Behaviour & Information Technology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tbit20

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To cite this article: Sebastian Linsner, Enno Steinbrink, Franz Kuntke, Jonas Franken & Christian Reuter (2022) Supporting users in data disclosure scenarios in agriculture through transparency, Behaviour & Information Technology, 41:10, 2137-2159, DOI: 10.1080/0144929X.2022.2068070

To link to this article: https://doi.org/10.1080/0144929X.2022.2068070

Published online: 10 May 2022.

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BEHAVIOUR & INFORMATION TECHNOLOGY
2022, VOL. 41, NO. 10, 2137–2159
https://doi.org/10.1080/0144929X.2022.2068070

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Supporting users in data disclosure scenarios in agriculture through transparency

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ABSTRACT

Business collaboration in the era of digital transformation requires the exchange of operational data. Since data are hardly controllable once they have been published or shared with others, it is highly important that users are clearly informed about who has access to which data and how certain settings can prevent the disclosure of sensitive data. However, giving end users more control over their data through increased transparency could also lead to information overload. This is particularly true in the field of agriculture, where tight schedules put pressure on employees of small enterprises. We conduct an empirical prestudy with 52 German farmers to investigate current data sharing scenarios. From these insights, we derive requirements and a concept for data sharing solutions providing data flow transparency for users. To investigate the behavior of users and the effects of transparent UI controls, we evaluate a prototype with 18 persons. Our evaluation shows that farmers demand flexible and secure tools that adjust to their workflows. Also, data should be stored and processed locally, granting farmers data sovereignty. Although the controls require additional effort, the evaluated transparent controls for data disclosure are easy to use and raise user awareness.

ARTICLE HISTORY
Received 16 October 2021
Accepted 21 March 2022

KEYWORDS
Data sharing; transparency; data disclosure; agriculture

1. Introduction

Collaboration and digitized work processes require the collection, processing, and exchange of data (Paunov and Planes-Satorra 2019). However, not all data should become available for everyone. The value of privacy protection often depends on the circumstances of use, as Steinbrink et al. (2021) has shown by the example of the behavior of refugees during flights and its impact on the management of personal data. In business contexts, it is necessary to administrate the access to operational data in order to provide third parties with necessary information, but without becoming too transparent for competitors (Atik and Martens 2021). Negative consequences of data disclosure in agriculture can be very severe. Gupta et al. (2020) summarize some consequences of data leakages as potential threats to modern farming ecosystems, like competitors or hostile actors taking advantage of that information. Farms usually are small and medium-sized enterprises (SMEs) according to the definition of the European Union (EU).[1] Many farms are even entirely family-run (Eurostat 2018). The weaker market position of these businesses is not only noticeable in the supply chain, but is also reflected in the technology development: Innovation is driven by the big players in the supply chain, often leaving perspective and needs of SMEs, e.g. in agriculture, underrepresented (Rotz et al. 2019; Linsner et al. 2021). This especially holds true with regard to IT solutions. There are many tools available for farmers to manage their operations (Runck et al. 2021; Linsner et al. 2021). However, these mostly require the farmers to upload their business-related data to third party servers. In doing so, they often permit the platform-providing companies to use and sell their data by accepting the terms of use (Rotz et al. 2019). Becoming too transparent to competitors or other actors along the supply chain is problematic for farmers: If their operations are visible to others, they might get bought out by bigger companies that use the operational data of the former landowners and cheaper workforce to cultivate the land for a greater profit (Fraser 2019). In order to prevent the consequences of unwanted or excessive data disclosure, transparency could be beneficial for end users. By making the disclosure process more transparent and highlighting the data that is made available for others, mistakes and unintended data leakage could be prevented. However, increased transparency could also lead to information overload for the operators. Especially in agriculture, the owners

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of small farms have tight time schedules to fulfill their work routine. Office work is not the core of that routine and has to be done efficiently, often in the evening. To assist users in making informed decisions about the disclosure of their data, we integrate and evaluate transparent controls to raise awareness about data sharing scenarios.

In this paper, we investigate the current status quo of data sharing practices in SMEs in agriculture by conducting a qualitative prestudy including 52 German farmers. Based on this, we derive requirements for confidentiality preserving data sharing in agriculture. To investigate whether transparency eases the task of data disclosure for business cooperation or is a mere data overhead that leads to information overload, we evaluate our system with nine users from the agricultural domain and, in contrast, nine users without agricultural experience. Due to the comparable nature of the disclosure of sensitive business data by SMEs and the disclosure of personal data of end users, the results could also be applicable in privacy-related contexts.

The structure of this paper is as follows: Section 2 gives an overview of related work and background information and identifies a research gap. In Section 3, we derive our research approach and formulate two research questions. Subsequently, we present our qualitative study with 52 German farmers and investigate data sharing scenarios in Section 4. In Section 5, we derive requirements for information systems in agriculture based on the prestudy and present a concept to address these. The evaluation of the system will be presented in Section 6. Section 7 discusses our results and concludes this paper.

2. Related work

In this section, we present related work on two main topics: Firstly, we present current research on the state of digitalization and data sharing in agriculture. Together with the results of the prestudy presented below Section 4 the literature is later used for the identification of requirements Section 5.1. Secondly, we elaborate on advances in the HCI community on transparent user interfaces, which could apply to our use case of data sharing for non-expert users. In this way, these works contribute to the design of our data sharing concept Section 5.2.

2.1. Data sharing in agriculture

Regarding the question of how farmers perceive the processes of digitalization in their domain, several studies exist: Fountas et al. (2005) asked 198 farmers in the U.S. and Denmark about their attitude towards precision agriculture. They found that main obstacles existed in too time-consuming data handling and that 80% of farmers wanted to store their data locally on self-hosted servers. Carbonell (2016) identifies power asymmetries between farmers and big agribusinesses as a problem. The author sees open source tools and open data as promising approaches. An overview of the adoption of digital tools by 287 participants from agriculture in seven EU countries is provided by the study of Kernecker et al. (2020). It revealed that farmers need better instructions and security. It also became clear that most farmers with more than 500 ha land run fully digitalized businesses, whereas smaller farms still lack digitalization. The fact that in particular small enterprises lack digitalization has also been concluded by Annosi et al. (2019) and Regan, Green, and Maher (2018). Regan, Green, and Maher (2018) illustrate this by means of agriculture in Ireland, which consists largely of family-run farms. The authors present an interesting view on data ownership and privacy of farmers. They 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. Furthermore, previous work has outlined that access to corporate data is an existential problem for farmers, as noted by Fraser (2019): Increasing 'data grab' can lead to 'land grab'. Once companies have access to business data, they can easily take over the farm by estimating the effort and profit of the farmers and buy them out. By acquiring many smaller farms, companies can manage large-scale 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. In this context, Ferris (2017) sees opportunities in technologies for precision agriculture, but also discovers dangers that arise from massive collection of data: Exposure of personal data, income, or yield of the fields. Ferris states that farmers fear disadvantages if this data is accessible to their competitors. Therefore, the author calls for governmental regulation. The fact that this affects not only individuals but an entire domain is supported by the demographic situation in Germany, as shown by federal statistics (Statistisches Bundesamt 2019): The majority of farmers cultivate less than 200 ha of land. This underlines the need for research on SMEs in this domain and their role in business collaboration and data exchange. Utilizing transparency for user interfaces is a possible solution, as shown in the next subsection.

2.2. Assisting users with transparency in data sharing scenarios

For many users of data sharing applications, the concept of individual privacy and corporate data sovereignty often remains abstract. At the same time, the process of viewing data or the act of granting access rights are very concrete issues, which have monetary consequences – particularly in business-to-business (B2B) constellations. Visualization as a means to better communication and incentive for conscious data sharing decisions can lead to an increase in general trust towards data recipients and prevent cognitive overload among users (Becker et al. 2014; Hartwig and Reuter 2021a; Hartwig and Reuter 2021). Nevertheless, it was found that the extension of choices in some cases leads to an unintended, opposite effect, called the control paradox (Brandimarte, Acquisti, and Loewenstein 2013; Gerber, Gerber, and Volkamer 2018). In these constellations, users who have more confidence in controlling their data tend to disclose more than they would have without transparency supporting technology. Therefore, improving transparency does not necessarily lead to advantageous decision-making by users. Mitigation of the control paradox should be considered when designing transparent tools. Guidance for this process can be found in many privacy patterns from existing literature. An overview of existing patterns can be found at Iacono, Smith, and Gorski (2021). Patterns which are relevant for our implementation are referenced in Section 5.2.

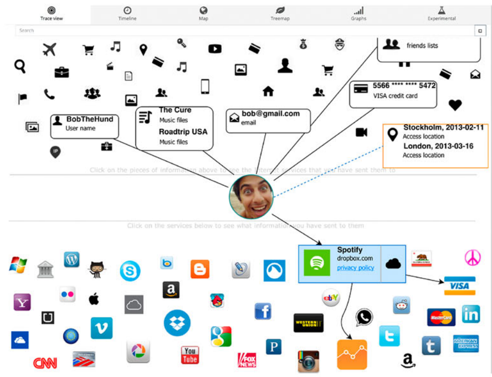
A rich body of literature exists on the visualization of privacy aspects in different contexts (e.g. social media Lipford, Besmer, and Watson 2008; Ghazinour, Majedi, and Barker 2009; Iannella and Finden 2010; Holtz, Nocun, and Hansen 2011; Wang et al. 2015), but authors rarely refer to other fields of data sharing. Overall, research on the visualization of privacy and corporate data sovereignty seems to be intertwined with the presuppositions, methods, and theories of several disciplines. This has therefore led to very different approaches in the visualization of data sharing between companies. In the following, we aim to organize the diverse literature to identify the research gap that our paper intends to address.

