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ABSTRACT

Managers of health in livestock systems are asked to shift from a curative approach to a more preventive approach. This change requires sociological and technical reconfiguration and raises the issue of how changes are implemented by farmers and their technical support ecosystem (advisors, trainers, veterinarians). Here, we report work conducted in western France by an Agricultural European Innovation Partnership Operational Group bringing together animal scientists and sociologists to advance knowledge on animal health in a range of livestock sectors, i.e. dairy cattle, beef cattle, small ruminants (sheep, goats), poultry and pigs. In this study, our aim was to answer this question: what are the Informational Resources (**I.R.**) that farmers use to promote animal health of their herds? First, we used a survey to characterize 129 I.R. used by advisors, then, we used statistical analysis to classify these I. R. into six clusters. Second, we organized eight focus-group sessions that involved a total of 50 farmers from across all livestock sectors to find out how they mobilize the I.R. and what they see as important for animal health monitoring practice. Finally, we performed individual interviews with 42 farmers to expand the data captured in the collective focus groups. Results showed that farmers and advisors have a broad and diverse range of I.R. to help monitor animal health. We identified six clusters of I.R.: regulatory tools, periodic reports, tools for farmer-led monitoring, tools and indicators for national reference datasets, slaughterhouse and laboratory indicators, and training delivered to farmers. During focus group, livestock farmers identified some of their I.R. within these clusters but they also cited other daily routines that help them monitor animal health that were not cited by advisors. We found that farmers mainly use sensory indicators (typically smell, sight, touch) in their daily practice whereas advisors mainly use relatively sophisticated retrospective monitoring tools. Farmers also cited the importance of indicators that can rapidly objectify any change in animal condition, behavior, or health. This work finds a split in the distribution of animal health management roles, with farmers implementing daily checks whereas advisors run periodic health surveillance, thus revealing differentiated roles and needs between farmers and their advisors.

Implications

Numerous tools exist to help livestock farmers monitor animal health, but there are gaps between farmers and advisors in terms of indicators and tools they used, i.e. in the informational resources, they use to monitor health. Farmers primarily use informal sensory indicators based on daily herd observations. Sensory indicators, which are very often underestimated in advisory services, can lead to a gap in communication between farmers and their advisors.

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Introduction

Numerous challenges tied to animal welfare, food safety, and minimizing medical inputs require livestock farmers, advisors and scientists to make numerous changes in their practices and perceptions on animal health. Reducing medical inputs, for example, requires the implementation of more preventive approaches. These may be medical (vaccines for example) but can also be based on moving to a more systemic management model, i.e. applying biosecurity principles at the herd level to prevent internal and external transmission of infectious diseases, reduce the use of medical inputs and emission of pollutants, planning a more balanced diet for the whole herd or individuals, prioritizing animal welfare, and possibly even reconsidering herd stocking densities or individual animal performance goals (Lamothe et al., 2017) at the farm level, these last solutions requiring a change in the strategy of the whole farm. All these farming practice changes demand the development of a more systemic and integrative vision of animal health. While livestock farmers, as the leaders of herd management, are effectively at the forefront of these large-scale challenges, they cannot be expected to perform actions alone (Ducrot et al., 2022). They need support from their veterinarians, but also from all the technicians and advisors who can offer herd management support, such as cooperative technicians, nutritionists, performance monitoring advisors, and so on. Food commodity chains (Adam et al., 2020) and/or government (e.g. the French government EcoAntibio plan) compel measures to decrease antimicrobial use as part of a more systemic preventive approach to animal health.

According to the literature, decreasing antibiotic use revolves around farmer-led herd health management and monitoring (Poizat et al., 2017), but farmer compliance with veterinarians and farm-advisor recommendations is also a key factor for success (e.g. Vaarst et al., 2002). Duval et al. (2017) sought to explain the lack of trust between farmers and veterinarians and identified a gap in values and objectives between organic farmers and veterinarians. Other authors have also stressed the role of the methods used to give advice, from face-to-face relationship to farmer exchanges of experience or continuing education (Morgans et al., 2019; Cabaret and Nicourt, 2009; Vaarst et al., 2007). Finally, Ducrot et al. (2019) insist on the need for a negotiated relationship between farmers and veterinarians to implement effective actions. They emphasize audit-type advisory approaches accompanied by personalized action plans as pivotal to supporting farmers in animal health management.

The ongoing development of numerous digital tools and datasets in agriculture (Hostiou et al., 2017) is an opportunity to further develop herd monitoring science and individual or herd-level understanding of animal health status. This monitoring aspect is an important part of animal health and safety (Toma et al., 1999), and there is a growing number of purpose-developed tools for farmers. However, besides these tools, some authors underline the importance of the "farmers' eye", which translates the practice of farmers using their knowledge of their animals with daily observation and sensory data to monitor animal health and well-being (Mougenot et al., 2020; Fischer et al., 2019). One can ask the question of the place of this sensory data in a world that is increasingly full of data produced by various sensors and other media: does it replace subjective data derived from experience, or does it complement it? The present study is part of a partnership project that aimed at understanding how livestock (ruminants and monogastrics) farmers manage herd health, to identify their herd health management needs and expectations, and to propose exploratory tools to address these expectations. In the present study, we propose to focus on the following questions: how do farmers promote the health of their herds? What informational resources (tools, indicators) do they use commonly? Are they missing elements, tools or approaches to effectively manage herd health? From literature, we can hypothesize that these informational resources are based on numeric data, and observations of their herds. To answer our question: 'how do farmers promote the health of their herds?', we have led a series of individual and collective interviews with farmers, advisors (including veterinarians), and other livestock professionals.

