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Insights into the post-adoption use of decision support systems in dairy farming: comprehensibility, reliance, challenges and opportunities

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Digital decision support systems (DSSs) are increasingly used in dairy farming, yet little is known about how farmers work with these tools after adoption. This study examines post-adoption use among 105 German dairy farmers across feeding, breeding, and health and claw care, focusing on perceived comprehensibility of DSS recommendations, its relationship with DSS reliance, and the challenges farmers face. Using a nationwide online survey, we combined descriptive statistics, Spearman correlations with Benjamini-Hochberg correction, multivariable regression, and qualitative analyses, complemented by a sensitivity analysis to examine robustness. Results show that DSSs are primarily used for structured monitoring, while their role in judgment-based decisions remains limited. Perceived DSS comprehensibility consistently correlates with DSS reliance across all three areas, with multivariable regression confirming this relationship holds independently of socio-demographic factors. Educational background, farm size, and economic dependence on dairy farming also correlate with both constructs at the bivariate level. Qualitative feedback highlights recurring challenges including poor interoperability, unclear recommendations, and mismatches between system assessments and on-farm observations. Overall, our study positions DSS comprehensibility as the most actionable lever for increasing practical value, while interoperability as the most frequently cited challenge likely requires cross-industry coordination and regulatory support.

Keywords
Decision support systems, dairy farming, post-adoption use, explainability

The agricultural sector is an essential pillar of society, and its importance is well known to the public. The sector provides food for the growing population, produces energy, and can contribute to climate protection as well as the preservation of resources and biodiversity by ensuring environmentally responsible practices (Becker et al. 2018).

Agriculture is a wide field with many specializations, such as arable farming (e.g., cereals, vegetables, fruit, viticulture), livestock farming (e.g., dairy cattle, beef cattle, pig farming), or forestry, among others. Given the fundamental differences across the various areas (e.g., typical tasks, daily decision-making processes, and operational challenges), it is worthwhile to narrow the focus of agricultural research to enable deeper insights rather than just general perspectives. With this in mind, we dedicate our study to the dairy farming sector in Germany as the largest milk producer in the EU

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to date (Eurostat 2025). The focus on Germany is also a result of local networks and contacts that proved valuable for the dissemination and implementation of various work steps in this study.

Digitalization has enabled many innovations that can help to monitor the health and well-being of animals (Neethirajan and Kemp 2021). Traditionally, herd management has relied largely on personal experience and observations of farmers and their staff. Today, the sector is increasingly exploring new innovations to support decision-making and productivity (Walter et al. 2017, Tullo et al. 2019). A wide range of digital systems are being integrated into traditional farming practices, offering farmers data-driven solutions to manage everyday tasks (Rutten et al. 2013, Eastwood et al. 2021). For instance, automated milking systems (AMSs) can reduce labor costs and provide insights into milk production parameters (e.g., milk yield, temperature) that also allow for animal health monitoring. Likewise, wearable sensors can track health data and animal activity (e.g., body temperature, rumination patterns, time spent standing or lying), thus enabling early detection of health issues (Lamanna et al. 2025).

A well-known problem in dairy cows is mastitis, an infectious disease of the udder that reduces the yield and quality of milk and is a major cause for the administration of antibiotics. Similarly, heat stress can lead to drastic and sustained declines in milk yield. Monitoring relevant animal parameters for abnormal changes (e.g., body temperature, lying times) can provide early warning signs and help farmers take timely action (Steeneveld et al. 2008).

Decision support systems (DSSs) offer further support. We refer with this term to digital systems that offer farmers data-driven insights or recommendations for their operational decisions. Examples of DSSs are herd management systems that help monitor and optimize herd performance, AMSs that track milk yield, feed management systems that optimize feed composition and rations, fertility tracking systems that suggest optimal breeding times, and health monitoring systems that enable early detection of illnesses or lameness (Zhai and Martínez 2020).

Despite their potential benefits, DSSs face limited acceptance among many farmers, and their adoption in practice remains generally low (Michels et al. 2019, Gabriel and Gandorfer 2023). There is a considerable gap between their theoretical potential and actual use, which we believe is worth investigating. Are today’s digital systems not as good as we think? Are they too costly, too difficult to use, or simply not well aligned with the needs of farmers? Or do many farmers simply prefer to rely on their own experience and observations over digital support?

Most previous studies focus on the adoption (or planned adoption) of digital systems and related barriers, among which the lack of interoperability between systems is often highlighted as a key challenge, which leads to fragmented and inefficient workflows (Schulze Schwering and Lemken 2020, Dibbern et al. 2024). Other studies focus on socio-demographic factors (e.g., farm size, age, educational background) and how they correlate with the willingness to adopt digital systems (D’Antoni et al. 2012, Paustian and Theuvsen 2017, Pfeiffer et al. 2021). General findings are that larger farms typically have greater financial resources, making it easier for them to invest in new technology and positioning them as the primary target group for many digital systems (Isgin et al. 2008, Giua et al. 2021, Shang et al. 2021). Another finding related to socio-demographic factors is that, as of 2021, older farmers were still less likely to own smartphones, which in turn reduces their adoption of smartphone-based solutions (Michels et al. 2021). Additionally, a higher educational background of farmers was generally found to be associated with a positive effect on the adoption of digital systems (Palma and Toledo 2010, Tey and Brindal 2012, Giua et al. 2021).

There is also increasing research into the complexity of systems. Excessive complexity can hinder adoption, especially if recommendations given by digital systems are not comprehensible enough to users (Schukat and Heise 2021, Islam et al. 2022). With the increasing advent of artificial intelligence (AI), this issue is likely to become even more relevant, as such systems usually are black boxes, making it difficult for end users (and sometimes even developers) to understand how decisions are reached. Our work adds to this line of research and examines how the comprehensibility of systems could support the management of complexity. However, in doing so, we do not limit our focus to AI-based systems, but understand the term explainability in a broader and more general sense.

Adoption in the context of most studies essentially implies the acquisition of systems, meaning the purchase and deployment on the farm. While there are many studies on the adoption of various systems in the literature, we consider insights into the post-adoption use an even more meaningful indicator for the practical benefits of systems. Such insights are, however, limited due to a lack of dedicated studies. We aim to contribute to this line of research by focusing on how farmers perceive the comprehensibility of DSSs and whether this perception correlates with their willingness to rely on such systems in daily operations.

To summarize, this study explores the post-adoption use of DSSs in the German dairy industry to better understand farmers' requirements, challenges, and practical needs. We examine which barriers farmers encounter when working with DSSs, how strongly they rely on these systems across key management areas, and how socio-demographic factors are associated with their perceptions and usage. In addition, we examine the perceived comprehensibility of DSS outputs and its relationship with farmers' willingness to rely on them. Together, these insights aim to inform the design of DSSs that are better aligned with the requirements of dairy farming practice.

Material and methods

We use an online survey with both quantitative and qualitative components to investigate the following research questions:

- RQ1: To what extent do farmers rely on personal or staff experience versus decision support systems (DSSs) when making decisions?
- RQ2: How comprehensible are DSSs in the eyes of farmers?
- RQ3: How important is the comprehensibility of DSSs to farmers?
- RQ4: Do socio-demographic factors correlate with perceived DSS comprehensibility?
- RQ5: Does the perceived comprehensibility of DSSs correlate with farmers' willingness to rely on them?
- RQ6: What challenges and possible improvements do farmers suggest when using DSSs?

This study was conducted between July 2023 and June 2024. We contacted dairy farmers across Germany through various farmers associations and consulting companies, which forwarded the survey via emails and newsletters. A total of 194 farmers participated, of which 105 completed the survey in full. Only the fully completed responses were included in the analysis. The limited completion rate likely reflects the survey's length, which aimed to generate rich insights. Engaging farmers and collecting data for scientific research poses a challenging task due to their demanding workloads and the frequency of participation requests they receive.

Scientific literature on research acceptance in German agriculture highlights various approaches to engaging farmers. These include surveys conducted at agricultural trade fairs (Reichardt et al. 2009), recruitment through social media platforms (Michels et al. 2019), and qualitative data collection via in-person interviews (Kutter et al. 2011). However, obtaining unbiased and representative data from farmers remains a persistent challenge, except through costly surveys conducted by commercial providers (Mohr and Kühl 2021). Despite the well-known difficulties of recruiting large numbers of farmers for academic research, our survey reached a considerable number of participants. Although the sample size is not fully representative of all German dairy farmers, the findings provide meaningful insights. The results not only contribute to the body of research in the field of digital farming, but can hopefully also serve as a basis for targeted follow-up studies.

Survey design

We created the survey with LimeSurvey (LimeSurvey GmbH, Hamburg) in German. The survey was pre-tested with eight farmers, and their feedback was used to refine the questions and response options in multiple iterations. Figure 1 illustrates the survey process, from the initial design to data analysis.

