of the participants identified themselves as female and 45 as male, thus the proportion of female participants is 13.5%. According to the 2016 Eurostat database, the overall gender ratio of agricultural workers in Germany was 32.4% female compared to 67.6% male at the date of the census. Nevertheless, as this paper focuses on the operational level of farm managers, the gender ratio of the survey is very similar to the gender ratio of 9.0% for female farm managers in Germany (see [11]).

We recruited most of the participants in the three events with Hofgut Neumühle through a nationwide advanced training institution for agriculture that offers different degrees for farmers after a few years of practical experience. In fact, it is mainly relatively young farm managers who attend this institution to further their education and skills. Therefore, these 42 participants are in the age segment between 20 and 30 years, which is why our study has a focus on the younger generation. However, all these participants grew up on farms and

2 Machinery rings are associations of farmers which organize collaborative work orders and the use of shared machinery

have been familiar with the daily work of a farmer since childhood. The rest of the participants were between 30 and 60 years old.

It should also be mentioned that all of the businesses surveyed were small and medium-sized enterprises. This is because most of the farms in this domain are family-run farms which are inherited over generations. Additionally, according to [8, 35], the adoption of digitalization is a major challenge, especially for SMEs, e.g., in raising equity capital for the adoption. Furthermore, Cravotta and Grottke [8] point to social reasons as challenges for family-run enterprises, such as focusing on owner vision rather than efficiency. This makes these businesses interesting for investigation of the role of privacy in their adoption decisions. For an overview of the fields of work of our participants, see Table 1.

Table 1. Branches the participants work in (multiple possible)

Branch			Amount
Cultivation of grain			22
Viticulture			3
Cultivation of vegetables			1
Husbandry	Beef raising	Dairy cattle	12
		Breeding	4
	Pig housing		4
	Laying hens		3
	Biogas production		3
Service provider			6

3.2 Study Design and Ethical Considerations

We interviewed the participants in focus groups [24, 29] because this gave them the opportunity to discuss among themselves as well. In our case, these discussions brought to light new aspects that might have remained undiscovered in individual interviews. All focus groups were led by two researchers to mitigate the likelihood of subjective bias. The entire process, including the creation of an interview guideline, recruitment, conduction of the focus groups, and data analysis and storage followed the guidelines of the Ethics Committee of the Technical University of Darmstadt.

The 52 participants in this study were interviewed in twelve sessions: For the first focus group, we consulted the local machinery ring. This way, it was possible to form an expert panel that included the head of the machinery ring, the soil laboratory owner, and the federal counselor. The aim was to conduct an exemplary focus group interview with them and to review and validate our interview guidelines with these domain experts. The second and third focus groups were conducted with the help of our project partner, John Deere ETIC, who invited customers to participate in the interview. The participants split into two groups, avoiding any (unconscious) bias by manually selecting participants. The remaining nine focus groups were conducted during the three events with Hofgut Neumühle. The participants were farm managers who took part in a federal graduation program to earn the title "state-recognized technician in the field of agriculture (German: Staatlich geprüfte(r) Techniker(in), Fachrichtung Landbau)". Again, the participants divided into groups to attend the different sessions of the event. In view of the limited time available for the interviews, we decided to outsource some background information into a survey in order to give more room for discussion in the focus groups. The survey was filled out before the focus groups and contained some general information about the branches they work in and their experience with digital tools.

In the focus groups, we asked about their understanding of digitalization, positive and negative aspects, fears, and (if not mentioned by themselves) questions regarding privacy and data ownership. It has to be noted that nearly all groups mentioned privacy aspects on their own initiative. Therefore, we conclude that it is an important issue worth investigating from their perspective as well.

We encouraged the participants to discuss freely about the topics we gave them. Nevertheless, we prepared some questions to give impulses to the discussion, mainly aimed at exploring the perception and state of digitalized agriculture within the focus groups, as the direct question about privacy is susceptible to the acquiescence bias:

- *What is your perception of digitalization in agriculture?*
- *Which digital tools or machines do you use?*
- *Does your farm have its own server or other network infrastructure?*
- *What are your experiences with digitalization in the daily work routine?*

3.3 Data Analysis

Data from the focus groups were obtained through audio recordings. Later, these recordings were transcribed

and anonymized for coding. We segmented the data into meaningful expressions using the open coding method [7]. We then grouped the codes into categories: digitalization in agriculture, privacy, and data ownership as an important aspect of privacy which was mentioned often. Based on this grouping, we were able to get an overview of all statements on the given topics. This allowed us to derive our results, which are presented in the following section. The categorization was performed by one of the researchers who conducted the focus groups. We decided to do so in order to ensure a homogeneous analysis of the data. To avoid subjective bias, the coding was reviewed by the second researcher who participated in the focus groups. The coding resulting from this process was then presented to the other authors. The recorded interviews are in German, however, we translated the statements as literally as possible into English..