Material and methods

To answer our questions, first, we defined 'informational resources' (**I.R.**), as all the indicators, tools, and training-type advisory systems that provide information for farmer-led animal health monitoring. In line with Magne et al. (2010), we consider that "*information can exist without it being mobilized by the farmer and that farmers make sense of informational input while acquiring and using this information in a given situation*" (Magne et al., 2010). The origin of information can be internal to the farming system (based on its own experience for example), or external (other actors than farmers) (Magne et al., 2010). Then, three successive collection systems were combined.

First data collection phase: collection of data on existing informational resources via telephone and internet

Design of data collection

The first data collection phase aimed to capture the diversity of I.R. available in France for farmers and their advisors. An online survey was conducted among two types of persons: (i) the inner circle of advisors to farmers (Redfern et al., 2021): veterinarians, livestock advisors such as technicians, performance monitoring advisors, nutritionists; (ii) other livestock health professionals from research and development organizations. Hereafter, in order to simplify the text, the rationales of these two types of operators will be termed as "advisor vision" (in opposition to "farmer vision" that has been identified in the following steps of data collection). The participants were working in the ruminant livestock (cattle, sheep and goats) or monogastric livestock (pig and poultry) sectors. This online survey was composed of open-ended and closed-ended questions to respectively encourage free expression by the respondents and refine the information collected (see Supplementary File 1 at https://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/1a21feb7-a892-46eb-873e-10b9c6283d89). The questions were designed to capture and identify the I.R. used by farmers and advisors, the sectors in which they were applied, the types of information collected, and the methods used to enter and store the data recorded by these resources. In order to minimize any scope for misunderstanding or bias induced by using an online questionnaire, we included a video at the start of the questionnaire to explain the objectives of the project and this first survey phase. The online questionnaire was disseminated through mailing lists and announcements on the European Innovation Partnership (**EIP**) project partners' social media. One hundred and ninety-two persons have looked at the video on internet, 228 persons answered to the questionnaire but only 135 persons from all around France gave complete answers: 70 veterinarians, 41 advisors in public, private or associative support structures for farmers, 16 people in research and development institutes or in public education and research, 1 farmer with professional responsibilities, and 18 other people who did not give their main activity. Following this first step of I.R. identification, we completed data obtained with a second survey made by phone with a restricted list of 96 respondents (out of the original 135 respondents). The objective was to obtain more precise data and complete data when the first answers were not complete. This restricted list was selected because these respondents had cited I.R. that were not known by project experts and information on these I.R. was not available on the net. This second survey phase was conducted by four different project partners with expertise in the different livestock sectors (monogastrics and ruminants). When information was available on the net, this second survey was filled out by partners of the project. For these two surveys, interviewers guaranteed confidentiality of data.

Statistical analysis

Analysis of this survey data focused on inventorying and classifying the I.R. identified by this group of livestock experts who are not farmers. Multiple Correspondence Analysis (**MCA**), followed by hierarchical ascending classification (**HAC**) was carried out to classify 129 I.R. for which the data were completed after this two-step survey. Statistical analysis was chosen because the number of tools and of variables available were too numerous to allow a "manual" classification. MCA and HAC allowed the identification of clusters of I.R, characterized by a similar combination of modalities of variables. Analysis was performed in R (version 4.1.1) using the FactoMineR (version 2.4) and factoextra (version 1.0.6) packages. The ggplot2 (version 3.3.5) and dplyr (version 1.0.7) packages then served to generate the graphs and illustrations. For statistical analysis, an inductive process was used to establish the final clustering. A large number of sets of categorical variables (23 quantitative variables for which data was complete) were tested for clustering (MCA and HAC were realized on these 23 variables or restricted set of variables) but only seven active variables were finally used for the final clustering (see Table 1) until clustering revealed understandable clusters for experts. In supplementary files, it is possible to consult the diagrams of contribution to dimensions 1 and 2 of the analysis, with five variables selected because they contribute more than 5% to these dimensions. Two other variables were retained because they were necessary for experts to understand the tools described in each Cluster (see Supplementary File 2 at https://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/4a97204b-43a7-4fbb-98d6-56392393f427). These final variables and clusters were empirically validated by the project steering committee, because they were the only ones to reveal a relevant clustering, i.e, clusters illustrated categories of tools well known by professionals. Literature, using MCA and HAC for farming systems clustering, is used for this empirical validation (see for example: Madry et al., 2013). The results of this first step are presented in first part of the results.

Second data collection phase: focus groups

The second data collection phase was based on eight focus groups bringing together farmers within a same sector with the objective of collecting their uses, perceptions, and needs on different I.R. During these collective meetings, after a presentation of the participants and the project, results of the first stage of data collection (classification of I.R.) were presented to farmers in order to facilitate discussions. Then, the discussion was animated by project partners around five themes: (i) farmers' point of view on what animal health management on their farms covers (ii) description of the indicators they use, (iii) construction of a graph of their relations with health partners, (iv) discussion around the tools and approaches previously identified by the surveys, (v) discussion around a particular method of animal health–hygiene support, i.e. a care protocol (the Bovine health-check visit, an annual audit realized by French veterinary practitioners).