In general, the complexity of collaborative work leads to less overview and clarity than in the classic provider-user relationship, as found, e.g. in the selection of cookie policies on websites. Moreover, within supply chains, the trade-off between closer networking in collaborative systems and security and privacy aspects is more substantial, as already described byTolone et al. (2005). They found that collaborative systems are generally characterized by a higher quantity of users and operations, as well as more variation in enterprise models, object types, and tasks. Compared to single-user systems, these features make it more challenging and time-consuming to implement discrete transmission paths. In their comprehensive review on future security and privacy challenges in agriculture, Gupta et al. (2020) note that the complexity of collaborative data sharing will further increase with the adoption of smart farming hard- and software. Considering the collaboration between lay and non-expert users, which is a common characteristic of many SMEs, the dire need for an understandable and transparent presentation of complex data sharing constellations becomes apparent (Paci, Squicciarini, and Zannone 2018). In the following, we will present those approaches from research that can be classified as privacy-enhancing technologies. Please note that technologies which help to provide or enhance privacy for personal data may also be used to protect sensitive data and prevent involuntary disclosure in business contexts, even though business data is not subject of privacy per definition. Also, the presented collection of approaches does not claim to be exhaustive in this regard, since, especially in the B2B context, commercial platforms are often used for data sharing, to which access is only possible via subscriptions. Rather, the compilation is the result of a thorough analysis of existing academic literature, where we cluster the different approaches for data sharing policy visualization into three categories: access control matrices, network approaches, and privacy dashboards (see examples of each category in Figure 1).

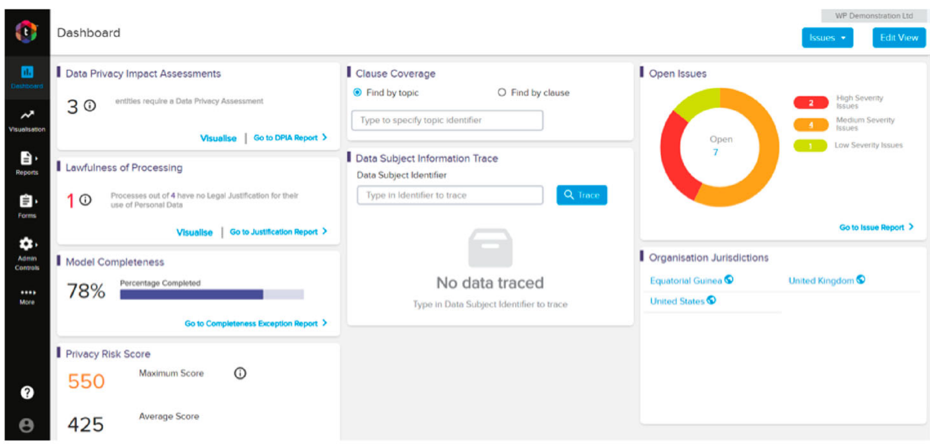
First, the access control matrix represents one of the initial forms of access rights management (Lampson 1974; Kizza 2015; Paci, Squicciarini, and Zannone 2018). It provides potential users with access rights by assigning the access to certain sensitive objects (*y*-axis) to specific actors/users (*x*-axis) in the form of a simple table (see Figure 1(a)). From this starting point, the concept of the access control matrix has been further developed by different approaches. Using shared data in social networks as an example, (Hu, Ahn, and Jorgensen 2011) developed a color-coded representation of conflicting privacy settings between linked users. This proposal was complemented by two pressure indicators as metaphors in the tools' interface, which allows users to weigh the privacy risks against the loss of audience reach. Through the application 'Expandable Grid', Reeder et al. (2008) also propose a modified access control matrix in which colors stand

Objects → Subjects/groups ↓	R1	R2	R3	R4
A	W	R	R	W
B	R			
Group G1	W			
Group G2		W		
C				R

(a)



(b)



(c)

Figure 1. Examples for the three clusters of data sharing policy visualization. (a) Access Control Matrix(Kizza 2015). (b) Network Visualization(Angulo et al. 2015). (c) Privacy Dashboard(Disney 2018).

for different, potentially overlapping sets of data access rules. Conversely, the proposal by Kolomeets et al. (2019), which was developed for hierarchical contexts within a company, resorts to triangular matrices. Here, different colors were assigned to different categories of access rights, adding the distinction between reading and writing rights to the binary concept of access versus denial (Kolomeets et al. 2019).

Second, network diagrams form another large cluster of proposals for visualizations of data flows (see Figure 1 (b)). The nodes usually represent the entities which have data in- or outflows. The edges represent the data paths (see e.g. Angulo et al. 2015; Bier, Kühne, and Beyerer 2016). Depending on the approach, edges are modeled as directed or undirected. By assuming directed edges, it is implied that data is sent only one way, and data exchange cannot take place in both directions. For example, in Wang's proposal for a hierarchical access role system, directed edges are adopted (Wang 2019). For scenarios of collaborative work, instead, it is more appropriate to apply undirected edges, since transparency is created here by disclosure of certain data between entities in the process of mutual data exchange. An example of representation via an undirected network is given by Chou et al. who model a social network (Chou, Bryan, and Ma 2017).

The third and final cluster comprises privacy dashboards, which generally tend to focus on overall assessments of data exposure risks rather than on the depiction of data flows themselves (see Figure 1(c)). Examples of this approach include the work by Wilkinson et al. (2020) and Bagnato et al. (2020). It is conceivable that dashboards could include aspects of both of the aforementioned categories. The 'Impromptu' prototype by Rode et al. (2006) visualizes privacy via a map of concentric circles on which files can be interactively mapped, and multiple levels of warning about unwanted data exposure have been integrated. Current projects such as 'TrUSD' (Feth and Schmitt 2020) and 'Poseidon' (Bagnato et al. 2020) show that there is currently a trend towards visualizing data transparency more clearly by using dashboards, although research in this area is still in its initial stages. As Tolsdorf, Fischer, and Iacono (2021) pointed out recently, implementations of privacy dashboards do not yet comply with the General Data Protection Regulation (GDPR) by the European Union, leading to information deficiencies for lay users.

While applying different methods of evaluation (see Section 6.1), all of the studies on the various visualization approaches reported positive impacts on the data sharing decision-making. Differences also exist in the various formats of visualization concerning the point in time at which they become visible to the user. Some proposals work with dynamic live visualizations, some of which are interactive (Rode et al. 2006; Angulo et al. 2015). Other approaches offer post-decision visualization as feedback, such as the tool by Vaniea et al. (2008), where the output of privacy policy decisions and arising conflicts are presented in tabular form. However, their tool explicitly targets professional IT expert groups, which contradicts the focus of this paper. Meanwhile, the analysis by Wilkinson et al. (2020) is explicitly aimed at non-expert users and tries to achieve an improved understanding of data exposure through an interface that is as transparent as possible for current data extraction. Kolter, Netter, and Pernul (2010) suggest a different approach by presenting solely the visualization of data streams that took place in the past user history.

2.3. Research gap

In agriculture, the exchange of data is an important factor in state-of-the-art work routines. Digitized machinery operates on the basis of pre-processed data (Runck et al. 2021). Moreover, division of work is a widespread practice due to the fact that most farms in Germany are SMEs or even family businesses and only able to gain access to expensive, new machinery through cooperative business models (Braun, Colangelo, and Steckel 2018; Eurostat 2018). Accordingly, technological innovation is mainly driven by large companies which offer their products to farmers (Wolfert et al. 2017). For using the products (e.g. crop management or telemetry tools), farmers are often required to upload their operational data to third party servers (Fraser 2019). Subsequently, they no longer have control over their data. There are also services that offer free tools to attract farmers who otherwise could not afford expensive enterprise products. However, by using these services, the farmers grant major upstream companies access to their farm data and plans for the current season (Linsner et al. 2021). In order to identify important aspects of farmers' perspectives on data sharing in their domain, a study with affected farmers, especially from small farms, is important.

Transparent user interfaces for farmers could be a promising approach to grant individual farmers more control over their data. The positive evaluations of the diverse visualization approaches mentioned in Section 2.2 showed that transparent controls in data sharing applications could help to prevent unintended data leakage (Rode et al. 2006; Reeder et al. 2008; Kolomeets et al. 2019; Wang 2019). Data loss in agriculture is often caused by disadvantageous interfaces or centralized cloud solutions where farmers have to upload all data to third party servers, which may even be affected by non-EU laws (van der Burg, Wiseman, and Krkeljas 2021). However, transparent user intervention poses the risk of information overload. Related work tested transparent software technologies with user samples consisting mostly of university students in tech majors, e.g. Reeder et al. (2008); Angulo et al. (2015); Wang (2019), despite the fact that Parker and Sinclair (2001) identified the importance of actual end user-centered design in agricultural IT as early as 2001. Farm managers and employees usually do not have expert computer skills, and their workflows often suffer from tight time constraints (Linsner et al. 2021). Since many of the evaluations were conducted with IT expert users (Kolter, Netter, and Pernul 2010; Reeder et al. 2011; Wang 2019; Kolomeets et al. 2019), we can hardly apply their results to our target group.

Another aspect concerns the fact that most of the literature cited in this section deals with visualizations of privacy and transparency in the private sphere. Despite an extensive literature search, no work could be found that explicitly considers the matter of usable visualization in the B2B context of supply chain dependent SMEs. Consequently, a research gap in the use case of non-IT-expert users in information sensitive collaborative commercial contexts can be identified. Therefore, investigations on the effect of transparent user interventions on users from SMEs such as farms are urgently needed.

3. Research approach and questions

To address the lack of lay user-specific, transparent data sharing solutions for SMEs identified in related work, we pursue to answer the following research questions:

- RQ1 Which requirements exist for agricultural information systems to allow small enterprises to participate in cooperative work scenarios without becoming transparent for competitors?
- RQ2 (How) Can transparent controls contribute to better privacy behavior for farmers who are often time-constrained due to their daily work routine?

