SCIENTIFIC OPINION

Scientific Opinion on the assessment of dairy cow welfare in small-scale farming systems[1]

EFSA Panel on Animal Health and Animal Welfare (AHAW)[2,3]

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ABSTRACT

This opinion reviews information on small-scale dairy cow farming systems in Europe, including the impact of production diseases on welfare of cows, and proposes a methodology for welfare assessment in those systems. To address specific expectations of consumers that food be produced locally or regionally or maintaining acceptable animal welfare conditions, in addition to herd size, criteria to define farms as "non-conventional" were proposed. Several sources were investigated for identifying criteria for the description and categorisation of small-scale farms, including dairy umbrella organisations and literature. In addition to herd size (up to 75 cows), proposed criteria related to small-scale farming comprise the workforce source, input level, indigenous breed use and production type certification. To cover the large diversity of farming systems across Europe, it was proposed that farms meeting at least two of these criteria be considered non-conventional. To adapt the welfare assessment to small-scale farms, the same risk factors and welfare consequences, as measured by corresponding animal-based measures identified in previous opinions for intensive farming systems were considered to be also relevant for small-scale systems. In addition, factors related to resources provided on pasture (e.g. shelter), management of pasture (e.g. mixing herds) and management of the cows (e.g. use of local breeds) were considered more likely to be present in small-scale systems. An on-farm survey was run to collect data for welfare assessment from 124 European farms. The distribution of risk factors and animal-based measures varied across the full range in study farms and showed similar patterns in farms with different grazing systems (from no time to full year on pasture). The animal-based measures identified for intensive farming are well suited for application in small-scale dairy farms. Production disease impact on the individual animal's welfare state does not depend on herd size or farming system.

KEY WORDS

small-scale farming, dairy production, welfare assessment, animal-based measures, production diseases

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[4] The updated version of this scientific opinion includes changes of an editorial nature that do not materially affect the contents. The changes relate to the question number in the footer, the annex where it is now referred to mapped data instead of raw data in relation to the published dataset, and figures 18-22 where the acronyms used to indicate the sampled farms have been replaced by serial numbers. To avoid confusion, the original version of the output has been removed from the EFSA Journal, but is available on request, as is a version showing all the changes made.

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SUMMARY

Sustainability, animal welfare, environmental and climate concerns and awareness of social responsibility towards the community have increased consumers' interest in knowing how, where and by whom food is produced and handled on its way from the farm to the table. A growing number of consumers want to buy food, produced locally or regionally directly or under farm certification schemes whereby acceptable animal welfare conditions play often an important role. For this reason, the EU Commission is examining the feasibility of drafting EU guidelines for the "animal welfare friendly" keeping of dairy cows to be used voluntarily by farmers and requested EFSA to deliver a scientific opinion on welfare assessment of dairy cows kept in small-scale farming systems.

This opinion reviews the information on small-scale farming systems for dairy cows in Europe. In the first section, the available descriptions and categorisations of small-scale farms in relation to the sizes and types of farming systems and husbandry practices are reviewed. The second section proposes a practical adaptation of existent dairy cow welfare assessment protocols for application in small-scale farms. The third section investigates the impact of diseases on welfare of cows kept in small-scale farms.

Several sources were investigated concerning the criteria for the description and categorisation of small-scale farms, including collection of information from dairy umbrella organisations and literature. The maximum size of a herd was set at 75 cows (present as lactating or dry) based on the definition in the mandate. To address the issue, raised in the mandate, of specific expectations of consumers that food be produced locally or regionally directly or under farm certification schemes whereby acceptable animal welfare conditions often play an important role, in addition to herd size, criteria to define farms as "non-conventional" had to be proposed. The criteria for definition of small-scale farms are based on three dimensions reflecting use of local resources or enrolment in a certification scheme: (1) the type of enterprise (ownership and workers), (2) the use of inputs in the production process, including the use of local feed and local breeds, and (3) the production type (certification schemes). Therefore, throughout this document, the term "small scale" refers to small-scale/non-conventional dairy holdings as outlined above. To cover a broad spectrum of small-scale farms, it was considered reasonable that farms meeting at least two of these criteria be considered non-conventional.

For the adaptation of welfare assessment in small-scale farms, the same risk factors identified in previous opinions for intensive farming systems were also considered to be relevant for the systems addressed in this opinion. In addition, some factors were considered more likely to be present in small-scale systems related to resources provided on pasture (e.g. shelter), management of pasture (e.g. mixing herds) and management of the cows (e.g. use of local breeds). Similarly, the welfare consequences, as measured by the corresponding animal-based measures, identified for intensive farming systems were also considered relevant for the systems addressed in this opinion. An on-farm survey was run to collect data for welfare assessment. It was conducted in a total of 124 farms from four EU countries—Austria, France, Italy and Spain—which display a variety of farming systems. Farms were selected in order to cover farms with up to 75 cows and different aspects of non-conventional farming, as specified above. Based on the on-farm survey outcomes, risk factors do not differ among categories of farms divided by time spent on pasture. However, distinct clusters of farms were identified related to shared risk factors. The major factors differentiating clusters relate to pasture management (e.g. water provision, mixing of different herds during the summer), housing related to lying and feeding area, procedures used for disbudding of calves and cleanliness of the animals (as a risk factor for mastitis, for example), indicating that the majority of these factors are not related to the criteria used for the categorisation of small-scale farms. As shown by the risk ranking, some risk factors that can be present in small-scale farms (e.g. stocking density at feeding, herd milk yield, overgrown claws, stocking density at pasture, amount of concentrate fed at peak lactation) have been shown to be associated with lameness prevalence in the study population. No ranking of risk factors could be obtained for mortality, prevalence of very lean animals and prevalence of animals with skin lesions or swellings. The Welfare assessment protocol provided in this opinion allowed efficient

collection of data on a large number of animal-based measures in small-scale farms. Animal-based measures not used previously gave useful information and showed variation between farms: (1) age at culling reflecting longevity, (2) rising behaviour, (3) claw conditions and (4) clinical mastitis. Overall, the distribution of risk factors and animal-based measures varied across the full range in the farms and there were almost no farms that consistently displayed a certain level of risks or welfare. Regarding the suitability of animal-based measures, the ones identified in the previous EFSA opinion for intensive farming are well suited for application in small-scale dairy farms. The difficulties in recording animal-based measures are similar in small-scale farms and in intensive farms. There are only few specific difficulties (e.g. longer time needed to achieve sufficient sample size for behaviour measures).

Finally, very little of the literature addresses specifically the risk factors for the occurrence and welfare consequences of diseases in small-scale farms. However, it has to be noted that the impact of diseases on the individual animal's welfare state does not depend on herd size or farming system.

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1. Introduction

1.1. Background and Terms of Reference as provided by requestor

Sustainability, animal welfare, environmental and climate concerns and awareness of social responsibility towards the community have increased consumers' interest in knowing how, where and by whom food is produced and handled on its way from the farm to the table. This constitutes a business opportunity for farmers as a growing number of consumers want to buy food, produced locally or regionally directly or under farm certification schemes whereby acceptable animal welfare conditions play often an important role.

Council Directive 98/58/EC lays down minimum standards for the protection of animals kept for farming purposes, including dairy cows. Whilst there are no specific EU rules on the farming of dairy cows, based on the EU Strategy for the protection and welfare of animals 2012–2015 the Commission is examining the feasibility of drafting EU guidelines for the "animal welfare friendly" keeping of dairy cows to be used voluntarily by farmers.

Farming systems for dairy cows, including housing and management conditions, are important factors affecting their health and other aspects of their welfare, partly through housing and equipment and partly through management and handling practices. There is a high variability and number of farming systems for dairy cows, ranging from grazing all of the year to remaining in a building with zero-grazing. While European dairy production is based mainly on specialized intensive farming, there is however considerable diversity in how cows are housed and managed.

Scientific work was already carried out on the welfare of dairy cows, accompanied by a number of scientific opinions adopted by the EFSA AHAW Panel. EFSA assessed the welfare risks related to the most commonly used and specialised dairy cows farming systems, integrating the use of animal-based measures to assess their consequences. Moreover, following these opinions EFSA also launched a pilot project on the "Identification, validation and collection of data on animal-based measures to create a database for quantitative assessment of the welfare of dairy cows". In order to give stakeholders better accessibility to science-based information and good practices on small scale livestock farming, a similar risk and outcome based assessment should also be carried for these types of farming systems, where such assessment and harmonized description are currently lacking.

In this context, the European Commission requested EFSA to deliver a scientific opinion to assess the welfare of dairy cows in small scale farming systems. More specifically, the European Commission considers it opportune to request EFSA moving towards a practical application of its risk assessment methodology and scientifically categorize small scale farming systems on the basis of quantified welfare risks.

Such quantification of welfare risks is to be achieved through the assessment of suitable animal-based measures. An animal-based measure (ABM) is a response of an animal - or an effect on an animal - used to assess its welfare. An animal-based measure can be taken directly on the animal or indirectly and includes the use of animal records. It can result from a specific event, e.g. an injury, or be the cumulative outcome of many days, weeks or months, e.g. body condition. The use of animal-based measures (ABMs) to assess animal welfare has been the focus of several research projects over the past five years, and ABMs are now included in various schemes (e.g. Welfare Quality®) used on the field in order to evaluate the welfare status of animals.

The Commission therefore requests EFSA to develop a scientific opinion on the assessment of animal welfare in small scale dairy farming systems according to the following terms of reference.

ToR1: A review of the available description and categorization of small scale farms in relation to the size and types of farming systems and husbandry practices should be carried out. The risk assessment should cover dairy cows during both lactation and dry period and it should be carried out for the following categories of small scale dairy farms (with up to 75 dairy cows on the farm):

– farms where animals are kept inside throughout the entire year;

– farms where animals are kept outside on pasture throughout the entire year;

– farms where animals are kept outside on pasture during the summer and inside during the winter;

ToR2a: To identify the main factors and welfare consequences under the above-classified farming systems and apply the risk assessment methodology for risk ranking;

ToR2b: To assess if the animal-based measures for dairy cows, identified by 2012 EFSA scientific opinion1 on the use of animal-based measures to assess welfare of dairy cows, are suitable to assess animal welfare in the above-classified farming systems;

ToR2c: To assess the impact on welfare of production diseases in small scale dairy cows farming systems. The assessment should take into account the assessments already performed by EFSA as well as the ongoing work on the welfare of dairy cows.

1.2. Interpretation of the Terms of Reference

The first Term of Reference (ToR) of the mandate requests that a review be carried out of the available descriptions and categorisations of small-scale farms in relation to the sizes and types of farming systems and husbandry practices. To successfully address the ToRs, it was deemed necessary that a working definition of the farming systems of interest be provided for this opinion.

The maximum size of a herd was set at 75 cows (present as lactating or dry) based on the definition in the mandate. To address the issue, raised in the mandate, of specific expectations of consumers that food be produced locally or regionally directly or under farm certification schemes whereby acceptable animal welfare conditions often play an important role, in addition to herd size, criteria to define farms as "non-conventional" as set out in the ToR had to be proposed. The criteria for definition of small-scale farms are based on three dimensions reflecting use of local resources or enrolment in a certification scheme: (1) the type of enterprise (ownership and workers), (2) the use of inputs in the production process, including the use of local feed and local breeds, and (3) the production type (certification schemes). Therefore, throughout this document, the term "small scale" refers to small-scale/non-conventional dairy holdings as outlined above.

Besides the criteria used for the definition, it was considered important to provide information to further describe the systems with additional criteria regarding husbandry practices. In ToR2a, the mandate requests that the risk assessment be carried out for different housing and pasture management systems, namely: (1) farms where animals are kept inside throughout the entire year, (2) farms where animals are kept outside on pasture throughout the entire year and (3) farms where animals are kept outside on pasture during the summer and inside during the winter. The different grazing systems are not used to stratify the study population, as it was expected that different types of housing and pasture management would be included when considering the other factors mentioned above. However, based on previous experiences of farming systems in a number of European countries, the two extremes are likely to be rare on small-scale farms. Because the impact of the amount of grazing on welfare will be considered in the assessment, the categories of housing and pasture management were refined considering the time spent on pasture across the year.

ToR 2b requests to identify the main factors and welfare consequences under the above-classified farming systems and apply the risk assessment methodology for risk ranking. To address this task, risk factors and animal based measures from existing assessment protocols were reviewed and adapted where deemed necessary. The adapted protocol was applied in a sample of farms in a standardised way in an on-farm survey, as it was considered highly beneficial to develop a pilot methodology and evaluate it under practical conditions as there are no data available specific to welfare assessment in small scale farming systems. However, due to time constraints, the on-farm survey could not cover all categories of farming systems (because there is a great variety) nor all risk factors (e.g. provision of shade, watering, conditions of tracks, toxic plants, predators), especially because the on-farm survey took place during the winter period when most cows are housed. This means that the protocol's feasibility during the grazing period (e.g. reliable methods for avoidance distance testing on pasture) was not fully assessed. Instead of doing a risk ranking, it was decided to assess and rank the risk factors included in the protocol according to their predictive value for some of the most relevant welfare consequences in small scale farming systems.

The aim of this mandate is not to compare welfare in small-scale farms with other systems, or between the different categories of small-scale farms. Instead, a tool is provided to be used for welfare assessment that can be applied to small-scale farming systems.

To assess the suitability of animal-based measures for welfare assessment in small-scale farming systems, it was assumed that their outcomes are similarly relevant whatever the system, but specific problems in these farming systems may arise with regard to feasibility.

The working group agreed to divide the answer to ToR2c, related to the impact on welfare of production diseases in small-scale dairy cow farming systems, into two subsections. The first section updates the assessments already performed by EFSA in 2009 regarding the impact of the different diseases on the individual animal, as no differences are to be expected between farming systems. While it can be assumed that production diseases at individual level will have the same impact on cow welfare in small- and in large-scale farms, the prevalence might be different. Therefore, to assess the impact of production diseases on welfare, the specific risks leading to the disease in small-scale farming systems and the prevention and handling of the disease on small-scale farms are considered to be a relevant focus of the assessment.

2. Data and Methodologies

2.1. Addressing ToR1: a review of the available descriptions and categorisations of small-scale/non-conventional farms

To obtain an overview of the current European situation regarding small-scale dairy farms, several sources were investigated concerning current descriptions and categorisations of small-scale dairy farms.

The first step, regarding the herd size threshold of 75 cows, involved using data from the Eurostat Farm Structure Survey (FSS) carried out in 2010 to obtain an overview of the European Union (EU) dairy cow population size per country. The FSS was carried out by the EU-28 Member States plus Norway, Switzerland, Iceland and Montenegro.

The second step was a call for data from umbrella organisations launched by a consortium of different institutions under an outsourced project (Leeb et al, *in press*). An open invitation for umbrella organisations of dairy farmers to participate in the call for data was published on the Food and Agriculture Organization (FAO) website and disseminated via multiple communication channels (e.g. EFSA stakeholders, EU Commission stakeholders, SlowFood partners, FAO stakeholders and others). The aim of the call was to create a representative sample of the small-scale farming sector and to identify major criteria that are used to characterise "small-scale farms".

The third step for identifying the criteria for describing and characterising small-scale dairy farms was a narrative literature review. It used published papers, national databases and sources of raw data (e.g. PhD theses, surveys, etc.). The starting point for the literature review was the information and criteria collected from the call for data from relevant umbrella organisations. The search terms were selected to cover the three major criteria requested from the mandate. In particular, the terms used were (small OR non-conventional) AND farm AND (family-based OR family workforce OR LU/AWU[5] OR

[5] LU/AWU: labour unit/annual work unit.

family incomes-subsidies) OR (low-input OR restricted to Earth's resources) AND (arable land use OR non-arable land use OR meadows) AND (sustainable OR organic farming OR biodynamic farming OR permaculture) OR (local breed OR rustic dairy breeds OR low-input breeds OR free-range) AND (short marketing chains OR farm direct selling) AND (natural pasture OR integrated system) AND (stock density OR farm surface area) AND (productivity per ha) OR (smaller herd size) AND (seasonal calving OR grassland farms OR mountain farms).

The fourth step was an on-farm survey—performed by the consortium of the procurement project—principally aimed at collecting data on risk factors and animal-based measures, but also on the criteria for small-scale farm description (also called "farm descriptors"). The results of this survey were used to identify and distinguish between the farms and to assess the variability of those farms in relation to such descriptive criteria. More details about this on-farm survey are given in Section 2.3.3.

2.2. Addressing ToR2a: the main factors and welfare consequences under the above-classified farming systems and risk assessment methodology for risk ranking

2.2.1. Identification of risk factors, welfare consequences and animal-based measures

The list of risk factors evaluated in the scientific opinion of 2009 (EFSA, 2009) was cross-checked with the resource-based and management-based measures proposed in the Welfare Quality protocol for dairy cows (Welfare Quality®, 2009).

A final list of risk factors, which goes beyond the resource-based and management-based measures of the Welfare Quality protocol, was produced by the working group and used in the on-farm survey performed in the context of the procurement project. Similarly, the list of animal-based measures evaluated in the EFSA scientific opinion of 2012—linking the welfare consequences listed in the opinion of 2009 with the animal-based measures proposed in the Welfare Quality protocol—was scrutinised.

2.2.2. Protocol for the on-farm data collection on farm descriptors, risk factors and animal-based measures

Final revised lists of risk factors and animal-based measures, and methods for their measurement, were agreed within the members of the working group and members of the consortium performing the on-farm survey in the context of the outsourced procurement project. The list of all variables and the methods for their measurement can be found in the external report (Leeb et al, 2015) from the procurement project mentioned above.

The protocol for the on-farm data collection was structured around three major categories of variables:

1. Farm descriptors, i.e. variables covering the criteria for farm description and categorisation (e.g. herd size, breeds, etc.). It has to be noted that some of these were believed to also be risk factors (e.g. number of water points, use of pasture). The full list of farm descriptors can be found in Appendix A.
2. Risk factors at herd level, i.e. any aspect of the environment of the animal related to housing and management, animal genetic selection, transport and slaughter, which may have the potential to impair or improve their welfare. The full list of risk factors can be found in Appendix B.
3. Animal-based measures, i.e. the response of an animal or an effect on an animal. This measure can be taken directly from the animal or indirectly and includes the use of animal records. The full list of animal-based measures can be found in Appendix C.

For feasibility reasons, it was decided that the total time needed to perform the assessment in the pilot project would be limited to not more than four hours. Therefore, all measures related to the social behaviour of cows were not further considered for inclusion in the final protocol. Likewise, the behavioural measures of comfort related to resting (e.g. duration of lying down movement, collision with housing equipment when lying down) and the recording of coughing were excluded from the final protocol, as, according to the Welfare Quality assessment protocol for dairy cattle, they are recorded simultaneously with social behaviour observations. However, to obtain some animal-based information on resting comfort, the assessment of lying position (i.e. animals lying partly or completely outside the lying area) was retained in the protocol and a qualitative assessment of getting-up movements was added. Moreover, age at culling reflecting longevity, as well as claw conditions and clinical mastitis, were added to the welfare assessment protocol.

2.2.3. On-farm data collection

The on-farm data collection from, in total, 124 farms was conducted in four EU countries—Austria, France, Italy and Spain—which display a variety of farming systems. Farms were selected by umbrella organisations or directly by the contractor in order to cover farms with up to 75 cows and different aspects of non-conventional farming, as specified under the interpretation of the mandate (see Section 1.2). Data collection was carried out by, in total, nine observers (two to three per country) who had been trained together during one three-day workshop before farm visits started. This workshop included classroom training and practical application of the different measures (both animal-based and resource- and management-based measures). Inter-observer agreement for the animal-based measures was tested using—depending on the measure in question—video clips, photographs and direct examination of animals. Findings of the different observers were compared with the ones from an experienced assessor, who served as the “gold standard”, using percentage agreement, Kappa statistics and Spearman correlations. Observers not meeting the criterion of sufficient agreement (70 % agreement, 0.7 Kappa coefficients, 0.7 r_s) were retrained. In addition, observers were retested for measures where inter-observer agreement testing was done using video clips or pictures.

2.2.4. Identification of risk factors for selected animal-based measures

The statistical analysis addresses the three independent sets of variables mentioned above: (1) farm descriptors, (2) risk factors and (3) animal-based measures.

Two approaches were applied to each of the three recorded data sets in order to group the variables based on their information content (cluster identification) and, additionally, to group farms based on their similarity regarding the recorded data for each of the sets of variables (1–3 above). This led to six proposed cluster structures (or partitions): three of the recorded data and three of the farms based on each data set.

In the first approach, variables were grouped, i.e. farm descriptors, welfare measures and risk factors. Generally, only variables in the data sets that had less than 50 % missing values (i.e. evaluation feasible on more than 50 % of the test farms) were included in the clustering and only when, for non-categorical variables, the recorded values were different for more than 50 % of the farms visited.

The clustering was performed using the R package ClustOfVar (Chavent et al., 2012). The stability of the proposed cluster structure can be assessed using an index of similarity between the two alternative cluster structures using the adjusted Rand index (Hubert and Arabie, 1985). The Rand index measures how often two variables were put together in one cluster when comparing two alternative cluster structures. The index has a value between 0 and 1, with 0 indicating that the two cluster structures do not agree on any pair of points and 1 indicating that the proposed clusters are exactly the same. Stability of the original data clustering is assessed by random sampling and re-clustering of subsets of data and subsequent comparison with the original structure using the adjusted Rand index. The stability assessment was performed in three steps:

1. 500 bootstrap samples were taken of the observations and the corresponding 500 cluster structures created;

2. 500 adjusted Rand indices were calculated;

3. the median of the 500 index values was used to determine the stability of a proposed cluster structure.

The plausible number of clusters is defined as the number of clusters that produced the larger mean of adjusted Rand index values.

In the second approach, farms were grouped based on the recorded values of farm descriptors, welfare measures or risk factors. Before farms were subjected to a clustering procedure, the between-farm variability in the observations (i.e. farm attributes, welfare measures or risk factors) was covered by a principal component analysis (PCA). Obviously, each farm's data can be represented as one point if each variable constitutes one coordinate (i.e. the recorded values of all welfare-related variables). The PCA then transforms all these points of the farm data into a new coordinate system with the lowest number of dimensions possible (if n welfare-related variables were recorded, the farms are represented by n dimensions and PCA is meant to reduce this number of dimensions as much as possible while the information about the variability between farms is maintained). The resulting dimensions (or principal components) explain the maximum of the total variability and are uncorrelated to each other, but have additional meanings compared with the originally assessed variables. For further analysis, all the principal components that together covered 70 % of the total observed variability were selected. Following that selection, farms were hierarchically clustered within the principal components and based on their corresponding values in the new dimensions (FactoMineR; Lê et al., 2008).