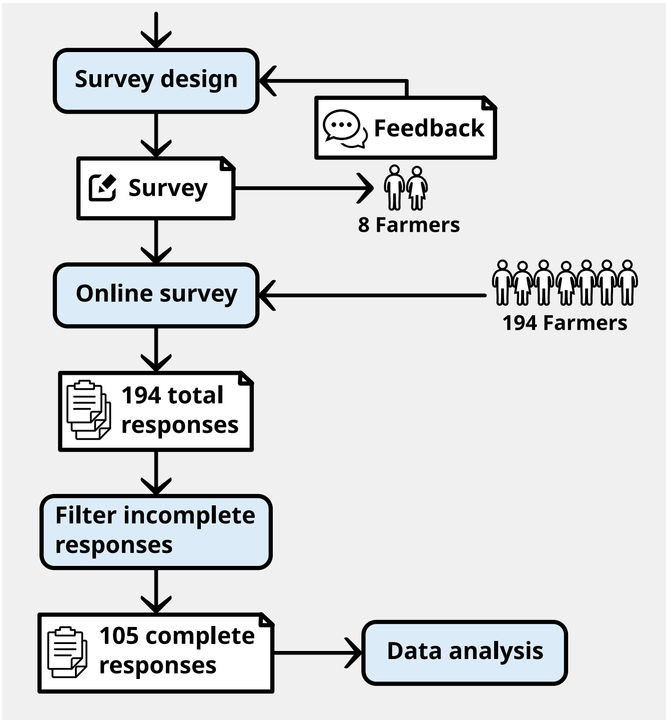

Figure 1: Study methodology overview

We focused on three main areas of dairy farming: feeding, breeding, and health and claw care. In collaboration with practitioners, we divided each of these areas into tasks, which reflect the most important aspects of decision-making. The breakdown of areas into tasks is shown in Table 1. Furthermore, we provide the original German task names (as presented to the survey participants) in Table T.1 of the Supplementary Material (see the link at the end of the article).

Table 1: Breakdown of the three areas into tasks

Area	Tasks
Feeding	Ration planning, monitoring concentrate intake, forage quality assessment[1)], evaluating ration structure[2)], pasture management, feed quantity management
Breeding	Bull selection[3)], planning first insemination, detecting fertility disorders[4)], selecting animals for housing, fertility management[5)], heat detection, documentation
Health and claw care	Monitoring rumination activity, performance recording[6)], recording claw findings, lameness detection, body condition scoring (BCS), treatment decisions, drying-off[7)], monitoring udder health[8)]

[1)] Silage quality [2)] Structural effectiveness of the ration [3)] Selection criteria [4)] Including cysts, corpus luteum [5)] Selection, pregnancy checks [6)] Including milk yield, daily weight gain [7)] Antibiotic or non-antibiotic [8)] Mastitis detection

In the survey, we collected socio-demographic and decision-making variables from participants, as shown in Table 2. The decision-making variables were recorded using sliders ranging from 1 to 100.

Table 2: Overview of the socio-demographic and decision-making variables collected in the survey

Socio-demographic variables	Age, education, farm location[1)], farm size[2)], main source of income[3)], DSS-based reports to HI-Tier[4)]
Decision-making variables	Importance of good decision-making[5)], DSSs reliance[6)], perceived DSS comprehensibility[7)], importance of DSS comprehensibility[8)]

[1)] By German federal state [2)] Measured by number of cows [3)] Whether dairy farming is the main source of income [4)] Whether a DSS is used to report to HI-Tier [5)] Perceived importance of good decision-making for farm success [6)] To what extent farmers rely on DSSs rather than on personal or staff experience [7)] How comprehensible participants find the decision support provided by DSSs [8)] How important DSS comprehensibility is to participants

Lastly, farmers were asked to name the DSSs they currently use and to share any challenges or suggestions for improvement. These responses were collected as free-text input.

Data analysis

We evaluated the 105 complete data sets extracted from the survey. The analysis is divided into four parts: robustness checks, descriptive, inferential, and qualitative analysis (Figure 2).

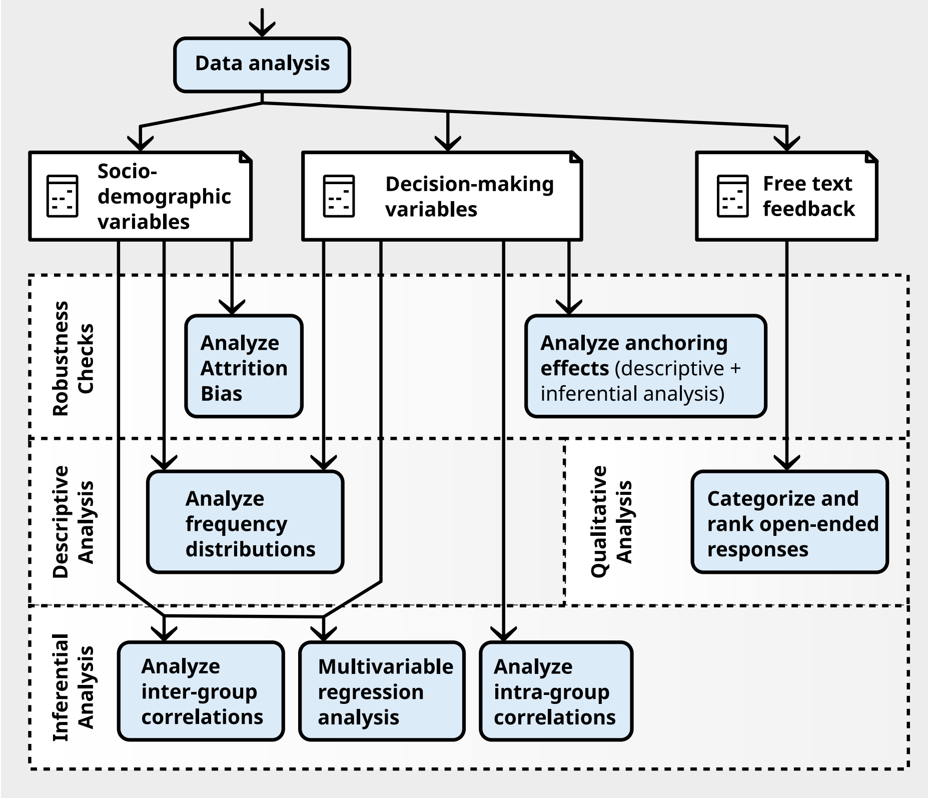

Figure 2: Data analysis methodology overview

Robustness checks

Prior to the main analysis steps, we conducted two robustness checks. First, we performed an attrition bias analysis comparing completers and non-completers across six socio-demographic variables to assess whether survey drop-out was systematic. Second, we conducted a sensitivity analysis examining the influence of slider default values on the decision-making variables, as participants who left sliders at the default position of 50 may not have provided genuine ratings for those items.

Attrition bias analysis

Participants who did not complete the survey (non-completers) were excluded from the analysis. Only complete questionnaires (completers) were used. To assess potential attrition bias (whether survey drop-out was systematic and skewed the sample toward particular demographic groups), we compared both groups across five socio-demographic variables using chi-square tests, Fisher's exact test for 2×2 tables, and a two-tailed Mann-Whitney U test for farm size as a continuous variable. Since many non-completers answered at least some socio-demographic questions before abandoning the survey, we used all available responses per variable, resulting in varying sample sizes.

Sensitivity analysis: anchoring effects of slider defaults

Decision-making variables were collected using sliders ranging from 1 to 100, initialized at the midpoint of 50. A number of participants left the default value unchanged on certain questions, plausibly reflecting indifference or non-applicability rather than a genuine rating of 50. Where the median of an item equaled the default, it cannot be reliably determined whether this value reflects true central tendency or anchoring to the default. To address this, we conducted a sensitivity analysis comparing medians computed on the full dataset (including default values) against a restricted dataset in which exact default values were excluded per item. Items where the median shifted by ten or more points between the two sets were flagged as potentially anchoring-influenced. As the restricted dataset better captures deliberate farmer responses, it is treated as the primary basis for reporting and interpretation throughout this paper. Full-dataset medians are provided alongside for transparency.

Descriptive analysis

In the descriptive analysis, we generated an overview of the dataset, the participants, and the state of practice in dairy farming as reflected in our data by evaluating the socio-demographic and decision-making variables shown in Table 2. This analysis step provides the basis for answering RQ1, RQ2, and RQ3.

For ordinal variables, such as age (recorded in age groups) and education (based on educational backgrounds and programs), and the categorical variable farm location (by German federal states), we report the frequency distributions. For the continuous variable farm size (measured by the number of cows), we calculated the minimum, maximum, quartiles, median, and mean. For the continuous decision-making variables, we report the medians.

To validate the representativeness of our dataset, we assessed how the distribution of socio-demographic variables aligns with publicly accessible national data where such data was available.

Inferential analysis

In the inferential analysis, we examined statistical relationships between different variables. First, we examined inter-group correlations between the socio-demographic variables and the decision-making variables. The goal was to examine whether knowledge about end users (their socio-demographic characteristics) can provide clues about their likely preferences regarding decision-making, thereby addressing RQ4. Second, we examined intra-group correlations within the decision-making variables, more specifically, between the perceived comprehensibility of DSSs and the reliance on them to assess whether our data supports the RQ5 assumption that greater comprehensibility is associated with higher willingness to rely on the systems. We based the inferential analysis on Spearman's correlation and multivariable regression. Below, we describe both methods, including our reasoning for choosing Spearman's correlation and our approach to controlling for Type I errors through False Discovery Rate analysis.

Spearman's correlation

Spearman's correlation coefficient quantifies the strength and direction of a monotonic relationship between two variables. It is calculated based on the ranked values of variables (rather than raw values). The resulting rho-coefficient ranges from −1 (perfect negative monotonic relationship) through 0 (no monotonic relationship) to +1 (perfect positive monotonic relationship). This method is well suited for data with a monotonic, but not necessarily linear, relationship. Moreover, Spearman's correlation is robust to outliers and does not require the data to follow a normal distribution.