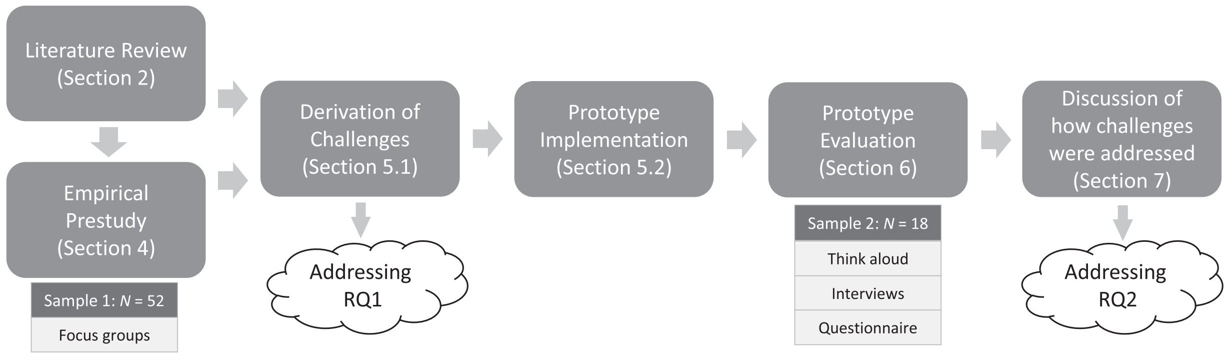


Figure 2. Flow chart of the research approach.

The research approach of this paper is illustrated in Figure 2. In this work, we present an approach consisting of several steps: After our literature review presented above Section 2, we share the results of our qualitative study with German farmers to shed light on data sharing practices from their work routine Section 4. Here, the perspective of SMEs is highly relevant, as, in contrast to large enterprises that can afford dedicated departments for different activities, e.g. a legal department, small enterprises rely on workers who usually have to perform many different activities. This heavy workload reduces the time available for carrying out office tasks and thinking about the consequences of possible data flows. For this reason, awareness of data protection in the exchange of business details probably differs between SMEs and large enterprises. Therefore, SMEs especially need easy-to-use and easy-to-understand solutions that set the bar high for the development of an appropriate user interface. Furthermore, since the conflict between the time one can spend in the office and the time available for practical activities is particularly challenging in agriculture (Pedersen, Ferguson, and Lark 2001; Fountas et al. 2005), our assessment focuses on employees in small farms. However, the results could also potentially apply to other sectors.

Second, the results of the prestudy are used to derive challenges and requirements regarding data sharing applications and a data sharing model designed to address these challenges Section 5, intended to answer RQ1. We then use the identified model properties to design and implement a interface prototype which enables data sharing within an agricultural context.

In a third step, we evaluate the prototype qualitatively to investigate user behavior in data disclosure scenarios and the effectiveness of transparent control options Section 6. Last but not least, we will discuss the results of the prototype evaluation with regard to the previously identified challenges, thereby answering RQ2 Section 7.

4. Empirical prestudy

This section presents the prestudy we conducted with members of the target user group to gain insight into data sharing in agricultural B2B relations, to enable us to derive requirements for our data visualization model, and to give a general overview of digitalization in agriculture.

4.1. Method

This subsection covers the methods applied for our prestudy. The entire process, comprising creation of an interview guideline, recruitment, conduction of the focus groups, and data analysis and storage, followed the guidelines of the ethics committee of *Technical University of Darmstadt*. Previous to this contribution, we have published a paper on the current state of digitalization in agriculture, based on the same data (Linsner et al. 2021). One of the various concerns about digitalization in agriculture was data security. Frequent mention of a lack of tools for sharing data for decision making motivated us to elaborate on the specific needs of data exchange between farmers and develop our own solution approach. In this paper, while analyzing the same data in the empirical prestudy, we focus on the future and on demands for upcoming approaches, as well as topics relevant for HCI. We specify the observed subtopic on the demand for usable applications in order to design an implementation application Section 5.2, which is subsequently evaluated Section 6. These contributions have not been published before. Therefore this paper differs substantially from the previous work and builds on it towards designing mechanisms for usable security.

4.1.1. Study design

We identified focus group interviews as the adequate method for the prestudy. This method consists of analyzing guided expert discussions in groups. Focus group interviews (Morgan 1997; Lazar, Feng, and Hochheiser 2017) belong to the standard of qualitative-exploratory research approaches. The group approach enables a conversation between experts in which the researcher adopts only the role of observer and interested listener. To support the participants in case of a halting conversation, we created a set of supporting impulse questions, which only had to be resorted to in a few instances. Readers can find the interview guideline in the Appendix A.1. The appendix only includes the guiding questions relevant for this publication. Due to interview economics we also discussed resilience capacities of the farms (Kuntke et al. 2022) and blockchain technology in their domain. For the latter, a brief explanation was offered. To keep the subjective bias as small as possible, the focus group interviews were guided by two researchers experienced in conducting interviews and the focus group method. As the interviewed farmers are located at a variety of places, our project partners identified occasions when several potential participants would gather to conduct the interviews. Finally, we ended up with 12 focus groups: Nine at an education center for aspiring agricultural technicians (FG1-FG9), two at an innovation center of a farming machine manufacturer (FG10 and FG11), and one at a machinery ring (FG12). We conceptualized all phases of the study based on the guidelines for ethical research of the ethics committee of *Technical University of Darmstadt*. These guidelines involve a self-assessment checklist of the risks for the participants that turned out unproblematic. Therefore, no further actions were required to to satisfy the ethics committee's requirements.

4.1.2. Participants

The sample consisted of $N = 52$ farmers. All surveyed farmers hold responsibility and decision-making power in SMEs, as family farms dominate the land structure in the studied region. With 45 people identifying as male and seven identifying as female, a balanced gender distribution could not be achieved, but the proportion corresponds to the share of female managers in the agricultural industry (Eurostat 2018). Due to predominantly younger participants at the educational center (42 in the segment 20–30), the age average of our study is significantly lower than the average age of the agricultural labor force. For an overview of the fields of work of our participants, see Table 1. Participation in the focus groups was voluntary and unpaid. We ruled out overlapping of the prestudy sample with participants in the later described usability study to provide an unbiased usability analysis.

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

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

4.1.3. Data analysis

The focus groups were conducted in German as this is the native language of all participants. Audio recordings were made, which we then transcribed and anonymized. The length of the group sessions varied between 15 and 27 minutes. Using the open coding method of grounded theory, we formed text segments (Corbin and Strauss 1990), which were then categorically coded to assign them to specific semantic categories. The classes could be expanded during the process, whereby all previously coded segments were re-examined. In line with the quality criterion of intercoder reliability, two of the authors conducted the classification in constant consultation to minimize subjective bias in the coding. Ultimately, the categories and assignments were cross-checked by the team of authors. The English translations of segments cited in the results section are as literal as possible. Participants often used names of companies (machinery manufacturers, suppliers of feed, fertilizer and seed, contractors, laboratories). These were replaced by general descriptions that do not allow the readers to draw conclusions about a specific company.

4.1.4. Limitations

Limitations in the prestudy are mainly rooted in the sampling. Most importantly, we cannot rule out a gender or age bias. Additionally, the regional distribution of the experts is skewed towards the former Western German States. For an in-depth discussion of these limitations, we refer the readers to Section 7.

4.2. Results

To ensure an improved data model, this result section initially presents our findings and reveals the challenges farmers face in the present state of agriculture. The section starts with a general description of the digitalization status at the whole sector level by briefly summarizing the results of the previous contribution (Linsner et al. 2021), to aid the reader in understanding the topic. As a second step, we derive new and original insights based on the material on specific characteristics of data sharing in the sector Subsection 4.2.2. Moreover, new challenges are identified that currently hamper data sharing for farmers Subsection 4.2.3.

4.2.1. Agricultural digitalization

First, we turn to the status of digitalization in Germany's agricultural sector. The participants' responses paint a differentiated picture of the advantages and disadvantages of digitalization. The level of experience with digital tools among the participants ranges from occasional data entries on stationary PCs to advanced on-farm network architectures. In addition to home PCs, most participants primarily use mobile devices such as smartphones, tablets, and embedded computers on large-scale equipment. Windows 10 and Android are the most used operating systems, but Windows 7 and macOS/iOS were also mentioned in a few cases. All focus groups identified certain advantages and disadvantages, which are listed in the following. Databases and accounting programs offer assistance in this respect and make the formerly handwritten work of farm management and bookkeeping easier and more comprehensible. In addition, the physical work on the farm changes as a result of digitalization, as it is an essential prerequisite for smart and precision farming. Both farming strategies promise efficient and reduced resource use, improved yields, and environmental friendliness in the process. Or concisely in the words of a participant:

> Q1 (Quote1) (FG2): Be more productive, save resources, and be more environmentally friendly.

We learned that precision farming uses accurate global positioning, area-wide sensor networks (weather, soil), and automated equipment (vehicles, fertilizer distribution, irrigation) to achieve the highest possible efficiency in the cultivation process. The data generated by these processes is hereafter referred to as operational data. For example, by relying on geodata stored in digital orders, tractors already drive with automatic steering at many of the respondents' farms. For some operators, time-consuming and monotonous work at the steering wheel is thus transformed into monitoring while simultaneously completing administrative tasks.

> Q2 (FG5): D]riving with automated steering systems is, of course, truly advantageous and practical, saves time, money, and protects the environment.

In contrast, other participants argue that increasing automation can change mentality if too much trust in and reliance on precision farming leads to unintended inattentiveness.

> Q3 (FG11): – Automation means that one is no longer as focused on your work as one used to be. You drive down the field, on the way you make three phone calls, write another mail, because the technology does it all automatically – That's one problem with automation, that you then rely too much on the system.

Overall, the focus groups agree that the job profile of a farm manager will undergo major changes in the future. According to them, there will be greater demand for training on technical equipment, and the classic image of a profession in which workers spend relatively little time on administrative work will be blurred. According to several focus groups, there is also a tendency for the fairly small-scale farm structure in the examined region to give way to larger cooperatives or individual companies.