Finally, a regression tree (CART) technique was applied to identify risk factors and estimate their predictive value for some of the most relevant welfare consequences (lameness score 1 and 2, lameness score 2, mortality, body lesions, lean cows). CART is a technique that identifies risk factors (from the list of risk factors available) that could be used to split the farms into subgroups that are more homogeneous in terms of farms having similar outcomes. The method constructs disjoint subsets of the data following specific splitting rules. These subsets are called nodes. Further splitting is repeated several times within these nodes. In this opinion, binary splits for regression trees have been applied where splitting occurs into exactly two child nodes. This partitioning process results in a saturated tree. The saturated binary tree is then pruned to an optimal-sized tree in a pruning process. In the final selection process, the final tree is determined. To evaluate the performance, the mean squared error is computed using cross-validation methods to obtain an unbiased estimate. Furthermore, a variable of importance based on the proposal of Breiman et al. (1984) was used to prune the tree; the measure is computed as follows:

$$\mathcal{I}_l^2(t) = \sum_{t=1}^{J-1} \hat{\imath}_t^2 \cdot I\,(v(t) = l)$$

measuring the relevance for each predictor variable X_l. The sum is over the $J - 1$ internal nodes of the prune tree. At each such node t, five of the best input variables $X_{v(t)}$ that could be used for partitioning the region associated with that node into two subregions are identified; within each, a separate constant is fit to the response values. The particular variables chosen are the ones that give maximal estimated improvement $\hat{\imath}_t^2$ in squared error risk over that for a constant fit over the entire region. The squared relative importance of variable X_l is the sum of such squared improvements over all internal nodes for which it was chosen as the splitting variable.

2.3. Addressing ToR2b: the suitability of animal-based measures for dairy cows, identified by the 2012 EFSA scientific opinion, for assessing animal welfare in the above-classified farming systems

The suitability of the animal-based measures was assessed by applying the full protocol on different farm types that fulfil the criteria for being small scale, as set out above in ToR1 of the mandate. Limitations of the animal-based measures were evaluated based on the completeness of data obtained and information on the time and feasibility scored by the assessors after each farm visit. In a further step, the potential for reduction of the protocol was also assessed through cluster analysis of the animal-based measures (as explained in Section 2.2.4).

2.4. Addressing ToR2c: an assessment of the impact of production diseases on welfare in small-scale dairy cow farming systems

2.4.1. Impact of production diseases on dairy cow welfare

The production diseases and other health-related problems that are addressed in this review are lameness, mastitis, metabolic diseases and reproductive diseases (i.e. dystocia and metritis) because these were found to be the most relevant diseases in terms of impact on dairy cow welfare (EFSA, 2009). Although the main effects of the various diseases on the dairy cow do not depend on the farming system, it was considered important to update (after 2009) the previous findings concerning the aetiology and the impact of the different diseases on dairy cow welfare.

The literature was obtained from the PubMed, Web of Knowledge, CAB abstracts and Science Direct databases.

For lameness, the search terms were "Dairy" AND ("Cow" OR "Cattle" OR "Bovine") AND ("Lame*" OT "Hoof" OR "Claw") AND ("Welfare" OR "Pain" OR "Analgesia").

For mastitis, the search terms were "Dairy" AND ("Cow" OR "Cattle" OR "Bovine") AND "Mastitis" AND ("Welfare" OR "Pain").

For metabolic diseases, the search terms were "Dairy" AND ("Cow" OR "Cattle" OR "Bovine") AND ("Metabolic" OR "Ketosis" OR "Acidosis" OR "Milk fever" OR "Parturient paresis" OR "Grass tetany" OR "Hypomagnesemia") AND ("Welfare" OR "Risk factors").

For reproductive disorders, the search terms were "Dairy" AND ("Cow" OR "Cattle" OR "Bovine" OR "Heifer") AND ("Dystocia" OR "Metritis") AND "Welfare".

2.4.2. Risk factors for production diseases that may apply to small-scale farms

A review of literature on the effect of farm-specific characteristics (i.e. risk factors) on disease prevalence and/or the level of severity of a given disease condition was carried out. The review focused on the correlation between disease incidence/prevalence and/or severity and a number of criteria that have been used to define the farms addressed in this report or that were additionally deemed relevant in the context of small-scale farms as interpreted in this scientific opinion: (1) degree of intensification, (2) herd size, (3) housing type, including access to pasture or outdoor run, (4) nutrition (concentrate input, use of forage, concentrate–fibre ratio), (5) milk yield per cow, (6) human factor (management, human–animal relationship) and (7) breed.

The literature was obtained from the PubMed, Web of Knowledge, Science Direct and CAB Abstracts databases using the search terms listed in Section 2.5.1, to which specific terms were added: "organic", "breed", "low input", "low resources", "high milk yield", "high milk production", "high concentrate", "small size", "pasture", "local or autogenous breed", "family run" or "risk factor".

3. Assessment

3.1. Assessment of ToR1: a review of the available descriptions and categorisations of small-scale/non-conventional farms

3.1.1. Cow populations and holdings in the EU, Norway, Switzerland, Iceland and Montenegro

According to the census of 2010, approximately 1 810 300 agricultural holdings kept 24 378 080 dairy cows in the 32 countries. Figure 1 shows the proportion of the dairy cow population in each FSS country. Germany, France, Poland, the UK, Italy, the Netherlands and Romania had the largest populations.

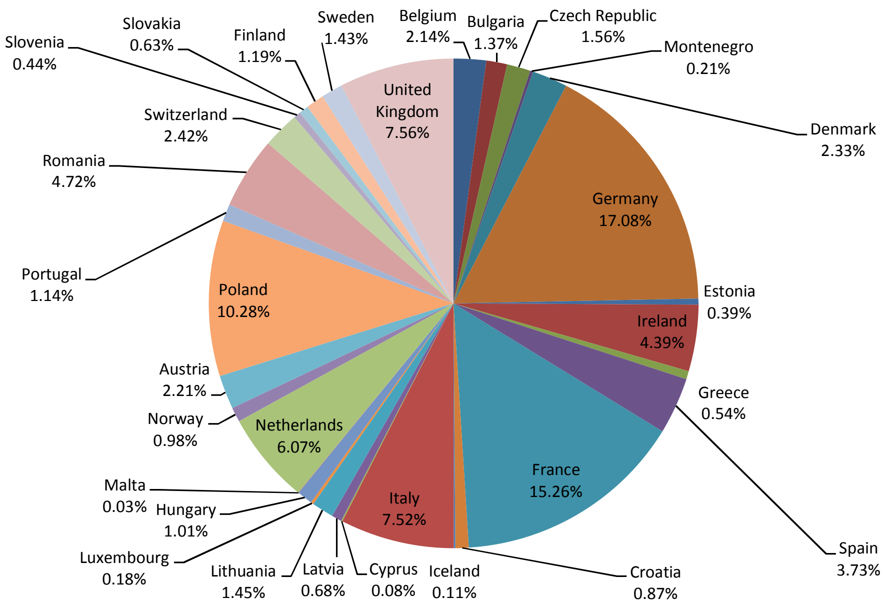


Figure 1: Proportions of the dairy cow population in the different FSS countries

Table 1 shows the distribution and proportion of the dairy cow population in the FSS countries by agricultural holding herd size. Holdings were classified by the number of dairy cows in order to (1) determine the most common herd size by geographical location and (2) reveal if there are any major differences in size within the population of small-scale farms that keep up to 75 dairy cows.

Table 1: European dairy cow population and holdings by herd size class in the FSS countries (2010)

Holding herd size	Head: dairy cows	% of dairy cow population	Holdings with dairy cows	% of holdings	Average number of dairy cows per holding
1–5 head	2 042 120	8	1 249 580	69	1.6
6–10 head	906 540	4	115 980	6	7.8
Total < 10 head	2 948 660	12	1 365 560	75	2.2
11–20 head	2 075 710	9	137 340	8	15.1
21–30 head	2 058 590	8	81 640	5	25.2
31–40 head	1 926 970	8	54 510	3	35.4
41–50 head	1 877 500	8	41 320	2	45.4
51–60 head	1 722 650	7	31 060	2	55.5
61–75 head	2 182 780	9	32 280	2	67.6
Total in herds < 75 head	14 792 860	61	1 743 710	96	8.5
Total in herds > 75 head	9 585 220	39	66 590	4	143.9
Total	24 378 080	100	1 810 300	100	13.5

Approximately 61 % of the dairy cow population in the FSS countries belonged to agricultural holdings that kept up to 75 dairy cows. In total, approximately 14 792 860 dairy cows were kept on 1 743 710 agricultural holdings with herd sizes of up to 75 dairy cows.

Figure 2 shows the distribution of dairy cows on small-scale holdings that keep up to 75 dairy cows; the population distribution is spread evenly across the size classes. However, holdings that kept 1–10 dairy cows made up a greater proportion of the population than any other class. A further breakdown of this class (see Table 1) reveals that 69 % of the animals belonged to holdings that kept up to five dairy cows, with on average 1.6 dairy cows per holding.

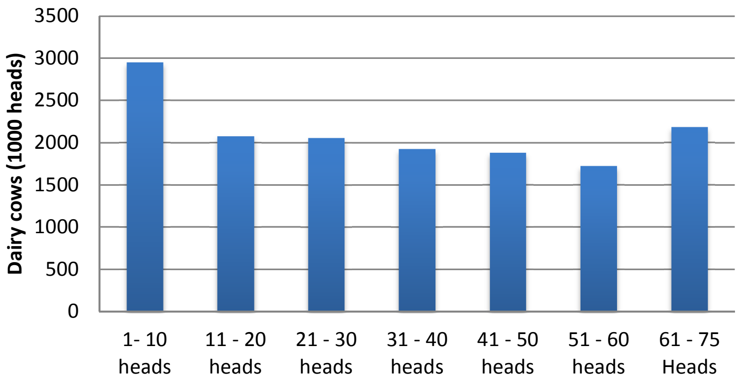


Figure 2: Distribution of dairy cow population by holding size class

Figure 3 shows the relative distribution of dairy cows kept on small-scale farms in the FSS countries. France, Poland and Germany each had populations of over two million dairy cows in this farm size category, followed by Romania with a population of over one million.

Most countries had herd sizes of above 10 cows. However, Romania and Poland had average herd sizes of five and below. Romania had a particularly low average herd size of 1.75 per holding.

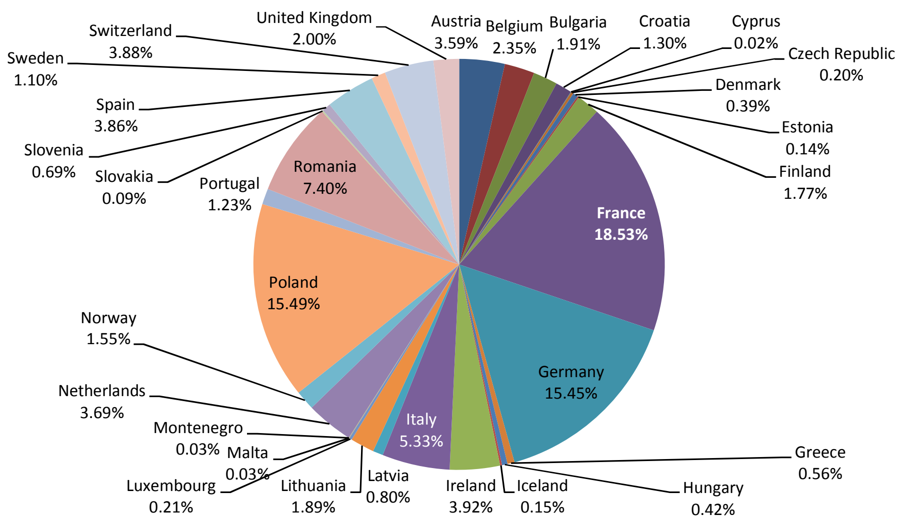


Figure 3: Dairy cow population proportions in the FSS countries on small-scale holdings (≤ 75 cows)

Table 2 shows the FSS countries with the largest numbers of small-scale holdings. Very high numbers of such farms were found in Romania and Poland. Again, there is some disparity between average dairy cow herd sizes per holding. Some countries have comparatively large average herd sizes, while others have very small ones.

Table 2: Countries with the largest proportion of dairy cows kept on small-scale farms (≤ 75 cows)

Country	Holdings	Head: dairy cows	Average number of dairy cows per holding
Romania	624 660	1 091 840	1.8
Poland	424 580	2 284 240	5.4
Bulgaria	85 620	280 990	3.3
Lithuania	84 660	279 020	3.3
Germany	77 080	2 279 120	29.6
France	72 540	2 733 260	37.7
Austria	47 630	529 820	11.1
Italy	45 690	786 390	17.2
Croatia	41 250	191 810	4.7
Switzerland	31 970	571 830	17.9
Latvia	29 800	118 240	4.0
Spain	27 100	569 440	21.0
Montenegro	23 770	50 680	2.1

The figures and tables in this section demonstrate that there are some clear differences between the proportion and number of cows in small-scale holdings across the 32 FSS countries. Such findings are consistent with the general picture of farming across Europe. In other words, there are clear differences between small-scale farmers in Eastern Europe and those located in the rest of Europe, with markedly smaller holdings in the Eastern European countries. In terms of agricultural holding types, most dairy cows were kept on agricultural holdings that specialise in dairying (71.3 %). Agricultural holdings specialising in dairying tend to keep larger herds. Those that do not specialise in dairying (other) tend to have smaller herd sizes, and most of the dairy cow population in this group falls into the one to five head herd size class.

3.1.2. Review of the available information regarding criteria for small-scale farms from dairy umbrella organisations

A total of 140 associations/organisations that represent dairy cattle farmers filled in the questionnaire (79 from Europe, 28 from Africa, 19 from Asia, 12 from America and two from Oceania). More details can be found in the separate report from the procurement project (Leeb et al, *in press*). The responses from Europe came from 17 countries.

A total of 53 responses were obtained from the four countries in which on-farm visits were carried out as part of the project: France (26), Italy (13), Austria (8) and Spain (6). The main outcomes for these four countries may be summarised as follows:

- All responding organisations of each country include small-scale farmers. For example, 95 % of these have up to 75 cows in Austria, 87 % in France, 96 % in Italy and 79 % in Spain.
- All organisations of each country have information on farmers on a regional basis.
- Of all of the respondents, 83–100 % have members who use pasture or grazing for at least four months per year.
- All French and Austrian respondent organisations include organic or biodynamic farms among their members, but this percentage is markedly lower in Italy and Spain. Some of the associations represent only organic producers.
- In two countries, Italy and Austria, a majority of respondent organisations (77 and 75 %, respectively) promote the protection and conservation of indigenous/local breeds, while this number is lower for the other countries.
- The highest percentage of organisations which provide inspection and products or production certifications is found in Austria (75 %), followed by France and Italy (31 and 23 %, respectively).
- In two countries, France and Austria, the majority of respondent organisations (77 and 75 %, respectively) promote animal welfare and provide assistance to the farmers to implement animal welfare practices.

There are many organisations which represent small-scale farms. However, limited data to characterise the small-scale farms were derived from the responses of the umbrella organisations, and therefore were complemented with literature review and on-farm data collection.

3.1.3. Review of the available information regarding criteria for small-scale farms from the literature review

3.1.3.1. Herd size

The literature review was aimed at identifying the criteria for describing and characterising small-scale dairy farms. Information was extracted from a total of 54 peer-reviewed publications (45 papers in scientific journals, one doctoral thesis and eight deliverables of EU projects), 35 technical papers and six books identified by this search.

The mandate specifies a threshold of up to 75 cows (including both dry and lactating cows). However, in the literature, a clear threshold cannot be found. A limit of 75 cows has also been considered in the Netherlands (Reijs et al., 2013). In contrast, in the context of Nicaragua, Ecuador and Paraguay, FAO (2012), as a relevant umbrella organisation, stated that, to be considered as small-scale farming, herd size may not exceed 50 cattle. These figures agree with data from Perea et al. (2010) and Mata (2011) for organic dairy farms in northern Spain, where the average number of cows per herd is 46 ± 8.7 and at least 40 cows is considered to be a profitable herd size.

In the EU-funded Sustainable Organic and Low Input Dairy Systems project (SOLID), the average number of cows in the participating dairy farms was 67, but the survey included only three EU countries (the UK, Spain, Romania) (Moakes et al., 2012). In Austria, the average herd size is 29 cattle per farm, corresponding to 15.9 dairy cows per farm and 11 dairy cows for organic farms (Grüner Bericht, 2012). In France, in 2011, 16 % of farms had fewer than 20 dairy cows, 13 % had between 20 and 29, 18 % had between 30 and 39, 17 % had between 40 and 19 and 36 % had more than 50 dairy cows (Institut de l'Elevage, 2012). In Portugal, the average number of cows per farm is 28.6 (INE, 2009).

The minimum herd size as a criterion for professionalism of the farms reported by RENGRATI (National Typical Farm Network, part of the International Farm Comparison Network, 2012) was 15 cows.

3.1.3.2. Husbandry practices: grazing

The amount of time dairy cows are permitted to graze varies widely across Europe and depends on soil and climate conditions, land availability, animals' nutritional needs, farm management, socio-economic factors and cultural aspects. Intensification and changes in high-yield dairy cows' nutrition has led to a decline in grazing that is expected to continue.

Reijs et al. (2013) reports that the proportion of farms using grazing in the north-western European countries varies between 30 % in Denmark and 100 % in Ireland. In contrast, in many farms across southern and eastern Europe, zero grazing is the main production system. On the other hand, there are farms in which dairy cattle graze during only specific parts of the production cycle—mostly young stock and/or dry cows.

Apart from the time spent grazing, pasture management is very important to adjust the stocking rate to the farm capacity. Furthermore, reproductive performance and the level and duration of supplementary feeding required to meet seasonal feed shortages under different stocking rate regimes are among the key economic parameters which influence grazing output (Catrileo et al., 2009).

For the categorisation of farms by duration of the grazing period throughout the year, the working group decided to adapt and extend the classification suggested for the north-western European countries based on the report of Reijs et al. (2013):

All-year grazing: access to pastures for at least 300 days per year. Cows will have access to pasture almost all year round. During a small period of a maximum of two months, animals may be housed if climatic conditions are very harsh or pasture is too poor. All-year grazing occurs, for example, on most dairy farms in Ireland, on the Azores (Portugal) and in parts of southern Italy.

Extended grazing: access to pasture for between 120 and 300 days per year. This is the case when farms allow for grazing during the spring and summer months but keep cows housed during the cold seasons. This is the situation in most northern European countries (e.g. the UK, Sweden, Denmark, the Netherlands, Germany, France).

Restricted grazing: pasture is only periodically used for 15 to 120 days per year. This is typically found in mountain dairy farms (Austria, Switzerland, France or Italy) or for dry cows on farms where the milking herd is permanently housed.

Zero grazing: access to pasture is null or very exceptional. This production system may be found across Europe. Cows may be housed in straw yards, cubicle housing or tie-stalls. Some farms may provide access to paddocks or even fields for exercise, but these cannot be considered similar to "access to pasture".

3.1.3.3. Work source

Cattle holdings are often family-based enterprises (including a workforce made up of partners and their families, e.g. cooperation of farms, neighbours and partner farms). It was agreed that the minimum percentage of the family workforce should be above 80 % to comply with the criterion. In a study performed in the Spanish organic dairy system, Perea et al. (2010) reported that an average of 89 % of the workforce were family members. The Dutch NTA8080 (www.sustainable-biomass.org) states that two-thirds of the workforce must be composed of family members. Additional help is usually hired in the form of seasonal workers for crop and forage production.

3.1.3.4. Level of input

As described by Pointereau et al. (2012), low-input farm systems could be used as a way to optimise the management and use of internal production inputs and to minimise the use of exterior production inputs, wherever and whenever feasible and practicable (see Figure 4), i.e. purchased concentrate, fertilisers and pesticides. This could lead to lower production costs and reductions in surface and groundwater pollution (e.g. lower nutrient input), pesticide residues in food and farmer's overall risk, resulting in both short- and long-term farm profitability increases.

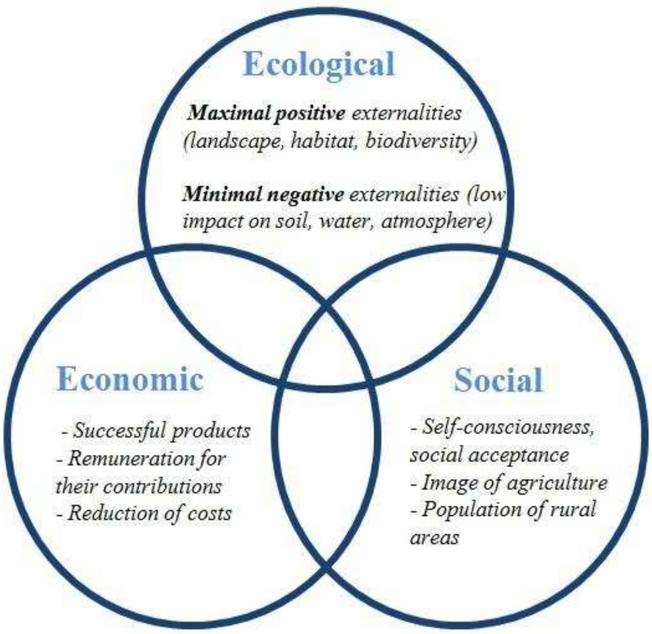


Figure 4: A concept map, including the main criteria of low-input farming systems (from Poetsch, 2007)

The level of input can be defined in many ways. For each farming system, it is possible to calculate the level of input used per hectare (intensity) or per quantity of product (efficiency) (Pointereau et al., 2012). A number of basic elements and considerations have been described by Poetsch (2007) (see Table 3), which make up important aspects of the potential association between low-input factors and animal welfare in small-scale dairy farms.

Table 3: Basic elements of low-input farming systems (from Poetsch, 2007)

Elements	Needs/consequences/advantages
Reduction of external resources (concentrates, mineral fertilisers, fossil energy)	Improve forage quality, legume-based forage systems, enhance manure efficiency, mechanical and biological weed control, use of renewable energy
Maximisation of grazing	Full grazing systems, harmonisation of lactation time with vegetation period, improve forage conversion efficiency, synchronisation of calving, animal welfare and health; reduce forage conservation costs, natural hay drying systems, no maize (or little)
Optimised animal husbandry	Low replacement rate (dairy cows), high life-performance, site-adapted local breeds, e.g. lightweight animals to avoid sward damage
Cheap and labour-extensive animal housing systems	Free-range husbandry, wooden stable houses and farm buildings, stable cooperation
Reduction of costs for farm machinery and other farm equipment	Inter-farm cooperation, use of machinery rings, management cooperation for larger areas (valleys)

In the SOLID project, three farm categories were defined: low input (LI), medium input (MI) and high input (HI) (Moakes et al., 2012). The LI indicator chosen by SOLID refers to the total farm expenditure for purchased feed (for grazing livestock), fertilisers, crop protection and energy, expressed as euros per grazing livestock unit (euros/GLU). Farm types were defined as low-input farms spending less than 80 EUR/ha per year on fertilisers, crop protection and concentrated feedstuff; medium-input farms spending from EUR 80 to 250/ha per year for the above-mentioned costs and high-input farms exceeding EUR 250/ha per year regarding these inputs (EEA, 2005).

However, for dairy farms, concentrate use should be the main indicator considered, as it is objective and well described in the literature and reflects high use of forage. The working group proposed a threshold value of 800 kg/cow/year for classification as low input. Nevertheless, there is a broad range of values described in the literature that are related to geographical and husbandry differences. Ferris (2014) considered 560 kg per cow and lactation to be the low concentrate input in the UK. In the SOLID project (Horn et al., 2014a), experiments were completed in spring 2014 and the data are currently being analysed. From the preliminary results, concentrate levels of the low input and reference groups were 286 versus 656 kg in Austria, 717 versus 1 657 kg in Northern Ireland and 1 359 versus 2 880 kg in Finland. These figures differ from what has been considered to be extreme low input with 200 kg dry matter of concentrates per cow per year and 6 000 kg of milk yield in Germany (Müller-Lindenlauf, 2008).