In this paper, we refrain from disclosing the clear names of companies mentioned by the participants in order to guarantee a neutral perspective. These companies can be suppliers of agricultural machinery and equipment, e.g., tractors, irrigation systems, or soil sensors. They may also be contracting firms and suppliers of seeds, fertilizers, or animal feed.

4 Results of the Empirical Study

In this section, we present the results of the qualitative study. We derive general aspects of digitalization in agriculture, followed by a presentation of the interviewees' positions on privacy and data ownership in particular. We also present some direct citations of statements that expressed farmers' experiences in a concrete and precise way. In this section, citations refer only to the focus group (*fg*) in which they were mentioned in order to ensure the anonymity of the individuals. The quotes in this paper are numbered (e.g., *Q1*) for further reference in the discussion of the results.

4.1 Heterogeneous Levels of Experience and Dependencies on Digital Tools

This study found varying levels of decision-making regarding the adaptation of digital technology. Three branches stand out in terms of benefits and freedom of choice regarding adoption; they are provided as examples to illustrate potential differences: **cattle farms** that rely heavily on digitalization, **plant farms** that reported benefits of digitalization but do not necessarily need to take advantage of it, and **winery productions** that benefit the least from digitalization and therefore have the least motivation to use digitized tools. Reasons for this are highly heterogeneous levels of available technology to benefit from, the need for technology (e.g. milking robots), or legal requirements, such as animal welfare laws which require every affected farmer to provide emergency generators for ventilation systems or milking robots in order to ensure animal health.

Cattle farms rely on digital solutions, as they cannot maintain their operations without machines and robots. Dairy farms cannot guarantee the welfare of the animals without milking robots (fg8), as dairy cows need to be milked daily, otherwise they suffer from severe pain and poisoning that can lead to death. Without robots, this work would be impossible to accomplished, as it takes 30 minutes to milk a single cow manually. In breeding farms, it is necessary to install intelligent ventilation systems, as the evaporations of the animals would otherwise lead to suffocation. For this reason, farmers who raise animals are under legal obligation to possess generators to keep the machinery running in the event of a power outage.

Since cattle farms rely on the use of state-of-the-art technology, there is little inhibition to adapt to digitalization. Moreover, subjects reported additional optional advantages, such as digital automatic feeding machines, which allocate the optimal amount of nutrients to each individual animal and optimize the performance of the animals (fg11).

Plant production companies are representatives of businesses who do not necessarily rely on the use of high-tech machines and robots, but can rely on a wide range of digitized agricultural machinery and administrative tools. The focus groups in our study also report on the advantages they have experienced through the use of new technologies. These include, for example, agricultural machines that are automatically controlled by satellite signals and can seed fields by making the best use of land and resources. These machines are particularly suitable for angled fields (fg12). This form of precision agriculture is particularly useful in the context of legal requirements such as distance regulations that define zones where agricultural substances may not be used or regulations to protect groundwater and soil quality. In such cases, digitized machines help to apply resources precisely and use them optimally.

Winery productions are least affected by digitalization. Usually, production steps are carried out manually or with non-digitized mechanized equipment, be-

cause there are rarely any digitized machines for viticulture (fg2). Only logistics and administration can be optimized by digitalization, but the few advantages are hardly an incentive for winery productions to invest in it. Therefore, some wine producing companies do everything manually or handwritten and even without computers or other machines.