> Q4 (FG4): If the process continues like this, it will lead to the small ones quitting the market more and more, and the bigger ones will need to merge or cooperate.

In the interviewees view, this conceivable structural sector transformation lacks behind, on the one hand due to the average age of farmers on small farms and their unwillingness to integrate new technologies into operational processes. This opinion of our significantly younger sample of interviewed farmers could be subject to age bias. On the other hand, participants mentioned high investment costs, which usually pay off the sooner the larger the farm revenue is.

> Q5 (FG7): The small sideline farm with 20, 30 acres will not purchase a smart farming tool because it does not pay off financially and has no significant benefit. But on large farms, smart farming is already part of everyday business.

Then again, the scenario was described that in the long term, smart farming technologies would also become more affordable for farms with less than 50 acres of arable land due to rising proliferation and lower production costs. Furthermore, part-time farmers are reluctant to digitalize their farms. Most focus groups agreed that digitalization is mainly a competitive burden for smaller farms – and a worthwhile investment for large farms or cooperatives. Digitalization consequently provides some disadvantages in addition to the advantages as mentioned earlier, which the focus groups identified through differentiated discussion.

4.2.2. Data sharing in the agricultural sector

As previously noted, agriculture became a data-intensive sector due to its collaborative structure and complex supply chains (2.1). For more insight into current data sharing behavior, focus groups discussed the media used and expressed needs and critical issues. The majority of farmers communicate with business partners through online media such as email and messenger services. The latter was highlighted several times as being particularly practical, as it offers the possibility of easily sending images and locations. Depending on the urgency of a matter or the proximity of the business partner, respondents also find face-to-face meetings and phone calls convenient, especially if they have built up a certain level of trust through decades of collaboration.

> Q6 (FG8): I am a technical advisor for a large seed community, and we actually still do business personally. Also by phone, of course, but you need trust in agriculture, which is not easy to build up.

Field data is frequently transferred via USB stick to be compatible with the automated equipment. Print letters and faxes are a rare exception, mentioned at best in the context of contracts. For extensive transfer of field data, the latter two options are barely chosen anymore.

There is an awareness among all participants about the intrinsic value of farm data and its potential utility for companies upstream and downstream of the supply chain and the associated risks.

> Q7 (FG9): I believe that many companies are interested in the data. I have seen offers that a digital crop field card gets cheaper by ten euros a month if company *XY* is allowed to look into the data.

In most focus groups, skepticism about the intentions of other companies about what happens to the data after it is transferred and whether it is sold to third parties, predominates. Profiles derived from the data could result in individualized prices, which in turn would lead to reduced profits. Some focus groups took the line of argumentation a step further and warned of the risk that companies could draw numerous conclusions from comprehensive and multi-year farm data that experience-based workflows could be inferred from it. In particular, for smaller family-run farms, experience in farming and knowledge of the land is considered one of the most critical assets. The more data large companies have pooled, the more likely farms are to be vulnerable to takeovers.

> Q8 (FG5): Now, many companies want to have our information on how we proceed in the field or what we have learned over the years. […] Through the many years of experience that we have built up, if someone has the same information, we could then be replaced.

Two focus groups discussed the financial value of the operational data. According to them, current compensations from chemical companies and equipment manufacturers tend to provide access to data platforms or fertilizer recommendations at a lower price. Some participants see data as another profitable resource with its own supply and demand dynamics. Risks from disclosing operations should be compensation by fair quid pro quos:

> Q9 (FG9): As soon as other companies want to have the operational data, then they can, of course, also get it at a certain price. Depending on what kind of data it is, there has to be corresponding compensation.

In-house, some farmers face data overload due to a lack of compatibility between different systems and platforms. Data sets would need to be prepared differently for automated vehicles, regulatory applications, or contracting orders, creating significant additional work for farmers. For example, one participant complains,

> Q10 (FG11): that we produce an incredible amount of data junk and that us farmers have between two and five different systems which we have to maintain separately.

On the contrary, one of the participants envisions an extended mode of data sharing on a cooperative level between farms for mutual benefit. Data overflow or data demand could depend on the size of the farm and its digitalization status. However, our focus group method did not allow for an examination of this connection in individual cases. Not only does the quantity of data burden some participants, but the quality of the data collected by automation may also be a concern. German authorities closely monitor the application of certain fertilizers and pest control. Forwarding data that an automated device may have incorrectly collected can result in the inference of a violation of regulations. Checking the data, however, takes a similar amount of effort and time as the conventional manual entries:

> Q11 (FG11): We don't save time; we just distribute it differently. First of all, we have complied with the law by documenting fertilization directly, but afterward, we have to check whether what we have documented is also what we have done outside.

According to the focus groups, increasing carelessness while operating automated vehicles (see quote 2) is part of the problem. Time savings and trust in automatically gathered data and its direct forwarding to authorities are consequently rated low in the focus groups. Involuntary data disclosure through hacking attacks – especially ransomware – was also identified as a risk, increasing alongside digitalization.

4.2.3. Current challenges in data sharing

We identified five areas that represent challenges for data sharing for the model from the focus groups. First, many participants are bothered by the fact that a lack of compatibility of different systems limits the

Table 2. Challenges and requirements for data sharing platforms.

Challenges	Literature and Prestudy	Platform Requirement
Challenge 1: Compatibility	Soft- and hardware of different services and product families are not compatible because of differing data formats (Q10) and lock-in effects for machinery (Q12) (Carbonell 2016; Linsner et al. 2021).	Application of standard data formats to facilitate compatibility across products. Independence of internet connectivity through local accessibilty.
Challenge 2: Sector Diversity	The agricultural sector and the food supply chain is characterized by a multitude of actors and roles (Q5, Q6), (Carbonell 2016; Gupta et al. 2020).	Flexibility of the platform to account for different actors and roles.
Challenge 3: Media Diversity	Farmers have a broad spectrum of media usage, ranging from pen-and-paper, telephone and fax to PC and mobile phone (Q3, Q4, Q6). The level of digitalization often depends on the size and type of the farm (Kernecker et al. 2020; Linsner et al. 2021).	Support of interfaces on desktop PCs and mobile phones as most commonly used media.
Challenge 4: Transparency Balance	While greatly demanded from upstream and downstream actors, full transparency of farm processes may lead to SMEs finding themselves in disadvantegous market positions towards larger companies (Q7–Q9) (Ferris 2017; Regan, Green, and Maher 2018; Kernecker et al. 2020).	Improvement of data sharing choices and provision of job specific approvals. Restrictive pre-selection to meet privacy by default.
Challenge 5: Retraceability	Currently, not all data disclosures can be traced in retrospect, which is a hindrance to the legal sanctioning of data breaches by the receiving parties (Q11) (Ferris 2017; Gupta et al. 2020).	Ex-post traceability of data sharing decisions and contents provides evidence of all transactions for legal proceedings.

current state of farm digitalization. One reason for this is that large manufacturers are trying to lock customers into individual product families.

> Q12 (FG1): But once you have started with [machinery supplier], you are also dependent on their system. [···] With the high follow-up costs, there is also the question of whether you can ultimately increase yields or quality.

Second, the focus groups reveal how diverse the agricultural sector is. Different types of farms, farm sizes, crops, and levels of digitalization face different specific data sharing risks and data ownership expectations. Some farmers are in a dual role, acting as labor or equipment rentals, consultancies, or vendors in addition to their production. Third, farm management and employees use very diverse forms of media to communicate and share important data. Fourth, data sovereignty over critical agricultural data is threatened by rising data demand from both upstream (machinery producers, biochemical companies, and seed producers) as well as downstream entities (retail, consumers) of the food supply chain. While specific data sharing is necessary for the fulfillment of contracts, complete transparency of farm processes is perceived as weakening the market position, as the risk for SME farms to be bought up by larger companies increases. Lastly, to be able to provide evidence in legal proceedings following data breaches, subsequent traceability of sharing activities is perceived as helpful. Current practices, involving mail or cloud solutions, only allow for this to a limited extent.

5. Designing transparent controls for data disclosure

This section describes the challenges derived from the prestudy and the concept as well as an implementation of a prototype for a formalized data sharing control. First, it is explained how the problems identified in the prestudy (see Section 4.2) can be addressed and which requirements should be included in the solution concept. Since farmers demand more control over their own data, a prototype is implemented to investigate whether offering transparent control options actually helps users in this regard. Since data management by centralized third party applications has been criticized, and measures to protect data ownership have been demanded, an independent and decentralized system is targeted in our concept.

5.1. Challenges, requirements and concept

Based on the prestudy Section 4.2 and relevant literature Section 2.1, we were able to derive the challenges of (1) Compatibility, (2) Sector Diversity, (3) Media Diversity, (4) Transparency Balance, and (5) Retraceability. We then derive corresponding requirements for data sharing platforms and data disclosure scenarios, as well as a respective concept addressing them. These are listed in Table 2.

The *first challenge* arises from the lacking compatibility of existing products, which leads to vendor lock-in effects. To address this problem, the use of open-source tools and standards is recommended – a claim which can also be found in related work (Carbonell 2016). Furthermore, the system should be independent of a specific implementation or background technology and enable local processing of data sharing decisions. This way, the model can be applied to various technologies: Data exchange via email is supported as well as client-server architectures, cloud-systems, and blockchain ecosystems. The latter are experiencing a boom in the industry and are seen as a promising approach for the food industry, as they offer transparency along the supply chain and not merely simplify quality assurance, but can also prove the origin of products to end consumers. Therefore, when designing systems, they should be compatible with blockchain architectures.

The *second challenge* concerns sector diversity, since actors and roles in agriculture are highly diverse and can change over time. This requires individual data disclosure for each actor in changing situations. To meet this requirement, form-based workflows could be useful. Templates could be provided for different workflows and complemented by different actors. If access control matrices are used to customize data disclosure, the addition of further parties in a contract would be easy. For each participant, a new row has to be added. For further rights of use, a new column has to be added.