Overall, low-input farm types showed positive effects on the impact on animal welfare (Müller-Lindenlauf, 2010).

Other indicators of interest are the percentage of home-grown concentrates and the percentage of home-grown roughage in the diet of dairy cows.

3.1.3.5. Breeds

Indigenous or local breeds, which may be defined as breeds “originating from, adapted to and utilized in a particular geographical region”, often form the basis for production systems. Indigenous breeds may be distinguished from “locally adapted” breeds, which “have been in the country for a sufficient time to be genetically adapted to one or more of traditional production systems or environments in the country” (FAO, 2005), or from “international” transboundary breeds that are those that have spread across countries (FAO, 2007).

Because of the type of production, product uniqueness or quality, or simply because of tradition and patriotism, European society has long recognised the environmental, social, cultural, market and public importance of local cattle breeds (Hiemstra et al., 2010).

Smallholders aim for optimisation of the farming system, not the individual animal, in a multifunctional way (Vellinga, 2012) and many farms pursue diversified production. Indigenous breeds may provide added value such as local breed-specific products (e.g. cheese) or associations with brands such as “local food”, “slow food” or others (see Section 3.1.3.6) (Hiemstra et al., 2010). They may also contribute to the landscape and biodiversity management of rural areas.

It is important to ensure that locally adapted breeds remain functional parts of production systems to maintain adaptive fitness traits, as these are genetically complex and cannot easily be achieved by selection over a short period of time (CGFRA, report on breed categories[6]). Identifying the factors affecting the dynamics of indigenous breeds across Europe is valuable, and should be carefully considered in conservation and development policies common to all European countries. To guarantee breeds’ survival and original characteristics, while ensuring genetic diversification, there are usually representative organisations and protection schemes that contribute to a more self-sustaining production (Hiemstra et al., 2010).

According to Gandini et al. (2010), almost all indigenous breeds are kept, by a certain percentage of farmers, together with other breeds. In some cases, the animals of an indigenous breed represent a small percentage of the total herd, which puts them at risk of disappearing as a sustainable breed. It can be questioned whether this type of farming really does protect rare/local breeds or if it is just continued as a hobby. To ensure these unique genes are protected, crossing with more selected and high-yielding breeds should be avoided. Therefore, a minimum percentage of 50 % indigenous breed(s) adult dairy cows in the herd is suggested for this report.

Examples of the most prevalent indigenous dairy breeds in Europe are Albanian (Albania), Grauvieh, Pinzgauer (Austria, Romania), Danish Jersey (Denmark), Angler, Murnau-Werdenfelser (Germany), Agerolese, Burlina, Reggiana (Italy), Blaarkop, Groningen (Netherlands), Canaria, Pasiega, Menorquina, Rubia Gallega (Spain), Original Braunvieh, Évolène (Switzerland), Ayrshire and Dairy Shorthorn (UK).

3.1.3.6. Production type

As an additional criterion to characterise small-scale dairy farms that goes beyond the herd size, the type of production may be considered. Four different categories may be distinguished.

Organic/biodynamic production

Organic production is an overall system of farm management and food production that seeks to combine good environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produced using natural substances and processes (IFOAM, 2014). Basic requirements are described in EU regulations (834/2007/EC[7], 889/2008/EC[8]) and include organic feeds (at least 60 % should be own production), maximum use of pastures (as long as climatic conditions allow it), limited medicine use, etc. Biodynamic farms fulfil all requirements for organic production but comply with further standards such as the obligatory use of horned dairy cattle

[6] Commission on Genetic Resources for Food and Agriculture (CGRFA), 2012. Report of a consultation on the definition of breed categories. CGRFA/WG-AnGR-7/12/Inf.7.

[7] Commission Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. OJ L 189/1–23.

[8] Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. OJ L 250/1–84.

or the use of biodynamic field and compost preparations (Leiber et al., 2006; Demeter International, 2014).

Protected designation of origin (PDO), protected geographical indication (PGI) or traditional specialities guaranteed (TSG) products

The following EU schemes encourage diverse agricultural production, protect product names from misuse and imitation, and help consumers by giving them information concerning the specific character of the products: protected designation of origin (PDO), protected geographical indication (PGI) and traditional specialities guaranteed (TSG) (EC Regulation No 1151/2012[9]).

A geographical indication legally identifies and formally recognises food products as originating from a specified territory or region, whereby the noted quality, reputation or other characteristic of the product are essentially attributable to its geographical origin and/or the human or natural factors there. Geographical indications are recognised as a unique expression of local agro-ecological and cultural characteristics and are valued as signals of high quality and local tradition in more than a hundred nations (Padel, 2010). PDO covers agricultural products and foodstuffs which are produced, processed and prepared in a given geographical area using recognised knowledge. PGI covers agricultural products and foodstuffs closely linked to the geographical area. At least one of the stages of production, processing or preparation takes place in the area. TSG highlights traditional character in either the composition or the means of production (an example of TSG is “Hay Milk” in Austria).

3.1.3.7. Other descriptive criteria

Other criteria regarding husbandry practices were found in the literature; they are presented secondly as descriptors in order to complete the overview on small-scale dairy farms.

Total land size in hectares (ha)

Reijs et al. (2013) considers that, in northern Europe, small farms vary between 30 and 35 ha/farm and have different grazing systems (out of which 80–90 % correspond to grassland). For instance, Leach (2012) found sizes ranging from 21 to 204 ha per organic farm, depending on the country studied in northern Europe. According to Perea et al. (2010), northern Spanish organic dairy farms operated with less than 50 ha (88 % of farms), with an average of 44.9 ± 9.7 ha. This is similar to the Italian average (42 ha), but less than in Germany (55 ha), the UK (59 ha) and Denmark (66 ha).

In the context of Latin America, FAO (2012) considered land area as a basic criterion to delimit small-scale dairy farms. The maximum was established at 50 ha, despite large variability between countries, and usually the values were around 20 ha.

Stocking density

The livestock unit (LSU or LU) is a reference unit which facilitates the aggregation of livestock from various species and ages via the use of specific coefficients established initially on the basis of the nutritional or feed requirement for each type of animal. Grazing livestock units (GLU) are the livestock units of grazing livestock (cattle, sheep, horses, deer and goats). The reference unit used for the calculation of livestock units (= 1 LU) is the grazing equivalent of one adult dairy cow producing 3 000 kg of milk annually, without the additional use of concentrates (Eurostat, glossary).

In general, this is a variable value ranging from 0.8 to 1.6 LU/ha in organic dairy farms in northern Europe (Leach, 2012). For instance, in northern Spanish organic dairy farms, the average is 1.12 LU/ha, and Mata (2011) concluded that the technical optimal value is 1 LU/ha. According to EU regulation 889/2008/EC, 2.0 LU/ha is the maximum stocking rate in organic farming.

Ownership of farms

[9] Commission Regulation (EC) No 1151/2012 of 21 November 2012 on quality schemes for agricultural products and foodstuffs.

Ownership of farms may be another criterion to take into account, as well as the level of engagement (full-time farmer, part-time farmer or opportunistic farmer). For example, the legal enterprise form in organic dairy farms in Spain was mostly single-family farms (46.6 %), with lower proportions of community properties (26.6 %) or mercantile associations (26.6 %) (Perea et al., 2010).

Labour capacity: workforce

The annual work unit (AWU) corresponds to the work performed by one person who is employed on an agricultural holding on a full-time basis. Full time means the minimum hours required by the relevant national provisions governing employment contracts. If the national provisions do not indicate the number of hours, a minimum of 1 800 working hours per year should be taken as the reference. This is equivalent to 225 working days of eight hours each (Eurostat, glossary).

In Spanish organic dairy farms, Perea et al. (2010) reported an average number per farm of 2.2 ± 2.44 AWU and Mata (2011) found an average of 3.21 ± 0.66 AWU, corresponding to 6.06 AWU/100 cows. Leach (2012) found 3.8 (Austria), 1.2 (Denmark), 2.3 (Finland) and 1.9 (UK) AWU/100 ha in organic dairy farms.

Output: milk yield

This criterion has to be considered with caution for the categorisation of small-scale dairy farms because it has to be considered in parallel with the level of input. It can be measured as an overall measure of intensification of the land or of the animals. For instance, Reijs et al. (2013) considered the farm unit as small if it produces < 600 000 kg of total milk equating to approximately 75 cows. Leach (2012) reported an average milk output of 4 576 (Austria), 6 444 (Denmark), 7 765 (Finland) and 5 603 (UK) L/cow/year in organic dairy farms. Nehring et al. (2011) estimated an average milk production per 305 days' lactation in small farms (< 50 cows) in several European countries: Denmark (6 629 kg), France (5 797 kg), Germany (6 070 kg), Italy (4 823 kg), Spain (5 757 kg) and the UK (5 410 kg).

Economic size

The European size unit (ESU) is a standard gross margin of EUR 1 200/farm/year that is used to express the economic size of an agricultural holding or farm. For each activity (or 'enterprise') on a farm, the standard gross margin is estimated based on the area used for the particular activity (combined with the number of head of livestock) and a regional coefficient. The sum of all such margins derived from activities on a particular farm is its economic size, which is then expressed in European size units by dividing the total standard gross margin in euros by 1 200, thus converting it to ESU (Commission Decision 85/377/EC[10], Commission Regulation (EC) No 1242/2008 (867/2009[11]), Eurostat). Skarżyńska (2013) considered less than 8 ESU small, 8–16 ESU medium–small, 16–40 ESU medium–large and more than 40 ESU large dairy farms. According to Błażejczyk-Majka et al. (2011), the Farm Accounting Data Network of the European Commission distinguishes six classes of farm size, i.e. very small farms (0–4 ESU), small farms (4–8 ESU), medium-sized farms (8–16 ESU), large farms (16–40 ESU), very large farms (40–100 ESU) and the biggest farms (over 100 ESU).

Commercialisation

There are quite a lot of criteria related to the commercialisation of products that are very interesting, although currently there is no information available regarding reference standards. Criteria relevant to the commercialisation of products include:

- Type of supply chain—before it gets to the hands of consumers, milk goes through the following main channels:

[10] Commission decision 85/377/EEC of 7 June 1985 establishing a Community typology for agricultural holdings

[11] Commission Regulation (EC) No 867/2009 of 21 September 2009 amending and correcting Regulation (EC) No 1242/2008 establishing a Community typology for agricultural holdings.

  - traditional chain or long channel (wholesale)—milk collected through this circuit is used for the production of pasteurised milk and milk derivatives, which is ensured by industrial units and privately owned dairy cooperatives (Bensaha and Arbouche, 2014). It includes conventional supermarkets, big stores, superstores, mass merchandisers (Dimitri and Kathryn, 2007).
  - Parallel chain or short channel (retail)—used by farmers who sell milk directly to consumers or after transformation into various products in a controlled manner (Bensaha and Arbouche, 2014). It may consist of natural-product supermarket chains, independent stores and health food stores (Dimitri and Kathryn, 2007).
- For milk produced from local breeds, on average, most (39.9 %) of the production is sold to dairy companies, followed by local markets (25.4 %), and some is sold on the farm as raw material (9.6 %) and some is sold on the farm as processed material (5.9 %) (Gandini et al., 2010).
- Type of sale—the percentage of direct sales and the percentage of milk delivered to the dairy processing industry.

3.1.4. Selection of criteria for categorisation of small-scale dairy farms

Based on the literature review, six criteria and thresholds were defined for the categorisation of small-scale farms (Table 4) and were cross-checked with the information collected from umbrella organisations. They include the herd size, the amount of access to pasture, the type of enterprise, the amount of input in terms of concentrate use, the use of local breeds and the production type.

The upper limit regarding herd size of 75 cows had already been defined by the mandate. This upper limit is in the range of values found in the literature used to categorise small-scale farms; in addition, the analysis of farm structure data confirmed that a considerable proportion of European dairy farms can be described as having fewer than 75 cows.

Management strategies regarding pasture use are highly variable in Europe. Access to pasture may provide benefits for animal welfare and is also often connected with less intensive production, while zero grazing has become increasingly common with the intensification of dairy farming. Owing to climatic conditions, permanent, all-year-round access to pasture is rather uncommon in Europe. Moreover, depending on the farming system, grazing may occur for part or all of the vegetation period. Therefore, an additional category of access to pasture (part of the vegetation period, i.e. < 120 days, versus the majority of the vegetation period, i.e. > 120 days) has been introduced.

With regard to the categorisation of a farm as small scale, four other criteria have been identified from the literature to classify farms as “non-conventional”, as set out in the ToRs. These include the source of the workforce, the level of input in terms of concentrate use, the use of indigenous breeds and the production type in terms of affiliation with a number of certified programmes.

Taking the high variability of European dairy farming systems into account, the working group proposes that the fulfilment of at least two out of the four criteria is regarded sufficient (e.g. family-run AND organic farm, or low concentrate use AND traditional specialities guaranteed).

The diversity of farming systems and local conditions across Europe was taken into account. For example, in terms of concentrate use, the threshold values for a given criterion was adjusted to the median of the threshold values as identified from the literature.

Table 4: Criteria for the categorisation and selection of small-scale dairy farms used in the analysis of this opinion

Criteria	Threshold value	Short description
Herd size	< 75 cows	Number of cows including dry and lactating cows. Reference for 75 cows: Reijs et al. (2013)
Source of the workforce	Family workforce: > 80 %	Percentage of workforce from family members (including partners and their families, e.g. comprising cooperation of farms, neighbours and partner farms)
Level of input (concentrate use)	< 800 kg/cow/year	Lower limits for low input regarding concentrate use range from 200 (Ireland) to almost 1 400 kg/cow/year (Finland) (Horn et al., 2014a). The suggested threshold of 800 kg/cow/year is considered to be close to the median of what is considered low-input concentrate use in Europe and will thus include most of the low-input farms
Use of indigenous breeds	At least 50 % of the herd belonging to an indigenous breed with a local/regional protection scheme	Includes farms that keep indigenous, mostly dual-purpose, breeds (Hiemstra et al., 2010). See a list of breeds in Section 3.1.2.5
Production type (certification for marketing purposes)	At least one of the certifications for production type	Organic/biodynamic production, protected designation of origin (PDO), protected geographical indication (PGI), traditional specialities guaranteed (TSG)
Total grazing time	> 300 days/year 120–300 days/year 15–120 days/year < 15 days/year	All-year grazing Extended grazing Restricted grazing Zero grazing

Total grazing time, included at the end of Table 4, was included in the categorisation of small-scale farms post hoc.

Beyond the criteria defined in Table 4, further aspects have been identified from the literature that may be used to categorise the farms. These descriptors are reported in Table 5. They comprise information which was not regarded as crucial to distinguish between farm categories but may be used to further characterise the farms, and was therefore (partly) assessed during the on-farm survey.

Table 5: Additional descriptors for small-scale dairy farms

Descriptor	Reference range or value	Reference	Short description
Total farm land area	< 50 ha	FAO (2012)	In Europe, total farm size is very variable between farms and countries. This also applies to organic farms, with an average ranging from 21 to 204 ha Leach (2012)
Stocking density	< 1.2 LU/ha, range 0.8–1.6 LU/ha	Leach (2012)	Livestock unit (LU) is a reference unit which facilitates the aggregation of livestock from various species and ages via the use of specific coefficients established initially on the basis of the nutritional or feed requirement of each type of animal (Eurostat)
Ownership	–	–	Ownership of farms, level of employment (full-time or part-time farmer), enterprise legal form
Workforce	1.2–3.8 AWU/100 ha	Leach (2012)	Annual work unit (AWU) corresponds to the work performed by one person on a full-time basis (i.e. minimum hours required by the relevant national provisions governing contracts of employment). If not nationally specified, 1 800 hours are taken as the minimum annual working hours per year (Eurostat)
Milk output	4 576–7 765 L/cow/year 7 000–8 300 kg/cow/year	Leach (2012): organic farms Reijs et al. (2013): farms < 75 cows in the Netherlands and use of pasture	Milk yield is highly variable both at cow level and on a per hectare basis, also in organic farms
Economic size	8–16 ESU medium size < 8 ESU small size	Skarżyńska (2013) Błażejczyk-Majka (2011)	European size unit (ESU) is a standard gross margin of EUR 1 200/farm/year that is used to express the economic size of an agricultural holding or farm (Eurostat)
Commercialisation	–	–	Short chain: farms that sell their products directly to the consumers Long chain: farms that bring their milk to the collection point and from there to the dairy companies

3.1.5. Definition of small-scale dairy farms

Following the interpretation of the mandate (Section 1.2), small-scale dairy farms are defined as farms with different managerial and structural characteristics that have a herd size of up to 75 cows and comply with at least two of the following criteria: (1) more than 80 % of the workforce comes from family members (including partners and their families, e.g. cooperation of farms, neighbours and partner farms); (2) less than 800 kg of concentrate per cow per year; (3) the use of indigenous breeds (at least 50 % of the herd should belong to an indigenous breed); and (4) certified for a certain production type (i.e. organic/biodynamic production, PDO, PGI or TSG).

Small-scale farms can apply various grazing systems and can be further categorised based on the time spent on pasture as indicated in Table 4.

3.2. Assessment of ToR2a: the main factors and welfare consequences under the above-classified farming systems and risk assessment methodology for risk ranking

3.2.1. On-farm data collection: results of inter-observer reliability test

Data on farm descriptors, risk factors and animal-based measures were collected for, in total, 124 European farms. The project was conducted in four pilot countries, with 32 farms in both Austria and Spain, 37 farms in Italy and 23 farms in France sampled. Data collection was carried out by, in total, nine observers, and inter-observer reliability testing results are shown in Appendix D.

Based on percentage agreement and kappa coefficients, inter-observer reliability was moderate to satisfactory for body condition, cleanliness measures (except cleanliness of teats), indicators of clinical disease (such as nasal discharge) and evaluation of the rising movement. However, especially for the clinical indicators, true prevalences were very low (e.g. signs of diarrhoea), which has to be taken into account when interpreting the results for these measures.

Measures for which not all observers reached the kappa threshold of 0.4 for moderate agreement included cleanliness of teats, integument alterations (hairless patches, lesions/swellings), lameness, and the qualitative assessment of (difficulties in) rising behaviour and of the emotional state of the animals (qualitative behaviour assessment (QBA)). Inter-observer reliability regarding lameness was higher when tested using video clips, but did not further improve when retested after feeding back the initial results to the observers.

Variation between observers regarding the agreement with the gold standard was high, thus indicating that satisfactory agreement may generally be achieved or further enhanced by more intensive training.

3.2.2. On-farm data collection: results for farm descriptors

The analysis of results from the on-farm data collection about farm descriptors are reported here below for the most relevant variables i.e. the variables that are used as criteria for small scale farm description. The whole list of variables including short names, complete description and descriptive statistics with raw results are given in Appendix A (list of farm descriptors).

For all descriptors, a large variability exists. Although restricted to 4 countries, the survey confirms the high variety of farming systems in small scale farms. Because of the small size of the herd, some figures calculated on a yearly basis may rely in fact on very few animals, resulting into very low or very high extreme values. Therefore, in very small farms, these figures should be taken with caution when compared with usual references.

The information related to herd size showing the number of cows (nDairyCows) per farm is summarised in Figure 5. Within the surveyed farms, the whole range of size from 10 to 75 cows was sampled, thus demonstrating that those farms are highly variable in size. The majority of cows are kept in farms that have either up to 20 or up to 40 cows/farm. The mean number of cows per farm is 34.3. The minimum number of cows per farm is 10, which was set by the working group to control for bias in prevalence in the outcomes of the surveys with very low numbers of animals (for instance, one sick animal = 20 % prevalence in a five-cow herd). The total number of cows in the sample is 4 253. The maximum number of cows per farm is 75, as was required by the mandate. Among the sampled farms, herd size categories from 10 to 75 are all represented. In small-scale herds with fewer than 75 cows, there is a huge variability in herd size across Europe, and this is covered in the farms sampled in the survey. Therefore, the risk factors found in this survey cover the full range of herd sizes between 10 and 75 cows.

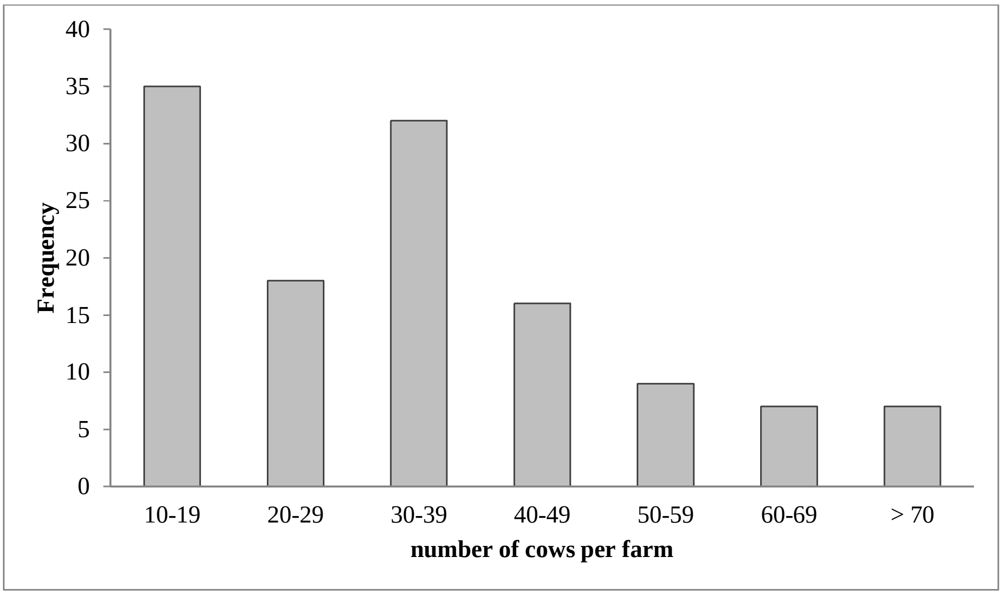
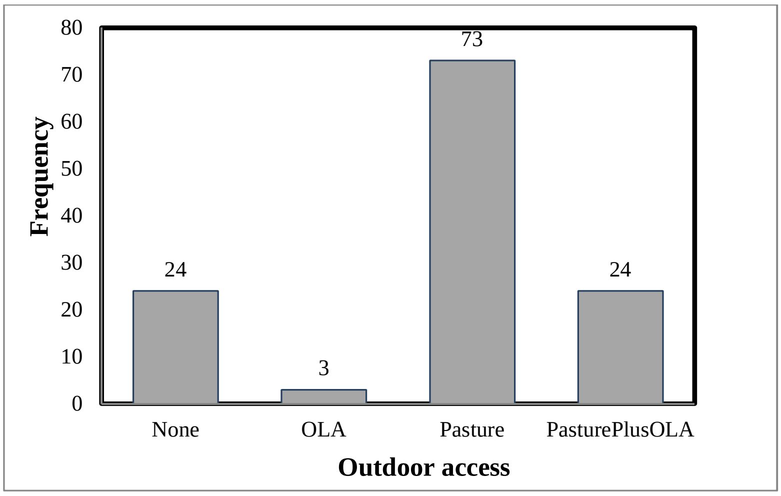


Figure 5: Frequency of farms of different herd sizes (n = 124)

The information related to husbandry practices (total grazing time in hours per cow per year) is summarised in Figure 6.Visited farms covered all the categories required by the mandate in terms of access to outdoor loafing area or pasture. This criterion is expressed in hours per year and spans between 0 and 8 760. Across all farms with outdoor access (100 farms), the mean value is 2 843 hours of access to an outdoor loafing area (OLA) or pasture per year. For farms providing access to pasture (73), the mean time spent on pasture is 3 504 hours per year. Within the surveyed farms, only a minority do not provide any outdoor access. Across sampled farms providing this information (100 farms), the minimum number of days was 0 and the maximum was 365 days. The mean number of days on pasture per cow per year was 210. Within the sampled farms, 21 % provided fewer than 15 days on pasture to the cows, 8 % provided between 15 and 120 days on pasture, 60 % provided between 120 and 300 days and 11 % provided more than 300 days. In the majority of the farms there is a summer shelter on pasture. Although few farms do not have any pasture area, most of them have more than 15 hectares which is a good area for a small farm allowing a great amount of pasture. Mixing herds is very frequent during summer grazing.