The p-value tests the null hypothesis that the true correlation is zero, indicating no association between the variables. A p-value below a predefined threshold is interpreted as evidence of a statistically significant correlation. In this study, we set the significance threshold at $\alpha = 0.05$, following standard statistical practice.

Considerations for choosing Spearman over Pearson

We also considered but ultimately discarded Pearson's correlation coefficient (Rebekić et al. 2015) for our dataset. Pearson's r quantifies the strength and direction of a linear relationship between two continuous variables. It assumes normally distributed data, measured on at least an interval scale, with numeric distances interpreted meaningfully. Pearson's r is sensitive to outliers and may fail to detect non-linear relationships or those distorted by extreme values. In our dataset, farmers with strong opinions tended to select values at the lower or upper ends of the scale, increasing the likelihood of outliers and making a normal distribution unlikely. Although the decision-making variables (1–100) can be considered continuous, it is questionable if participants treated the scale as a true ratio scale, i.e., interpreting numeric distances meaningfully. This is particularly true as participants were instructed to provide quick assessments to reduce survey fatigue. Under these conditions, we consider Spearman's correlation the more robust measure.

False discovery rate

When conducting multiple simultaneous correlation tests, the probability of obtaining false positives (Type I errors) increases with the number of tests performed. To control for this, we applied the Benjamini-Hochberg (BH) procedure (Benjamini and Hochberg 1995), which controls the false discovery rate (FDR), meaning the expected proportion of false positives among all rejected null hypotheses. Given the predominantly exploratory nature of this study, which aims to identify patterns (rather than confirm pre-specified hypotheses), we consider preserving statistical power important. The BH procedure is therefore preferable over stricter family-wise error rate corrections such as Bonferroni. We computed adjusted p-values for each correlation matrix separately. The significance threshold ($\alpha = 0.05$) was applied to the BH-adjusted values throughout.

Multivariable regression analysis

To more rigorously address RQ5, we examined whether perceived DSS comprehensibility is independently associated with DSS reliance after controlling for demographic factors, conducting multiple linear regression analyses for each area (feeding, breeding, and health and claw care). The dependent variable was DSS reliance, aggregated by averaging the task-level responses within each area (range 1 – 100). Independent variables included: (1) perceived DSS comprehensibility (range 1 – 100), (2) age (ordinal), (3) education (ordinal), (4) log-transformed farm size (number of cows), and (5) main income (binary). Farm size was log-transformed to account for its wide value range and to reflect the proportional rather than absolute nature of farm size effects (e.g., an increase from 50 to 100 cows represents a more substantial change than from 1000 to 1050 cows). We used ordinary least squares (OLS) regression. Statistical significance was assessed at $\alpha = 0.05$.

Qualitative analysis

As part of the qualitative analysis, we analyzed the free-text survey feedback to address RQ6. We reviewed and interpreted each response, grouped similar statements into categories, determined the frequency of each category, and ranked them by number of mentions. The feedback included reported challenges and suggestions for improvement in using DSSs, as well as listings of the DSSs used by the participants. The purpose of this compilation was not to map the reported feedback to individual systems, let alone to compare individual systems, but to provide a general overview of common issues encountered in practice and the system landscape represented in our dataset. The full categorization of participant feedback for each area is provided in Tables Q.1, Q.2, and Q.3 of the Supplementary Material.

Some systems named by participants do not meet our definition of a DSS, such as HI-Tier, customized Excel spreadsheets, or agricultural machinery without software components. While customized spreadsheets can offer decision support, they are highly individualized and difficult to compare across farms. These entries were excluded from the analysis.

We translated the original free-text feedback into English for presentation purposes. In doing so, we aimed to preserve the tone and intent of the statements as closely as possible. Spelling and grammatical errors in the original responses were corrected during translation.

Results

The following sections present our findings, structured according to the three analysis steps outlined.

Robustness checks results

Attrition bias analysis

Of the 194 participants who began the survey, 105 submitted complete questionnaires (completers) and 89 did not (non-completers). No significant differences between both groups were found for age, education, or farm size. A significant difference was found for main income source (Fisher $p < 0.001$): completers more frequently reported dairy as their primary income than non-completers (90.5 % vs. 66.7 %), suggesting that the final sample may over-represent farmers for whom dairy is the core business. Farm location showed a near-significant difference ($p = 0.066$): Bavarian farmers were considerably more prevalent among non-completers than completers (54 % vs. 28 %). Although this difference did not reach statistical significance, its practical magnitude is acknowledged as a potential limitation on the generalizability of findings. The full demographic comparison is provided in Table A.1 of the Supplementary Material.

Sensitivity analysis: anchoring effects of slider defaults

The sensitivity analysis confirmed that results from the restricted dataset are largely consistent with the full dataset, supporting the robustness of our findings. For full comparison, see Tables S.1–S.8 in the Supplementary Material.

Descriptive analysis results

We begin with an overview of the socio-demographic characteristics of our sample, followed by the decision-making variables collected in the survey.

Age

The majority of farmers in our sample fall within the 26–40 age group, accounting for 52.4 % of all participants. Official statistics from the German Farmers' Association indicate that, in 2023, most farmers in Germany were between 55 and 65 years old (28 %), followed by those aged 45–55 (18.2 %) (Deutscher Bauernverband e.V. 2025). This indicates that the participants in our data set are, on average, younger than the national farming population. The age distribution is shown in Figure 3.

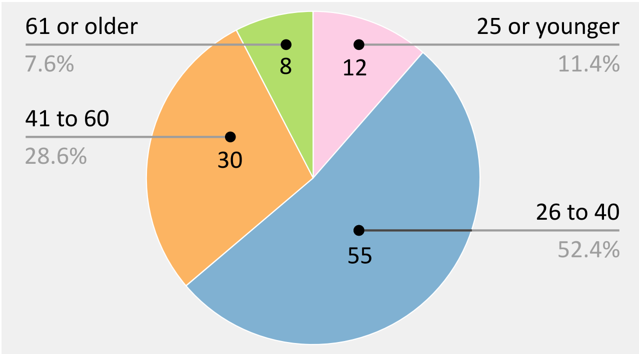

Figure 3: Age distribution of participating farmers in our data set (n = 105)

Education

Educational backgrounds varied considerably among participants (Figure 4). The rankings are indicated with superscript numbers (1 – 5), where higher numbers imply higher qualifications.

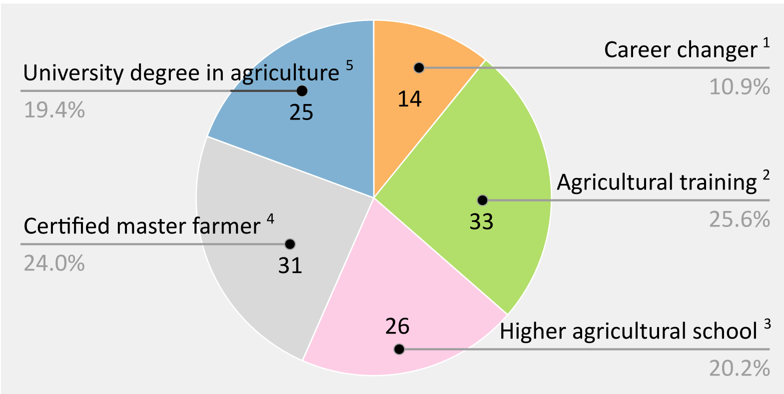

Figure 4: Educational backgrounds of the participating farmers (n = 105)

A large proportion of 25.6 % have completed agricultural training2, while 24.0 % hold the title of certified master farmer4, followed by 20.2 % who attended a higher agricultural school3. Farmers with a university degree in agriculture5 account for 19.4 %, and 10.9 % reported entering dairy farming as career changers[1]. The German names of the educational qualifications as originally presented in the survey are provided in Table T.2 in the Supplementary Material. To our knowledge, no comparable official statistics are available.

Farm location

The federal states of the participating farms are shown in Figure 5. The majority originate from Bavaria, 27.6 %, and North Rhine-Westphalia, 26.7 %, which together account for more than half of the respondents. They are followed by Rhineland-Palatinate with 19.0 %, Hesse and Lower Saxony with 5.7 % each, Saarland with 4.8 %, and Schleswig-Holstein with 3.8 %. The category “Others”, with 3.8 %, includes German regions with two or fewer respondents (Brandenburg, Mecklenburg-Western Pomerania), as well as neighboring German-speaking countries with a total of four participants. Although these participants lie slightly outside the scope of our study, we chose to include them due to the high similarity in farming conditions and our aim to maximize sample size.