Addressing the *third challenge* of media diversity, this requirement must be extended in regard to the problem of sector diversity. Because of the huge differences in procedures and media used, workflows within a data sharing platform should be adjustable on the fly, for example while driving a machine in the fields. Regarding the media, farmers indicated PCs and mobile devices as the most common media. Support of both media types should be available as a minimum requirement for a successful platform implementation. Responsive tools should be used to provide workflows that are usable on every device.

As for the *fourth challenge* of transparency balance, data ownership was identified in the prestudy as one of the core problems in current data sharing scenarios. For farmers, who often rely on third-party services for planning, management, and task execution, data sharing is indispensable. This gives third parties access to planning and accounting data. In an independent system, users should be able to decide for themselves who gets access to which data. Data owners should be empowered to control who receives data, and purposes for using the data should be documented. This confirms the findings of Fountas et al. (2005) that farmers prefer local storing and processing of data. To make the control over the data flow more transparent for users, form-based workflows with built-in transparent control features should be used for data disclosure. To minimize the number of actions the user has to fulfill, we propose that the items in a form are sorted and grouped in semantic units. Each of these units is given a control option to configure which participants in the order are allowed to see the data and which are not. We describe a concrete example implementation in more detail in Section 5.2.

The *fifth challenge* deals with ex-post traceability of data. Since data cannot be retrieved once it is made public, compliance is very important. Lawsuits may arise if data is misused, which requires permanent and tamper-proof documentation of granted rights of use. These rights have to be defined in the moment of data disclosure and stored in a tamper-proof manner. To provide evidence in court in case of data breaches, the final requirement is the ex-post traceability of shared data by documented rights of use, whose integrity is proofed by the system. If a blockchain architecture is used, these can be documented in a tamper-proof manner. However, this is in conflict with applicable deletion periods. To solve this problem, various technical precautions should be taken: First, it must be possible to delete the data in a timely manner. For this purpose, reliable maintenance mechanisms must be in place for client-server architectures or cloud systems. In the case of a blockchain environment, this is more difficult, as integrity is an essential aspect of the blockchain. However, since this paper presents an approach that is neutral to specific implementations, this problem exceeds the scope.

5.2. Implementation

We implement and evaluate a prototype to gain empirical evidence on the willingness to define usage rights and on the perception of control over the disseminated data, and to explore how the previously identified challenges could be addressed. A conceptualized view of the data processing can be found in Figure 3. The prototype consists of two parts: First, there is a form service (*'To complete'*), which enables the user to fill out provided commission forms for business partners and to define rights of use (Figure 3, *Define*). Based on the inputs of the users, a splitting script creates separate views for each participant in the form of JSON documents (Figure 3, *Process*). In this way, it is ensured that only the designated data leaves the local storage. The second service for viewing (*"Check"*) can use the exported files to render an individualized form for each recipient based on the selected data (Figure 3, *View*). As mentioned in the previous section on the fifth challenge,

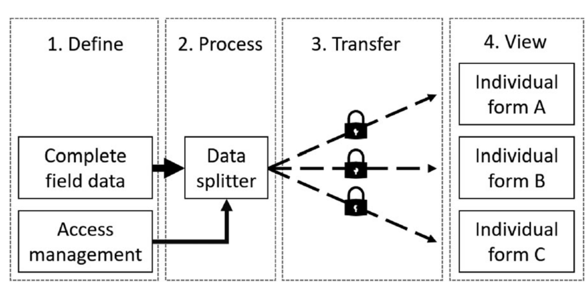


Figure 3. Derived concept for required data flow.

the third step within the data flow (Figure 3, *Transfer*) was out of scope for the prototype.

The prototype was implemented as follows: Both services were embedded into a single progressive web application based on `Ionic/Angular`. In this way, the app could be delivered as a web page for remote evaluation purposes, but also later embedded in a standalone app for mobile devices or desktop computers, which addresses the third challenge of media diversity. The form rendering was done with the npm package `formio/angular` of the *form.io* project. Via a floating menu at the bottom of the screen, the user can switch between the two services. For the evaluation, the application was hosted within a docker container on a server. However, a local instance would be viable in a real-world application. The form service requires the user to load a JSON template for a form and provides the possibility to load another optional JSON file to load previously selected values. This way, the farmers would have the possibility to reuse the planning from the year before for convenience reasons. The loaded JSON files would then be used to render the form, which could then be filled out by the user. Using a template approach, we took up the second challenge to enable sector diversity. The then rendered form provides access control matrices to define the visibility of data for each data category (e.g. details on seeding material, required equipment), addressing the fourth challenge of transparency and the privacy pattern of 'Direct Access to UI Components' (Iacono, Smith, and Gorski 2021; MuIacononoz-Arteaga et al. 2009). Users are presented with the control options close to each data item to ensure that they can immediately specify who could get access to that data. Therefore, the control matrices show the different involved parties for the job in rows with radio buttons to select the data visibility for each party. Examples are shown in Figure 4.

If no previously selected data was loaded, the default value for data visibility is *'must not see data'*. In this way, an approach was chosen that preserves privacy by default, supporting the privacy pattern of 'Disable by Default' (Garfinkel 2005; Iacono, Smith, and Gorski 2021). After completing the form, the user can press a button *'Submit'* to process the data. When clicked, the data is processed in a splitting script, generating two JSON files for each recipient. One contains the disclosed information and the second a corresponding form to display the values properly. Within the prototype, these files could be exported and distributed (e.g. via email, blockchain, clouds, client-server). By using a standardized format such as JSON, we wanted to address the first challenge of compatibility, since it enables an easy implementation or conversion to another data format.

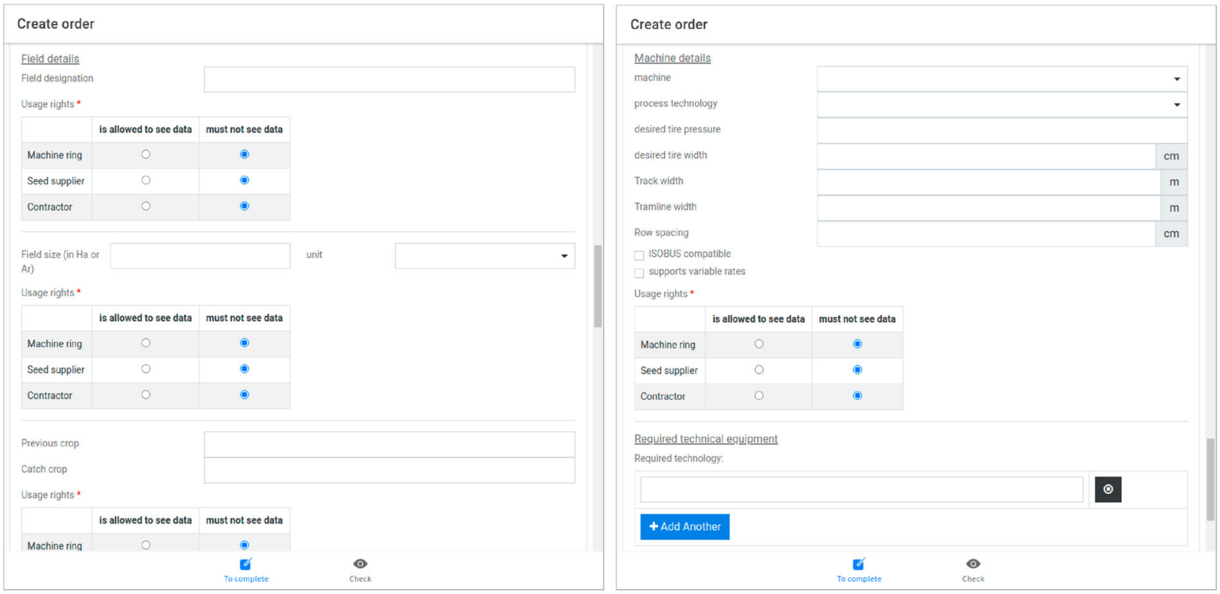
The exported files could now also be used to be loaded into the check service by farmers to verify the individual forms before sending them. This way we implemented the privacy pattern of 'Delayed Unrecoverable Action' (Garfinkel 2005; Iacono, Smith, and Gorski 2021). Since data can not be made private after publication, this is a crucial step to ensure that users get the chance to preview the released data before submitting it. To do this, the service requires the user to select the exported form file as well as the file with the disclosed values. The service then uses *form.io* to render a non-editable view of the individualized form.

6. Evaluation

To test how the participants from the agricultural domain would respond to a solution providing control over data visibility for business partners, we have evaluated the prototype we conceptualized after the prestudy in a think-aloud study, followed by semi-structured interviews and two questionnaires. The entire process comprising the creation of an evaluation guideline, recruitment, conduction of the evaluation, and data analysis and storage followed the guidelines of the ethics committee of *Technical University of Darmstadt*. In the following, we will describe the evaluation steps in detail.

6.1. Method

Understanding the methodology of related works on the evaluation of individual visualizations is essential to identify a method that is best suited for the objectives of this paper. Authors from several research disciplines have already developed and evaluated visualizations with contributions ranging from purely descriptive comparisons of various approaches to complex usability studies of individual applications. After conducting a comprehensive comparison of visualizations in commercial community-centric visualization systems, (Paci, Squicciarini, and Zannone 2018) identified several requirements. Feth and Schmitt (2020) also identify system requirements (for dashboards that are used internally in a company) but obtain these through qualitative workshop surveys. The testing of individual visualizing applications is dominated by analyses of usability, which is accomplished by assessing the effective execution of tasks (Rode et al. 2006; Reeder et al. 2008; Kolter, Netter, and Pernul 2010; Angulo et al. 2015; Bier, Kühne, and Beyerer 2016). In some cases, eye-tracking was applied simultaneously, for example by Bier, Kühne, and Beyerer (2016). There, the System Usability Scale of the seminal work by Brooke (1996) was used as an evaluation standard for usability. Overall,



(a) (b)

Figure 4. Screenshots of the prototype with examples for control matrices in one loaded form. (a) Section about field details. (b) Section about machine details.

the usability analysis via task performance – possibly paired with think-aloud approaches or eye-tracking – seems to be the most suitable method to map important aspects of human-computer interaction.