Further information revealed that some farmers mix cows from different farms on a single pasture or use common grazing of different species (26 % and 20 %, respectively). In addition, in most farms (63 %), animals are not tethered. Dairy cows housed in tied stalls were reported in 46 out of 124 farms surveyed (37 %). In 95 % of those farms, cows have access to pasture.



OLA: access to outdoor loafing area; Pasture: access to pasture; PasturePlusOLA: access to pasture and to outdoor loafing area

Figure 6: Type of outdoor access available in the sampled farms (n = 124).

Information related to the workforce was also collected. In all but one farm, more than 80 % of the workforce came from family members (including partners and their families, e.g. cooperation of farms, neighbours and partner farms). The number of family members working routinely on the farms ranges from one to five, with a mean of two family members per farm. Only 15 % of the farms had full-time employees, with a maximum of two full-time employees per farm. Among the surveyed farms, most (99 %) rely on family labour.

The information related to the level of input is summarised in Figure 7. The level of input is defined as the amount (kg) of concentrate given to cows at different lactation stages (dry or lactating) and different husbandry conditions (pasture or indoor). Several measurements, including the amount (kg) of concentrate given to dry and lactating cows indoors and on pasture were collected to assess and quantify the level of input. The amount of concentrate given at peak lactation to indoor dairy cows ranges between 0 and 14 kg/day, with a mean value of 5.2 kg/day/cow. Figure 7 shows data from 90 farms in Austria, Italy and France (data from Spain were removed from the analysis because of a lack of consistency). Overall, farms which have cows on pasture give a median of 300 kg concentrate/cow/year, with 73.4 % of the farms giving less than 800 kg, which is in line with the threshold of 800 kg found in the literature and established by the working group as the threshold for the “low input” criterion. The collected information on the use of concentrate showed that most farms stop giving any concentrate at the beginning of dry period which is in line with what is done in conventional farms. However, the maximum value seems very high maybe due to some outlier values or submitted data quality issues. For the amount of concentrate during peak lactation, the median is lower than in intensive farms. Again, the maximum seems a bit too high maybe due to some outlier values or submitted data quality issues. For the amount of concentrate for cows at pasture, a high variability from 0 to 5000 Kg per cow per year was observed. Most of the concentrate is bought outside but a few farms do not buy any concentrate which is not so frequent. Most of the forage is produced on the farm but a few farms have to buy all the forage. On average an amount of 25 % of forage bought outside is high but can it can occur in farms with limited production of forage (e.g. a mountain farms).

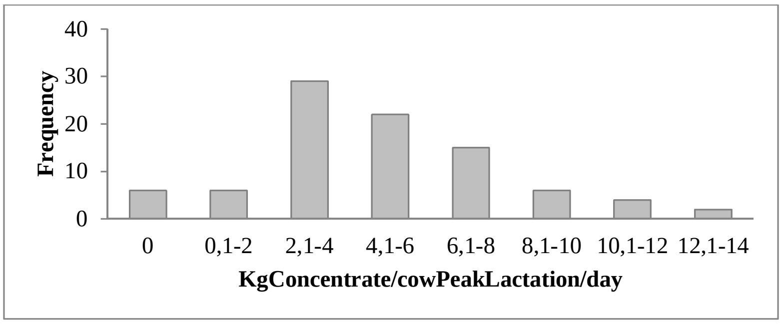
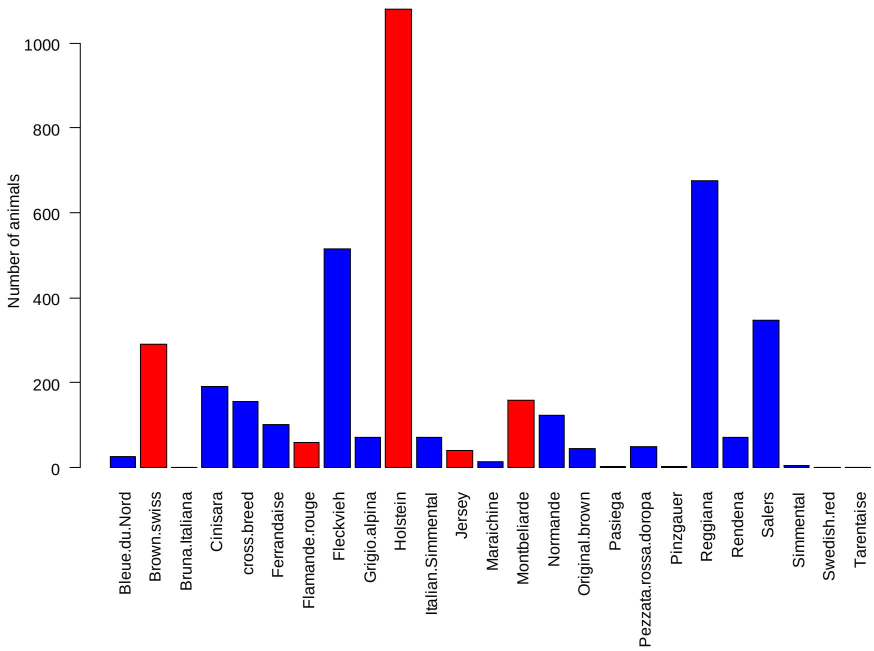


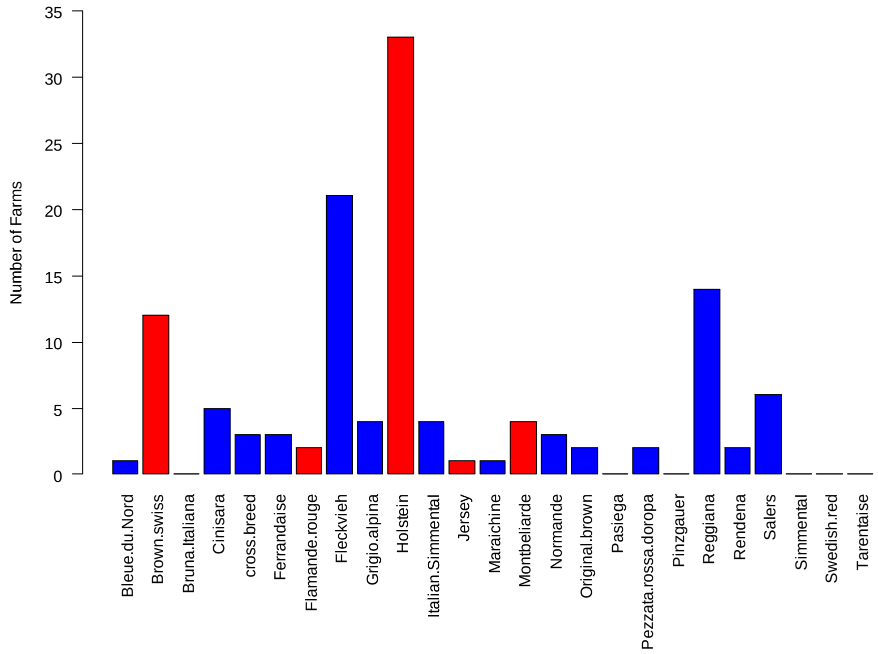
Figure 7: Amount of concentrate (kg) given to cows at peak lactation per day in the sampled farms (n = 90)

The information related to breeds is summarised in the following figures, which show the most abundant breeds in total (figure 8) and the number of farms with at least 50 % of a given breed (Figure 9). In total, 24 dairy or dual-purpose breeds were reported in the survey. Cross-bred cows were reported in 23 farms. Although dual-purpose breeds make up the majority in terms of number of breeds, a specialised dairy breed (Holstein) was the most common breed in the farms surveyed. In Figures 8 and 9, specialised dairy breeds are shown in red: Jersey, Holstein, Brown Swiss, Montbeliarde, Rouge Flamande and Tarentaise. The remaining breeds, shown in blue, are dual-purpose breeds. From Figure 9, it can be seen that, among the sampled farms, the use of indigenous breeds is comparatively frequent compared with other breeds. However, in some of the farms, indigenous breeds do not represent more than 50 % of the cows.



Specialised dairy breeds are shown in red and dual-purpose breeds are shown in blue

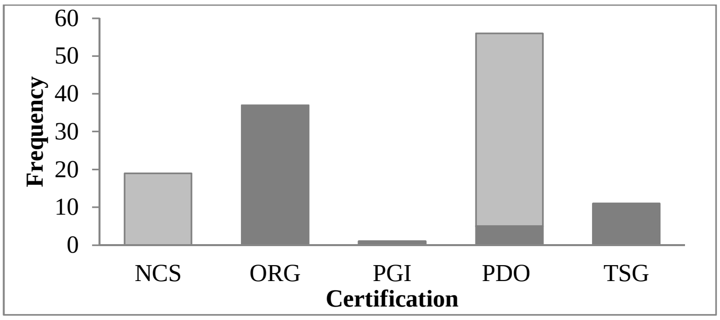
Figure 8: Total number of cows per breed found in the sampled farms (n = 124).



Specialised dairy breeds are shown in red and dual-purpose breeds are shown in blue.

Figure 9: Number of farms with at least 50 % of a given breed in the sampled farms (n = 124).

Dairy farms were classified as organic or conventional production systems. In total, 54 farms were recorded as organic, while 70 were classified as conventional farms. The information related to the certification scheme is summarised in Figure 10. The majority of the sampled farms are certified as either organic or linked to the origin of the product. The number of farms that do not hold any certification is 19, and the number that hold an organic certification only is 37. Overall, 68 farms obtained EU certification: PDO (5 out of 56 are organic), PGI (one is organic) and TSG (11 organic).



Organic farmers are represented in dark grey. NCS, no certification scheme; ORG, organic certification only; PGI, protected geographical indication; PDO, Protected designation of origin; TSG, traditional specialities guaranteed.

Figure 10: Certifications used by farms (n = 124 farms).

Although the selection of the farms was based on the fact that two criteria had to be fulfilled, each of the four criteria was often fulfilled (99 % of farms have more than 80 % of family workforce, 73 % of the farms give less than 800 kg of concentrate/cow/year, 49 % of farms have more than 50 % of cows from indigenous breeds, 85 % of farms have a certification).

3.2.3. On-farm data collection: results for other descriptive criteria

3.2.3.1. Total land for forage production and pasture (hectares)

The mean land for forage production owned or rented by farmers is 29 ha (minimum 0, maximum 120). The mean pasture area owned or rented by farmers is 32 ha (minimum 0, maximum 190). The mean percentage of forage bought by farmers is 25 % out of the total amount consumed (minimum 0, maximum 100). In farms where concentrate feed is used, the mean percentage of concentrate bought by farmers is 80 %.

3.2.3.2. Outputs: milk yield

The milk yield (kg milk/cow/year) per farm ranges from a minimum of 2 100 to 10 709 kg. The mean milk yield for the sample is 6 125 kg. The milk yield at herd level varied from very low values to typical high dairy production again showing a high variability between these farms.

3.2.3.3. Commercialisation

The percentage of income from dairy production in the farms surveyed ranges between 15 and 100 %, with a mean value of 81 %; however, some farms have other key productions corresponding to up to 85% of their income. Again it shows that there is a high variability with respect to the income. Almost one-third (41) of the farmers surveyed sell their products through cooperatives. In total, 14 farms commercialise their products directly through a farm shop; 21 and 26 farms sell their products through wholesale and retailers, respectively; and 22 farmers commercialise their products through multiple channels (Figure 11). Small farms use more frequently multi-herd collection of milk because they are too small for separate milk collection.

Figure 11: Types of commercialisation of dairy products in the sampled farms (n = 124)

3.2.3.4. Longevity

Longevity is considered a constitutive element of animal welfare. Direct (i.e. lameness) or indirect (i.e. reduced productivity) welfare reasons can lead to premature culling. The average age at culling (months) can be considered a measure to assess longevity. The minimum average (within a farm) age at culling is 30 months, while the maximum age is 216 months. The average age at culling in the sample is 89 months.

Another measure that was considered to assess longevity is the percentage of cows per farm in each lactation year (i.e. number of cows at first lactation, number of cows at second and third lactation, number of cows at fourth and fifth lactation and number of cows at sixth lactation and above). Owing to recording issues, the data cannot be presented and discussed.

3.2.3.5. Management

Machine milking (at the stall or at the milking parlour) was the most common milking system (96 %). Two farms were milking manually while three farms were using robot milking systems. The age of the milking system ranged from a few months to 45 years, with an average of 15 years.

For the milking frequency, it was observed that a few farms milk only once per day, a practice that is not very frequent in conventional farms. There are few farms that need to use a different milking system for when cows are on pasture.

Related to the period of time the newborn is left with the mother after birth, the maximum value can be explained as associated to specifications e.g. in organic farms where the calf has to stay with the mother for a longer period. Similarly, it can be observed that, contrary to common practice on Holstein farms, in small-scale farms it is more frequent here to keep cows with horns.

The values related to the average calving rate (number of calvings on the number of cows) showed a high variability, ranging from 23 to 144 %. In most farms calving interval at the herd level stays in around 13 months (390 days) and this is probably linked to the use of seasonal calving. Indeed, seasonal calving is frequent in farming systems where grass provides a high proportion of forage.

For the age at culling, the observed minimum and maximum values seem unexpected, and the reason could be that some of these figures are calculated on a very small number of animals. Overall mean and median values are 84 months.

The number of functional claw trimming events in a year ranged from zero to seven, with a mean of one per year per cow. Claw trimming is most often outsourced as well as the vaccination plans.
The values related to the average calving rate (number of calvings on the number of cows) showed a high variability, ranging from 23 to 144 %. In most farms calving interval at the herd level is around 13 months (390 days) and this is probably linked to the use of seasonal calving. Indeed, seasonal calving is frequent in farming systems where grass provides a high proportion of forage.

Related to the ratio of heifers in the farm, there is a high variability in the number of heifers and few farms don't have any heifers, so they outsource the raising of cows which could be explained by a lower availability of production factors (e.g. workforce, land etc). The majority of farms don't buy heifers and have a closed herd.

The collected data on the number of bulls per farm showed that the majority of farms use only artificial insemination but some also use bulls for natural mating. Related to the proportion of cows in different parities, the value of 0 as a minimum is unexpected and could be explained by the fact that some of these figures are calculated on a very small number of animals as explained above. Overall mean and median show that the majority of cows are in their on 4th, 5th or higher lactation. This is in line with the collected information showing a high median age at culling and confirms that cows are kept for a quite long period in these small scale farms.

The percentage of dehorned/disbudded cows per farm spans from 0 to 100 %, with an average of 64 % dehorned/disbudded cows per farm. Of the farms surveyed, 30 % keep cows with horns.

3.2.4. On-farm data collection: results for risk factors and animal-based measures

The results from the on-farm data collection about risk factors and animal-based measures are reported here below. For both datasets, the whole list of variables including short names, complete description and descriptive statistics with raw results are given in Appendix B (list of risk factors) and C (animal-based measures). The results from the on-farm data collection about risk factors are described in Table 6 and Table 7 (continuos and categorical variables respectively) and are divided by categories of time spent on pasture.

Table 6: Description of results from the on-farm data collection about risk factors divided by categories of time spent on pasture (continuous variables)

Continuous Variables		**15 days or less**		**Between 15 and 120 days**		**Between 121 and 300 days**		**More than 300 days**	
		Mean	**StdDev**	**Mean**	**StdDev**	**Mean**	**StdDev**	**Mean**	**StdDev**
Number of dairy cows	n	50	18	24	9	30	15	32	15
Percentage of heifers bought from outside the farm (closed herd)	%	9	22	8	12	4	11	12	29
How many days before calving do you start to give concentrate feed?	days	37	23	9	7	12	15	19	18
Number of hours on pasture per year	(hours/year)	0	0	1611	925	3130	1737	6939	1874
Number of hours on Outdoor Loafing Area per year (hours/year)	(hours/year)	294	871	810	2263	1497	3033	152	567
Milk Yield at herd level (During previous 12 month)	Kg	7152	1931	5632	830	5993	1696	5267	2541
Kg of concentrate fed at the beginning of dry period	Kg	1.3	1.2	1.4	1.7	0.7	1.8	0.9	1.2
Amount of concentrates fed for housed lactating cows at peak lactation	Kg	11.0	6.1	6.0	2.6	5.5	4.1	5.5	5.3
LengthDryPeriod	days	61	6	60	12	59	14	55	20
Maximum distance in Km of summer shelter from pasture	Km			8	18	1	6	0	0
Times/day food is pushed towards the cows	n	2.5	0.7	2.5	1.1	1.8	1.2	1.4	1.2
nMealsDay	n	3.3	2.2	2.2	0.6	2.3	1.3	2.1	0.7
Number of Calving Pens	n	0.6	0.9	0.4	0.5	0.7	1.2	0.4	0.5
AreaPasturePerCow	ha	0.1	0.2	3.6	4.1	1.1	1.5	1.6	1.5

Table 7: Description of results from the on-farm data collection about risk factors divided by categories of time spent on pasture (categorical variables)

Categorical Variables		**15 days or less**		**Between 15 and 120 days**		**Between 121 and 300 days**		**More than 300 days**	
		Mean	**Percentage for each value within the column**	**Mean**	**Percentage for each value within the column**	**Mean**	**Percentage for each value within the column**	**Mean**	**Percentage for each value within the column**
Change of the milking system (or personnel)during summer	missing	96	25						
	0 = no	4	1	80	8	93	69	100	14
	2 = yes			20	2	7	5		
Availability of equipment for claw trimming	0 = no trimming	58	15	30	3	47	35	86	12
	1 = portable claw trimming chute shared with neighbours	4	1			18	13	14	2
	2 = own equipment on farm	38	10	70	7	35	26		
Dairy cows have access to pasture	0 = no	100	26			1	1		
	2 = yes			100	10	99	73	100	14
Dairy cows have access to outdoor loafing area/pasture	0 = no	88	23	80	8	72	53	93	13
	2 = yes	12	3	20	2	28	21	7	1
Presence of dead ends	missing	35	9	50	5	39	29	71	10
	0 = yes	62	16	50	5	45	33	21	3
	2 = no	4	1			16	12	7	1
FunctioningWaterPoints	missing					1	1	57	8
	0 = yes	81	21	100	10	91	67	29	4
	2 = no	19	5			8	6	14	2
Mixing with other herd during summer grazing	missing	96	25						
	0 = no	4	1	30	3	92	68	100	14
	2 = yes			70	7	8	6		

Categorical Variables		15 days or less		Between 15 and 120 days		Between 121 and 300 days		More than 300 days	
		Mean	**Percentage for each value within the column**	**Mean**	**Percentage for each value within the column**	**Mean**	**Percentage for each value within the column**	**Mean**	**Percentage for each value within the column**
Water Availability at Pasture	missing	96	25						
	0 = no	4	1			7	5	7	1
	2 = yes			100	10	93	69	93	13
Water points at pasture	missing	96	25			5	4		
	0 = natural sources of water	4	1	20	2	26	19	21	3
	1 = drinker			70	7	43	32	36	5
	2 = mixed			10	1	26	19	43	6

In all categories of time spent on pasture, the presence of risk factors varies widely between farms. The farms in which animals are kept inside throughout the entire year or almost the entire year (on pasture for less than 15 days) tended to be larger in size, to have a higher milk yield per cow and to use more concentrate. The access to an outdoor leafing area (OLA) is more used in the farms that have a medium access to pasture (between 15 and 120 days and between 121 and 300 days). As mentioned above, the use of concentrate, especially at peak lactation, is higher in farms with limited access to pasture; however, no significant difference was observed in the other pasture based categories of farms. The length of the dry period does not differ among the farm categories, thus indicating that it is not related to the grazing system. In the category of farms with more than 300 days on pasture the cows have direct access to shelter when they are on pasture. The higher surface of pasture per cow in the category between 15 and 120 days on pasture shows that farms with restricted pasture time use in fact higher surface per cow. This is probably related to lower grass production of this pasture (maybe in some of the mountain systems). The number of water points at pasture is similar for all pasture categories.The results from the on-farm data collection about animal-based measures divided by categories of time spent on pasture are described below in Table 8.