A total of 50 volunteer farmers invited by their veterinarians participated in these eight focus groups: one group of six dairy farmers, one group of eight beef farmers, one group of seven sheep or goat farmers, two groups of five pig farmers, and three groups with a total of 19 poultry farmers. Focus groups took place in different areas of the region, according to the farmers' localization in each animal production sector, to optimize their participation. Veterinarians chose the list of farmers they invited. Farmers and veterinarians originated from three distinct zones of Pays de la Loire territory chosen to represent the diversity of production contexts of Pays de la Loire area. The meetings were facilitated by a pair of facilitators (EIP partners), composed of a sociologist and a technical expert of the sector, who were asking the farmers' group open questions, reformulate some points and encourage each participant to be active. A third person was also specifically present to record the farmers' words. The meetings were recorded, and the recordings were used with the note-taking documents compiled during the meeting in order to draft summary reports on the themes discussed. Notes were not shared for confidentiality of data but used only for analysis of focus group. The facilitators attempted to foster a friendly atmosphere and give positive constructive feedback in order to encourage free expression by each participant. Common features that emerged in the three sectors are presented in Results Part 2.

Table 1
Variables of characterization of Informational resources (I.R.) used for statistical clustering. Statistical clustering was made using these seven variables. For each variable, the percentage of each modality is given for the global livestock sector (ruminants and monogastrics), and for each sector (ru = ruminant sector; mon = monogastric sector; both = ruminant and monogastric sector).

Description of the variable	Percentage (%) of I.R. per modality (n = 129)
Use of national databases for references (ref)	No: 91% (34.9% ru; 46.5% mon; 9.3% both) Yes: 9% (4.5% ru; 4.5% mon)
Training courses for farmers (gpeformations)	No: 92% (25.6% ru; 28.7% mon;4.7% both) Yes: 8% (4.5% ru; 3.1% mon)
I.R. use-case (decid)	Farmer alone or with advisors: 66% (30.2% ru; 31% mo; 4.7% both) Advisors only: 27% (9.3% ru; 14% mon; 3.1% both) Regulatory tool: 7% (5.4% mon; 1.6% both)
Based on slaughterhouse data (dbabatttoir)	No: 73,6% (30.2% ru; 38% mon; 6.2% both) Yes: 8.5% (0.8% ru; 5.4% mon; 2.3% both) Data not available: 17.8%
Monitoring tool with options for farmer-led assessment and data recording (pilotage)	No: 38% (20.2% ru;11.6% mon; 6.2% both) Yes: 62% (28% ru; 31% mon; 3.1% both)
Periodical reports (bilan)	No: 64,3% (23.3% ru; 37.2% mon; 3.9% both)Yes: 35,7% (16.3% ru; 14% mon; 5.4% both)
Reporting of animal health events (prob)	No: 59,7% (23.3% ru; 31% mon; 5.4% both)Yes: 40,3% (16.3% ru; 20.2% mon; 3.9% both)

Third data collection phase: face-to-face qualitative interviews

A third data collection device used individual face-to-face qualitative interviews with farmers who had not participated in the previous group meetings. The objective of these individual interviews was to expand the elements collected in focus groups. These individual interviews focused on the farmer's visions of animal health management, on their advisors in this field, and their needs in terms of different types of I.R. The interviews were carried out by two Master-level students in animal husbandry. These students received a three-day training to qualitative interview and tested the guide on one farm with their tutor. Due to the Covid lockdown, most of the interviews were conducted by videoconference or phone instead of physically face-to-face initially scheduled. In total, 12 dairy farmers and 12 beef farmers, 9 pig farmers and 9 poultry farmers were interviewed (1 farmer per farm). Eighteen of these 42 farms were mixed farms, but the farmer was interviewed on the main species of his activity. These farmers were contacted through a diversity of professional partners (extension services, institutes of development of each sector, veterinarians and one structure specialized in organic agriculture) in order to avoid selection bias possible during the first step, as only veterinarians selected farmers. A diversity of farmers regarding informational resources used was asked to partners: use or not of more common I.R (numeric tools, individual audit with veterinarians, peer exchange training sessions). Farmers were all from Pays de la Loire region and did not participate in the first collective meetings. The interviews were qualitative, with open-ended questions to foster-free expression by the interviewees and closed-ended questions in order to describe the farming system concerned (see Supplementary Files 3 and 4 to view interview guidelines for monogastrics and ruminants, available at https://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/8e843302-4035-4044-a70c-0007043a2110 for Supplementary File 3, and https://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/cd-fc46a6-0c73-4dca-8291-4edb6fcf660f for Supplementary File 4). Each interview was recorded and then written up into full transcripts.

Qualitative analysis of data

We performed thematic and cross-sectional analysis of the individual and group interviews (see for examples of this type of analysis: Bernard, 2006; Fischer et al., 2019; Hellec et al., 2021). For this thematic analysis, we identified in the farmers' discourses from these interviews or focus groups (one Word® file per focus group and per farm) some themes of discussion, both arising from guideline and emerging from the particular answers of each farmer. For focus group, themes were then synthesized in a report. For individual interviews, the themes were coded in an Excel® sheet, with one theme per line and one farmer per column, in order to classify all the answers in the different themes in order to enable comparison and make a synthetic analysis of answers. Here, we report our analysis of farmers' practices and perceptions of animal health, and the types of I.R. they use on a daily basis to manage animal health on their farms. The results of this thematic analysis of the focus groups and individual interviews are presented in Results Part 2.