6.1.1. Study design

We conducted a think-aloud study to evaluate the prototype that was designed after the prestudy and to identify any obstacles the participants face when using a control matrix. This was followed by an interview and a questionnaire. Appendix A.2 provides an overview of the study flow for the evaluation. The implemented prototype (see Section 5.2) itself was provided as a web app and accessible with a browser. The entire evaluation was conducted via video conference using *Zoom* with screen sharing enabled for the participants so that the investigator could see the actions of the participants and provide additional instructions when needed. The whole session was recorded. The questionnaire was filled out by the participants after the session to guarantee that the results are not biased by the presence of the interviewer.

Think-Aloud Testing. First, the participants received an introduction about the purpose and the procedure of the study and were asked for informed consent. While testing the prototype, participants were asked to comment on their actions and encouraged to express every thought. Then they received a description of a hypothetical scenario which can be found in Appendix A.2. In the scenario, the user would be in the role of a farmer filling out a crop planning form providing information for a machinery ring, a service provider, and a seed supplier. The participant was then asked to load and fill out a form in the prototype and set the visibility functions of each data component. In the following step, the participant could download the data for each business partner and load the files to check how their business partner would see the form. Hence, the data with restricted access for the respective business partner would be left out in this view, and the participants could check whether the data in the form would be displayed correctly for each partner. In a third step, the hypothetical scenario was adjusted in that it would be one year later and the farmer would be planning the sowing for the same field. Now, the participants could load the previously filled out form, revise the data visibility, and then check the changes in the form again for each business partner.

Interviews. After the think-aloud test, interviews were conducted with the participants to inquire about a general impression of the prototype and to ask specifically about the perceived control the participants had. Here, we asked about the general perceived control in handling the prototype as well as about the control over who would receive which data. We asked the participants whether the forms for the business partners they checked were in line with their expectations. Also, we asked how the procedure would compare to the status quo within their own business practices. Lastly, we specifically asked for opinions on the control matrices.

Questionnaires. After the interviews, participants received a link to a questionnaire in the online survey tool *LimeSurvey*. While the small sample size was chosen for a qualitative approach and a quantitative analysis of the questionnaires would have limited meaningfulness statistically, we still wanted to inquire comparable data and get a more conclusive impression of the participants' attributes regarding technology affinity and their assessment of the prototype. To let them evaluate the usability of the prototype, we used the German version of the UEQ-S (Schrepp, Hinderks, and Thomaschewski 2017). For their affinity for technologies, we used the German version of the ATI (Franke, Attig, and Wessel 2018). The questionnaires were presented in the mentioned order.

6.1.2. Participants

For recruitment, we reached out to our partners in the project HyServ to ask their organizations for participation. This way, we could interview members of two different machinery rings. Furthermore, we sent a request for participation to a federal counseling agency for agriculture and asked research assistants from [university] to participate. A compensation of 20 C was offered, but most participants took part in the evaluation without accepting money. The sample (N = 18) consisted of nine participants with an agricultural background (A1–A9) and nine additional participants with no experience in agriculture (R1–R9). We decided to gain general feedback on the usability of the system. The participants from agriculture mainly gave feedback on the possible integration into their daily work routine and use cases from this domain. While this is very useful feedback, sometimes the discussion circled around the question how to phrase some items or in which unit an item should be measured (e.g. the amount of seeds in tons, kilograms or bags). To gain insight from a more neutral perspective and to identify possible use cases others than agriculture, the second sub-sample was needed. Another reason was that all participants with agricultural background were male which could be a limitation, as the perspective of women could be underrepresented. To address this, we approached research assistants of our institution, to recruit a second sample with a more balanced gender-ratio. The research assistants are not directly subordinated to the leading authors. Their voluntary participation was credited as working hours, enabling compensation through the monthly remuneration. The agricultural sub-sample consisted of six farmers, of which four were familiar with the work of a machinery ring (A3, A7, A8, A9), one federal counselor for agriculture (A6), and two IT-experts with extensive experience in agricultural workflows due to their work (A4, A5). The age range in this group was 24 to 63, resulting in an average age of M = 37.44 years (SD = 14.07). The other sub-sample consisted of research assistants, of which four had a technical background (R1, R3, R5, R8), and five had a background in social sciences (R2, R4, R6, R7, R9). Five of the participants were female (R2, R5, R6, R7, R9) and four male (R1, R3, R4, R8). The mean age of this group was M = 24.33 (SD = 1.41), with the minimum being 22 and the maximum being 26. Detailed information on the participants can be found in Table 3. This way, we could cover different backgrounds within our sample to assess how similar data sharing applications could be used even in contexts beyond digital agriculture. With regard to their affinity for technology, a Wilcoxon rank sum test showed no statistically significant difference between the two sub-samples regarding the ATI scores, which was contrary to our expectations (W = 47, p =.593). Our total sample scored an average of M = 4.41 (SD = 0.87) on the ATI scale, with only two participants scoring below the population mean of M_{quota} = 3.58 (SD = 1.09) as estimated by Franke, Attig, and Wessel (2018). A t-test showed the mean of our sample to be significantly larger than 3.58 (T = 4.03, df = 17, p ¡ .001). This could indicate that participants in our sample have relatively high affinity for technology. However, it should be noted that a high score of affinity for technology does not necessarily imply a high IT proficiency. Nevertheless, a high affinity could positively bias the assessment of usability and be a limitation.

6.1.3. Data analysis

The data analysis of the think-aloud data and the interviews was conducted in an analogous manner to the prestudy analysis described in Subsection 4.1.3. The

Table 3. Participants of the evaluation study.

ID	Age	Gender	Background
A1	29	m	Farmer
A2	26	m	Farmer
A3	63	m	Farmer and machinery ring worker
A4	53	m	IT expert with experience in agriculture
A5	32	m	IT expert with experience in agriculture
A6	32	m	Federal counselor for agriculture
A7	50	m	Farmer and machinery ring worker
A8	28	m	Farmer and machinery ring worker
A9	24	m	Farmer and machinery ring worker
R1	23	m	Research assistant (technical background)
R2	24	f	Research assistant (social science background)
R3	22	m	Research assistant (technical background)
R4	24	m	Research assistant (social science background)
R5	26	f	Research assistant (technical background)
R6	24	f	Research assistant (social science background)
R7	24	f	Research assistant (social science background)
R8	26	m	Research assistant (technical background)
R9	26	f	Research assistant (social science background)

length of the interviews varied from 19 to 65 minutes, with an average of 40 minutes. The questionnaires were analyzed according to the instructions of their authors.

6.1.4. Limitations

The evaluation is subject to limitations regarding the sampling. Just as in the prestudy, gender- or age-based biases are possible. The regional distribution of the participants with an agricultural background within Germany is uneven. For a detailed discussion of these limitations, we refer the readers to Section 7.

6.2. Results

In this section, we present the results of the evaluations regarding transparent control over data. We refrain from stating feedback for single UI elements and wording, since this is not the focus of this paper. Therefore, we will leave out comments on the wording of agronomic terms in the labels of the form and similar feedback.

6.2.1. Usability

The control matrix was seen by most participants as an effective means of controlling their own data. All were able to understand how the views of the different parties were generated and that they could control this data flow. The results from the UEQ-S usability questionnaire confirm this assessment: The prototype as a whole scored high on the *Pragmatic Quality* scale with a mean of M = 1.48 (SD = 1.26). The authors of the test state that values above 0.8 represent a positive evaluation. On the *Hedonic Quality* scale, the mean score was M =.62 (SD = 0.62), indicating an average result. The mean scores and confidence intervals are shown in Table 4.

However, there was also criticism of the system: A1 criticized that farmers could prevent orders from being carried out by being too restrictive. Through unawareness, important information necessary for execution of tasks by third parties would be withheld which was also stated by A3 and A17. The term "may see" would need to be changed to "must see" in many cases. Other negative experiences were stated: R1, R2, and R8 found that a lot of scrolling was necessary and that the form was very long. A6 added, that the form should be reduced to the necessary minimum of items. R9 and A8 shared the impression, that the control matrix takes up a lot of space and impairs clarity. The overall experience of R8 was that it would be annoying to do this more than once and stated: *'You hope that you get through eventually'*. A similar experience was stated by A7, but with a more positive meaning:

> Q13 (A7): At first it seemed annoying, but the further you got in the form, the more sense it made since certain data really isn't needed by everyone.

Some participants (R2, R4, R7) were surprised that every item could be managed separately, which was confusing at first. Furthermore, A8 brought up that farmers do not have the time it takes to manually configure the data access for everyone. In the case of multiple contractors, some would simply make separate disclosures for each contractor and set everything to visible. This view was also supported by the claim for pre-set values in the matrices by the participants A5, A6, A8, A9, and R5. In our prototype we gave a glance on these persistent settings by giving the opportunity to upload filled forms into the prototype. This way the participants would be able to reuse their settings from the first interaction with the tool. Furthermore, A8 and A9 stated that form-based workflows would only work if it would make further communication via phone obsolete. If additional phone calls could not be avoided with forms and the control matrix, using them would only be additional work for the farmers. As a solution, A9 proposed mobile support for these workflows so farmers could manage their data during meals or while waiting for the completion of other tasks, like the filling of a manure tank or supervising the satellite controlled machines in the field.

On the other hand, the control matrix was rated as easy to understand, even for first-time users (R3). A6, R3, and R7 found the two options easy to understand and approved the check, whether the rights are set correctly.