Table 8: Description of results from the on-farm data collection about animal-based measures divided by categories of time spent on pasture

Variable	**< 15 days (26 farms)**		**15–120 days (10 farms)**		**120–300 days (74 farms)**		**> 300 days (14 farms)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Number of dairy cows	50.46	17.70	24.20	9.16	30.45	14.93	31.86	14.55
Avoidance Distance Touched(0cm)	68.52	20.33	43.50	28.25	60.62	19.66	75.23	16.00
Avoidance Distance Closer50cm	37.48	15.86	26.38	16.42	42.00	16.46	39.08	17.05
Avoidance Distance 50-99cm	12.02	11.21	8.02	10.13	10.09	9.80	22.02	14.71
Avoidance Distance100cm or more	19.02	21.85	9.10	17.93	8.53	15.25	14.13	12.15
BCS VeryLean	7.42	7.42	5.36	10.22	8.48	11.80	11.67	14.25
BCS VeryFat	11.58	9.65	10.77	15.72	9.48	11.38	9.29	12.11
Nasal Discharge	5.09	6.67	0.33	1.05	2.76	7.19	0.25	0.92
Dystocia	3.57	4.45	1.36	2.37	5.63	10.04	2.95	5.29
Mortality	7.30	13.27	1.92	3.66	3.60	5.07	1.46	2.77
Claw Condition2	28.48	29.24	23.42	15.83	13.82	22.23	18.78	20.81
Downer Cows	3.72	3.75	1.01	2.35	2.30	3.52	0.84	2.48
Diarrhoea	1.64	3.61	1.62	3.10	2.25	8.42	7.29	17.81
Milk Somatic Cell Count	18.56	19.51	5.80	4.85	14.41	13.67	27.07	21.27
Hampered Respiration	0.24	1.23	0.33	1.05	0.33	1.25	0.00	0.00
Lameness1and2	29.55	22.05	7.07	7.71	20.07	17.46	14.64	14.93
Lameness2	18.33	17.69	2.62	3.36	8.92	8.61	10.11	11.27
OcularDischarge	0.24	0.87	0.32	1.02	0.30	1.14	0.31	1.16
QBA	53.98	14.20	53.61	12.45	60.01	18.55	52.82	20.94
Dirty Legs	45.23	32.16	50.32	38.50	61.31	31.16	61.35	43.91
Mud on the Legs	1.76	8.97	0.00	0.00	0.77	4.41	20.81	40.00
Manure on the Legs	43.47	31.76	50.32	38.50	60.54	31.32	40.54	44.12
Dirty Hind Quarter	48.07	30.40	30.20	31.41	50.54	31.95	35.44	29.89
Mud on the Hind Quarter	1.33	6.17	0.00	0.00	0.45	2.52	3.22	7.52
Manure on the Hind Quarter	46.74	29.41	30.20	31.41	50.09	32.17	32.22	30.98
Dirty Udder	31.56	19.44	37.10	20.39	48.21	26.42	28.01	28.98
Manure on the Teat	22.12	15.48	27.26	15.23	32.53	23.40	11.43	15.99
Mud on the Teat	0.95	4.00	0.00	0.00	0.28	2.42	4.56	11.64

Variable	< 15 days (26 farms)		15–120 days (10 farms)		120–300 days (74 farms)		> 300 days (14 farms)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Number of dairy cows	50.46	17.70	24.20	9.16	30.45	14.93	31.86	14.55
Manure on the Udder	23.11	18.36	15.26	22.88	32.96	27.46	17.13	26.78
Mud on the Udder	0.88	4.48	0.00	0.00	0.33	1.98	2.53	8.29
Hairless Patches	40.54	19.43	25.69	13.54	40.94	19.05	31.10	24.19
Swelling Or Lesion	16.96	10.47	14.18	12.30	17.41	15.12	17.05	13.56
Hairless on Lower Hind Leg	21.94	15.45	15.66	19.39	17.01	17.22	8.00	13.03
Hairless on Carpus	31.05	26.21	9.36	8.17	24.36	25.78	13.96	26.53
Hairless Body	30.19	17.79	20.06	12.53	34.57	22.74	26.81	22.52
Lesion on Lower Hind Leg	2.67	3.40	4.76	6.32	2.77	5.12	1.61	3.29
Lesion on Carpus	1.03	1.62	0.34	1.09	1.19	4.06	0.24	0.89
Lesion on the Body	6.84	6.18	7.51	6.12	9.07	9.67	13.76	10.03
Swelling on Lower Hind Leg	4.91	5.98	2.73	6.08	2.43	4.72	0.42	1.57
Swelling on Carpus	2.14	3.20	0.65	1.36	1.85	4.68	1.03	2.27
Swelling on the Body	1.28	2.24	0.53	1.66	2.53	5.11	0.48	1.23
Vulvar Discharge	1.82	2.72	1.33	4.22	1.40	3.11	0.84	2.24
Collision with equipment when rising	10.52	16.56	11.23	15.66	29.32	28.11	13.21	22.03
Rising Score 3or4	31.92	24.78	39.76	38.95	22.73	20.37	3.10	6.55
Rising Score 5	12.72	25.86	3.33	10.54	7.86	18.66	2.50	7.91
Animals lying outside the cubicle (%)	15.51	14.59	22.72	41.13	14.56	25.85	15.43	33.54
Proportion of Mastitis cases within 12 month (drying off not included)	0.17	0.13	0.18	0.17	0.18	0.22	0.11	0.11
Age at culling in months during last 12 months	0.63	0.12	0.63	0.10	0.58	0.17	0.52	0.15

The results showed that for all ABMs there is a high variability within each category as demonstrated by the fact that for all variables the standard deviation is always higher than the mean. There are slightly more lean cows and more cows with claw condition 2 in the category with less than 15 days on pasture, but the standard deviation is very high therefore it cannot be seen as a meaningful difference.

After describing risk factors and animal-based measures separately, cluster analyses were carried out to analyse if farm descriptors, risk factors and animal-based measures are independent from each other and if they all provide similar or different information useful for characterising a farming system.

The results of the clustering of variables are shown in Figures 12 to 17. The number of clusters that maximises the mean adjusted Rand criterion is 34, 21 and 33 (Figures 12 to 14) for farm descriptors, risk factors and animal-based measures of welfare, respectively. This implies that 34, 21 and 33 clusters reveal stable partitions, which is highlighted by the horizontal line in the right panel of each figure. The results suggest that—for the sample of farms investigated—it is not necessary to distinguish between some of the indicators collected, as they provide similar information.

For farm descriptors (Figure 15), similar information is given by milking frequency (dMilkFreq) and milking system (mSyst); by time spent on pasture in hours per year (AnnualHrsPasture) and access to an outdoor loafing area (OutdoorAccess); and by change of milking system during summer months (chMilkSysDSum), mixing during summer grazing with other cows (mixSummGra) and mixing during summer grazing with other species (mixSummGraOthSp); the final three descriptors are all linked to mountain grazing production systems.

Of all the potential risk factors (Figure 16), it does not appear to be necessary to make a distinction between soiling of the animals due to manure and due to other sources of dirt (DirtyUdder and ManureUdder, DirtyHindQ and ManureHindQ, DirtyLegs and ManureLegs); however, this may simply be because assessments were primarily carried out under winter housing conditions. Similarly, a group of indicators linked to grazing systems cannot further distinguish between farms, i.e. number of water points on pasture (watPoPast), change of milking system during summer months (chMilkSysDSum), mixing during summer grazing with other cows (mixSummGra) and water availability on pasture (watAvPast). In addition, similar information is provided by information related to water points, if water points are clean (CleanWaterPoints) or functioning (FuncWaterPoints), and bedding quantity (bQuant). Although these factors do not seem to be directly linked, they can reflect the level of attention the farmer pays to providing appropriate comfort to the cows. The results suggest that—for the sample of farms investigated—only a few of the risk factors for which information was collected provide similar information and, therefore, there is little potential to reduce the on-farm assessment protocol.

With regard to the animal-based measures of welfare (Figure 17), in addition to the lack of distinction between sources of dirt on animals (see risk factors above), differentiation between overall lameness prevalence (Lameness1and2) and prevalence of severely lame cows (Lameness2) and between hairless patches at the carpus (HairlessCarpus) and the overall occurrence of hairless patches (HairlessPatches) does not seem necessary. The results therefore indicate that the vast majority of measures provide independent information and that there are only a few measures where simplification seems to be appropriate.

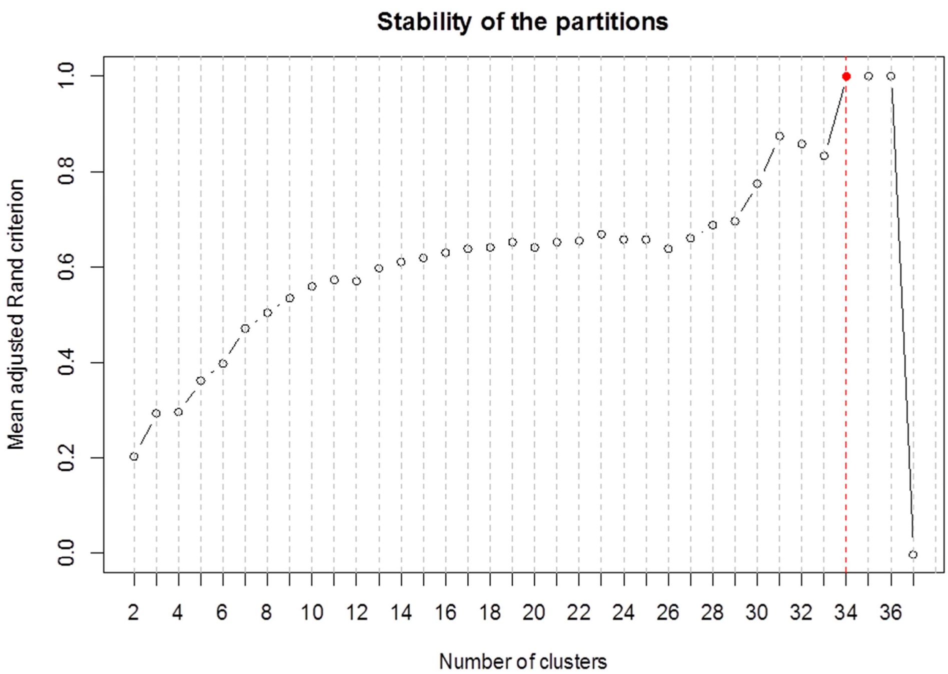


Figure 12: Stability of the clusters based on 500 bootstraps considering farms descriptors

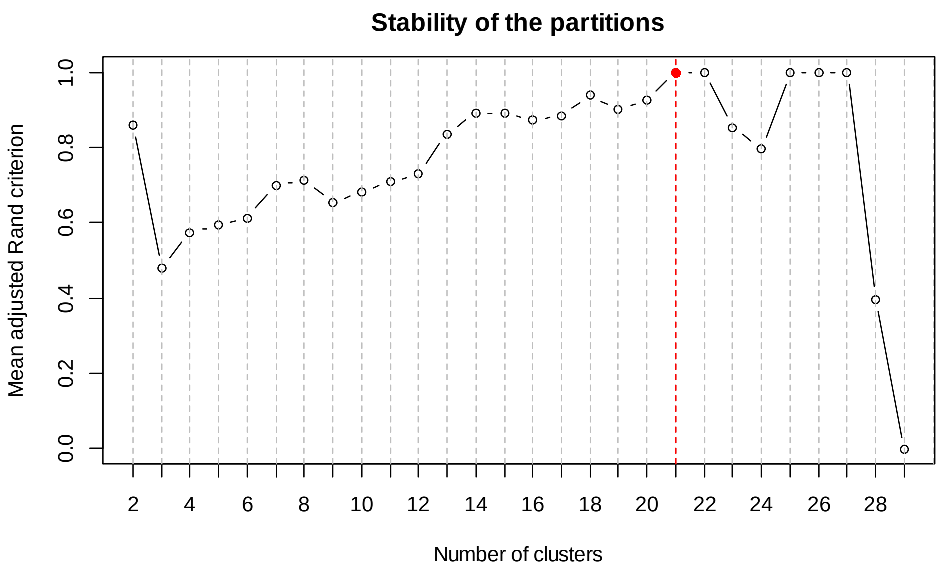


Figure 13: Stability of the clusters based on 500 bootstraps considering risk factors

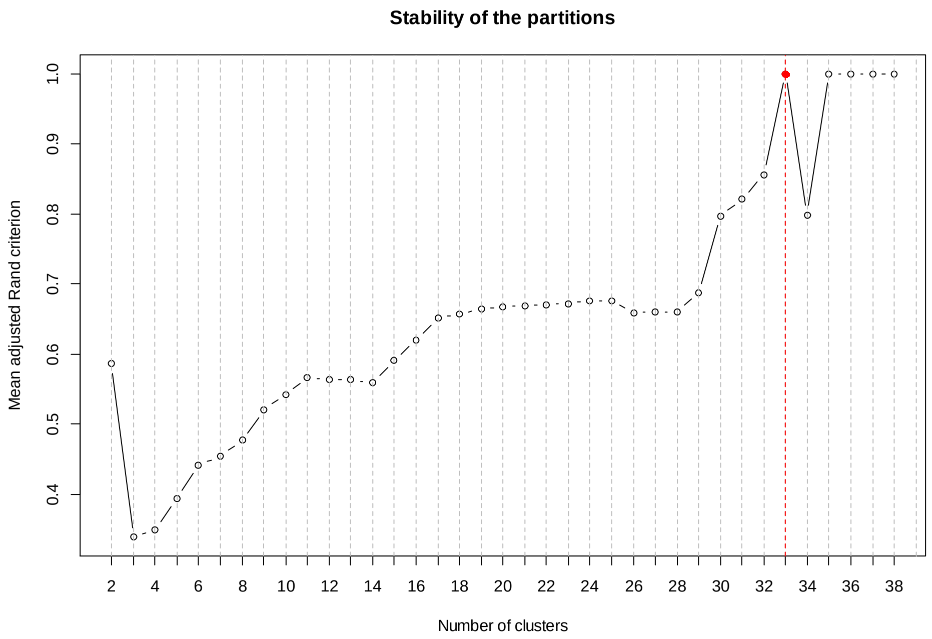
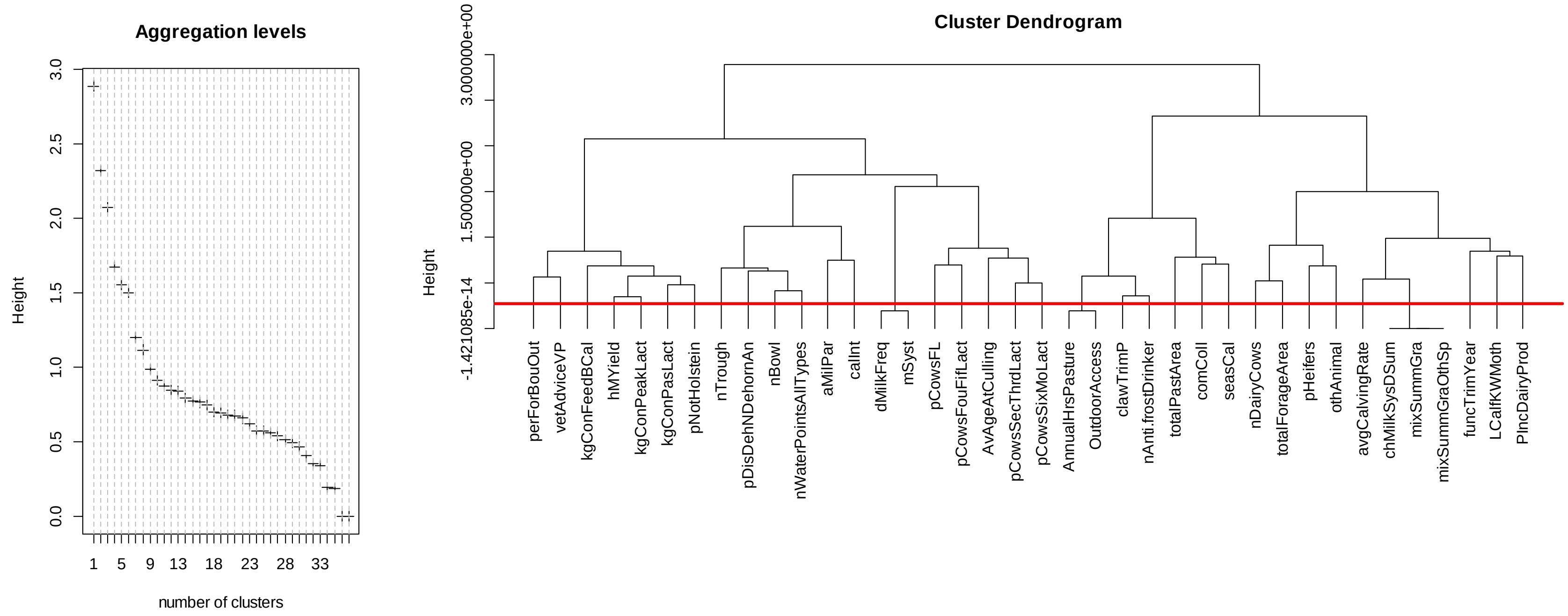
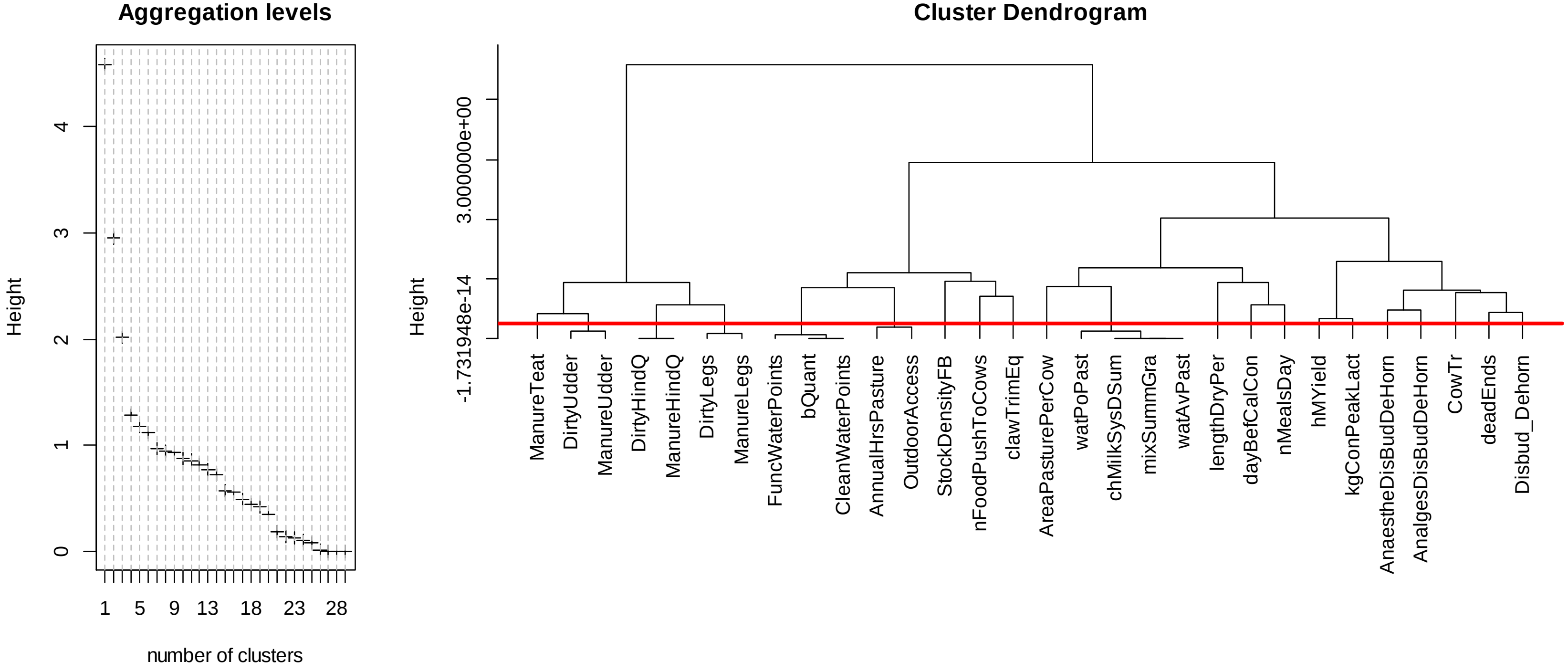


Figure 14: Stability of the clusters based on 500 bootstraps considering animal-based measures of welfare



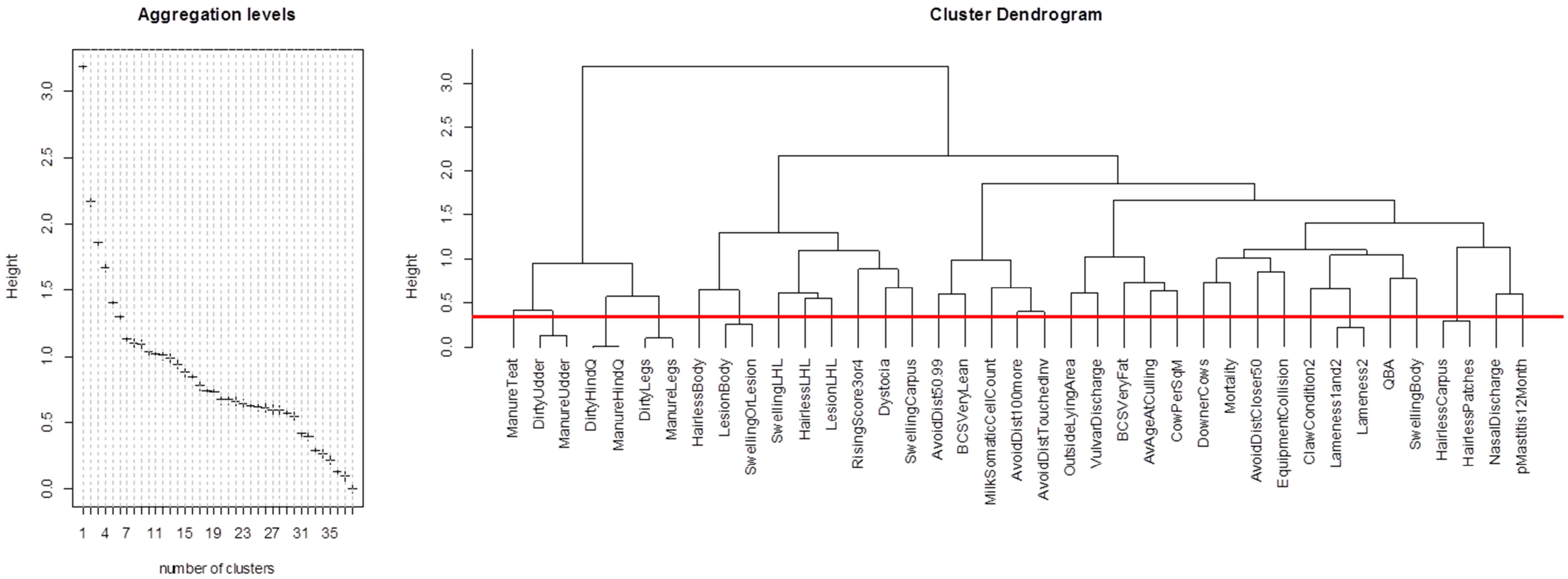
Left panel: measure of homogeneity achieved by the number of clusters chosen. Right panel: dendrogram which links the variables based on their similarities; grouped factors that are linked below the red line (e.g. sMilkfreq and mSyst) are considered to represent the same information. The list of variables, including their full description and transformation to normalise them for the analysis, is given in Appendix A (list of farm descriptors)

Figure 15: Clustering of farm descriptors.



Left panel: measure of homogeneity achieved by the number of clusters chosen. Right panel: dendrogram which links the variables based on their similarities; grouped factors that are linked below the red line (e.g. DirtyUdder and ManureUdder) are considered to represent the same information. The list of variables, including their full description and transformation to normalise them for the analysis, is given in Appendix B (list of risk factors)

Figure 16: Clustering of risk factors.



Left panel: measure of homogeneity achieved by the number of clusters chosen. Right panel: dendrogram which links the variables based on their similarities; grouped factors that are linked below the red line (e.g. DirtyUdder and ManureUdder) are considered to represent the same information. The list of variables, including their full description and transformation to normalise them for the analysis, is given in Appendix C (list of animal-based measures)

Figure 17: Clustering of animal-based measures of welfare.

3.2.5. Clustering of farms based on farm descriptors, risk factors and animal-based measures

When farms were clustered based on principal components derived from descriptors, risk factors or animal-based measures of welfare, in all three cases, three main groups were identified (Figures 18 to 20). The characteristics of the clusters depending on the information used for clustering are shown in Tables 9 to 11. The list of variables including short names and complete are given in Appendix A, B and C (list of farm descriptors, risk factors and animal-based measures respectively).