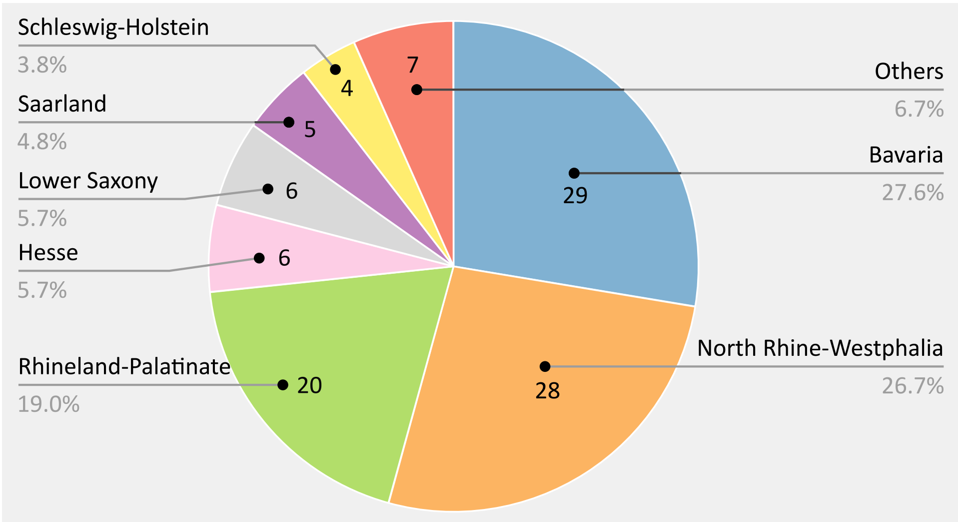

Figure 5: Distribution of participating farmers across German federal states (n = 105)

The regional distribution of responses largely reflects the way the survey was disseminated through organizations such as farmers' associations and agricultural consulting companies. Regions with a high number of participants benefited from more extensive or more effective outreach, while dissemination in other regions was less successful.

Farm size

The number of dairy cows among the surveyed farms ranges from 12 to 977, with a mean of 150 and median of 115, reflecting substantial variability. According to official statistics, the average herd size in Germany is 74 cows (Deutscher Bauernverband e.V. 2025). This indicates that the farms in our sample tend to be larger than the national average. This is consistent with the findings of the attrition bias analysis, which showed that completers more frequently reported dairy as their main income, likely indicating larger herd sizes. The distribution is illustrated in Figure 6.

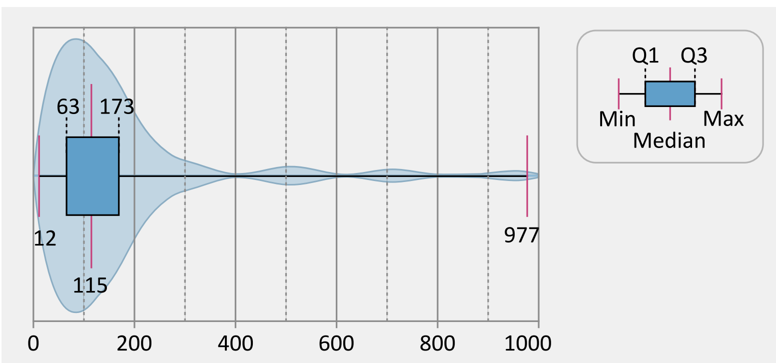

Figure 6: Distribution of farm size (number of cows) among the participating farmers

Main income

The majority of participants, 90.5 %, indicated that dairy farming is their primary source of income (Figure 7). This high proportion suggests that the survey may have predominantly reached farms with a strong economic focus on milk production rather than diversified operations. It is further amplified by the attrition bias finding that farmers without dairy as main income dropped out at a higher rate. To our knowledge, no official statistics on the share of German dairy farms relying primarily on milk production exist, so no comparison with national data is possible.

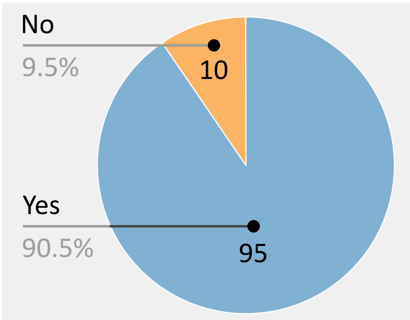

Figure 7: Distribution of farmers by whether they reported dairy farming as main source of income (n = 105)

HI-Tier reporting

HI-Tier is the national German livestock database, in which farmers are legally obligated to register cattle movements and relevant events. Compliance with these reporting requirements can be fulfilled through manual entry via the HI-Tier web interface or through integrated external systems, such as DSSs. Where data is already captured within a DSS, automated reporting to HI-Tier can substantially reduce the administrative burden on farmers. As shown in Figure 8, 74.3 % of the participants reported using a DSS for HI-Tier reporting, while 25.7 % indicated that they do not. This highlights that DSSs are already widely integrated into legally required processes. To our knowledge, no comparable official statistics are available for comparison.

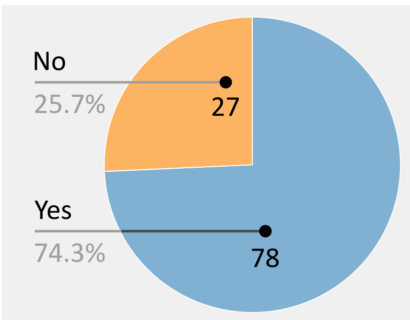

Figure 8: Distribution of farmers based on whether they use a DSS for reporting to HI-Tier (n = 105)

Importance of good decision-making

With regard to tasks related to feeding, farmers consistently rated good decision-making as highly important for business success. The highest importance was attributed to forage quality assessment (median 100) and ration planning (median 99), reflecting their fundamental role in ensuring adequate nutrient supply and herd productivity. Evaluating ration structure (median 90), monitoring concentrate intake (median 85), and feed quantity management (median 85) were likewise rated as highly important, reflecting that farmers place considerable value on closely controlling both the composition and quantity of feed provided to their herd. In contrast, pasture management received a substantially lower rating (median 30), which likely reflects the structure of the respondent sample: as the final sample skews toward larger, professional dairy operations (which tend to rely on zero-grazing or mixed systems) this task is less relevant for a substantial portion of respondents.

Sensitivity analysis confirmed that importance ratings for feeding-related tasks were robust to the exclusion of default values, with all items shifting by less than ten points (maximum Δ = 8 for pasture management). These ratings are therefore interpreted with confidence. The results are shown in Figure 9.

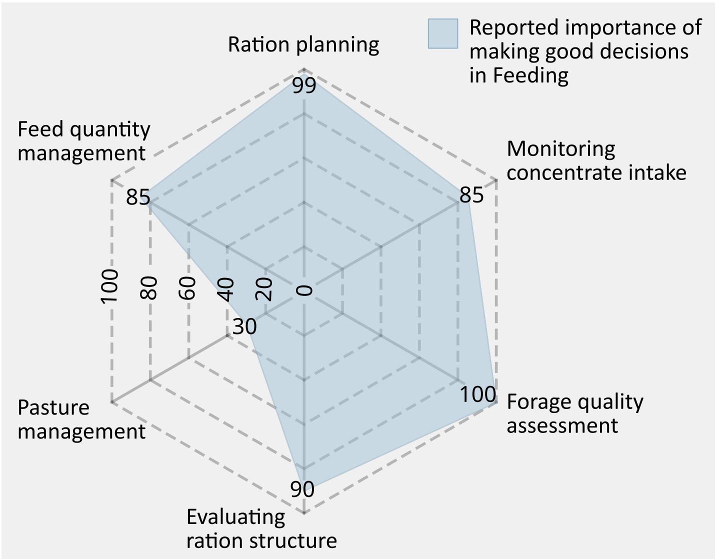

Figure 9: Perceived importance of good decision-making for farm success in feeding-related tasks

With regard to tasks related to breeding, farmers attributed high importance to good decision-making as well. The highest importance was recorded for heat detection (median 98), followed by detecting fertility disorders (median 85), fertility management (median 85), and documentation (median 80). Bull selection (median 75), planning first insemination (median 72), and selecting animals for housing (median 65) were also rated as clearly important, though to a lesser extent.

Sensitivity analysis revealed that the ratings are generally robust, with most items shifting by less than five points after exclusion of default values. The only exception was selecting animals for housing (Δ = 11), where the full-dataset median of 54 and the restricted median of 65 diverge notably, indicating sensitivity to anchoring. This item should therefore be interpreted with caution. The results are shown in Figure 10.

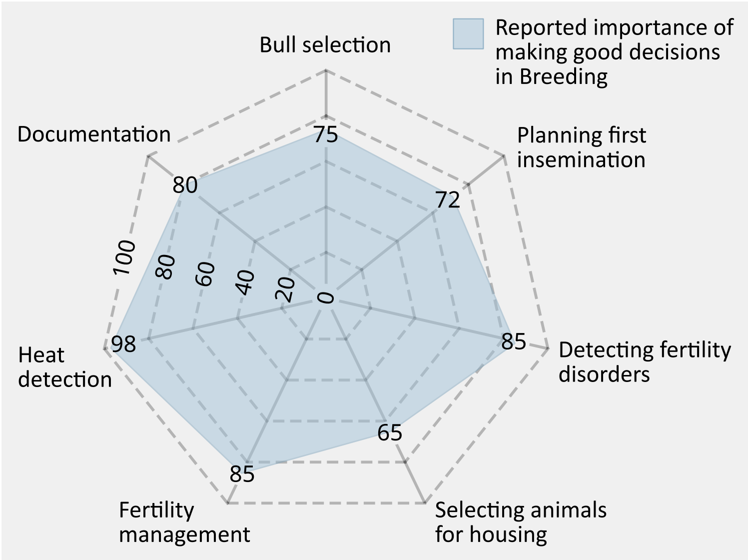

Figure 10: Perceived importance of good decision-making for farm success in breeding-related tasks

Regarding health and claw care, farmers attributed uniformly high importance to decision-making across most items. Monitoring udder health (median 99) and rumination activity (median 92) received the highest ratings, reflecting their central role in early disease detection and herd welfare. Performance recording (median 91), lameness detection (median 90), and treatment decisions (median 85) were likewise rated as clearly important, as were drying-off (median 83) and recording claw findings (median 80). Body condition scoring (BCS) received the lowest rating (median 61), possibly reflecting that it is perceived as less time-critical or delegated to veterinary professionals.