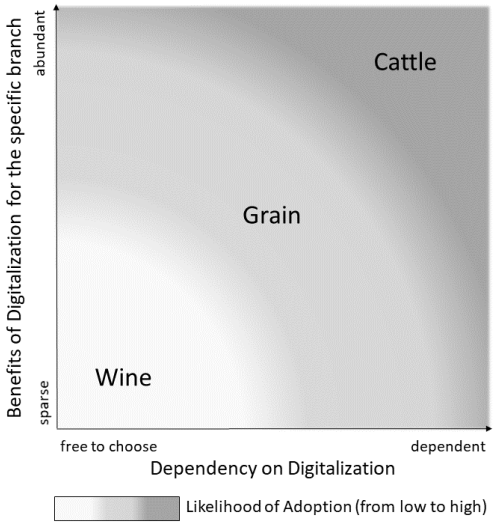

Fig. 1. Different agricultural subsectors and how they are affected by digitalization, influencing attitudes toward privacy and the likelihood of adopting new technologies

The fact that farmers differ in the way they are affected by digitalization influences their privacy behavior due to heterogeneous experience or external motivation to expose themselves and their businesses to digital services and privacy risks. In Figure 1, we have illustrated the three prominent agricultural branches of our study in relation to their dependency on digitalization and the benefits of technologies for their subdomain. This figure can be used to estimate the likelihood of adoption and thus exposure to privacy-related technologies of other subdomains.

4.2 Attitude towards Digitalization

To provide context for the privacy issues within agriculture, we will present some insights into the general attitudes of farmers towards digitalization in agriculture. Overall, interviewees displayed a balanced view on improvements within their field of work. However, we will elaborate more on the negative aspects, since these are more related to privacy concerns and impede digitalization. Regarding the production steps in the field, automated precision farming is evaluated as helpful for farming within complex field boundaries resulting from the small-scale and fragmented land structure in rural southwestern Germany (fg9), where the group interviews were conducted [9]. Not only is work on the fields affected, but office work is also transforming. Farmers already need to document their work in order to fulfill reporting duties towards authorities. This type of work can be done more efficiently with digitalized farm tools (fg8).

However, not all farmers were generally positive about digitalization and repeatedly mentioned arguments why digitalization is not adopted in all agricultural businesses. One argument is the high price, that is not yet affordable for owners of small and medium-sized enterprises (fg1). Farmers have to decide whether to adopt digital technologies, which ones to adapt and how this will influence their daily work routine (fg9).

> *Q1 (fg10): [...] it is my experience so far that we do not save any work, we just distribute it differently. And perhaps the documentation will then be more centralized, but the skill is to keep the overview*

Another topic that was addressed was that digitalization creates new dependencies. These mainly concerned the technical infrastructure and external services. This refers not only to support for the mechanical components, but also to software failures or mandatory internet connection which causes machines to exit automation mode. Farmers are only left with the option of restarting and hoping that the machine will work again. Otherwise, they have to lay down their work and wait for support services (fg4). The increased dependency on external services results from the need for external staff to fix problems that do not occur with non-digital farm equipment. Another dependency mentioned was availability: Especially the problem of poor mobile data reception in rural areas is a major issue for farmers, because it hinders the effectiveness of their processes on the field (fg10).

4.3 The Value of Privacy: What is Being Done with Data in Digitalized Agriculture?

Besides general challenges perceived by farmers, we were especially interested in privacy concerns, which were an

important factor for most of the focus groups, based on a lack of trust in the intentions and motives of agricultural companies.

4.3.1 The Importance of Privacy for Farmers

The role of farmers is shifting in the process of digitalization. This also affects the different perceptions of the consequences of data transfer towards companies. The scale ranges from fearing the end of the concept of the professional farmer on one side to the opinion that data can be seen as another important resource within the agricultural business on the other side.

> Q2 (fg7): *I see a danger that the farmer might fall behind at some point if the data is really processed in such a way that the companies can take over the planning of the cultivation by themselves.*

Some farmers perceive that they are disclosing more than just data when they give companies access to their documentation:

> Q3 (fg5): *There are people who want our information, how we proceed in the field, or what we have acquired over the years so that someone can analyze it. If they know who did what, where, and when, then almost everyone can copy that. We could be replaced through the many years of experience that we have built up when someone gets this information.*

These statements display the skepticism of some participants that companies are collecting data not only to improve technologies, but also to generate fundamental change in agricultural production itself. Experience and lifelong learning in farming, especially in regions with small to mid-scale farms, is perceived as an important factor for effective production. Replacing the factor of human experience with the appliance of accumulated movement patterns and activities could therefore lead to increasing automation and gradual deprofessionalization of agriculture. Most fundamentally, by giving up the exclusiveness of the knowledge of how to work in a specific field, farmers are at risk of being bought out by companies in the future.