Results

Livestock professionals report a broad and diverse range of informational resources

A total of 129 I.R. were identified by veterinarians, livestock advisors and scientific experts and retained in our database. These I.R were of very different nature and were cited by a registered trademark (ex: Cownote®, Audimat®), or by a short description of their content. Thanks to the second step of data collection, these 129 tools were then described by the seven variables described in Table 1.12 I.R. were used in all animal sectors, 51 in the ruminant sector, and 66 in the monogastric sector (see Table 2). The number of I.R. cited per professional ranged from 1 to 11 different I.R. These 129 I.R. were characterized by huge diversity, ranging from smartphone apps to farmer training sessions, animal health care dashboards, to laboratory analysis results or data recorded on the farm, e.g. indicators for monitoring the herd health status and/or technical performances. These resources were simple indicators available at the level of each animal (for example for slaughterhouse indicators) or herd monitoring tools, with data defined at the scale of the herd or batch (for example for welfare analysis grid). Tools at the scale of the herd or the animal were available both for monogastric and ruminants, but ruminants dispose of a greater number of tools at the animal level. In Supplementary File 5 (https://idele.fr/?eID=cmis_download&oID=workspace://Spaces Store/9a8f3566-8345-492d-ba4d-b6a0f4d73538), an exhaustive list of these tools is available. These tools contain mostly animal health indicators, but also animal performance indicators (35% of I.R.), feeding (23% of I.R.) and housing indicators (18% of I.R.).

Table 2
Description of the 6 clusters of Informational Resources (I.R.) for animal health monitoring in ruminant and monogastric sectors. Description of clusters by their name, example of one illustrative for each cluster, and importance of each cluster for each sector.

Cluster	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Name	Regulatory tools/indicators	Periodic reports	Tools for farmer-led monitoring	Tools and indicators for national or international reference datasets	Slaughterhouse and laboratory indicators	Training sessions for farmers
Example	Animal health-check records and data	Welfare Quality® assessment tool	Software for herd monitoring (e.g. Time4Cow ®)	Animal Level of Exposure to Antimicrobials (indicator of antibiotic use)	Antibiotic susceptibility testing	Peer-exchange group training session on agroecology
No of I.R. cited by advisors	9	35	52	11	12	10
No of I.R. cited by advisors for monogastrics only	7	13	29	6	7	4
No of I.R. cited by advisors for ruminants only	2	17	21	5	2	6
No of I.R. used for ruminants and monogastrics cited by advisors	2	5	2	0	3	0

I.R. = informational resource.