Considering information on farm descriptors, the clusters contain 79, 12 and 33 farms (cluster I, II and III respectively in Figure 18), with cluster III being more distant from the two other clusters. Factors related to forage/pasture management, calving, milk yield and breed mainly account for differences between the clusters. Compared with the two other clusters, cluster III is characterised by a lower annual calving rate, more land available for forage production but less pasture area, more summer grazing together with other cows (i.e. alpine pastures which are shared by several farms) and a higher percentage of farms with seasonal calving pattern; furthermore, the percentage of farms using veterinary advice for vaccination plans is intermediate between the two other clusters. On the other hand, the smallest cluster (II) has the lowest average milk yield, has the lowest total forage area and uses more concentrate for cows on pasture. The lowest proportion of seasonal calving and the highest proportion of use of veterinary advice for vaccination planning may also describe cluster II. In the largest cluster (I), the cows are predominantly from breeds other than Holstein, spend relatively more time on pasture/outdoors and are culled at a younger age; in addition, other farm animal species are rarely kept on these farms. The results show there is not a uniform category of small-scale farms. Patterns of farms can be differentiated but no simple categorisation of farming systems emerged from the classification.

Clusters obtained using information on potential risk factors contain 25, 91 and 8 farms (cluster I, II and III respectively in Figure 19). At this level of information, pasture management, housing related to lying and feeding area, water provision, procedures used for disbudding of calves and cleanliness of the animals (as a risk factor for mastitis, for example) are different between the clusters. The largest cluster (II) provides the largest pasture area per cow and more frequently provides water on pasture. However, milk yield is lowest and the proportion of dirty animals is highest for almost all measures of cleanliness, while the provision of bedding is only intermediate in this cluster. Cluster III always shares summer pasture with other dairy farms, water points (in the barn) were mostly considered dirty and the animals are rather clean. Anaesthesia/analgesia is comparatively rarely used for disbudding of calves. Cluster I shows the lowest use of pasture/outdoor areas, the highest amount of concentrates fed in peak lactation and the earliest start of concentrate feeding before calving; in addition, stocking density at the feeding places is highest in these farms.

Clustering based on animal-based measures of welfare also revealed three groups of farms, which contain 71, 23 and 30 farms (cluster I, II and III respectively in Figure 20). Criteria of distinction relate to both behavioural (e.g. avoidance distance as a measure of human–animal relationship, rising score as a measure of difficulties in getting up from the lying area) and health measures (lameness and claw condition, udder health, skin injuries, dystocia, etc.). Farms in cluster I have the highest percentage of animals with difficulties in getting up (RisingScore3or4) and of animals lying partly or completely outside the lying area (OutsideLyingArea), and the proportion of cows in the highest avoidance distance category (AvoidDist100more) is also highest in this cluster. In addition, health issues such as severe lameness (Lameness2), poor claw condition (ClawCondition2), mastitis incidence (pMastitis12Month), and nasal (NasalDischarge) and vulvar discharge (VulvarDischarge) are more prevalent in cluster I than in the two other clusters. Farms in cluster III either do not substantially differ from the other clusters or show a better state (e.g. ClawCondition2, NasalDischarge, SwellingCarpus). The farms allocated to cluster II show less hairless spots (HairlessPatches, HairlessCarpus) and swellings on the lower hind leg (SwellingLHL) but more swellings on the body (SwellingBody) than the other clusters, and the only health measure that is worse in this cluster is dystocia incidence during the last 12 months (Dystocia). Regarding behavioural measures, the cows had less difficulty in getting up (RisingScore3or4) and lay less frequently outside the lying area (OutsideLyingArea) in cluster II.

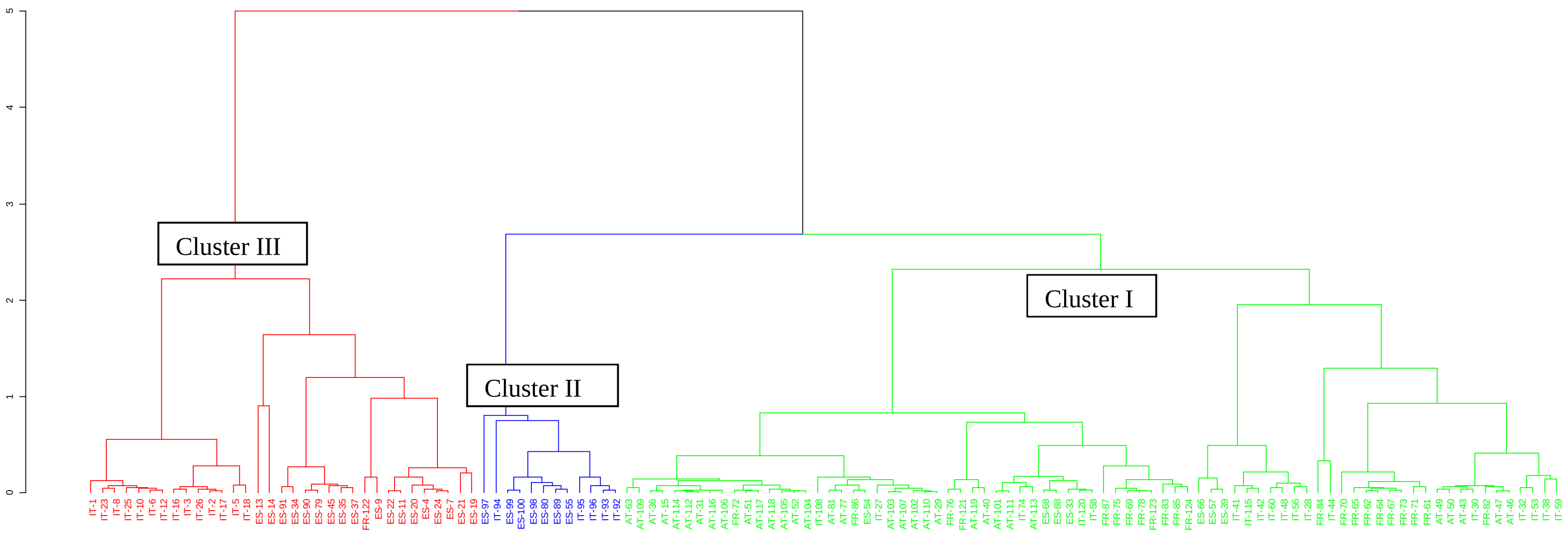


Figure 18: Hierarchical clustering of farms based on principal components obtained from analysis of farm descriptors

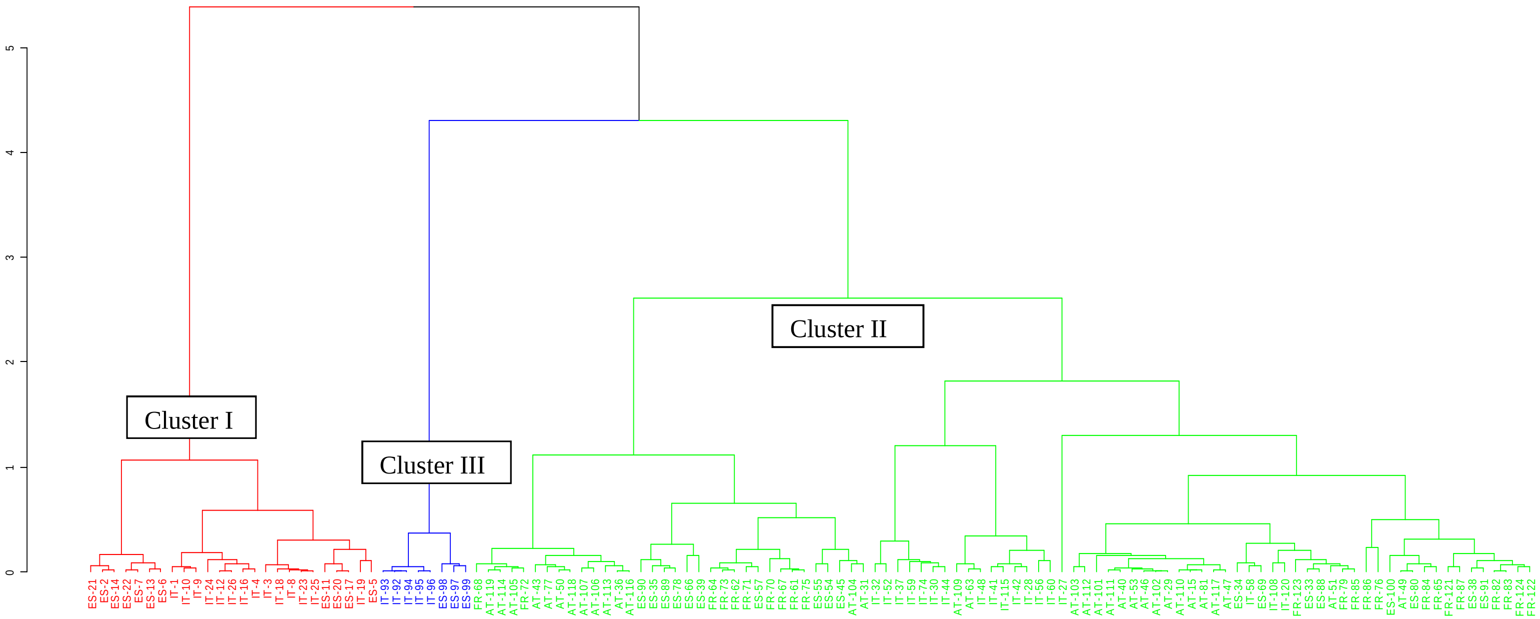


Figure 19: Hierarchical clustering of farms based on principal components obtained from analysis of risk factors

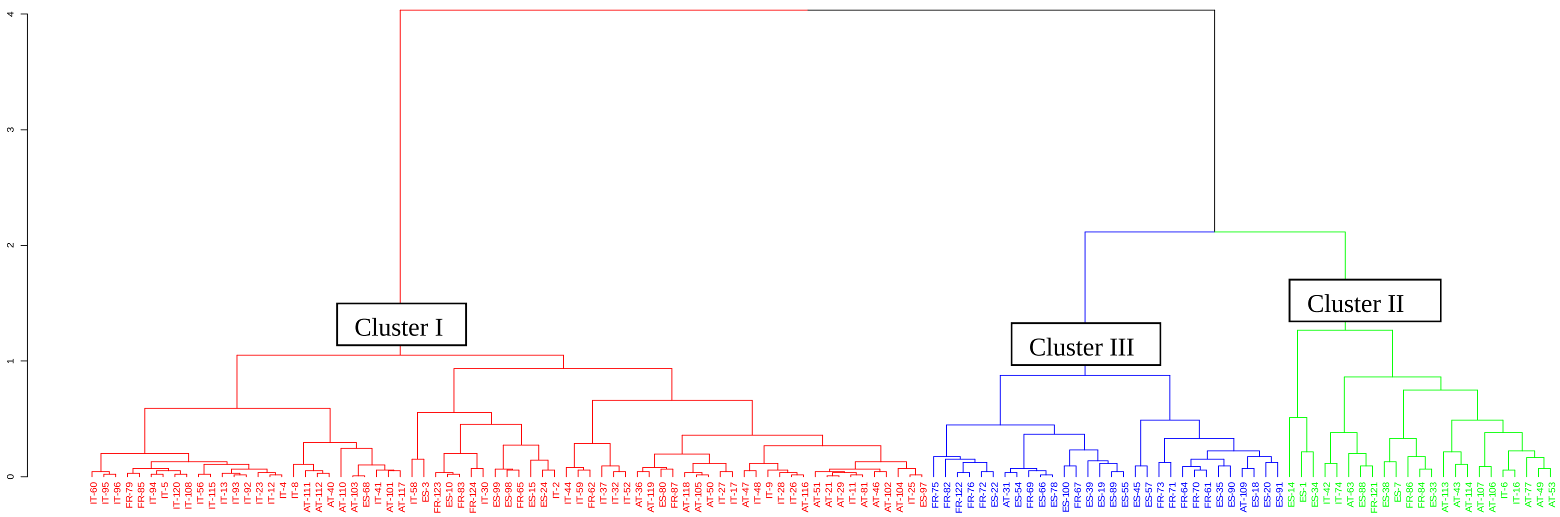


Figure 20: Hierarchical clustering of farms based on principal components obtained from analysis of animal-based measures of welfare

Table 9: Means and number of farms for clusters of farms based on farm descriptors (*, normalised values). Abbreviations are spelled in Appendix A.

Cluster	nDairyCows (n)	totalForageArea (ha)	totalPastArea (ha)	PincDairyProd (%)	pNotHolstein (%)	pCowsFL (%)	pCowsSecThrdLact (%)	pCowsFouFifLact (%)
I (n = 79)	35.2	30.1	29.6	84.0	0.66	0.22	0.35	0.23
II (n = 12)	36.8	22.3	36.8	76.1	0.66	0.25	0.42	0.19
III (n = 33)	31.2	27.9	35.1	76.9	0.77	0.23	0.36	0.25

Cluster	pCowsSixMoLact (%)	pHeifers (%)	AvAgeAtCulling (months)	avgCalvingRate (%)	hMYield (kg/year)	calInt (days)	othAnimal_0 (n farms)	othAnimal_1 (n farms)
I (n = 79)	0.16	0.56	92.2	66.4	6 210	386	43 (54 %)	2 (3 %)
II (n = 12)	0.14	0.59	97.8	78.2	5 317	392	8 (67 %)	0 (0 %)
III (n = 33)	0.14	0.59	82.0	75.6	6 215	391	23 (70 %)	0 (0 %)

Cluster	othAnimal_2 (n farms)	seasCal_0 (n farms)	seasCal_2 (n farms)	AnnualHrsPasture *	OutdoorAccess (h/year)	mixSummGra_0 (n farms)	mixSummGra_2 (n farms)	mixSummGraOthSp_0 (n farms)
I (n = 79)	34 (43 %)	63 (80 %)	16 (20 %)	0.38	2 325	48 (84 %)	9 (16 %)	50 (88 %)
II (n = 12)	4 (33 %)	8 (67 %)	4 (33 %)	0.37	2 867	6 (67 %)	3 (33 %)	7 (78 %)
III (n = 33)	10 (30 %)	30 (88 %)	3 (12 %)	0.47	4 073	32 (97 %)	1 (3 %)	32 (97 %)

Cluster	mixSummGraOthSp_2 (n farms)	perForBouOut (%)	kgConPasLact (kg/year)	kgConPeakLact*	kgConFeedBCal (kg/day)	mSyst_0 (n farms)	mSyst_1 (n farms)	mSyst_2 (n farms)
I (n = 79)	7 (12 %)	27.8	692	0.23	2.4	2 (3 %)	74 (93 %)	3 (4 %)
II (n = 12)	2 (22 %)	38.3	1120	0.21	2.4	0 (0 %)	12 (100 %)	0 (0 %)
III (n = 33)	1 (3 %)	11.9	749	0.18	1.9	0 (0 %)	33 (100 %)	0 (0 %)

Cluster	aMilPar (years)	dMilkFreq_1 (n farms)	dMilkFreq_2 (n farms)	dMilkFreq_2.2 (n farms)	chMilkSysDSum_0 (n farms)	chMilkSysDSum_2 (n farms)	comColl_0 (n farms)	comColl_2 (n farms)
I (n = 79)	13.9	0 (0 %)	77 (99 %)	1 (1 %)	51 (89 %)	6 (11 %)	56 (71 %)	23 (29 %)
II (n = 12)	18.5	0 (0 %)	12 (100 %)	0 (0 %)	9 (100 %)	0 (0 %)	10 (83 %)	2 (17 %)
III (n = 33)	15.3	1 (3 %)	32 (97 %)	0 (0 %)	32 (97 %)	1 (3 %)	16 (48 %)	17 (52 %)

Cluster	nWaterPoints AllTypes (n)	nTrough (n)	nBowl (n)	nAnti.frostDrinker_0 (n farms)	nAnti.frostDrinker_1 (n farms)	nAnti.frostDrinker_2 (n farms)	pDisDehNDehornAn (%)	funcTrimYear (n/year)
I (n = 79)	8.6	1.1	5.2	74 (96 %)	2 (3 %)	1 (1 %)	0.59	1.3
II (n = 12)	11.0	1.1	7.1	12 (100 %)	0 (0 %)	0 (0 %)	0.46	1.0
III (n = 33)	5.1	1.2	2.2	24 (89 %)	2 (7 %)	1 (4 %)	0.82	0.7

Cluster	clawTrimP_0 (n farms)	clawTrimP_2 (n farms)	vetAdviceVP_0 (n farms)	vetAdviceVP_2 (n farms)	LCalfKWMoth (h)
I (n = 79)	25 (35 %)	46 (65 %)	41 (52 %)	38 (48 %)	6.7
II (n = 12)	6 (55 %)	5 (45 %)	6 (50 %)	6 (50 %)	7.9
III (n = 33)	14 (58 %)	10 (42 %)	25 (78 %)	7 (22 %)	16.2

Table 10: Means and number of farms for clusters of farms based on risk factors (*, normalised values). Abbreviations are spelled in Appendix B.

Cluster	hMYield (kg)	lengthDryPer*	kgConPeakLact*	dayBefCalCon*	StockDensityFB	nMealsDay*	nFoodPushToCows*	AnnualHrsPasture*
I (n = 25)	6 872	0.46	0.31	0.57	3.18	0.69	0.17	0.07
II (n = 91)	5 855	0.48	0.19	0.79	1.02	0.77	0.42	0.41
III (n = 8)	6 860	0.53	0.22	0.89	0.97	0.74	0.04	0.46

Cluster	AreaPasture PerCow (ha)	OutdoorAccess *	mixSummGra_0 (n farms)	mixSummGra_2 (n farms)	deadEnds_0 (n farms)	deadEnds_2 (n farms)	CowTrainer_0 (n farms)	CowTrainer_2 (n farms)
I (n = 25)	0.23	0.04	4 (100 %)	0 (0 %)	17 (100 %)	0 (0 %)	22(88 %)	3 (12 %)
II (n = 91)	1.46	0.39	74 (85 %)	13 (15 %)	36 (72 %)	14 (28 %)	85 (93 %)	6 (7 %)
III (n = 8)	0.53	0.46	8 (100 %)	0 (0 %)	4 (100 %)	0 (0 %)	8 (100 %)	0 (0 %)

Cluster	beddingQuant_0 (n farms)	beddingQuant_1 (n farms)	beddingQuant_2 (n farms)	FuncWaterPoints_0 (n farms)	FuncWaterPoints_2 (n farms)	CleanWaterPoints_0 (n farms)	CleanWaterPoints_1 (n farms)	CleanWaterPoints_2 (n farms)
I (n = 25)	5 (20 %)	4 (16 %)	16 (64 %)	21 (84 %)	4 (16 %)	15 (60 %)	7 (28 %)	3 (12 %)
II (n = 91)	16 (19 %)	35 (41 %)	35 (40 %)	76 (89 %)	9 (11 %)	60 (70 %)	12 (14 %)	14 (16 %)
III (n = 8)	0 (0 %)	2 (40 %)	3 (60 %)	5 (100 %)	0 (0 %)	4 (80 %)	1 (20 %)	0 (0 %)

Cluster	watAvPast_0 (n farms)	watAvPast_2 (n farms)	watPoPast_0 (n farms)	watPoPast_1 (n farms)	watPoPast_2 (n farms)	chMilkSysDSum_0 (n farms)	chMilkSysDSum_2 (n farms)	clawTrimEq_0 (n farms)
I (n = 25)	1 (25 %)	3 (75 %)	0 (0 %)	2 (67 %)	1 (33 %)	4 (100 %)	0 (0 %)	9 (36 %)
II (n = 91)	5 (6 %)	82 (94 %)	24 (28 %)	37 (44 %)	24 (28 %)	81 (93 %)	6 (7 %)	31 (34 %)
III (n = 8)	1 (13 %)	7 (87 %)	1 (14 %)	5 (72 %)	1 (14 %)	7 (88 %)	1 (12 %)	3 (38 %)

Cluster	clawTrimEq_1 (n farms)	clawTrimEq_2 (n farms)	Disbud_Dehorn_0 (n farms)	Disbud_Dehorn_1 (n farms)	Disbud_Dehorn_2 (n farms)	Disbud_Dehorn_3 (n farms)	Disbud_Dehorn_4 (n farms)	AnaestheDisBudDeHorn_0 (n farms)
I (n = 25)	1 (4 %)	15 (60 %)	4 (16 %)	19 (76 %)	2 (8 %)	0 (0 %)	0 (0 %)	8 (32 %)
II (n = 91)	14 (16 %)	45 (50 %	27 (30 %)	51 (56 %)	6 (7 %)	5 (5 %)	2 (2 %)	54 (59 %)
III (n = 8)	0 (0 %)	5 (62 %)	6 (75 %)	1 (12 %)	1 (12 %)	0 (0 %)	0 (0 %)	7 (88 %)

Cluster	AnaestheDisBudDeHorn_2 (n farms)	AnalgesDisBudDeHorn_0 (n farms)	AnalgesDisBudDeHorn_2 (n farms)	DirtyHindQ (%)	DirtyLegs (%)	DirtyUdder (%)	ManureHindQ (%)	ManureLegs (%)
I (n = 25)	17 (68 %)	9 (36 %)	16 (64 %)	47.1	50.5	33.5	45.7	48.7
II (n = 91)	37 (41 %)	54 (59 %)	37 (41 %)	49.0	59.9	44.7	48.2	57.2
III (n = 8)	1 (12 %)	6 (75 %)	2 (25 %)	19.4	44.5	31.6	18.7	32.0

Cluster	ManureTeat (%)	ManureUdder (%)
I (n = 25)	24.0	24.5
II (n = 91)	29.1	30.1
III (n = 8)	20.9	10.3

Table 11: Means of continuous variables for clusters of farms based on animal-based measures (*, normalised values). Abbreviations are spelled in Appendix A.