Another advantage of the control matrix was noted by A3. In agriculture, it is common that work orders are brokered by machinery rings. The control matrix would be an effective means to provide the machinery ring with the data needed for the mediation and, at the same time, to determine which requirements the performing parties would have to fulfill with regard to data processing and storage. The machinery ring could then select contractors who only need the data that a farmer wants to share. In this way, the control matrix supports standard farming practices and reduces

Table 4. Mean UEQ-S scores of the prototype.

Scale	Mean	Std. Dev.	N	Confidence	Confidence interval*	
Pragmatic Quality	1.477	1.254	18	0.579	0.897	2.056
Hedonic Quality	0.616	1.094	18	0.505	0.110	1.121
Overall	1.042	1.009	18	0.466	0.575	1.508

*Confidence intervals for α = 0.05 per scale the risk of non-completion of contracts due to unreleased information.

6.2.2. Default values for the control matrices

The default setting for usage rights was met with mixed feedback during the evaluation. A1 and R2 were initially confused and thought it was a demanded default that everything was set to 'may not see.' Further, R2 stated:

> Q14 (R2): Without preset, I would have been more concerned about each [right of use].

However, other participants gave positive feedback. A6, R3, R4, R5, and R9 explicitly praised the default setting to 'must not see.' In addition, R5 stated that global settings for presetting would be useful.

> Q15 (R5): A global "may not see" or "may see" for a given contractor would be useful to save work.

Similar claims for 'global' settings for each contractor were made by A8, R2, and R3. Such a procedure would lead to an inverted workflow: A contractor receives a permission for all data and, if necessary, individual rights are withdrawn. Such a procedure saves time, but could also lead to unwanted data disclosure.

Sharing data too sparingly can also lead to problems: A1 stated that jobs might fail if necessary data is not available. To avoid hindering job execution, R8 suggested that important data could be released by default. R9 has a similar view:

> Q16 (R9): *One could preset which data goes to the creator of the form, since he knows which data is absolutely required.*

This concept was also brought up by A4: Forms could be provided by service providers that contained pre-filled usage rights for essential parts of the order and would not be editable. A4 further commented that it would increase transparency if farmers were informed about why the use rights for some data are pre-filled and why that is necessary. This statement is particularly interesting because the word transparency was not mentioned previously during the interview and was introduced independently by A4 himself. In the study design, the term of transparency was not mentioned to the participants to avoid creating bias through nudging.

6.2.3. Sharing everything

Some of the participants without an agricultural background (R2, R4, R6) shared all data with everyone in the evaluation. This can be seen as an effect of the control paradox described in Section 2.2. Despite having the opportunity to control the data, the participants decided not to limit the access to their data. For example, R2 stated:

> Q17 (R2): [It] is probably not relevant to everyone, but I am releasing it to everyone anyway.

This does not necessarily suggest a lack of concern for data protection, but may also be due to the circumstances of the evaluation. R6 stated in the discussion:

> Q18 (R6): [I]f I had my own farm, I would have thought more about who should see what.

These statements confirm what the agricultural test subjects also said: Accomplishing the task must be simple and fast. For farmers, digitization is extra work that they just want to get done. Form-based workflows are generally seen as a hassle compared to a quick phone call to the contractor. Also, passing on data to third parties is often tolerated in practice if there is a phone consultation beforehand. A9 reported based on his work experience for the machinery ring:

> Q19 (A9): Farmers do not care if everyone sees all the data, since most are not sensitive data. [⋯] The farmer is fine with the contractor calling in a third party to pass on the data directly [⋯] after consultation with the farmer.

In the agricultural sample the rating of whether data is sensitive or not differs: While A9 wants additional consultations before sharing certain data, A8 does not consider most of the data in our scenario as sensitive, because most of the information could be obtained anyway by third parties. For example: The profit of farmers could be estimated by the size of their fields and the crop that is grown. Third parties could get both of these information by looking up the size of the cultivated land in official statistics and by observing the crop type on each field.

On the other hand, A9 confirmed that a specified and more restrictive disclosure is nevertheless useful:

> Q20 (A9): The other [parties] have the advantage of seeing only what they need to see.

According to this, third parties even benefit from sparingly released data, as it facilitates the extraction of the relevant information from the order.

6.2.4. Advanced rights of use

In the interviews on the prototype evaluation, it was asked whether further rights of use for handling shared data should be included in the matrix. Examples of this would be the right to store the released data beyond the execution of the order or permission to share data with third parties.

From an agricultural perspective, A8 reported that the matrix should not be extended, as this would overwhelm users. This impression is shared by A8, A2, R2, and R3. Even if some participants consider the extension of the matrix by some specific columns useful (R1, R6, R7) or even necessary (R8), most of the participants agree that the system with two columns is particularly straightforward. Other solutions are suggested for the extended usage rights:

- Extended usage rights could only be granted globally for each contractor individually (A7).
- A third column could be added to the matrix, in which the use of the data can be specified via dropdown menu (R3).
- Additional columns could only appear when "may see data" is selected (R4).
- An individual definition of what exactly "may see data" should mean for the respective party could be added in a separate step (R5).

However, granting extended rights of use also has disadvantages, as R5 finds: Data can be disseminated unintentionally if the right to disseminate is granted by mistake. This shows, that the participants are aware of possible consequences of the control paradox, even if they are not familiar with the concept. According to R5, disclosure should always be prohibited. Sharing with subcontractors should only be allowed after explicit consultation with the data owner.

6.2.5. Differences between the sub-samples

In our evaluation we investigated the feedback of two sub-samples by including participants with agricultural background and research assistants without any agricultural background. The first sub-sample gave us detailed insights into possible integration of such data sharing applications. More feedback on the general usability of these systems without projecting them to the agricultural domain, was provided by the research assistants. We encountered the following differences between the sub-samples: The research assistants were more likely to be overwhelmed by the size of the form (R1, R2, R8, R9). This could be due the fact that they do not know the average amount of data that has to be shared in an agricultural scenario. The participants with an agricultural background seemed to be more familiar with the amount of data and were not surprised by the size of the form. On the other hand, the agricultural sub-sample was more likely to emphasize the need for time-efficient completion of the form (A5, A6, A8, A9). The familiarity with the frequency of data sharing situations in their working routine may be the reason for that. The third major difference exists regarding the pre-settings of the matrices. Many research assistants (R3, R4, R5, R9) praised the default setting of "not visible" to be privacy preserving. This was criticized by one farmer (A1) who sees the risk of a failing collaboration due to insufficient data disclosure. With regard of the usability questionnaire UEQ-S, we conducted t-Tests for the Pragmatic Quality (T = 1.58, df = 15.21, p =.40), Hedonic Quality (T = −0.12, df = 15.73, p =.91) and Overall Quality scales (T = 0.84, df = 15.81, p = .83), to test whether the groups differed significantly (p-values were adjusted using the Holm method (Holm 1979)). None of the differences was statistically significant, even though we noticed a higher mean for the pragmatic quality in the sub-sample of research assistants (M = 1.93, SD = 1.33) compared to the agricultural experts (M = 1.03, SD = 1.06).

Although the prototype is still lacking some usability features and left out the transport implementation (see Figure 3), the main goal of the evaluation could be fulfilled: We shed light on the willingness of users to control their data themselves, even if it comes at the cost of extra effort. Making controls transparent to users requires them to invest more time to configure the data disclosure, however, it also raises user awareness. By deciding who can access which data item, users reconsider whether anyone really needs to know the data. This way, data is withheld that otherwise might be disclosed thoughtlessly alongside other operational data to all participants. Even those who set everything to visible for all contractors had to reconsider whether they wanted to make their data accessible to all. This way, transparent controls contribute to more self-determined data disclosure and enable users to take responsibility for their data.

7. Discussion and conclusion

In this paper, we investigated two research questions:

(1) Which requirements exist for agricultural information systems to allow small enterprises to participate in cooperative work scenarios without becoming transparent for competitors?
(2) (How) Can transparent controls contribute to better privacy behavior for farmers who are often time-constrained due to their daily work routine?

After conducting a prestudy with 52 participants from agriculture in Germany, we derived five challenges for data sharing applications in the domain of agriculture to address our first research question. The selection of challenges is based on our qualitative prestudy and does not claim to be exhaustive. However, these challenges point out important aspects of the technological development in the domain of agriculture. Unlike the IT expert users targeted for testing previous data sharing approaches (Reeder et al. 2008; Angulo et al. 2015; Wang 2019), farmers have proven to have specific demands and expectations. We addressed these with requirements for IT solutions and presented considerations for the implementation of suitable tools. Based on these requirements, we implemented a prototype to investigate the second research question. By giving the participants direct control over data disclosure, we were able to verify findings from the prestudy. By means of our prototype, we evaluated that form-based access control with control matrices is a valid way to distribute data. This reinforces the finding of Tolone et al. (2005) that, despite the old age of the approach, access control matrices remain effective and intuitive visualizations for data-sharing users. Addressing the shortcomings of access control matrices (see Tolone et al. (2005)) offers potential for future work. However, especially the agricultural participants pointed out that time constraints are a major factor in their office work. This often favors time-saving data disclosure in the trade-off between effort and control. In the following, we will discuss the results in more detail.

To address the *first challenge* of compatibility, we developed a form-based demonstrator utilizing JSON files. The distribution of these files can be done in a variety of ways, depending on implementation or background technologies. Sending them via email is possible, as well as uploading them to a cloud or attaching them to a smart contract on a blockchain. JSON files are machine-readable, which allows automated processing and thus is suitable for integration into existing management tools. Additionally, the use of JSON as a data exchange format fulfills the open source requirement stated in related work (Carbonell 2016).

We addressed the *second challenge* of sector diversity by using a technology which allows the distribution of modified editors to generate JSON-based forms that could fit any purpose. By utilizing the control matrix, each user can decide which parts of the form should be available for whom. This way, the form can be used for different purposes and discloses as little information as required. In our evaluation, we presented a static form; however, via a drag and drop editor provided by *form.io* the customization of forms is easy to handle. In our scenario, the generation and customization would be done by expert users at the machinery rings or by contractors themselves.