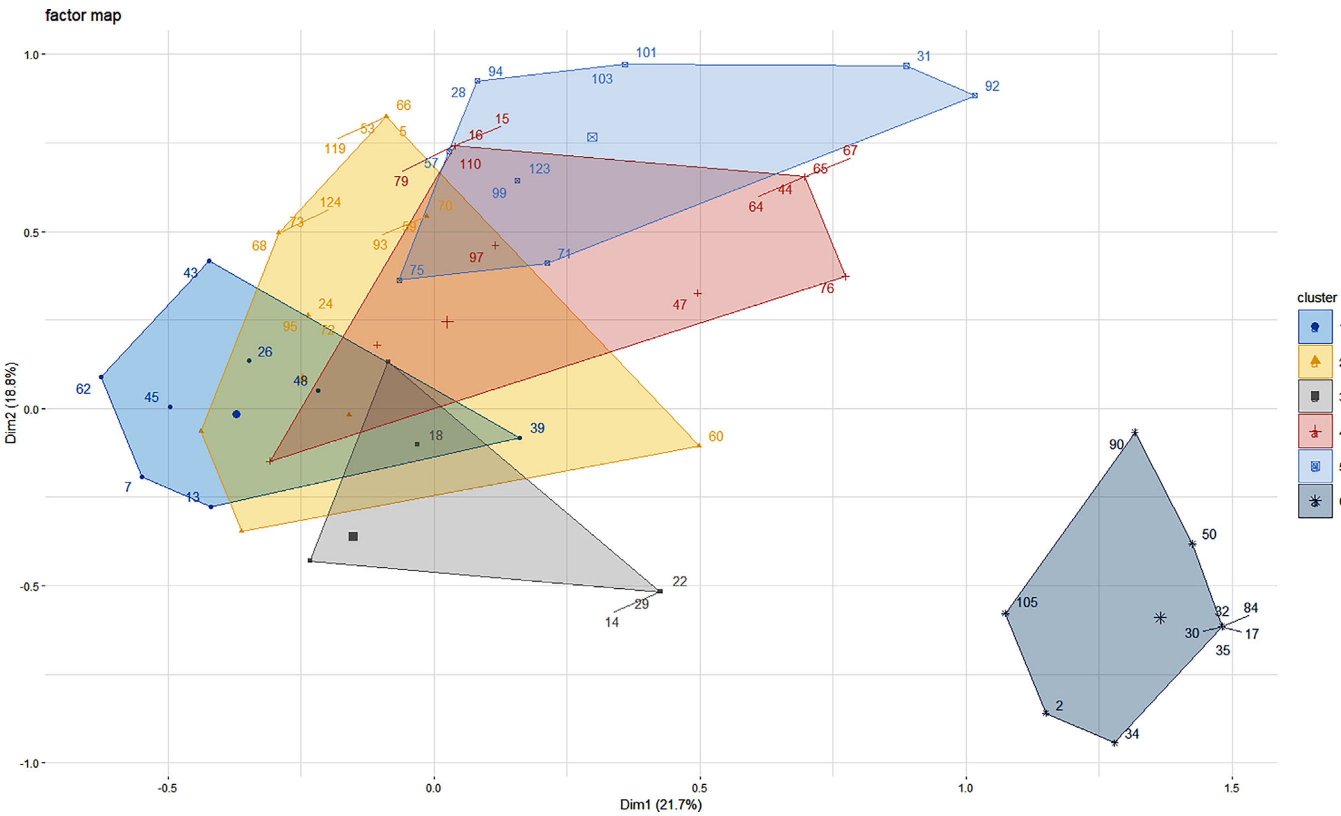

Fig. 1. Representation of the 6 clusters of Informational Resources (I.R.) used by ruminant and monogastric sectors. In this figure, each number represents one I.R., with a position on the two axis depending on the contribution to dimensions of each variable of characterization of this I.R. (=variables of Table 2). On this graphical representation, it is possible to distinguish 1 particular cluster (Cluster 6, blue) and 5 other Clusters, more similar but considered by experts as different entities. The variables making the greatest contribution to Dim1 and Dim2 are: gpeformations, dbabattoir, decid, ref; pilotage. Variables bilan and prob contribute less to these two dimensions, see Table 1 for the definitions of these variables.

Statistical analysis identified six clusters of I.R., with one particular cluster standing out from the others (see Fig. 1). These six different clusters of I.R. made it possible to distinguish different types of tools, depending on their use, as summarized in Table 2. Cluster 6, corresponding to training sessions, was the most discriminated cluster by statistical analysis. The other clusters differ by several variables: type of use of the tool (by the farmer and/or their advisors), type of data recorded (periodic reports and/or records of special events), and use (or not) of data from outside the farm (national reference data, slaughterhouse data). Cluster 1 includes regulatory tools designed to record farm data for government plans. Advisors consider these tools as useful too for monitoring animal health (e.g. the biosecurity notebook). Cluster 4 ("Tools and indicators for national or international reference datasets", see Table 2) and Cluster 5 ("Slaughterhouse and laboratory indicators", see Table 2) both include indicators that are also sometimes imposed by sector commodity chains. These indicators inform on the level of farm compliance with national or sectorial plans or participate to constitute national data references, but advisors also consider these indicators useful for monitoring animal health. One example is the Animal Level of Exposure to Antimicrobials, an indicator of antibiotic consumption that is very useful for informing on the level of farm compliance with antibiotic reduction plans. Other tools, such as the ones in Clusters 2 and 3, are both decision support tools, i.e. tools that have been specifically designed to help farmers and their advisors to take decisions for animal health management. Tools in Cluster 2 are periodic reports that demand farmer–advisor collaboration and cannot be used by the farmer alone. A well-known example in this category is the Welfare Quality ® audit tool (a version in France dedicated to poultry sector is the EBENE® tool). Tools in Cluster 3 are farmer-led monitoring tools, for example software that proposes analysis of numerical data. In this category, Time4 Cow proposed by Lely® was cited and is a tool for farm management using robot data. Even if they were designed for a use in autonomy, they can also serve to fuel farmer-advisor discussions. Finally, Cluster 6 refers to training sessions that farmers can use to gain or build their decision-making skills and/or competencies in animal health and/or animal production. As a conclusion, we can see that these six different clusters represent different levels of autonomy for farmers in the access or use of I.R., to help their decision-making.

In Table 2, one can also see that the number of I.R. varies widely, from 9 to 52 per cluster. Clusters 2 and 3 share the highest number of I.R. available. It is possible also to see that, even if the different sectors are represented in all clusters, they are not presented equally in each cluster: Clusters 6 and 2 are more for Ruminants for example.

Farmers' vision and expectations on the informational resources they need for animal health monitoring, expressed during the focus-groups' sessions

During the eight focus-group sessions, 50 farmers from across all livestock sectors were involved. Table 3 presents the characteristics of these farmers.

Farmer-side vision of the informational resources classification during focus groups

In the focus groups, farmers cited essentially the same types of I.R. as the experts (see Table 4). Taking all sectors together, the Cluster 2 and Cluster 3 I.R. were cited the most, whereas the Cluster 1 and Cluster 4 I.R. were rarely cited by farmers. The Cluster 6 I.

Table 3
Farmer–participants in the individual and collective interviews. Description of farmers who participated to focus groups and individual interviews in ruminant and monogastric sectors.

Item	Focus group	Individual interviews
Total number of farmers	50 from five sectors (6 dairy; 8 beef; 7 small ruminants; 10 pig; 19 poultry)	43 from four sectors (12 dairy; 12 beef; 10 pig; 9 poultry)
Percentage of women (%)	22%	25, 6%
Mean age (and range)	41 (18–64)	43 (28–60)
Percentage of diversified farms (i.e. with a second (or more) output in another livestock sector than the main one)	30%	21%

Table 4
Farmer feedback and expectations expressed in the collective surveys on the different clusters. During collective surveys in ruminant and monogastric sectors, farmers were asked to cite the informational resources (I.R.) they used and to position them in the different clusters. Their expectations on these I.R. were noted. The summarized answers are presented in the following table.

Cluster	Farmer citation of I.R. they know or use	Farmers' expectations
Cluster 1 (regulatory tools)	No I.R. cited in this category	No expectations expressed
Clusters 2 and 3 (decision support tools: periodic reports and monitoring tools)	The most cited category. Mean of 4.6 I.R. cited per dairy cattle farmer, 10.6 I.R. cited per pig farmer, and 4.34 I.R. cited per poultry farmer	Interoperability of tools (less registration repetition of data); sharing of data between operators; more valorization of data registered.
Cluster 4 (national reference data)	Very few cited	Better access to these databases
Cluster 5 (slaughterhouse or laboratory data)	Mean of 4.3 I.R. cited per dairy cattle farmer	No expectations expressed
Cluster 6 (training sessions)	No I.R. cited in this category	Strong expectations for better access to this type of training. Strong demand expressed from farmers in each livestock sector for group training based on peer exchange on health practices.