Sensitivity analysis revealed generally robust ratings, with most items shifting by less than five points after exclusion of default values. An exception is BCS (Δ = 11), where full-dataset and restricted medians diverge notably (50 vs. 61). The results are shown in Figure 11.

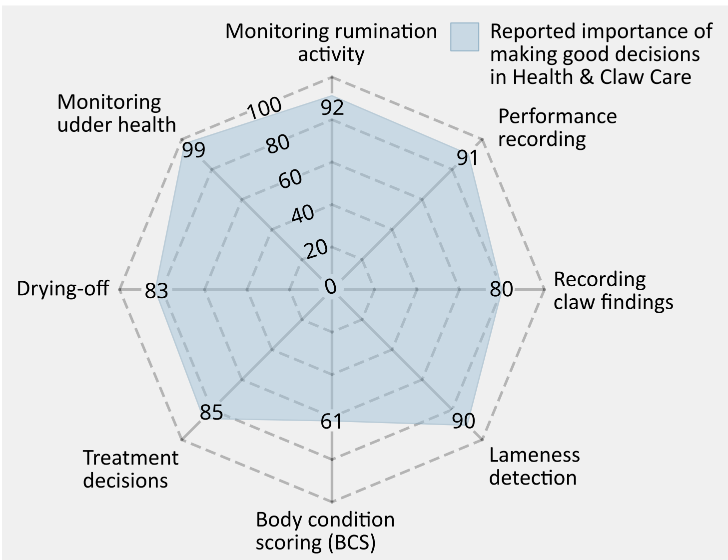

Figure 11: Perceived importance of good decision-making for farm success in tasks related to health and claw care

Reliance on DSSs for decision-making

Regarding DSS reliance in the feeding area, medians span a wide range and tend to fall at or below the neutral midpoint. The highest DSS reliance was reported for monitoring concentrate intake (median 67) and forage quality assessment (median 59), suggesting that farmers find DSS support most useful where quantitative data (e.g., feed composition or intake measurements) is available and actionable. Ration planning (median 39), feed quantity management (median 39), and evaluating ration structure (median 34) received below-neutral ratings, suggesting that farmers tend to rely predominantly on their own judgment or that of staff for these tasks. Pasture management showed the lowest DSS reliance by a considerable margin (median 4), consistent with the low importance rating reported earlier. This likely also reflects the sample composition, as larger professional dairy operations commonly rely on zero-grazing rather than pasture-based systems.

Sensitivity analysis revealed substantial anchoring effects in this category. Five of six items had a full-dataset median of exactly 50, and most shifted by more than ten points after exclusion of default values (Δ ranging from 11 to 18). This confirms that the full-dataset medians were largely uninformative for these items. The results are shown in Figure 12.

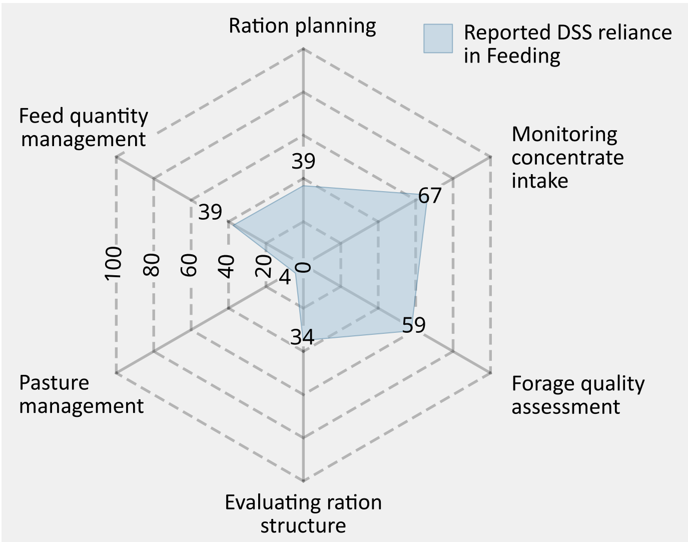

Figure 12: Farmers' reliance on DSSs for decision-making in the feeding area

With regard to DSS reliance in the breeding area, results were more evenly distributed, with most items clustering in a moderate range around the neutral midpoint. The highest DSS reliance was reported for heat detection (median 66), fertility management (median 60), documentation (median 55), and detecting fertility disorders (median 49), suggesting that farmers find DSS support most valuable for tasks involving continuous monitoring and record-keeping. Bull selection (median 45), planning first insemination (median 33), and selecting animals for housing (median 30) received below-neutral ratings, suggesting that DSS reliance remains limited for more strategic, infrequent decisions despite their acknowledged importance.

Sensitivity analysis revealed substantial anchoring effects. Six of seven items had a full-dataset median of exactly 50, and three shifted by more than ten points after exclusion of default values (Δ ranging from 10 to 20). Again, the restricted dataset serves as the primary basis for interpretation, as full-dataset medians were largely uninformative for most items. The results are shown in Figure 13.

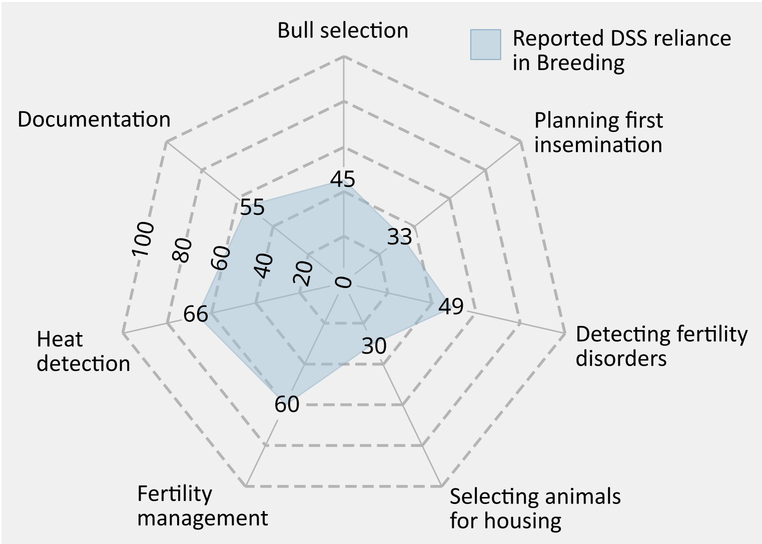

Figure 13: Farmers' reliance on DSSs for decision-making in the breeding area

Regarding DSS reliance in health and claw care, results were predominantly below the neutral midpoint. Performance recording (median 70) was the only item above neutral, consistent with its suitability for automated data collection. Monitoring rumination activity (median 48) and udder health (median 43) followed, while drying-off (median 30), recording claw findings (median 28), treatment decisions (median 25), lameness detection (median 24), and BCS (median 24) clustered at low values, indicating limited DSS reliance for tasks requiring clinical observation and hands-on judgment. Sensitivity analysis again revealed substantial anchoring effects. Four of eight items had a full-dataset median of exactly 50, and five shifted by more than ten points after exclusion of default values. The results are shown in Figure 14.

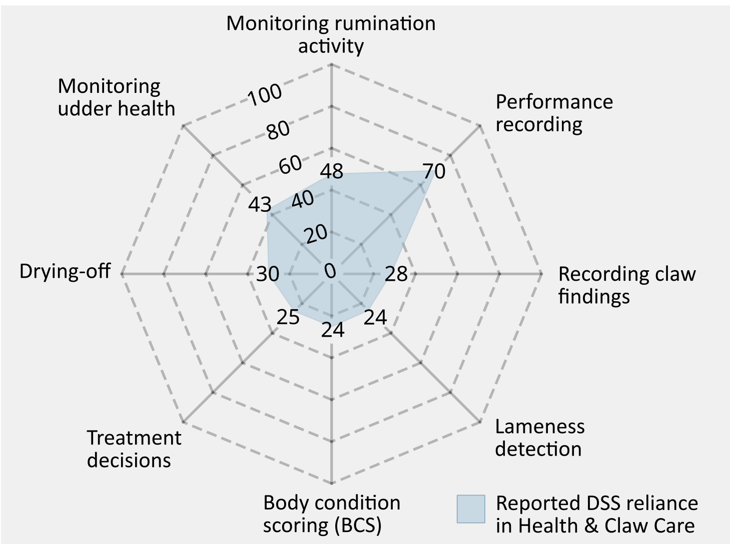

Figure 14: Farmers' reliance on DSSs for decision-making in the area of health and claw care

Perceived comprehensibility of DSSs

With regard to perceived comprehensibility, farmers rated DSS outputs as most comprehensible in the feeding area (median 70), followed by breeding (median 65) and health and claw care (median 60). While these ratings are above the neutral midpoint, they suggest meaningful room for improvement, particularly in the latter two areas. The comparatively lower comprehensibility rating for health and claw care is consistent with the low DSS reliance observed there, suggesting that limited comprehensibility may contribute to farmers' reluctance to rely on DSSs for clinical tasks.

Sensitivity analysis revealed anchoring effects across all three items, with full-dataset medians of 60, 50, and 50 shifting to 70, 65, and 60 respectively after exclusion of default values (Δ = 10, 15, and 10). The results are shown in Figure 15.