The *third challenge* of media diversity was considered in the concept, but not fully implemented: In our evaluation, we did not support mobile versions as the interviews were conducted remotely during the COVID-19 pandemic. However, mobile support was not only a requirement from the prestudy, but was also mentioned during the evaluation: A9 suggested that farmers might fill out forms during meals or while in the field. Although our prototype had a responsive design to fit monitors of each size, full mobile support is still lacking and urgently needed. Using the *ionic* framework, we were able to build a responsive user interface. The extension to mobile support would only be a small step.

To investigate on the *fourth challenge* of transparency balance, we conducted a qualitative study with a prototype that gave users control over the data flow. We found that forms with control matrices are a proper measure to control the access to operational data within a job order. With the positive feedback on the prototype, being easy to understand for first-time users, we conclude, that the privacy pattern of 'Direct Access to UI Components' (MuIacononoz-Arteaga et al. 2009; Iacono, Smith, and Gorski 2021) was successfully implemented. However, the additional control comes at the cost of time and effort spent configuring data access. We tried to minimize this effort by offering a pre-fill option to load previously completed forms to facilitate the use of follow-up contracts. With this feature, users just need to take the time to fill out the form once. Additionally, there are approaches that individualize the data sharing default, either through ex ante policy definitions or feedback-aware ex post mechanisms (e.g. machine learning). The work of Paci et al. offers a comprehensive overview of potential approaches to include an enhanced presetting for future work (Paci, Squicciarini, and Zannone 2018). Overall, the feedback was mixed: The workflow was clear and well structured and the possibility to decide for each data object was appreciated. However, giving users control will take more time. Our study gave a peek on the willingness of users to make this trade-off. Furthermore, some participants stated the fear, that data could become disseminated unintentionally, if controls become too complex and users get confused and have no overview anymore. This could be seen as awareness for the effects of the control paradox. We tried to minimize this risk by setting all values to 'must not see' by default according to the privacy pattern 'Disable by Default' (Garfinkel 2005; Iacono, Smith, and Gorski 2021). This design decision was appreciated explicitly by many participants (R3, R4, R5, R9). Furthermore we provided the user with an option to preview the data before sending in order to comply with the privacy pattern of 'Delayed Unrecoverable Action' (Garfinkel

2005; Iacono, Smith, and Gorski 2021). This is a safeguard for the irreversible data disclosure. In the questionnaires, the pragmatic quality was rated good which leads to the conclusion that form-based access control is a promising approach. The hedonistic quality was rated neutral, which could be due to the fact that the prototype is still immature or the effort required in use. Another factor is that form-based tools are not yet widely used in agriculture. The amount of digital management is increasing, but many farmers still place orders by telephone. Compared with these calls, which can be made during work, form-based approaches are more complicated. On the other hand, we were able to prove that access control matrices with two usage rights ('is allowed to see data', 'must not see data') were easy to understand and did not lead to information overload. However, further investigation on the trade-off between effort and control is needed, for example with a qualitative follow-up study to validate our results. An important criterion for such a follow-up study is the investigation on the users' perception of their own possibilities to protect their data. In our study, we were able to gain insight into the fact that the sensitivity of business data was seen differently. While some farmers rated their data as very sensitive, others (e.g. A8) find the protection of this data tedious and unnecessarily time consuming, because third parties might find other ways to acquire this data anyway.

The *fifth requirement* is not yet met by our prototype. Due to the independence from a background technology, the tamper-proof store of the rights of use is lacking. The users are able to store the JSON files themselves, but since the transport of data was out of scope, the ex-post traceability is not yet implemented.

The results are subject to *limitations*: (1) Our study has a focus on agricultural SMEs, because in this domain it is common that job orders include multiple actors and operational data needs to be distributed for highly digitized machines that require precise data. Nevertheless, these factors may also apply to other domains where SMEs are facing powerful up- and downstream players, which may gain advantages over them by access to operational data. (2) All interviewees from the agricultural sector (from both studies) run their farms in southwestern Germany, where the land structure differs fundamentally from eastern Germany due to the former division of Germany and former inheritance rules. Consequently, the study is not representative for agriculture in all of Germany, but readers should interpret it as a local picture of the western federal states in Germany. (3) Moreover, gender bias cannot be entirely ruled out, as the proportion of female participants for the agricultural samples in the study is well below 50 percent, potentially leading us to overlook challenges that affect women more than men. (4) Additionally, the sample included mostly young professionals, potentially reproducing negative stereotypes of the use of technology by older people (Mariano et al. 2021). (5) The qualitative method of the focus groups allows exploratory findings, but it cannot be used to test the hypotheses derived. (6) Also, in the prestudy, we could not always identify individual correlations between farm characteristics and challenges as it would have been possible in individual interviews. Despite these limitations, we have gained a detailed insight into farm processes and, in particular, data flows and corresponding challenges on which we can base the design of the data model.

For *future work*, we are planning to develop novel user-centered interventions that make the process of data disclosure even less time consuming. In the current prototype, we used control matrices since these are hardened constructs that were validated in previous research (Tolone et al. 2005; Kolomeets et al. 2019). We opted for this conventional control measure to prevent the bias that the control measure itself would not be usable and therefore the main focus of the evaluation on the effect of transparency on controls would not be accessible. Additionally, our findings could be used to construct a quantitative survey to validate our findings and get a more general impression of how farmers deal with the trade-off between effort and control.

To *conclude*, our contribution is threefold:

(1) We conducted an empirical study with 52 German farmers to derive requirements for information systems in agriculture in order to minimize the threats of data misuse.
(2) We then presented a data sharing model designed for decentralized data sharing systems such as blockchain ecosystems, which offers required features such as deletion periods and the definition of usage rights for data assets while preserving integrity and accountability to fight data misuse.
(3) We developed a prototype with transparent controls to assist users in the data disclosure process for their business collaborations. This feature was then evaluated to estimate its impact on the working routine of non-expert users with time constraints such as farmers.

To summarize, farmers demand local processing of their data. Data ownership is a major issue in a domain where data sharing is a vital aspect of collaboration, while at the same time, however, this poses the risk of endangering the business continuity in case of data misuse. Form-based data disclosure with control matrices could assist users in minimizing the data they share with third parties while giving them transparency on who gets which data. However, users have to spend a certain amount of time and effort to adjust settings accordingly, which is not favored by users with tight time constraints.

Note

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

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the German Federal Ministry for Education and Research (BMBF) in the project HyServ (01IS17030B), by funds of the German Government's Special Purpose Fund held at Landwirtschaftliche Rentenbank in the project GeoBox-II and AgriRegio and by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - 251805230/GRK 2050.

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Appendix

A.1. Prestudy guideline

We are interested in whether and what role digitization plays in your company and how your company deals with risks that jeopardize operations (prevention). In addition, we are interested in your assessment of the resources or services you need to enable or facilitate the management of emergency situations and incidents. There are no answer specifications here, nor are there any "right" or 'wrong' answers. We ask you to answer as detailed and open as possible.

Aim of the interview:

- Insight into communication processes and planning tools.
- Determine the influence of digitization on the processes and orientation in the respective company (opportunities and threats).

Guiding questions for the focus group interviews:

- 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?

A.2. Evaluation guideline

Over the next 45 minutes, you will create an example seeding order for winter wheat. The following parties are involved in the order: yourself in the role of the client, the *maschinenring* as the settlement agent, a contractor who provides the machine and performs the work in the field, and a supplier who provides you with the required seed. Please note: the presented form is a shortened version to simplify the execution of the evaluation. For example, file upload options for shape files have been removed, and only data for a single plot is requested.

To understand your reasoning and how you interact with the evaluation tool, we would like you to 'think aloud', i.e. speak whatever thoughts come to your mind as you work through the tasks. This method is called 'think-aloud'.

Due to the COVID-19 pandemic, the evaluations will take place virtually. For this purpose, the conference tool *Zoom* will be used, as it works without installing a client in the browser. Moreover, to conduct the evaluation, you are supposed to share your screen. To conduct the evaluation, consent to record the conference session is required. The recordings will only be used pseudonymously, and the data will only be stored on university internal servers. Your consent is required for us to collect and process the data. Please read the separately enclosed consent form and return it completed by email.

Step 1: Fill out the form. Please upload the template you would like to fill out. In this scenario, you have been provided with an order form for sowing winter wheat from *maschinenring* (template.json). After filling in the form, please check your entries and then press 'submit'. The program will then process it in accordance with the usage rights you have assigned, to ensure that only data approved by you is sent to a specific organization. Two files will be created for each of the three recipients: one containing the structure of the visible form (e.g. maschinenringformularstruktur.json) and one containing the approved content (e.g. maschinenringinhalt.json). In addition, a file is created for your records (overallform.json). You can use this file, for example, to pre-fill follow-up orders based on your previous entries. Please save these seven files for the next step.

Step 2: Display form. In this step, you can take on the role of the other parties and see how the completed form looks from their perspective. To do this, please upload two related files. In the left upload the form structure.json file and to the right the corresponding content.json file.

Step 3: Prefill. The overall form.json file from the first step can be used to create a similar order for the following season if the parties involved remain the same. For this purpose, the file can be uploaded together with the template.json in step 1 and the form from step 1 is pre-filled with the previous entries. Now, only individual entries would need to be changed to create a follow-up job.

Step 4: Final interview and feedback. Following the completion of the above tasks, they are reflected upon during the interview and a short questionnaire is handed out to measure the subject's affinity for technology. This is done to better classify the subject's interaction with the system.

- Did you have a sense of control over the process?
- Did you feel in control of who gets what data?
- Were the results apparent in the 'Review' step, based on the input you gave in the 'Fill in' step?
- What is your opinion of the control matrix?
- Would this tool be suitable for defining further usage rights or would it then become too confusing?
- Have you had experience with data sharing in other contexts? If so, how was it handled?