Note: Cluster 2 and Cluster 3 were merged into one cluster by the partner project experts during the focus group exercise, as it was difficult to explain the difference between these two types of tools.

R. were not mentioned in any of the focus groups. Farmers in different sectors cited and used different tools. For example, dairy farmers very often cited the results of laboratory analyses, particularly milk quality analyses.

Farmers' expectations on the different categories of informational resources proposed with this typology

In Table 4, one can see that farmers appear to have no expectations at all for some Clusters, such as Clusters 1 and 5, yet very high expectations for others. They wish a better access to data (Cluster 4), when data are available only for other operators than farmers. They also ask for data interoperability between tools, in order to limit data recording (Clusters 2 and 3). Finally, they need data sharing between several actors (Clusters 2 and 3) in order to foster communication between their several advisors, to develop a common knowledge on health status with all their advisors or to improve problem-solving. Farmers also expressed strong expectations around having access to more peer-exchange group-based training (Cluster 6).

Farmers see that the classification is missing some informational resources

The presentation of the different clusters prompted reactions that led to the addition of other tools/approaches and thus other categories of I.R. that were not cited by advisors. Two points were stressed by farmers during focus groups.

First, farmers emphasized the importance of using informal and sensory indicators, which they see as indispensable and even more important than the tools mentioned in the different clusters. Before looking at more quantified or formalized indicators, farmers said that the first information they look for daily is of the sensory, unquantified, informal kind. An illustrative example was given by a suckler-cow farmer: "*The first thing I do in the morning is to get all my calves to suckle and see what's wrong*" (beef farmer, in the focus-group stage).

In addition to these sensory indicators that are gathered through the personal, day-to-day experience of working on a farm and are difficult to objectivize, the farmers cited the importance of indicators that can be used to objectivize changes in the condition, behavior or health of the animals. These formalized indicators were often quantified and can be collected on a daily basis to confirm their initial intuition. The farmers thus stressed the importance of daily monitoring, rather than periodic reports, as it enables them to react more quickly to problems on the farm. For example, poultry farmers frequently mentioned tools for daily monitoring of water and feed consumption, as well as weight monitoring tools such as electric scales and building environment monitoring (humidity and temperature). Regular monitoring of these data sources enabled them to promptly detect any drift and swiftly implement corrective measures.

Importance of sensory informational resources to execute health management, expressed by farmers during focus-group and individual interviews

We performed individual interviews with 43 farmers. Table 3 presents the characteristics of these farmers.

Prioritization of sensory information

Farmers insisted on the fact that to identify health problems in their herds, they used their various senses (hearing, smell, sight, touch) in a non-formalized way to capture any differences in the condition or behavior of the animals or in the atmosphere of the building. A verbatim account from discussions between dairy farmers illustrates the importance of these visual indicators for the farmer: "*The farmer's eye is the best tool for monitoring health*" *(a dairy farmer, focus-group meeting).* The pre-eminence of these observation-based signs was found in most of the comments and in all sectors: "*In fact, there are signs: the head is down, the animal is just yelling, or it's not in its place, or it's not drinking properly (...). It's up to us to observe the animals [to see what's wrong]*". *(dairy farmer, one-to-one interview*). The expression used to describe this type of indicator is *"the farmer's eye*", but in reality, the farmers mobilize all their senses to scan for the existence of a possible health problem. Poultry farmers especially described how all their senses are mobilized in those first moments when a change from a normal situation is detected in a non-palpable way: temperature, dampness, smell, listening to poultry vocalizations, and even touch (the softness of the litter, for example). In individual interviews, a duck farmer described his trick for getting a better feel for the atmosphere: "*So when I go round, I look at the animals (...), and I take time to sit down in the building, to sit for 10 or 15 minutes, to stop moving and simply listen to the ducks breathing and so on, to detect whether they have a lung problem or whatever, or if there's something going on (...). There too, I often go in a t-shirt.* Interviewer: *"Really? Why?*" Farmer: *"A t-shirt is just the basic thing you need to get the feel of the wind, the airflow, the ventilation in the building, to find out what I can feel myself and make sure the ducks don't feel too much wind*" *(*duck farmer, one-to-one interview).

The need to take time for observation

Another point that was stressed by many farmers was the need to take time to observe and feel the animals. In a one-to-one interview, a dairy farmer emphasized the need to take time out to properly observe: "*And you have to spend time, contrary to what people think. Just because we have robotic milking doesn't mean we don't spend time working. Because though I don't do the milking anymore, I still do everything else, and in fact, I spend a lot of time observing the cows*" (dairy cow farmer, one-to-one interview). This same point was echoed by a pig farmer, who said: *"Most of our time is spent observing batches and groups, and when you go out there every day, you too see it right away, you know; we just know what to look for—a pink pig, if it's under straw, you know it's doing well anyway*" (pig farmer, one-to-one interview). This time taken to observe the animals can be at a particular moment (such as before or after feed distribution, or milking, etc.) or be integrated into the daily routine. It can be done in a simple, intuitive way, and the farmers readily accept the subjective dimension of this information, and even used the terms 'intuition' or 'feeling'.