4.3.2 Data as a Valuable Resource

Then again, there are also opinions on how to balance the interests of companies in data collection in order to improve technology and the threats that comprehensive transparency poses to farmers. By regarding agricultural data not as a secondary product but as a precious core resource of farming, the prices for data should be commensurate with the advantages companies gain by obtaining data.

> Q4 (fg9): *As long as the data remains within a farm, and I have control over the data, I still see the whole thing [digitalization] relatively relaxed. But as soon as other companies want to gain access to the data, then of course they can also get it at a certain price. So, depending on what kind of data they want, they have to offer something in return.*

From this perspective, there is a need to restrict data access by companies to a certain extent, e.g., only for a short period of time or exclusively for the recipient and not for third parties.

> Q5 (fg6): *The companies that manage the digital crop field cards*[3] *can use the data to create their own personalized profile of you and also predict how you will act in certain situations in the future. That's actually frightening. And who guarantees me that the data will not be sold to other companies?*

Farmers fear that they will be at a market disadvantage if companies can predict their harvest and the effort a farmer has spent in one season. Thus, the perception of data collection is quite negative: if a farmer does not get any benefit from his data, the collection is just additional work with benefits for third parties. This is a serious hindrance to digitalization.

> Q6 (fg10): *We collect a lot of data and do nothing with it. We do collect them, but we cannot use them automatically.*

To conclude, none of the focus groups expressed indifference towards their privacy. Given the perceived risk of professional farmers becoming obsolete and the current situation of data exchange without substantial financial compensation, a need for a solution can be derived by limiting the visibility and accessibility of data by agricultural companies.

4.4 Different Actors with Distinct Intentions regarding Data Ownership

As a specific aspect of privacy, many concerns about loss of data ownership were expressed by the participants.

3 crop field card: administrative tool for planning what measures are applied to which piece of land

> Q7 (fg5): *Concerning the digital crop field cards[3] and their cloud versions too, we all agree on the issue of data ownership. That we reveal a lot about ourselves, a lot goes somewhere unknown or maybe people have access to it, and we don't notice.*

Furthermore, farmers argue that they like to stick with the old-fashioned ways of documentation in order to prevent others from getting insight to operational data:

> Q8 (fg2): *If you write your stuff on paper, you know you have it at home in your office. And if you just type it into a cloud, you don't know who can look in and where the data ends up. That's an unsafe context, because it's about important operational data. I think that is the biggest problem.*

4.4.1 Unintended Use of Data

As already mentioned in 4.3.1, if companies gain access to agricultural data, farmers run the risk of giving up part of their economic foundations. However, not only economic actors such as big companies or retailers may benefit from data, but also criminal groups or the authorities.

> Q9 (fg6): *I see opportunities in digital agriculture, but I also see risks in digital agriculture in the form of making the whole documentation transparent. That all the data that you collect, that you have on the farm, can or will become public. If data is in clouds, it can fall into the wrong hands, through hackers, for example, and then they can spy on our entire production data, analyze our professional knowledge and then evaluate what we do.*

But hackers are not the only ones who should be kept out: A much more present danger for farmers than ominous hackers are companies. That companies are trying to collect data from farmers is no secret, and some already have business models to share data with third parties:

> Q10 (fg4): *So, in some way, you can follow some [digitalization] trends, but you should always have a critical look at them and avoid jumping in headfirst. Because otherwise, you're transparent for the companies. With too much data provided, they can take too much advantage.*

> Q11 (fg9): *It is already quite sure that many companies are interested in the data. When I see offers for a digital crop field card[3], where every process on the field is documented, that you get the ten euros cheaper per month, but company "XY" can look into the data. [German Chemistry Company], for example, can look at this data to see what crop protection is being done, what is needed, and for what reason. [...] Not everyone needs to know what I do and what kind of strategy I apply.*

Instead of uploading their data to the servers and clouds of third parties, farmers who already adopted digitalization prefer their own solutions to store and manage their data in order to keep control over it.