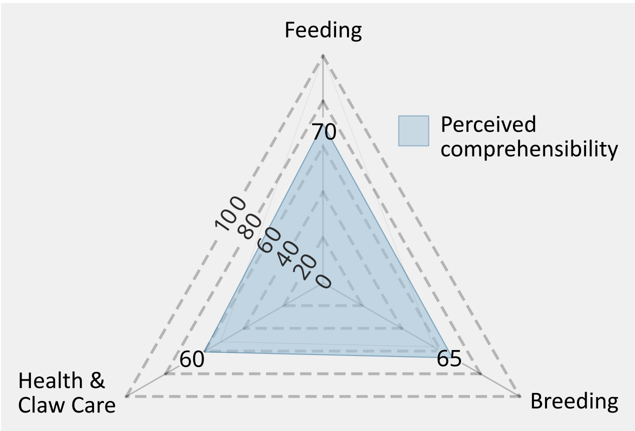

Figure 15: Farmers' perception of DSS comprehensibility in the three key areas

Importance of DSS comprehensibility

Farmers rated the importance of DSS comprehensibility as clearly important, with a uniform median of 80 across all three areas. This underscores DSS comprehensibility as a cross-cutting requirement (RQ3) and suggests that improvements in explainability could contribute to broader DSS acceptance across all areas of farm management. Sensitivity analysis confirmed robustness across all three items, with shifts of 7, 7, and 8 points after exclusion of default values, all below the ten-point threshold. The results are shown in Figure 16.

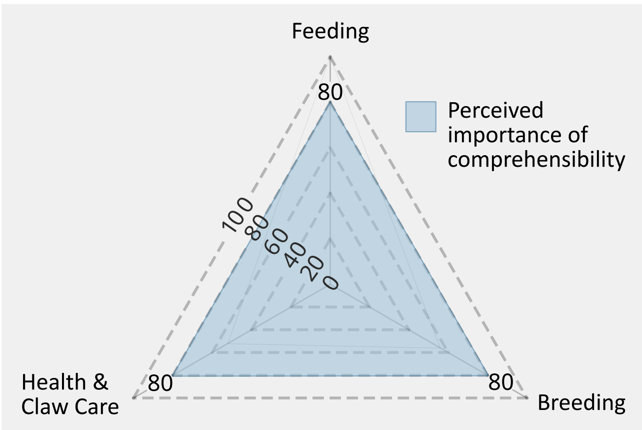

Figure 16: Farmers' perceived importance of DSS comprehensibility across the three areas

Inferential analysis results

In the inferential analysis, we examined statistical relationships between variables in our sample (Table 2) in order to identify patterns that may extend beyond the descriptive results. The analysis revealed several meaningful intra-group correlations within the set of decision-making variables, as well as inter-group correlations between socio-demographic and decision-making variables. We present the results using the classification scheme for Spearman's rho-values in Table 3.

Table 3: Classification of Spearman's rho-values and their interpretation

Value range	Visualization			Interpretation
[0.8, 1.0] or [−0.8, −1.0]	+++++	or	−−−−−	Very strong positive or negative correlation
[0.6, 0.8) or [−0.6, −0.8)	++++	or	−−−−	Strong positive or negative correlation
[0.4, 0.6) or [−0.4, −0.6)	+++	or	−−−	Moderate positive or negative correlation
[0.2, 0.4) or [−0.2, −0.4)	++	or	−−	Weak positive or negative correlation
[0.0, 0.2) or [0.0, −0.2)	+	or	−	Very weak positive or negative correlation

All of the tables in this section report results based on the restricted dataset. Where results from the full dataset differed notably (defined as a change in significance or effect size category) this is noted explicitly in the text.

Intra-group correlations between decision-making variables

Table 4 reports intra-group correlations between the two decision-making variables DSS comprehensibility and DSS reliance, aggregated for each of the three areas. The results show that farmers who perceive DSSs as more comprehensible tend to rely on them more in their daily work (RQ5). This relationship is evident in all three areas, with the strongest correlation observed in health and claw care. All correlations retained their significance after BH correction. Sensitivity analysis yielded identical results across all three correlations, with no difference in rho values, significance, or effect size category at the reported level of precision. This confirms that these findings are unaffected by anchoring and can be interpreted with confidence.

Table 4: Correlations between DSS comprehensibility and DSS reliance using Spearman's correlation coefficient, Benjamini-Hochberg (BH) corrected

Comprehensibility	Reliance	Correlation (rho-value)	Significance (p-value)	Adjusted p-value (BH)
DSS comprehens. in feeding[1)]	DSS reliance in feeding[2)]	0.200 (++)	< 0.001	< 0.001
DSS comprehens. in breeding	DSS reliance in breeding	0.291 (++)	< 0.001	< 0.001
DSS comprehens. in Health & CC.[3)]	DSS reliance in Health & CC.	0.421 (+++)	< 0.001	< 0.001

[1)] The perceived comprehensibility of DSSs in feeding [2)] The degree of reliance on DSSs in feeding [3)] Claw care

We further broke down the relationship between DSS comprehensibility and DSS reliance to the task level for each area, with full results provided in Tables I.1–I.3 of the Supplementary Material. The task-level analysis broadly confirmed the pattern observed in Table 4, with significant positive correlations found for the majority of tasks across all three areas. In feeding, significant positive correlations were found for three of six tasks: ration planning, monitoring concentrate intake, and evaluating ration structure, with the strongest association observed for the latter (rho = 0.437, +++).

In breeding, significant positive correlations were found for five of seven tasks: bull selection, detecting fertility disorders, selecting animals for housing, fertility management, and documentation, with the strongest associations for fertility management (rho = 0.442, +++) and bull selection (rho = 0.426, +++). In health and claw care, significant positive correlations were found across all eight tasks, with the strongest associations for drying-off (rho = 0.595, +++), monitoring udder health (rho = 0.576, +++), and recording claw findings (rho = 0.497, +++). Sensitivity analysis revealed minor differences for individual tasks across all three areas, none of which altered the overall pattern of findings.

Inter-group correlations between socio-demographic and decision-making variables

Table 5 presents the inter-group correlations between farmers' socio-demographic and decision-making variables. After BH correction, 13 of the 14 significant positive correlations were confirmed.

Table 5: Correlations between socio-demographic variables and decision-making variables using Spearman's correlation coefficient, Benjamini-Hochberg (BH) corrected

Socio-demographic variable	Decision-making variable	Correlation (rho-value)	Significance (p-value)	Adjusted p-value (BH)
Age	DSS reliance in feeding[1)]	0.101 (+)	0.011	0.024
Age	DSS reliance in breeding	0.110 (+)	0.003	0.007
Education	DSS reliance in feeding	0.105 (+)	0.008	0.020
Education	DSS reliance in breeding	0.170 (+)	< 0.001	< 0.001
Education	DSS reliance in health and claw care	0.162 (+)	< 0.001	< 0.001
Education	DSS comprehension in breeding[2)]	0.262 (++)	0.016	0.030
Education	DSS comprehension in health and claw care	0.269 (++)	0.012	0.023
Main income[3)]	DSS reliance in feeding	0.403 (+++)	< 0.001	< 0.001
Main income	DSS reliance in breeding	0.412 (+++)	< 0.001	< 0.001
Main income	DSS reliance in health and claw care	0.393 (++)	< 0.001	< 0.001
Main income	DSS comprehension in feeding	0.381 (++)	< 0.001	< 0.001
Main income	DSS comprehension in breeding	0.411 (+++)	< 0.001	< 0.001
Main income	DSS comprehension in health and claw care	0.398 (++)	< 0.001	< 0.001
Farm size	DSS reliance in health and claw care	0.070 (+)	0.043	0.074[4)]

[1)] The degree of reliance on DSSs in the area of feeding [2)] The perceived comprehensibility of DSSs in the area of breeding [3)] Whether dairy farming was reported as the main source of income [4)] Not significant after Benjamini-Hochberg correction (adjusted p > 0.05)

The results indicate that older farmers rely slightly more on DSSs in the areas of feeding and breeding, and that farmers with higher levels of education also tend to rely slightly more on DSSs across all three areas. In addition, farmers with higher educational backgrounds generally find DSSs more comprehensible in the areas of breeding and health and claw care. The findings further show that farmers with dairy as main income tend to rely substantially more on DSSs and report higher DSS comprehensibility across all three areas. Lastly, farmers with larger herd sizes showed a slight tendency to rely more on DSSs in health and claw care, however, this correlation did not survive BH correction (adjusted p = 0.074) and is not interpreted as a significant finding.

Sensitivity analysis revealed one notable difference: the correlation between main income source and DSS comprehensibility in health and claw care is categorized as ++ in the restricted dataset (rho = 0.398), compared to +++ in the full dataset (rho = 0.404), suggesting that anchoring slightly inflated this association. The finding remains clearly significant, and the overall interpretation is unchanged.

Multivariable regression analysis results

Table 6 presents the results of the multivariable regression analysis. Perceived DSS comprehensibility was significantly associated with DSS reliance across all three areas ($p < 0.05$), even after controlling for age, education, farm size, and main income. The effect was strongest in the area of health and claw care ($\beta = 0.41$, $p < 0.001$), followed by breeding ($\beta = 0.29$, $p < 0.001$) and feeding ($\beta = 0.23$, $p = 0.003$). Each one-point increase in perceived DSS comprehensibility was associated with a 0.23–0.41 point increase in DSS reliance, depending on the area.