Sensory indicators linked to know-how and experience

The importance of these sensory indicators is such that they are often associated with the farmer's identity, with a know-how that is difficult to put into words but is forged through years of experience in the job. "*Either way, livestock farmer is a job where you need a keen eye, you have to do a lot of close observing*" (dairy farmer, one-to-one interview). When asked how to identify a healthy animal, a pig farmer replied: *"When it's well-rounded, when it's not skinny, and when it has a good coat, straight ears, a good eye, that's it.... you just know because you're a farmer, it becomes obvious to you at first glance, and then it becomes a habit*" (pig farmer, one-to-one interview).

A variability of use of this sensory information

While all farmers explained the importance of this sensory information for health management, there was considerable diversity in terms of how easily (or not) they were able to detail their observational criteria. Some farmers listed a large number of criteria for observing animals (behavior in particular), whereas others patently struggled to explain their practices, which thus appeared to be tacit and incorporated knowledge. In all discussions —even the most detailed—, at one point or another, the farmers expressed the difficulty of giving precise details of their daily practices. Farmers sometimes used observation aids, such as certain animal welfare software (for example EBENE® or COWNOTE®) that gave them ideas for new observational criteria that they had not thought of (without relying entirely on using the tool).

Formalized daily monitoring indicators, when they exist (e.g. in poultry farming: monitoring building-environment parameters, animal growth, or water and feed consumption), can enable farmers to confirm their initial intuition or serve as a signal prompting a closer look at their animals. These data can be digitized and recorded by the software or in a spreadsheet and monitored on a daily basis without recording (which they find too time-consuming) or recorded on very simple media (on paper, on the wall in piglet nursery, on a board in the milking parlor).

This need for objectivity also reflects the need to be surrounded by animal health advisors: "*It's easier to get someone from the outside to make a judgment, because we're so used to our's (...), we see them every day, but sometimes (...) things can happen...*". (poultry farmer, one-to-one interview).

Finally, even if farmers tend to rely on day-to-day monitoring indicators, they also appreciated some of the tools in Cluster 2. One dairy cattle farmer, referring to tools based on a periodic diagnosis of animal health, called them *"the farmer's third eye*", complementary to the farmer's own judgment. Indeed, for pig and poultry farmers, these tools/approaches serve as 'back-up' for the sometimes fallible 'farmer's eye' and enable them to compare the performances of different batches or flocks within their farm.

Transversal analysis of results

Our key finding, thanks to different steps of analysis, is the difference of I.R. cited by farmers and other livestock professionals. Even if the tools cited sometimes coincide, there is nevertheless a real dichotomy between the farmers' vision of health and the advisors' vision in terms of the tools used (sensory tools versus assessments) and the timeframe of the monitoring (daily versus long-term). The statistical clustering reflected the vision and practices of advisors. Our final results showed that farmers only use some of these tools, and that they primarily mobilize a set of sensory indicators to monitor the health of their livestock. This result surfaces an informal division of roles between farmers and advisors in terms of farm health monitoring. On one hand, farmers rely on sensory indicators, and seek to detect daily changes in their livestock (in behavior, atmosphere, etc.) in order to take immediate corrective action; farmers thus perform day-to-day management of animal health. On the other hand, health advisors use tools to objectivize and measure production indicators in reference to average technical norms, which they collect and analyze over a longer period of time, and report back to the farmer at regular intervals (monthly, annually); advisors thus perform periodic health monitoring of the farm. Farmers and advisors thus jointly monitor the health of the farm, with complementary tools and I.R.., and need different types of tools depending if they are farmers or advisors.

Discussion

Crossing several data to identify a gap between farmers and advisors

In this work, we brought together the vision of different livestock stakeholders concerning the informational resources mobilized to manage animal health. We articulated different data collection methods (online and phone surveys, individual and collective interviews), which enabled us to cross-reference qualitative data on the vision of different stakeholders. This method enabled us to give the same legitimacy to farmers' vision and the vision of the technical experts in the farmers' ecosystem, which is not always the case in animal health studies but has been highlighted by certain authors as an important issue for improving animal health support (Ducrot et al., 2019). We identified an informal division of roles between farmers and advisors in terms of farm health monitoring. It is possible that this division of roles does not affect the performance of animal health monitoring, if it is acknowledged and well considered by each partner. But our results and scarcity of technical literature available on sensory indicators suggest that this gap is not so well known. We suggest that ignoring the importance of indicators favored by farmers, or the depreciation of these indicators, could lead to a lack of communication or misunderstanding between farmers and their advisors, as other cultural differences identified for a long time in human medicine (see for example Kleinman et al., 1978). These authors have indeed described the differences in perception and definition of diseases or illness between patients and medical professionals that can provoke problems of compliance or patient dissatisfaction.

Sensory indicators have been described in other studies not focused on livestock activities

The importance of observation and 'sensory' indicators for managing the performance of living organisms (plants or animals) has already been reported in work focused on the competences needed for example for agroecological transition (Toffolini et al., 2015). The "clinical gaze" is also an important dimension of clinical skills in human medicine, cited in literature on human health (Källestedt et al., 2023). It is described as a complex competence, involving "intuition (...), use of a sound, rational, relevant knowledge" (Källestedt et al., 2023) and learned by nurses for example, thanks to experience, and daily work with patients.