> Q12 (fg1): *The PC on which the system runs has a security system of its own, then another NAS system is attached to it, then there used to be a cloud backup all the time.*

4.4.2 Negative Experiences with Existing Systems

On the other hand, some farmers are using cloud-based systems on their farms, which, however, brings some disadvantages: The fact that many technological innovations in agriculture are developed and offered by the leading companies results in a dependency of farmers on company-specific systems. Another reason that makes farmers dependent on third parties is security. Digitalization is already increasing the office workload, and farmers who want to concentrate on farm work cannot guarantee cyber-security.

> Q13 (fg3): *Data protection, also with regard to the security of my data per se, can hardly be guaranteed by myself anymore. I assume that we will soon be looking for a company that will take over the whole thing, where you rent a server, and they take over the data protection part.*

Many responses displayed the skepticism about cloud servers offered by companies, which could potentially profit from the data. Indeed, at the same time, reading the privacy policies is perceived as too complex for farmers without in-depth knowledge of privacy law. One participant stated how frustrating it is to be confronted with privacy policies and unintended consequences of accepting them without fully understanding them:

> Q14 (fg3): *[Digitalization] is of course a great relief, and you can put an end to all this paperwork, but I don't know where my data will end up. It makes no difference whether I read through their privacy policy or not. Nobody can figure it out anyway. And in the end, there is somehow a [German chemistry company] behind it, which then has my data. And a few weeks later, a letter comes and there are some offers that happen to fit well for my farmland. (approving laughter by other participants) Yes, so you really wonder where this comes from.*

4.4.3 Traceability versus Privacy

According to the statements of the participants, newly developed field sensor methods are mostly perceived as convenient and helpful. New technology can provide benefits for the whole supply chain. Being able to trace products from their origin to the end consumer is helpful for marketing, trust building, and avoiding food scandals. Nevertheless, at the same time, this could also provide a loophole for companies like traders or upstream industries to collect data from farmers.

> Q15 (fg8): *Just the other week, I have read a report about field sensors from [two German technology companies], which measure all factors like precipitation, nitrogen level, soil compaction, and vegetation. If a company owns this data, they can do everything with it. They can send you your exact fertilization planning. Actually, that is none of their business.*

Technical innovations in the fields of tracking and navigation systems, automated driving, fertilization, irrigation, sowing, and harvest generate large amounts of data, that can be traced back. On the one hand, this is helpful for the farmers themselves, as it simplifies the operational management of a farm. On the other hand, the enhanced traceability of actions through permanent data collection increases the monitorability and accountability of farmers. For this reason, some participants perceive it as a risk that human as well as sensor errors during the whole process of data collection may result in more frequent, unjustified sanctions by the authorities, e.g., for violation of environmental protection rules due to sensor errors.

> Q16 (fg8): *A drawback is then, through the accurate data collection, on the one hand, that it is easier for inspectors to retrace activities, but that makes it harder for you to adhere to everything. Just because they see it that way does not mean that it went exactly that way. These are small things like typos or something that can get you into big trouble.*

But not only authorities demand traceability. Customers of farmers, especially in the subsector of organic food grocers, are increasingly requesting traceability in order to serve the demands of the final consumers. Accordingly, the provision of retraceable data serves not only to meet the mandatory requirements of authorities, but can also work as a purchase incentive for customers. At this point, market mechanisms put indirect pressure on farmers to offer more transparency.

> Q17 (fg7): *For retail, I have to provide all my data: when I sprayed [plant protection agents], what I sprayed, when, and what I fertilized. That is what the retail trade wants. In other words, all the encryption [of data] we want for the companies stands in contrast to the traceability that the retail trade wants from us. [...] We have to supply it to the retail trade, because they want traceability, but we don't want to give the data to the plant protection agent companies or [two German fertilizer producers]. But then they get the data from retail trade.*

Offering traceability for customers and consumers does not pose a problem as such for farmers, as it provides only small sets of operational information. At the same time, big retailers may gather a large quantity of data, which could possibly be sold to big agricultural companies (fg5). In this context, some of the focus groups identified a loophole for data leakage towards undesired recipients.

5 Discussion

In the following, the results obtained in the study are analyzed and placed in the overall context of privacy in this domain, and it is shown why agricultural SMEs are particularly vulnerable with regard to privacy. First, the impact on farmers is explained and reasons for (or against) adoption are discussed. We then look at the domain as a whole and identify facets that play a role in the adoption of digital tools for agriculture. Subsequently, we elaborate on the conflict between transparency and privacy along the supply chain. Further, we briefly highlight existing approaches from research which could potentially help address the identified problems in the future and place them into the context of our results.