Table 6: Multivariable regression results predicting DSS reliance in each area (feeding, breeding, and health and claw care): regression coefficients (β), standard errors (SE), n = 105

Predictor	**Feeding**			**Breeding**			**Health and claw care**		
	β	SE	p	β	SE	p	β	SE	p
Comprehensibility	0.23	0.08	0.003*	0.29	0.06	< 0.001*	0.41	0.06	< 0.001*
Age	2.05	2.71	0.452	2.09	2.28	0.363	1.18	2.09	0.576
Education	1.21	1.67	0.470	2.48	1.42	0.085	0.94	1.29	0.467
Farm size (log)	0.56	2.87	0.844	−3.10	2.41	0.202	−0.46	2.21	0.835
Main income	2.51	7.61	0.743	6.68	6.41	0.300	−1.23	5.83	0.834
R2		0.108			0.247			0.385	
Adjusted R2		0.063			0.209			0.354	
F-statistic		2.39*			6.50*			12.39*	

* Statistically significant ($p < 0.05$)

Socio-demographic variables showed no significant associations with DSS reliance. Age, education, farm size, and main income were not significant predictors in any area (all $p > 0.05$).

The overall model fit varied by area. The health and claw care model explained the largest proportion of variance ($R^2 = 0.385$, adjusted $R^2 = 0.354$, $F = 12.39$, $p < 0.001$), followed by breeding ($R^2 = 0.247$, adjusted $R^2 = 0.209$, $F = 6.50$, $p < 0.001$) and feeding ($R^2 = 0.108$, adjusted $R^2 = 0.063$, $F = 2.39$, $p < 0.05$).

Qualitative analysis results

In the following, we present the results from analyzing the participants' free-text feedback, highlighting recurring challenges and suggestions for improvement as well as the DSSs used.

Challenges and suggestions for improvement

The participating dairy farmers reported several challenges and suggestions for improvement regarding DSSs. The detailed mapping of participant feedback to categories is provided in Tables Q.1–Q.3 of the Supplementary Material.

In the feeding area (n = 18 responses), the most frequently reported issue was interoperability (7 mentions), referring to difficulties in integrating systems, such as interconnecting them, transferring data between them, and the absence of all-in-one solutions. Mismatches between DSS recommendations and on-farm observations were the second most frequent challenge (5 mentions), including overlooked environmental factors, discrepancies between silage analyses and actual intake, inaccurate nutrient classification, and corrective suggestions despite normative values. The third most common challenge was comprehensibility (3 mentions), including unclear recommendation logic, overly theoretical outputs, and confusion about corrective suggestions despite seemingly normal ranges. Missing functionality, cost, data privacy concerns, reliability issues, design flaws, and low life expectancy were each mentioned once.

In the breeding area (n = 16), comprehensibility was the most frequently mentioned issue (4 mentions). Participants found breeding recommendations intransparent and asked for clearer reasoning why certain bulls match breeding goals, what benefits specific pairings offer, and how risk of inbreeding is assessed. Interoperability and comparability were the second most frequently mentioned issues (3 mentions each). Farmers criticized poor system compatibility and noted that breeding values, especially between the USA and Europe, are difficult to compare due to different conditions and breeding-station-specific parameters. Participants also pointed to mismatches between DSS recommendations and reality, specifically unreliable heat detection (2 mentions). Lastly, system costs, data privacy concerns, and design flaws were each cited once.

In the area of health and claw care (n = 16), interoperability was cited most frequently (6 mentions), including missing options to store animal health records and link them with herd management software, problems connecting health data to antibiotic monitoring databases, and broader compatibility issues between data formats and systems. Comprehensibility and missing functionality were the second most frequently mentioned issues (3 mentions each). Regarding comprehensibility, participants noted that systems provide many figures but few explanations, that normal reference values are often lacking, and that explanatory functions are too often tied to special devices such as VR glasses. Regarding missing functionality, farmers reported missing diagnostic capabilities and unreliable features for identifying sick animals. Mismatches between DSS outputs and reality, including too many false positives and incorrect classifications of sick cows, as well as high costs and data privacy concerns were each cited twice. Low life expectancy of sensors was mentioned once. We aggregated the feedback from all areas to derive overarching insights (Figure 17).

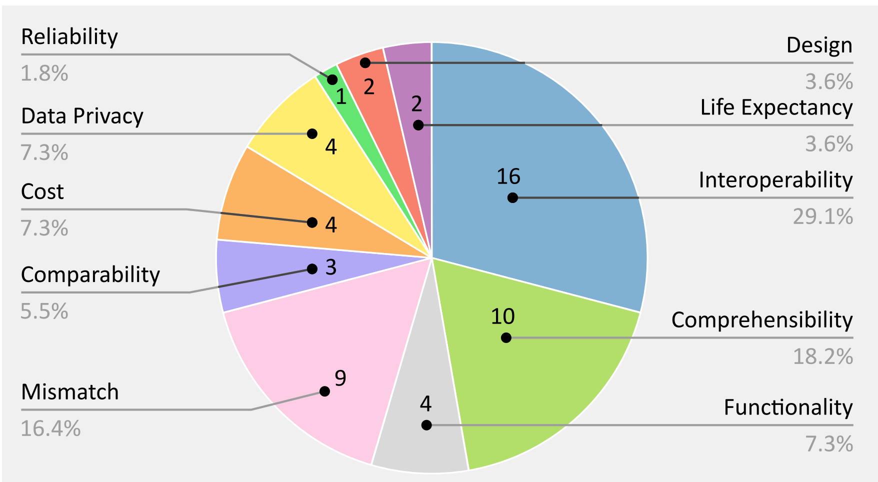

Figure 17: DSS-related challenges and suggestions for improvement reported by the participating farmers, aggregated over all three areas

Interoperability emerged as the most frequently mentioned challenge overall (16 mentions). The issue of missing interfaces and poor system connectivity has been known for some time (Roussaki et al. 2023). Addressing this aspect requires better alignment between systems from different manufacturers and the development of standardized interfaces. This poses a challenge in practice, as manufacturers typically seek to protect their intellectual property and are often reluctant to open their systems for collaboration with competing providers. Realistically, solving this problem likely requires cross-company working groups and regulatory initiative.

Comprehensibility emerged as the second most frequently cited challenge in our study (10 mentions). Our findings suggest that improving the clarity of system outputs can improve the trust of farmers and, in turn, enhance the usefulness of systems. We consider this a valuable finding, as this aspect can be addressed at the level of individual systems (unlike many interoperability issues).

The third most common challenge are mismatches between DSS assessments and the reality on farms (9 mentions). Solutions to this issue are context-specific and need to be examined separately for individual system functions, making it difficult to derive general takeaways. However, it is conceivable that some apparent mismatches might be mitigated through improved comprehensibility and clearer explanations. It is also worth noting that the general absence of regulatory standards governing the accuracy and reliability of DSS assessments may independently contribute to variability in output quality and resulting mismatches, an issue that could ultimately benefit from political and regulatory attention.

Missing functionality, high system costs, and data privacy received 4 mentions each. The decision on which functionality to provide is ultimately a company-level management decision, as are cost models, making general recommendations difficult in both cases. It is well established that data privacy concerns carry substantial weight in agricultural settings (Linsner et al. 2021).

This is followed by poor comparability of parameters between companies (3 mentions), design flaws and low life expectancy of systems (2 mentions each), and issues with system reliability (1 mention).

Decision support systems landscape

Figure 18 shows the DSSs that participants reported using in their daily work. For better clarity, we grouped systems mentioned only once under “Others”, including Calfguide (Holm & Laue), BAP (vit), MPR-Mobil App (Milchprüfring Bayern e.V.), ANIMALoffice Klauenmanager, SMARTBOW (Smartbow GmbH), RDV-App (Rinder Daten Verbund GmbH), QSX Qmilch, MultiRind (HELM), OptiBull, My Cattle Manager Farm App, NEXT Farming App (FarmFacts GmbH), UNIFORM-Agri, Velos (Nedap), HerdMetrix (SmartDairy), COW WATCH (Alta), MST (IMPULSA), Feedlync (CowConnect), AfiFarm (Afimilk), and TMR Tracker (Digi-Star).

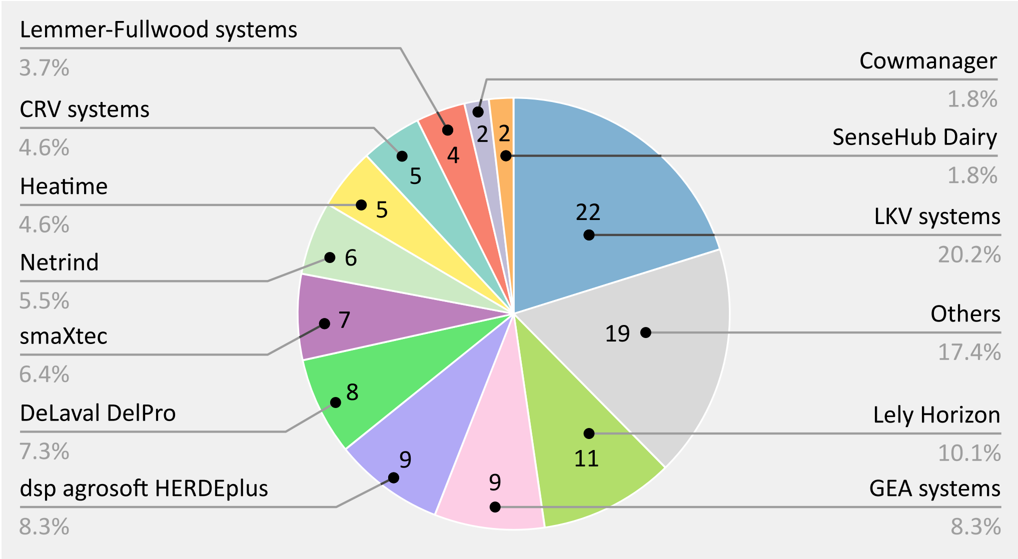

Figure 18: DSSs used by the participating farmers (n = 105) by number of mentions

Answers to the research questions

In the following, we revisit and answer the research questions of this study.