Cluster	BCSVeryFat (%)	BCSVeryLean (%)	DirtyHindQ (%)	DirtyLegs (%)	DirtyUdder (%)	ManureHindQ (%)	ManureLegs (%)	ManureTeat (%)
I (n = 71)	11.1	8.0	47.5	54.0	40.9	46.8	52.9	28.1
II (n = 23)	8.1	9.4	44.4	58.4	39.4	44.0	53.5	24.7
III (n = 30)	8.8	8.5	46.6	63.2	44.9	44.7	56.5	28.4

Cluster	ManureUdder (%)	HairlessPatches (%)	SwellingOrLesion (%)	HairlessLHL (%)	LesionLHL (%)	SwellingLHL (%)	HairlessCarpus (%)	SwellingCarpus (%)
I (n = 71)	27.8	40.6	15.8	17.4	2.3	2.9	26.3	1.8
II (n = 23)	26.1	39.1	17.1	17.9	3.2	3.4	24.0	1.0
III (n = 30)	28.6	33.0	19.8	15. 3	3.5	1.9	15.8	2.0

Cluster	HairlessBody (%)	LesionBody (%)	SwellingBody (%)	Lameness1 and2 (%)	Lameness2 (%)	ClawCondition2 (%)	MilkSomaticCellCount (%)	pMastitis12Month (%)
I (n = 71)	33.6	8.2	1.4	21.0	12.1	21.4	17.0	0.19
II (n = 23)	29.8	8.9	1.3	22.1	8.9	9.0	12.1	0.14
III (n = 30)	28.0	11.0	3.5	17.7	8.2	17.8	14.7	0.15

Cluster	NasalDischarge (%)	VulvarDischarge (%)	Dystocia (%)	Downer Cows (%)	Mortality (%)	AvAgeAtCulling *	CowPerSqM	OutsideLyingArea (%)
I (n = 71)	3.8	2.0	3.7	2.4	4.3	0.58	0.22	19.1
II (n = 23)	0.8	0.6	4.6	2.2	3.7	0.61	0.14	12.6
III (n = 30)	1.7	0.6	6.6	2.2	3.6	0.58	0.15	9.1

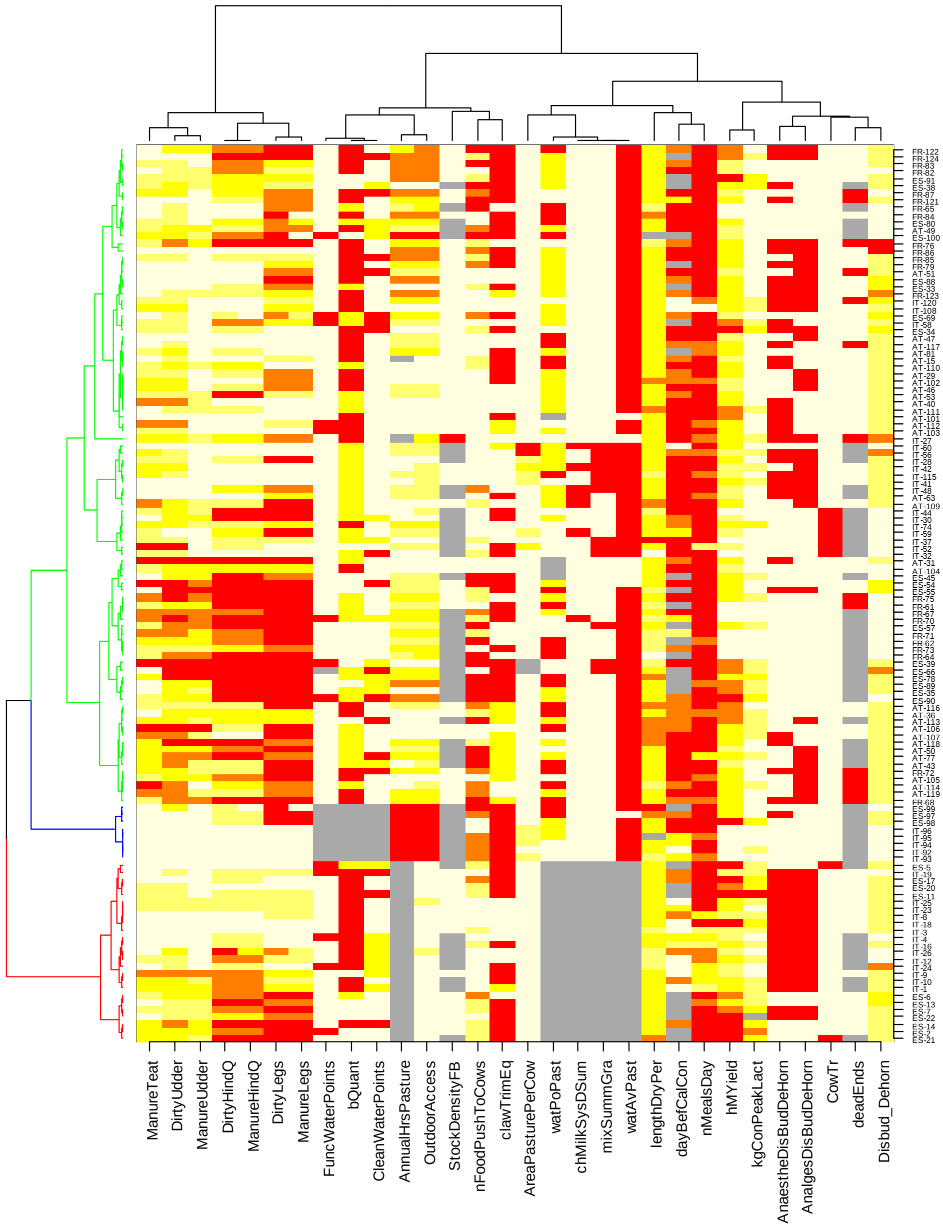
Cluster	RisingScore3or4 (%)	EquipmentCollision (%)	AvoidDistTouchedInv (%)	AvoidDistCloser50 (%)	AvoidDist50.99 (%)	AvoidDist100more (%)	QBA (score)
I (n = 71)	27.0	22.4	64.5	39. 4	11.2	14.0	56.4
II (n = 23)	23.2	20.0	62.0	40.1	13.2	8.7	56.2
III (n = 30)	18.5	25.5	57.7	39.5	10.7	7.5	60.7

Figures 21 and 22 display so-called heat maps, which constitute a cross-tabulation of the single farms in the clusters (vertical) with the results on variables (horizontal) considered to be risk factors (Figure 21) and considered to be animal-based measures of welfare (Figure 22). The colours represent the (level of) presence of a given risk factor in a certain farm and the level of a welfare issue. Five levels of shading were used in the cells, and these levels were determined by using the theoretically possible worst case as a reference value and then dividing the value of a given farm by this reference. The results were then expressed in different colours based on 20 % increments of this calculated outcome for each farm and variable/measure. For binary measures, two levels of shading were used.

Both Figures 21 and 22 show that the presence of potential risk factors on the farms and the measurements of the size of animal-based measures of welfare are rather uniformly distributed across the farms. There are almost no farms that consistently display a low level of risk or a high level of welfare across all variables/measures.

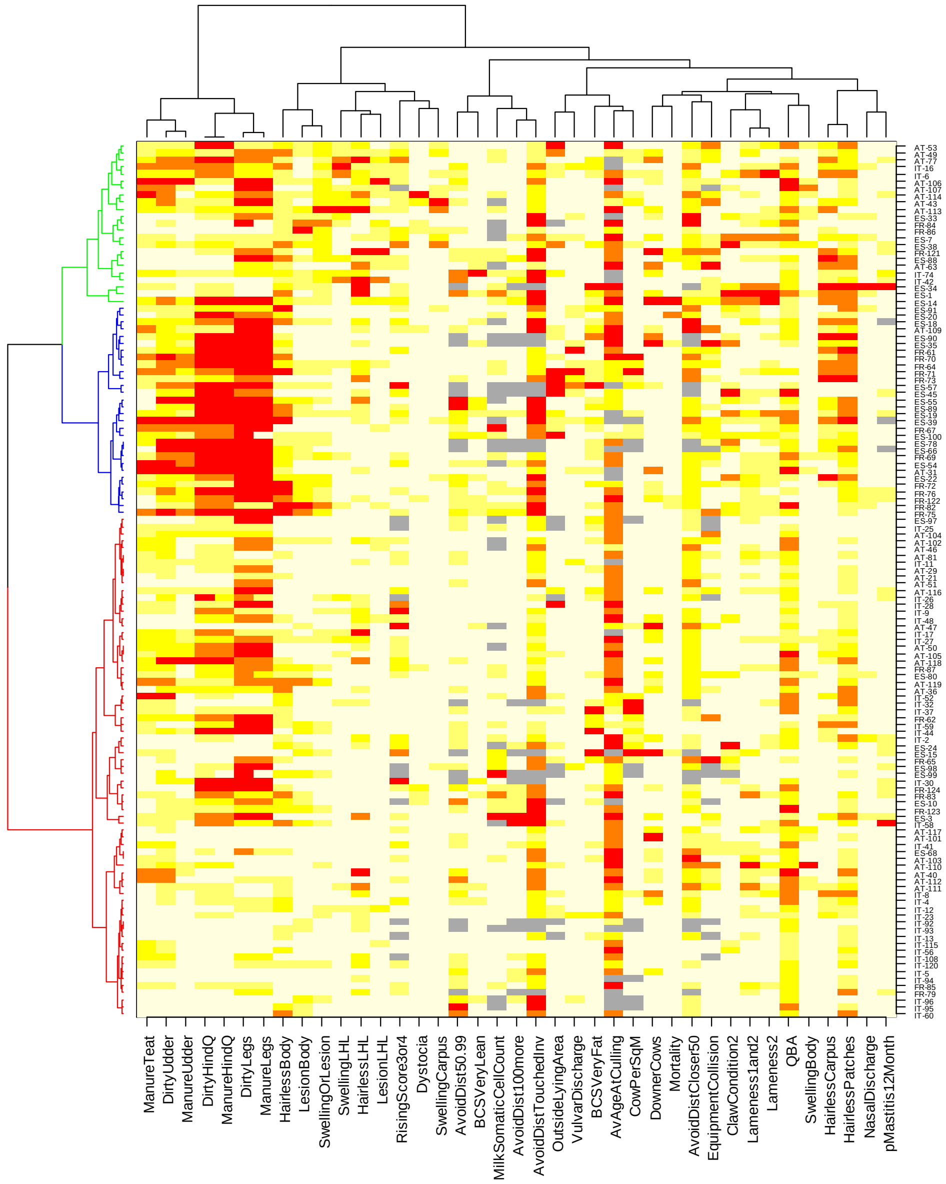
The heat map shown in Figure 21 shows clear distinctions between the farms (cluster 1 in red composed of farms in Spain and Italy), with missing information regarding risk factors related to summer changes (change of milking system during summer and mixing during summer grazing) and pasture (annual hours on pasture, water points on pasture and water availability on pasture), and most farms using anaesthetic and analgesic when dehorning the animals. Cluster 2 in green includes farms that, in general, exhibit issues with manure and dirt scores and farms that have scores of 2 for the presence of deadends. Cluster 3 in blue is largely composed of farms that have low values for manure and dirt in different parts of the animals. The similarities between the different risk factors considered are also clear from this figure, as are the difficulties that were experienced in collecting some of the scores (stocking density at the feed bunk, presence of dead ends, number of days before calving with concentrate feed). It is also clear that some of the factors are not useful for distinguishing between farms (change of milking system during summer, mixing during summer grazing, water availability at pasture and length of the dry period).

The heat map shown in Figure 22 does not show a clear distinction between the farms, but this could be attributed to the 20 % increments that were used to express the five colours per welfare indicator in the heat map. This figure clearly show the similarities between some of the welfare indicators; for instance, there is no differentiation between dirt and manure for the different parts evaluated, or between the scores for lameness combining 1 and 2 and scores of 2 only. This figure also shows that there were difficulties in collecting milk somatic cell count values, but, in general, the amount of missing information is relatively low, indicating that it is feasible to collect information regarding welfare for the small-scale farms visited in the period of the year in which this survey was conducted. It is also clear that some of the factors are not useful for distinguishing between farms (swelling on the carpus, dystocia, nasal discharge and swelling on the body).



Pale yellow–red: increasing level of welfare problem; grey: missing value

Figure 21: Result of the hierarchical clustering of risk factors that have less than 50 % missing values and that, for continuous variables, have no more than 50 % of the recorded values represented by a single value, based on the principal components obtained



Pale yellow–red: increasing level of welfare problem; grey: missing value

Figure 22: Result of the hierarchical clustering of animal-based measures that have less than 50 % missing values and that, for continuous variables, have no more than 50 % of the recorded values represented by a single value, based on the principal components obtained

3.2.6. Identification of risk factors for selected animal-based measures

Regression trees were constructed that best categorised farms based on, for example, similar percentages of cows with the most common animal-based measures (lameness score 1 and 2, lameness score 2 only, mortality, body lesions, lean cows) using the most predictive risk factor levels as classifying criteria. No significant results were obtained when constructing regression trees for mortality, body lesions and lean cows, but Figures 23 and 24 show the regression trees for lameness score 1 and 2 and lameness score 2, respectively.

The regression trees identified variables (e.g. risk factors) that could best distinguish between farms based on their expected percentage of lameness score 1 and 2 (Figure 23) and score 2 only (Figure 24). The bar charts on the right of both figures show a comparison of the relative importance of the variables for classification, i.e. longer bars indicate variables that show the strongest distinctions between farms when used in classification.

Figure 23, shows, for example, that the percentage of animals with lameness score 1 or 2 in farms was best categorised when the number of meals per day (nMealsDay) was less than or greater than 0.85, respectively, corresponding to 8.5 meals (with 10 the maximum value used for normalisation). Farms with a factor smaller than 0.85 show a lower lameness prevalence and are classified further depending on whether or not total pasture area (totalPas) was greater than 66 ha; if totalPas was greater than 66 ha, the prevalence of lameness score 1 and 2 was below 3.8 %. With less pasture available, farms were further distinguished based on herd size, with a herd size smaller than 20 cows having, on average, 12 % lame cows, whereas the proportion was 23 % in larger herds. Finally, farms having nMealsDay greater than 0.85 had a total lameness prevalence of 26 or 70 % when the classifier StockDens score was less than or greater than 1 (number of cows per feeding place), respectively.

In terms of the relative importance of variables for distinguishing between farms with regard to total lameness prevalence (lameness score 1 and 2, Figure 23), it should be mentioned that the five most important variables are stocking density at feeding (StockDensityFB), herd milk yield (hMYield.x), overgrown claws (ClawCondition2), stocking density at pasture (AreaPasturePerCow) and amount of concentrate fed during peak lactation (kgConPeakLact.x).

For lameness score 2 only (prevalence of severe lameness), Figure 24 shows that in the 106 farms for which the risk factor for overgrown claw condition (ClawCond) is present in less than 48 % of the cows with a claw condition score of 2 (severe lameness), 7.3 % of cows, on average, had severe lameness when the proportion of first lactation cows was greater than 5.5 %, while farms with a lower proportion had a prevalence of severe lameness of 29 %. In farms in which more than 48 % of cows had overgrown claws, the proportion of cows in fourth lactation was crucial: in farms with less than 16 % of fourth lactation cows, the proportion of severely lame animals was 15 %, while severe lameness prevalence was 44 % in farms with more than 16 % of fourth lactation cows.

The five most important factors contributing to the prevalence of severe lameness (lameness score 2) are (Figure 24) the proportion of cows in the fourth and fifth lactation (pCowsFouFiLact), the amount of bedding (bQuant), stocking density at pasture (AreaPasturePerCow), access to an outdoor area (OutdoorAccess.x) and total pasture area (totalPastArea).

In Appendix E, a table gives the means and number of farms in each category for clusters of farms for which, for risk factors, there are less than 50 % missing values and for which no more than 50 % of the recorded values are represented by a single value. Both the number of clusters and number of principal components needed to explain 70 % of the variability show that most of the data are needed to sufficiently describe the farms.

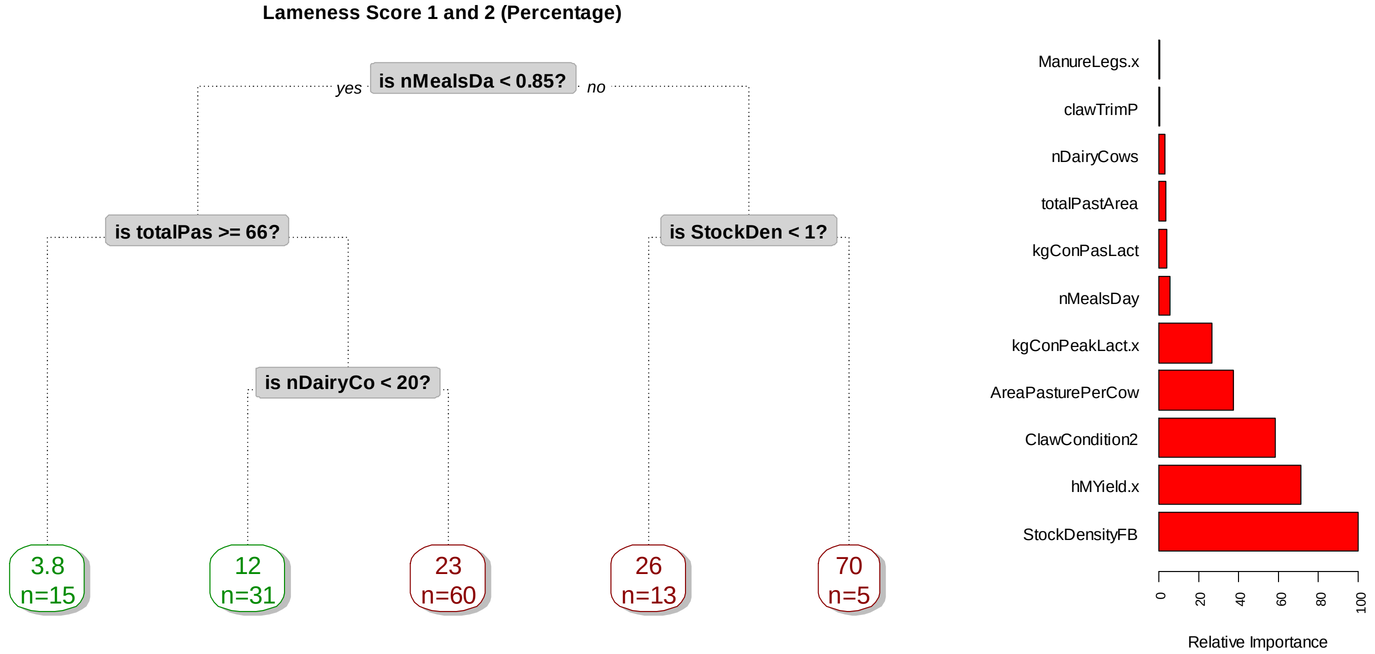


Figure 23: Regression tree for lameness score 1 and 2 obtained after pruning. Variable definitions and units are presented in Appendices A, B and C

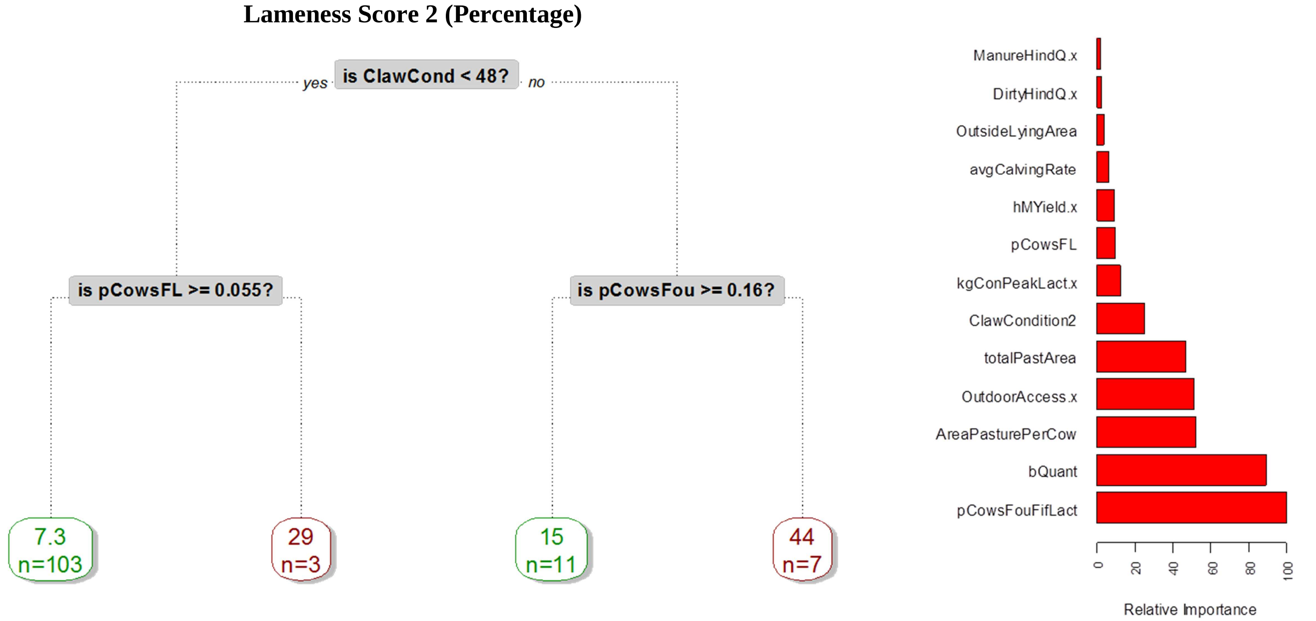


Figure 24: Regression tree for lameness score 2 obtained after pruning. Variable definitions and units are presented in Appendices A, B and C

3.3. Assessment of ToR2b: the suitability of animal-based measures in small-scale farms

Information on the time needed for the on-farm assessment and about the qualitative evaluation of feasibility of the protocol by the observers is shown in Table 12. The range in both the time needed and the feasibility score was high for most of the (groups of) measures. This is mainly because of the variation in farm size, but also because of the difficulties in carrying out a measurement on a single farm (e.g. when most of the cows were in an outdoor loafing area), thus resulting in very low durations.

Table 12: Time needed to perform the different sections of the protocol and information about the qualitative evaluation of feasibility undertaken by the nine observers (animal-based measures of welfare)

Measure(s)	n	Time needed (minutes)		Feasibility score			Main comments
		Median	Min–max	Median	Min–max	% score 0 + 1	
Avoidance distance at the feed place	112	15	2–40	4	1–4	18.6	Animals tied to the wall, limited space on feed bunk, too much feed in front of the cows, few animals at the feed place, animals on pasture
Qualitative behaviour assessment	123	20	10–35	3	0–4	2.5	Not all animals visible, poor light conditions
Lying position/rising behaviour	107	10	1–90	Lying position 3, getting-up behaviour 3	0–4	19.0	Lying position: few animals lying Rising behaviour: few animals lying, cows reluctant to get up
Clinical scoring	122	70	20–190	3	1–4	3.3	Dirty animals, cows tied closely together, front part difficult to see and sometimes dangerous (horned cows), cow trainer affects lameness scoring
Assessment of resources [(a)]	116	15	5–90	4	0–4	4.3	–
Management questionnaire [(a)]	123	35	10–120	3	1–4	1.7	–
Total time on farm	109	3 h 45 min	55 min–9 h	–	–	–	–

feasibility score: 0 = not at all feasible, 4 = very feasible

(a) Rather comprehensive collection of data for risk assessment purposes; if applied for certification, the assessment of resources and management would most likely be restricted to a limited number of key indicators (e.g. water provision, space allowance, procedures used for disbudding of calves) which will take much less time.

Previous experience during the outsourced project showed that animal-based measures may be applied in small-scale farms, at least during the housing period. Some problems were encountered with regard to avoidance distance testing and the assessment of the lying position/evaluation of the rising behaviour in up to 20 % of the farms. There are, however, no reasons to assume that welfare assessment in small-scale farms is, on principle, more difficult than or substantially different from that in larger, more intensively run farms (see also Heath et al., 2014).

On average, the assessment of animal-based measures took in total about two hours, with clinical scoring of a sample of animals requiring the largest proportion of time. Variation between farms was high, specifically with regard to the herd size but also the housing and management features of individual farms (e.g. accessibility of animals, feeding routines, etc.). However, there are some aspects that may be taken into account when implementing animal-based measures in small-scale farms:

- Behaviour observations: avoidance distance testing is difficult or impossible when animals are tied to the wall or the feed bunk is too narrow (and there are similar problems in larger farms when using round feeders, for example). Regarding observations of lying position (lying partly or completely outside the lying area) and assessment of rising behaviour, in very small herds (< 20 cows), sometimes more time was needed to obtain a sample size as requested by the protocol.
- Clinical scoring: if cows are tied up and too close one to another, the clinical assessment (especially for the front part of the cow) may be difficult and dangerous. However, this is again not necessarily different from assessments in, for example, loose housed animals locked in head gates at the feed bunk.
- Data obtained from records: for some farms, it was difficult to obtain data regarding, for example, milk somatic cell count. Most farms do not have electronic records, so the assessment has to rely on records other than electronic ones (e.g. written records) and/or farmer estimates.
- Data processing and interpretation: prevalence measures may be difficult to interpret for very small herd sizes (i.e. impact of single animals on prevalence at herd level).