5.1 The Impact of Digitalization on Farmers

When talking about privacy, the focus is always on management of digital data and its dissemination or protection. Therefore, privacy relies on digitalization to provide the infrastructure for privacy-relevant services and products. In 4.1 and 4.2 we presented some information on the impacts of digitalization on farmers. Building on the results of our study, this section analyzes the general impact of digitalization on the domain to provide a contextual basis for the privacy implications.

Technological change affects the work processes of a modern farm in a far-reaching way and changes the profile of professional farmers in the long term. Especially for SMEs this poses a big challenge, since the adoption of automation and digitalization processes are the more profitable the larger the area of tilled land or the number of cattle is. Moreover, the increased workload in the office is problematic for family-run farms with low workforce.

Before digitalization, farmers mainly had to perform manual work. This includes not only work in the field or barn, but also the maintenance of agricultural machinery. Although planning phases and agreements with other stakeholders also existed in the past, as modern agriculture is dependent on a large number of actors and specialized staff, the participants report that the planning and office workload is significantly increased by digitalization. Some even state that the promised reduction in workload due to digitalization is not noticeable, as work simply shifts to the office (see Q1, Q6). The process of data collection for automated machines is perceived as a nuisance by farmers, especially since the benefit for the own business is much smaller (see Q6), compared to the benefits for third parties through the collected data (see 5.2). The shift of work to the office requires the farmers, who formerly managed all work steps themselves, to rely on other parties for maintenance or data management. Thereby the risks posed by data propagation are increased even more. This problem of further dependencies also applies to customer retention by the manufacturers of digital tools. Customers may obtain all their digital tools from one supplier only, thus creating a vendor lock-in effect. Furthermore, farmers today are not only dependent on the weather, as they were in the past, but also on good network connections, nationwide mobile communications, and the availability of satellites.

Considering the identified privacy problems of farmers, it is not surprising that the adoption of digitalization is very heterogeneous in this domain. The results presented in section 4.1 showed that the subsectors differ regarding the likelihood and the extent of adoption based on the expected benefits and the need to adopt due to market pressure or legal requirements. A higher dependency on the use of technology can have different effects on the privacy behavior: On the one hand, more experience with the technology allows prejudices to be reduced which therefore have less influence on the data management behavior. On the other hand, the dependence on certain technologies can lead to a feeling of being forced to give the data away in any case. Both factors, prior knowledge and resignation, seem to decrease inhibitory factors resulting from privacy concerns. This shows, that privacy is a relevant factor that affects the adoption of digital technology. Another important point, is that in addition to financial and physical resources, farmers have to spend time, share their data, and have to be flexible to take advantages of the benefits of digitalized agriculture.

5.2 Conflicts of Interests regarding Privacy and Transparency

Privacy concerns do not only affect the adoption of digital tools, they also play an important role in the everyday life of farmers, since emerging technologies and trends force farmers to provide transparency along the supply chain. The transfer of data along the supply chain is a central feature of digitized processes in agriculture: Data from various parties involved have to be aggregated and exchanged in order to feed machines with the optimal farm data or to guarantee the traceability of certain quality characteristics along the entire supply chain. However, because all the parties involved have their own agendas, conflicts of interests arise.

Many **Farmers** consider the demand for transparency as problematic, as they fear competitive disadvantages. While transparency along the supply chain offers advantages for food safety, it weakens the market position of farmers, who have to fear price dumping if retailers know how the season went for each individual (see Q9, Q10, Q11). The constellation of the supply chain, in which producers consist of a large number of SMEs that are supplied by large companies and deliver to large wholesalers and processing companies, is very specific to agriculture. This puts farmers in a weak bargaining position when it comes to protecting their interests. Some of the interviewees reported about tailor-made offers for their farms (see Q14) which placed them in a subordinate position of power. Due to their weakened market position, farmers also have to fear take-over by large corporations, which are able to carry out cost-effective land management by unskilled workers, as they were able to obtain all relevant data from the farmers' experience (see Q2, Q3). Hence, it is difficult for farmers to assess whether the collection and transfer of data for a certain legitimate purpose, such as regulative reporting obligations or more precise services from service providers, may not lead to an unintended disadvantage (see Q17). Therefore, providing transparency and exchanging data is economically not necessarily in the farmers' interests.