RQ1: To what extent do farmers rely on personal or staff experience versus DSSs when making decisions?

Across all areas, DSS reliance varied substantially by task. In feeding, reliance ranged from a median of 4 (pasture management) to 67 (monitoring concentrate intake), with higher values reflecting greater reliance on DSSs over personal experience. Higher reliance was concentrated on tasks involving quantitative data such as feed composition and intake measurements. In breeding, DSS reliance was more evenly distributed, with the highest values for heat detection (median 66) and fertility management (median 60), reflecting the suitability of these tasks for automated monitoring. In health and claw care, performance recording stood out as the only item clearly above the neutral midpoint (median 70), while most clinical tasks clustered at notably lower values. Taken together, these findings suggest that DSS reliance is strongest for structured monitoring tasks where sensor data is available, and considerably more limited for tasks requiring clinical judgment or strategic planning.

RQ2: How comprehensible are DSSs in the eyes of farmers?

Farmers rated DSS comprehensibility above the neutral midpoint across all three areas, with medians of 70 (feeding), 65 (breeding), and 60 (health and claw care). While these values indicate that DSS outputs are generally understandable, they fall noticeably short of the upper end of the scale, suggesting room for improvement, particularly in health and claw care.

RQ3: How important is the comprehensibility of DSSs to farmers?

Farmers attributed high importance to DSS comprehensibility across all three areas, with a uniform median of 80, underscoring it as a requirement that transcends individual farm management areas.

RQ4: Do socio-demographic factors correlate with perceived DSS comprehensibility?

Our study found several significant correlations, though most were weak to moderate in strength. Educational background was associated with perceived DSS comprehensibility in breeding and health and claw care, indicating that higher levels of agricultural training may help farmers better interpret DSS outputs. Similarly, whether dairy farming was the primary income source correlated with perceived DSS comprehensibility across all three areas, likely reflecting that farmers who depend more strongly on dairy engage more deeply with digital systems, which in turn may support their understanding of system outputs. Together, these findings suggest that DSS outputs may not always be intuitive and require a certain level of prior training or sustained engagement. Improving DSS comprehensibility and reducing the required learning curve could therefore increase the value of DSSs for a broader range of farmers.

RQ5: Does the perceived comprehensibility of DSSs correlate with farmers' willingness to rely on them?

The analysis revealed significant positive correlations between DSS comprehensibility and DSS reliance across all three areas, with the strongest association in health and claw care (rho = 0.421). At the task level, this pattern was broadly confirmed, with significant associations found for the majority of tasks across all three areas. Multivariable regression further confirmed that perceived DSS comprehensibility remained a significant predictor of DSS reliance even after controlling for age, education, farm size, and primary income source. The effect was strongest in health and claw care ($\beta = 0.41$, $p < 0.001$), followed by breeding ($\beta = 0.29$, $p < 0.001$) and feeding ($\beta = 0.23$, $p = 0.003$), while no socio-demographic variable reached significance in any area. This indicates that DSS comprehensibility is not merely a proxy for farmer profile but an independent driver of DSS reliance. Combined with the finding from RQ3, which shows that current DSS comprehensibility leaves room for improvement, this suggests that improving DSS comprehensibility is a concrete and actionable opportunity for increasing DSS usefulness.

RQ6: What challenges and possible improvements do farmers report in using DSSs?

Interoperability was the most frequently reported challenge, with farmers highlighting missing interfaces, poor connectivity, and the absence of integrated solutions. Comprehensibility ranked second, with calls for more transparent reasoning behind recommendations and clearer explanations of indicators and normal values. Mismatches between DSS outputs and on-farm observations were the third major challenge. Additional issues included missing functionality, high costs, data privacy concerns, poor parameter comparability, design flaws, low system life expectancy, and occasional reliability concerns.

Discussion and conclusion

This study examined the post-adoption use of decision support systems (DSSs) among 105 German dairy farmers, focusing on the areas of feeding, breeding, and health and claw care. The results show that DSSs are most commonly used for tasks that require structured data collection and automated monitoring, while their contribution to tasks requiring clinical judgment or strategic planning remains limited. This suggests that many DSSs currently serve primarily as monitoring and documentation tools rather than fully integrated decision support systems.

A central finding of this study is the consistent and robust relationship between perceived DSS comprehensibility and DSS reliance. Farmers who find DSS outputs more comprehensible tend to rely on them more in their daily work, and this pattern holds across all three areas, at both the aggregate and task level, and after controlling for socio-demographic variables in the multivariable regression analysis. Notably, health and claw care simultaneously exhibited the lowest DSS comprehensibility rating (median 60), the lowest overall DSS reliance, and the strongest correlation between DSS comprehensibility and DSS reliance (rho = 0.421, β = 0.41). Taken together, these results point to a particularly strong relationship in this area: improving how health-related DSS outputs are presented and explained to users may yield the greatest gains in farmers' willingness to rely on DSSs for related tasks. Farmers rated the importance of DSS comprehensibility uniformly high across all three areas (median 80), further underscoring it as a cross-cutting requirement.

A further contribution of this study is the systematic examination of socio-demographic correlations. Higher educational background was associated with greater DSS reliance across all three areas and with higher perceived DSS comprehensibility in breeding and health and claw care, suggesting that more agriculturally trained farmers are better equipped to interpret and act on DSS outputs. Farmers for whom dairy is the primary income source showed substantially higher DSS reliance and DSS comprehensibility ratings across all areas, consistent with the expectation that full-time professional farmers engage more intensively with digital systems. However, when all socio-demographic variables were entered simultaneously into the regression model, none reached statistical significance, with DSS comprehensibility remaining the only significant predictor. This indicates that the socio-demographic effects observed in the bivariate correlations are at least partly mediated by or confounded with DSS comprehensibility, and that improving DSS comprehensibility may benefit a broad range of farmers regardless of their background.

Research on explainable systems offers a concrete approach to addressing the comprehensibility gap. Explainability can make a system's underlying logic more transparent, providing information on why a particular recommendation is generated, which factors contributed to it, and how farmers should interpret results in the context of their own observations. Previous work in this field has shown that clear explanations can strengthen farmers' understanding of how a system arrives at its assessments, improve decision-making quality, and generally increase trust in automated recommendations (Girmay et al. 2025, Girmay and Möhrle 2025).

In the qualitative analysis, interoperability emerged as the most frequently reported challenge overall, with farmers criticizing a lack of interfaces, poor compatibility, and the absence of integrated solutions. This issue has been noted in the literature for some time (Bahlo et al. 2019) and is difficult to address at the level of individual systems, as it requires cross-company coordination and potentially regulatory support. Comprehensibility was the second most frequently mentioned issue, with farmers calling for more transparent reasoning behind recommendations, clearer explanations of indicators, and explicit normal and abnormal value ranges. Mismatches between DSS assessments and on-farm observations emerged as a third recurring issue. While some mismatches likely reflect inherent technical limitations, it is conceivable that improved DSS comprehensibility could help farmers better contextualize and interpret system outputs, reducing the perceived frequency of such discrepancies.

These findings support several design implications. First, improving interoperability at the ecosystem level remains a priority. Second, comprehensibility should be treated as a core requirement in DSS design. This includes transparent thresholds for normative and deviating values, clear visualization of indicators, and task-specific explanation formats that align with farmers' decision-making logic. The consistently high importance farmers place on DSS comprehensibility, combined with the regression finding that it is the dominant predictor of DSS reliance, provides strong empirical grounding for this recommendation.

Several limitations of our study should be considered. First, our sample is not fully representative of all German dairy farms. The attrition bias analysis revealed that completers more frequently reported dairy as their primary income source, suggesting that part-time and hobby farmers may be underrepresented. Combined with the observed skew toward larger herds, results are most representative of professional, full-time dairy operations and may generalize less well to smaller or mixed farms. Although no statistically significant regional difference was detected, Bavarian farmers were more prevalent among non-completers. Second, the data are self-reported, limiting causal inference. Finally, the slider format with a default value of 50 caused clustering around the midpoint. While we addressed this through a sensitivity analysis confirming that most findings are robust and results from the restricted dataset are largely consistent with the full dataset, this remains a methodological limitation that may have influenced some results.

Despite these limitations, the study provides several empirically grounded insights into the post-adoption use of DSSs in dairy farming. Taken together, the findings highlight that enhancing the comprehensibility of DSSs, alongside broader efforts to improve interoperability, represents a promising and actionable path toward better aligning digital decision support with the practical needs of dairy farmers and supporting post-adoption acceptance.

Supplementary Material

Supplementary Material for this article, including the full socio-demographic comparison, sensitivity analysis tables, task-level correlation tables, qualitative feedback categorizations, and original German names for tasks and educational qualifications with English translations, is available at https://doi.org/10.5281/zenodo.20477446.

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