Complexity of sensory indicators

Our results also pointed to the diversity of senses involved in this informal observational practice, which also involves touching, smelling and listening. The expression "*the farmer's eye*" belies a complex sensory experience. In particular, the sense of touch enables the development of very specific skills, known as haptics (Sola, 2007), which have been described in several jobs (dressmakers, cabinetmakers, nurses) but tend to be ignored or underestimated in the livestock sector. Cognitive sciences consider touch as a central sense at the origin of the other (visual, olfactory, etc.) senses. De Grave (2007) described how modern Western-world societies devalue the sense of touch in relation to the other senses, in contrast to other cultures (e.g. Indonesian). In a Western-world society over-accustomed to visual indicators, it is important to re-emphasize the complexity of the indicators used by farmers in their day-to-day experience working with animals, and to develop learning that caters to this type of indicators.

Sensory information and numerical data: a complementarity

Furthermore, this study also highlights the gap between the large number of tools developed for farmers and their advisors, and the small number of tools that farmers actually consider useful for them. As digital agriculture continues to expand and use sensors that can record vast amounts of different types of data, it has brought numerous smartphone apps, software solutions and other decision-support tools, as our first survey phase clearly showed. However, while the development of these tools opens up an impressive range of possibilities for innovation in agriculture (e.g. Hostiou et al., 2017), it is surprising to see how little enthusiasm the farmers surveyed here showed for these multiple tools.

One hypothesis may be that these tools make little reference to the I.R. typologized here as 'day-to-day indicators' or 'sensory indicators'. Indeed, few digital or health management tools combine different types of I.R. The question of how to co-articulate digital indicators with non-formalized sensory information, which influences farmers' day-to-day decision-making, therefore emerges as an important issue when designing digital tools or developing training courses on animal health for farmers. This could be a way of improving animal health management and dialog between farmers and their various health advisors. Note, too, that farmers did not express strong expectations on improved data analysis or new sensors to help them in their decision-making process, but they did express a need for peer-to-peer exchange, which is where digital knowledge-sharing platforms can provide solutions (Thareau and Daniel, 2019).

Sensory indicators are important in a diverse range of livestock sectors

Other studies more specifically focused on livestock farming have already reported on the importance of observation for herd management or animal health management in ruminant dairy or beef herds (Mougenot et al., 2020; Fischer et al., 2019), for organic ruminant farmers (Manoli et al., 2021), or specifically for the use of alternative medicines by ruminant farmers (Hellec et al., 2021). Here, we demonstrated that the farmers' skill in observing their animals was equally important in all the livestock sectors surveyed, i.e. not just for ruminants. Thus, even in sectors with high levels of technical intensification and high productivity targets, the livestock farmers assert that this skill remains critical to their day-to-day work. Our methodology here was original in that we carried out the same type of survey but differentiated between the ruminant sector and the monogastric sector. This comparative approach was difficult to implement, as it required a high degree of coordination and harmonization between different partners specialized in each sector, and replication of the same methodology in substantially different contexts. Interviews, discussions and focus-group facilitation were therefore realized by a diverse set of people, which makes it difficult to give a concise report of all these actions. Nevertheless, this cross-industry approach provided a general overview of all the I.R. used by farmers to manage animal health, and highlighted commonalities between farmers and their advisors in various sectors. For example, an approach focused on the dairy sector would not have highlighted the use of laboratory analyses by advisors to manage animal health, whereas these laboratory analyses are hugely important to the monogastrics' sector.

Summary and perspectives

Taking into account, the vision of farmers and their advisors is a major issue for animal health management. Here, we identified a diverse range of I.R. known or used by livestock advisors, and we captured the needs and expectations of farmers regarding these numerous tools and indicators. We also found a possible gap between advisors' representations and farmers' daily needs for animal health monitoring. In practice, farmers use complex sensory indicators to monitor the health of their animals, and express a surprising lack of enthusiasm for the diversity of tools (including numeric tools) available for them. This study thus points to directions for further work: what are the advisory networks of farmers for health management in the different sectors? What are the specific roles of each advisor for animal health monitoring? For example, Redfern et al. (2021) have identified the specific advisory network around farmer for mineral supplementation and prevention of metabolic diseases. Other types of diseases request specific advisors and it could be interesting to investigate them in order to find if a gap exists between farmers and their advisors. Our study also suggests that training should be developed and delivered to all the AKIS (Agriculture Knowledge Innovation Systems, Coquil et al., 2018) stakeholders to educate them on these observational health monitoring practices, their limits and opportunities. Particular forms of training should be considered as it is a complex competence that one acquires also by field experience (Källestedt et al., 2023). It would also be instructive for further studies to identify profiles of farmers and advisors more or less concerned by sensory indicators, factors explaining this diversity of profiles and modes of learning for the ones who use more these sensory indicators.

Our results are also interesting for animal production professionals, who are sometimes accused (Porcher, 2011) of having created a productivist and purely utilitarian vision of farm animals that has led to all the welfare and ethical problems concerning farm animals today. In this context of societal demands requiring more welfare, taking into account the complex dimension of working with animals that requires for farmers to use numeric but also numerous sensory indicators, acquired during their daily work with animals, seems an important challenge.

Ethics approval

Not applicable.

Data and model availability statement

None of the data was deposited in an official repository. During the surveys, farmers signed a document of approval to participate in this project, mentioning the anonymity in the use of the data. Anonymous data are available upon request.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the first author used DeepL® in order to translate in English most part of the article. After using this tool, a native English-speaking editor corrected the language; authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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Declaration of interest

The authors declare no conflict of interest.

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