However, when discussing about digitalization in agriculture and the impact of privacy (concerns) on the adoption of digital tools, the farmers' perspective is not the only one to be considered. There are several important actors and stakeholders with legitimate data collection intentions which conflict with the before mentioned fears stated by the farmers in the focus groups. Table 2 summarizes these conflicts of interests. In the following, we present three prominent stakeholders and their respective interest in receiving data as well as the farmers' concerns with which they are associated.

Agricultural machinery manufacturers: By accessing farmers' operational data and, in particular, telemetry data from machines, agricultural machinery manufacturers can improve their own products and offer optimized maintenance. If a certain part is found to wear out particularly quickly or frequently, farmers' data can be used to better reconstruct and understand the cause and thus optimize maintenance and product design. In this way farmers can hope for better service and warranty evidence, but they must trust that the data is kept and managed securely so that data leakage or deliberate collaboration with third parties do not have a detrimental effect on the farmers. Thus, farmers need to trust business partners, as they have no control over the further use of their data. If this trust is not assured, farmers will refrain from using digitalized services (see 4.4.1). This does also apply to cloud services and reflects the fear of loss of control of sensitive business data. The feeling of loss of control is not only limited to the domain of agriculture, as shown by Zimmermann et al. [47].

Further tensions arise from producer dependencies: Manufacturers may benefit from high customer loyalty, but farmers thereby become dependent and are not protected from arbitrary pricing. This is the case, because to a certain extent it is more expensive for the farmer to change supplier and convert the entire farm than to pay higher fees from the current supplier. In addition, farmers fear that their farming operations will be recorded and then, after the agronomic knowledge has been appropriated, used to oust the farmers (see Q2, Q3). This results in fears of becoming obsolete, in that companies could gather the experience and knowledge of their profession, take over the farms and use cheap work forces to do the work.

Suppliers and buyers: Farmers depend on suppliers who supply them with seeds, feed, fertilizers, or pesticides. In this area, farmers benefit from transparency, as they can ensure that they receive products that are compliant with the regulations they face, e.g. legal regulations concerning plant protection and fertilization. It is therefore important that farmers document and plan exactly what they apply on their land. Furthermore, this way food scandals could be prevented or detected more efficiently [22] and in the case of food with certain quality characteristics (e.g. "organic") it is easier to prove that the product meets the quality requirements.

In the opposite direction, however, transparency causes problems: If the suppliers know how the farmers cultivate their fields and what they earn from it, the farmers are strongly dependent on the good will of the suppliers. One interviewee reported that suppliers could increase prices for the products in such a way so that hardly any profit remains for the farmers (see Q10). In this way, prices are at a level at which farmers just barely avoid bankruptcy, but at the same time can hardly generate any profit and thus no reserves. A similar problem arises with the buyers: if they get insight into the farm data they can offer individualized, lower prices, which is a enormous disadvantage for the farmers. Our participants stated their own experiences with these offers (see Q14). This problem of unfair competition also endangers existing structures in agriculture. As Linsner et al. [25] showed, farmers tend to think of business partners as part of their social environment and do not want to give up partnerships that lasted for generations.

Government supervisory authorities: Farmers receive subsidies from public funds, for example from the European Union. In order to receive these subsidies, they must comply with certain conditions such as upper limits for fertilizers, use of certain plant protection products, or distance zones to water bodies in order to protect drinking water. In this regard digitalization would make it easier to document processes on farms, but many farmers feel at the mercy of government control. Also, trust in technology is not very strong. Farmers know from their daily work how susceptible to faults high-tech agricultural machinery is. Therefore, they do not trust that the automatic recording of operational processes by sensors is so precise that they would make their subsidies dependent on it (see Q16).

To conclude, agriculture is a domain in which a large number of small and medium-sized farms depend on large companies to supply them with machines and working materials, offer services such as soil sampling or buy up the yield. Additionally, the farmers are often reliant on IT service providers to digitalize their businesses. Governmental actors need access to data to ensure compliance with regulations. Within this large number of stakeholders, each actor has its own inter-

Table 2. Legitimate reasons for transparency and the fears of farmers regarding different actors

	Machine manufacturer	Suppliers and buyers	Government authorities
Legitimate reasons for transparency	– Better maintenance due to telemetric data	– Better compliance to quality standards (e.g. 'organic') – Increased food safety	– Better execution of restrictions and regulations for public safety
Fears of farmers	– Vendor lock-in effect – Extradiction of agricultural knowledge and experience	– Price dumping	– Interference and control by government authorities – Loss of funds

ests and expectations regarding digitalization and data handling. Above all, the transparency and traceability of agricultural products creates tensions in the sector. In order to resolve those, suitable and data protection sensitive processes and tools are needed that take into account the needs of individuals and make the advantages of digitalization available to all.

5.3 Outlook on Future Research Possibilities

Concluding our findings on the effect of privacy on digitalized agriculture, we very briefly want to point towards possible measures to address these problems in the future and hence give some impulses for future research.

Our results show that one of the key problems for SMEs lies in their position in the middle of the supply chain and their size resulting in a weaker bargaining position. Sharing too much data towards commercial purchasers or suppliers of necessary primary products and machinery can lead to higher prices and economic pressure. Hence, it is crucial for SMEs to retain the control over the access to and flows of their farm data. This is also important from the perspective of potential (interstate) conflicts [36] or data breaches [38], that may affect farmers. Privacy-enhancing technologies could help to achieve this, by creating usable solutions and access control mechanisms. This could be done with tools based on blockchain-technology, which has the additional benefit of non-repudiation and is favored by the food industry for providing transparency for supply chains [2, 19, 22]. However, granting control over data flows for the data owner remains a challenge. For example, if a machinery manufacturer collects data to perform computations on it, even with data access management, data leakage or misuse of data for personalized offers cannot be ruled out. For this purpose, secure multiparty computation methods could enable the manufacturer to perform computations on encrypted or obfuscated data without having access to the actual data. By this, a misuse of data for personalized offers and similar issues could be prevented. While this technology has been suggested for the use in other domains [17, 33], future research could work on creating more possibilities for such an application in agriculture.

Last but not least, we want emphasize the importance of raising awareness for privacy. A situation, in which the sharing of data leads to financial advantages (see 4.3.2), could create economic pressure for other producers to share data as well to remain competitive. Hence, in this situation the producers are played off against each other and put under pressure to give up their privacy. As a consequence, greater awareness for these problems could foster the demand for privacy-enhancing technologies and rule out any privacy risks that hinder digitalization in agriculture.

5.4 Limitations

Although our study addresses our research question, it still has limitations. (1) Because of the qualitative methodology of this study, the value of it is exploratory and hypothesis-generating. Thus, no quantitative insights can be gained from it and the results may not be applicable to all farms. (2) Moreover, our study focuses on SMEs, because they are the least likely to use digital tools and are therefore worth investigating. However, this is also a limitation, since our findings do not represent every type of agricultural business. (3) While representing the gender ratio of farm managers closely, our study consists of mostly younger participants. A more diverse sample regarding age could offer additional insights.

6 Conclusion

In our study, we examined how privacy affects the process of digitalization in agriculture. Such a study might be a valuable background for the research on privacy-enhancing technologies, provided that it presents empirical evidence on privacy-related obstacles and conditions. First, we presented the influence of digitalization on the daily work of farmers and their wishes with regard to privacy (5.1). Furthermore, we have shown that different actors along the supply chain have different interests regarding digitalization (5.2). Concluding from this analysis, we have presented challenges and possibilities for future development in this domain (5.3).

The role of transparency in the industry is controversial. While it offers advantages especially for downstream actors in the supply chain such as retailers, it also creates conflicts of interest for upstream actors such as suppliers who fear being overcharged in price. Asymmetries in market position between SMEs and large agricultural companies seem to amplify these conflicts. For the successful adoption of digitalization without individuals being left behind, it is necessary to establish mechanisms that make relevant data accessible to all without exposing the operational data of individuals for misuse. Therefore, privacy and especially the fear of its violation by new technologies and business practices remains an important factor in the adoption of digitization in agriculture. Many businesses of different sizes have to weigh up whether the promised advantages outweigh the feared disadvantages. Transparency in particular is a double-edged sword: it creates trust, but can also be threatening if business secrets are disclosed to third parties.

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