The protocol used in the procurement study has been designed for housed animals. If used when animals have access to pasture, parameters may have to be adapted (e.g. avoidance distance) and time points may have to be defined (before and after milking, during pasture) to safeguard reliability.

3.4. Assessment of ToR2c: assessment of the impact of production diseases on welfare

The review of publications revealed a scant number of controlled studies investigating the effects of a particular system on cattle diseases and other disorders.

3.4.1. Impact of lameness, mastitis, metabolic and reproductive disorders, and downer cows on welfare

The assessment of the impact of a production disease on the welfare of an individual cow applies to dairy farms in general and is not specific to small-scale farms.

3.4.1.1. Impact of lameness

The 2009 EFSA report on dairy cow welfare highlights that lameness affects cows' welfare in terms of their physical state (fitness) and mental state (suffering). The main welfare effects on individual animals are pain (frequently with peripheral and central hyperalgesia), discomfort, distress, changes in behaviour and premature culling. It is also stated that the foot is the most common site of lesions causing lameness in dairy cattle.

In spite of a tremendous amount of research done on this subject, there is no evidence of a decreasing incidence of lameness in dairy farms (Barker et al., 2010; USDA-APHIS National Animal Health Monitoring System, 2011; Huxley, 2013; Becker et al., 2014a). Some authors even suggest its incidence to be on the rise in most countries (Bicalho and Oikonomou, 2013). In addition, new technology is being used to diagnose and score lameness and has continuously confirmed that even subclinical lameness is an important cause of pain and suffering in dairy cows (Chambers et al., 1994; Chapinal et al., 2010; Pastell et al., 2010; Schulz et al., 2011; Alsaaod et al., 2012; Bruijnis et al., 2012; Van Hertem et al., 2013). Therefore, lameness should continue to be considered the main threat to welfare in dairy cows and one of the main causes of loss (e.g. yield, fertility, culling) in the dairy industry.

Another issue that has received much attention since the EFSA report is lameness diagnosis and scoring. Together with use of traditional ordinal scales, other methods such as visual analogue scales, pressure mats, weighing platforms, algometers, accelerometers, ALT-pedometer, and neck activity and ruminating sensors are nowadays used to record and analyse naturally occurring lameness (Chambers et al., 1994; Chapinal et al., 2010; Pastell et al., 2010; Schulz et al., 2011; Alsaaod et al., 2012; Van Hertem et al., 2013). This has allowed for a better understanding of the pain involved in foot diseases, especially in subclinical cases.

Some of the consequences of lameness that have received new scientific input have been changes in feeding, lying and social behaviour in affected cows. Severely lame cows eat faster and eat larger meals but spend less time feeding and ruminating per day (Palmer et al., 2012; Miguel-Pacheco et al., 2014) and most of these changes are evident even before lameness is clinically diagnosed (Norring et al., 2014). Lame cows show long lying times and a higher variability in the duration of lying bouts (Ito et al., 2010; Groenevelt et al., 2011). However, it was also found that more chronically lame cows are seen standing up in the early hours of the morning, and the authors suggest that this may be a way to avoid conflict over feed (Blackie et al., 2011). In contrast, another study showed that lame cows get up later and lie down earlier after feed is distributed, suggesting less time feeding (Yunta et al., 2012). Being lame also affects the time budget of the dairy cow: lame cows show longer lying times and spend less time standing, walking and expressing oestrous behaviour (Morris et al., 2011).

It is well known that lame cows frequently have a low or very low body condition score (BCS) (Wells et al., 1993; Dippel et al., 2009a) and this has been linked to pain and a consequent low feed intake that may start four weeks before clinical signs of lameness (Alawneh et al., 2012). However, this cause–effect relationship probably occurs in both directions (Huxley, 2013). Green et al. (2014) showed that cows with BCS < 2 are more prone to develop horn-related lameness. It has been proposed that high-yielding cows that lose body condition during periods of negative energy balance become lame because of a reduction in the fat content of the digital cushion, allowing for extra trauma to the chorion by the third phalanx (Bicalho et al., 2009).

Very recently, Lim et al. (2015) showed that cows with a low BCS at calving or suffering a significant loss in BCS after calving were more likely to become lame and, if lame, were less likely to recover.

Recent studies have also confirmed what was reported in the 2009 EFSA document: lameness has important indirect effects on welfare by increasing the risk of mastitis, ketosis, displaced abomasum and other diseases. Lameness also decreases fertility (Alawneh et al., 2011; Morris et al., 2011) with the odds of pregnancy being reduced 5.1 times and that of calving reduced 3.5 times (Garcia et al., 2011).

3.4.1.2. Impact of mastitis on welfare

The main well-known welfare effects of mastitis are pain, discomfort, mortality associated with some acute cases, and premature culling. More recently, sickness behaviour of mastitic cows has been described. Signs of sickness behaviour can last several days after treatment of the cows (up to at least 10 days). Mastitic cows show decreased feeding time (Fogsgaard et al., 2012), decreased lying time (Cyples et al., 2012; Fogsgaard et al., 2012; Medrano-Galarza et al., 2012; Fogsgaard et al., 2014), which is interpreted as pain or soreness in the infected udder during lying, reduced rumination (Fogsgaard et al., 2012), reduced feed intake starting one or several days before the diagnosis of clinical mastitis (Bareille et al., 2003; Fogsgaard et al., 2014; Sepulveda-Varas et al., 2014a), and increased restlessness during milking, manifesting as kicking and tripping (Fogsgaard et al., 2014).

Decreased lying time may result in frustration owing to conflict because of an expected increased motivation for lying of diseased animals (Dantzer and Kelly, 2007; Sepulveda-Varas et al., 2014b).

In contrast to clinical mastitis, there is a lack of data on welfare consequences of subclinical mastitis. This gap should be addressed, as the animal-based measures most frequently used to capture udder health in a herd rely on indicators based on increases in milk somatic cell counts (SCC) reflecting subclinical intramammary infections.

Based on available register data in Sweden, mastitis incidence was found to be one of the six indicators used to identify herds with poor welfare based on nine animal-based measures (Nyman et al., 2011).

3.4.1.3. Impact of metabolic diseases: milk fever, fatty liver and ketosis

The EFSA 2009 scientific opinion showed that metabolic disorders are independent of the housing system used, although pasture-kept animals are less likely to have metabolic problems. Nutrition and feeding-related hazards have a major influence on metabolic disorders. Ruminal acidosis (acute and subacute) and parturient paresis (milk fever) can cause very poor welfare in dairy cows.

Changes in lying behaviour after calving were associated with postpartum health status in grazing dairy cows (Sepúlveda-Varas et al., 2014).

Subclinical ketosis in the first or second week after calving was associated with increased risk of displaced abomasum, metritis, clinical ketosis, endometritis, prolonged postpartum anovulation, increased severity of mastitis and lower milk production in early lactation (LeBlanc, 2010).

Standing behaviour of cows with clinical ketosis was changed compared with non-ketotic cows during the calving day, as they showed fewer standing bouts with longer duration (Itle et al., 2015). In addition, feeding behaviour was altered before and after calving in cows with subclinical ketosis (Goldhawk et al., 2009).

Subclinical and clinical ketosis was associated with a higher milk yield, a higher milk fat percentage and a lower milk protein percentage at first test day. Major risk factors for both subclinical and clinical ketosis are increasing parity, overconditioning of animals prepartum, season of calving and dry period length. Previous lactation length and litres of colostrum produced have been identified as additional risk factors for the development of ketosis (Vanholder et al., 2015).

Cows with subclinical hypocalcaemia produced more milk during the transition period, did not consume more water and ate more dry matter in week 2 after calving, although they did not make more visits to water troughs or to feed bins (Jawor et al., 2012).

During the 24-hour period before parturition, cows with subclinical hypocalcaemia stood 2.6 hours longer and spent 2.7 hours less time standing during the first week post partum, suggesting that these animals experienced increased discomfort at calving (Jawor et al., 2012).

3.4.1.4. Impact of reproductive disorders (dystocia and metritis)

The search yielded 43 (dystocia) and 272 (metritis) references, of which 40 were relevant for this section (inclusion criteria were welfare relevance in terms of pain, changes in behaviour, disease incidence associated with reproductive disorders, reduced fitness; the main exclusion criteria were clinical treatment and biochemical studies); another five publications which had been published before 2000 were retrieved from reference lists of the selected papers.

Dystocia may be defined as calving difficulty resulting from prolonged spontaneous calving or prolonged or severe assisted extraction (Mee, 2008). Reported incidences in dairy cattle vary considerably from 1.2 % (Gröhn et al., 1990) to 18 % (Stevenson, 2000); however, in most studies incidence ranges between 5 and 10 % (Fourichon et al., 2001; Mee et al., 2011; Stafford, 2011; Atashi et al., 2012; Coignard et al., 2013; Ribeiro et al., 2013). According to Mee (2008), dystocia rates have increased in Sweden, Canada and the USA, have remained unchanged in Australia and have decreased in Ireland in recent years.

Dystocia is associated with prolonged pain and has been ranked as highly painful, together with fracture of the tuber coxae and serious mastitis (Kielland et al., 2010) or claw amputation and left abomasal displacement surgery (Huxley and Whay, 2006). Behavioural indications of discomfort are present even before parturition. For example, after parturition, dystocic cows showed less dry matter and water intake and more transitions from standing to lying (Proudfoot et al., 2009). While the duration of calving is not different, more contractions occur in assisted calving and the cows are more restless and raise the tail for longer (Barrier et al., 2012b). After parturition, dystocic cows showed less self-grooming than cows delivering naturally, but there was no difference in other pain-related behaviours such as tail switch or posture transitions (Barrier et al., 2012c). In the case of caesarean section, beef cows receiving a non-steroidal anti-inflammatory drug treatment spent significantly more time lying in the first 16 hours following surgery than cows receiving placebo and had more bouts of lying in the first 24 hours; however, there were no differences in the number of steps taken (Barrier et al., 2014).

Apart from these short-term effects, dystocia may be associated with retained placenta and metritis (Benzaquen et al., 2007; Dubuc et al., 2010; Hossein-Zadeh and Ardalan, 2011; Galvao, 2012), as well as early veterinarian-treated mastitis (Svensson et al., 2006) and higher mortality risk (Alvasen et al., 2014). It decreases milk yield (Gröhn and Rajala-Schultz, 2000; Atashi et al., 2012) and fertility in terms of higher risk of repeat breeding (Gustafsson and Emanuelson, 2002; Bonneville-Hebert et al., 2011), leads to more days open and longer time from first breeding to conception (Maizon et al., 2004) and causes lower overall pregnancy rate (McDougall, 2001; Ribeiro et al., 2013). Dystocic cows are therefore at increased risk of being culled (Beaudeau et al., 2000).

Dystocia may be stressful not only for the cow, but also for the calf, as calves have higher salivary cortisol levels than naturally born ones (Barrier et al., 2013). They suffer from a decreased transfer of passive immunity (Arnott et al., 2012) and are increased risk of perinatal mortality (Hoedemaker et al., 2010; Hossein-Zadeh, 2014), which is even higher for calves that have been born through caesarean section (Hossein-Zadeh, 2014). Malpresented calves require more non-routine treatments during the first 60 days (Barrier et al., 2013) and are at higher risk of mortality to weaning and to first service, but show similar growth to weaning and fertility performance to heifers born naturally (Barrier et al., 2012a).

Metritis most commonly occurs within 21 days of delivery and is characterised by an abnormally enlarged uterus and purulent discharge. More severe stages of the disease are associated with systemic signs of ill health such as fever (Giuliodori et al., 2013). According to a review by Galvao (2012), the average incidence is about 20 %, but reported incidences vary substantially, from as low as 2–4 % (Gröhn et al., 1990; Fourichon et al., 2001; Koeck et al., 2010; Yin et al., 2014), to 8–11 % (Garcia et al., 2005; Hossein-Zadeh and Ardalan, 2011; Koeck et al., 2012) and even 39 % (Martinez et al., 2012). This variation may at least partly be due to the different definitions used.

Early metritis is associated with a drop in milk production (Gröhn and Rajala-Schultz, 2000) and an increased risk of early veterinarian-treated mastitis (Svensson et al., 2006). Estimates of the risk of culling are variable (reviewed by Beaudeau et al., 2000), with some studies finding an "unfavourable association" between metritis and culling, but others not (see also Bonneville-Hebert et al., 2011). Similarly, Giuliodori et al. (2013) found a lower risk of pregnancy and Ribeiro et al. (2013) a lower pregnancy rate per artificial insemination for cows with metritis, while metritis did not affect first-service conception rate or 150 days' pregnancy rate in the study of Benzaquen et al. (2007).

3.4.1.5. Impact of downer cows

Primary recumbency in dairy cows is caused by numerous metabolic, traumatic, infectious, degenerative and toxic disorders. If recumbency is prolonged (more than six hours) and occurs on a hard surface, cows may develop a secondary recumbency from pressure damage to muscles and nerves termed “downer cow syndrome”(Curtis et al., 1975; Cox et al., 1982).

The welfare impacts of downer cow syndrome are tremendous and include pain (acute and chronic), stress, fear, emaciation, dehydration and, ultimately, death. Welfare can deteriorate further when farmers try to move (drag) these animals or decide to kill them on the farm. Adequate and careful management of the downer cow by the farmer is crucial for recovery, because it includes regular lifting and physiotherapy (Kronfeld, 1976). The prognosis is very poor unless regular lifting and continuous treatment are established (Curtis et al., 1975; Cox et al., 1986).

Welfare may be further negatively affected if feed and water are not provided in proper conditions (e.g. easily accessed and in bowls that the animal cannot spill).

The main risk factors for primary recumbency are milk fever, stillbirth and dystocia (Correa et al., 1993). High-yielding dairy cows are more susceptible to several peripartum diseases, including ketosis, left displacement of the abomasum, retained placenta, milk fever and downer cow syndrome (Oikawa and Katoh, 2002). Intensive feeding in the dry period is also a predisposing factor for metabolic and downer cow syndrome (Julien et al., 1977).

Downer cow syndrome will be more likely in farms with no soft-bedded maternity and infirmary, or if time is limited or those responsible for managing the down cow have limited knowledge. Treatment of downer cows is very labour intensive. Stockpersons in large and very intensive farms will usually have very little time for the careful management of these animals. On the other hand, farmers of small farms may lack the knowledge and instruments (e.g. hip clamps, slings or water flotation) necessary for the treatment of this condition.

3.4.2. Health management in small-scale farms

Early and competent diagnosis and treatment of diseased individuals is paramount to the welfare of animals. To achieve this, two factors are crucial: stockpersons’ empathy for and knowledge about identifying sick animals, and quick access to veterinarian assistance. The same can be said about animals that have to be killed on-farm (e.g. downer or chronically ill cows). A study of small Swedish farms found that those that made little use of a veterinarian to treat clinical mastitis often waited to call the veterinarian until the general condition of a cow was altered. At the same time, they undertook less claw trimming than those farms that used more veterinary assistance (Nyman et al., 2007).

Very little research has been done on the role of veterinarians in small and in non-conventional dairy farms. Nevertheless, it is the opinion of the working group that potential welfare problems that may occur in small dairy farms should be recognised.

In small farms, veterinary assistance may consist of response only to emergency clinical calls and only rarely will include routinely scheduled visits and provision of disease prevention programmes. Not having a full-time veterinarian or one who regularly visits a farm may also lead to a reduced use of records, lack of health promoting programmes and lower or no pain management for some procedures (e.g. disbudding). In addition, those working on small farms (full or part time) are usually less accustomed to dealing with sick or suffering animals (Becker et al., 2014c) than those working in very large dairy farms. Therefore, because a private veterinarian is not economically viable for small farms, assistance or euthanasia of diseased or injured animals may be postponed for financial or other reasons.

There could also be differences in veterinary assistance and health management between conventional and organic farms because of different policies in treatment and prevention measures (Bennedsgaard et al., 2003; von Borell and Sørensen, 2004). Organic farmers' surveys show that veterinarians are more involved in treating individual clinical cases than in disease prevention at herd level (Vaarst et al., 2002, 2006). Organic farms are generally associated with less frequent veterinary visits and use less outside support (e.g. nutritionist) than conventionally managed farms (Valle et al., 2007; Cicconi-Hogan et al., 2013; Richert et al., 2013a) and so fewer veterinary-treated cases of disease are reported in organic than in conventional farms (Hardeng and Edge, 2001; Hamilton et al., 2002; Bennedsgaard et al., 2003; Valle et al., 2007; Mayen et al., 2010) and organic farmers are more likely to initiate therapy themselves (with no veterinarian involvement) using alternative treatments (Hamilton et al., 2002; Vaarst et al., 2006; Valle et al., 2007).

Fewer organic and conventional-with-grazing dairy farms called a veterinarian to examine and treat cows with clinical mastitis (Ruegg, 2009). Farms that use less veterinary assistance are more likely to have high SCC (Stiglbauer et al., 2013). In contrast, Hardeng and Edge (2001) found that less veterinary treatment did not lead to more chronic subclinical mastitis in organic farms. In the USA, organic farmers, compared with conventional farmers, relied less on a veterinarian and more on other farmers for advice regarding treatments (Zwald et al., 2004). It is suggested that some choices about veterinary care are associated more with farm size or intensity than the decision to use organic management (Ruegg et al., 2011).

It is important to recognise and understand the reasons for the reduced or lack of veterinary supervision in small dairy farms, as it may have an enormous impact on dairy cattle welfare.

In organic farms, great emphasis is placed on high standards in product quality, animal health and welfare. It is generally agreed that health and welfare in organic farms is equal to or better than that in conventional farms, except for parasite-induced diseases (Lund and Algers, 2003). However, disease management should be carefully scrutinised to avoid the danger of some features (organic standards, environment impact and product quality) conflicting with animal health and welfare (Sundrum, 2001; Hovi et al., 2003; von Borell and Sørensen, 2004). Vaarst and Bennedsgaard (2001) stress the importance of increased cooperation between organic farmers and veterinarians. However, all these issues should be investigated more thoroughly in future research.

3.4.3. Risk factors for production diseases that may apply to small-scale farms

The vast majority of published studies on risk factors for production diseases are not specific to small-scale farming systems. Therefore, the focus in the review was on the risk factors which are related to the farming system and likely to be more or less frequent in small-scale farms. Studies investigating risk factors for production diseases often show statistical relationships, but study designs will usually not allow further inference of a causal relationship. The strength of the relationship is generally low (as shown by the low values of parameter estimates issued from models). For management-related risk factors, there are many contradictions between results obtained in different populations. Unravelling the role of different risk factors is extremely difficult, as there are many different factors involved in the aetiology and pathogenesis of these diseases. As explained in the methodology section, the review focused on a number of criteria that have been used to define the farms addressed in this report or that were additionally deemed relevant in the context of small-scale farms as interpreted in this scientific opinion: (1) degree of intensification, (2) herd size, (3) housing type including access to pasture or outdoor run, (4) nutrition (concentrate input, use of forage, concentrate–fibre ratio), (5) milk yield per cow, (6) human factor (management, human–animal relationship) and (7) breed.

3.4.3.1. Risk factors for lameness

In general, lameness prevalence varies tremendously between farms. Owing to the multifactorial aetiology of lameness, it is difficult to generalise the nature of the risk factors. However, scientific evidence is sufficiently strong to allow for the following correlations to be established. Lameness prevalence is higher in cows that are permanently housed (e.g. zero grazing or without outdoor pens) on concrete, that have to stand for long periods, that lose body condition after calving, that show very high milk yield and that belong to the Holstein breed. Laminitis has also been associated with diets high in starch or low in effective fibre. However, good management and husbandry conditions may allow farms to overcome or attenuate the consequences of some of these factors and, in contrast, poor outdoor conditions may be associated with a high prevalence of some foot lesions and diseases. Constant checking for lame cows and regular functional hoof trimming reduces lameness prevalence, severity and recovery time. Therefore, farmers' knowledge and empathy are crucial for lameness control. Table 13 reports the results from the literature review about risk factors for lameness.

Table 13: Risk factors for lameness from the literature review

Risk factor	Lameness
Prevalence	The prevalence of lameness varies in the studies conducted in different countries, ranging from 20 % (Espejo and Endres, 2007) to 48 % (Dippel et al., 2009a) for loose housing systems and from 1 to 21 % in tied systems (Cook, 2003; Sogstad et al., 2005; Zurbrigg et al., 2005)
Multifactorial: degree of intensification	There is higher prevalence in farms with a high level of concentrates, in the Holstein breed, in cows with high milk yield, in cows which are housed indoors all year and in cows with lower age at first calving (Fourichon et al., 2001). There are fewer lame cows in organic management farms. Herds with earlier age at first calving had more lameness (Rutherford et al., 2009). There are more lame cows in intensively managed groups (Onyiro et al., 2008)
Herd size	Animals in large herds have an increased risk of developing lameness probably because of more time standing waiting to be milked (Alban, 1995; Holzhauer et al., 2006; Espejo and Endres, 2007; Dippel et al., 2009b; Richert et al., 2013b; Chapinal et al., 2014). There is lower prevalence in smaller herds (Brenninkmeyer et al., 2013). However, other studies found that herd size had no influence on lameness prevalence showing that well-managed farms are able to control lameness (von Keyserlingk et al., 2012; Chapinal et al., 2013)
Housing type including pastures or outdoor pens	Cows permanently housed are more likely to show digital skin and horn disorders owing to standing constantly on concrete and wet manure (Wells et al., 1993; Bergsten and Herlin, 1996; Gitau et al., 1996; Wells et al., 1999; Cook, 2003; de Vries et al., 2005; Leach et al., 2005; Sogstad et al., 2005; Haskell et al., 2006; Holzhauer et al., 2012). Even limited access to pasture or simply allowing cows to exercise in paddocks was shown to reduce lameness incidence, severity and time to full recovery (Gustafson, 1993; Vermunt and Greenough, 1994; Loberg et al., 2004; Regula et al., 2004; Bielfeldt et al., 2005; Hernandez-Mendo et al., 2007; Rouha-Mülleder et al., 2009; Burow et al., 2013; Richert et al., 2013b). Cows with longer access to pasture had lower lameness prevalence (Rutherford et al., 2009; Barker et al., 2010). Being constantly tied with no exercise may affect limbs, joints and tendons affecting movement (Gustafson and Lund-Magnussen, 1995; Keil et al., 2006). However, the prevalence of lameness in zero-grazing cattle can be reduced by good husbandry conditions such as cubicles with adequate dimensions (Haskell et al., 2006; Cook and Nordlund, 2009; Rouha-Mülleder et al., 2009). However, a few studies have shown contradictory results: more lame cows were seen in straw yards than in free-stall housing (Barker et al., 2007); disorders of the skin and interdigital space were most frequently found in tie-stalls with exercise area (Bielfeldt et al., 2005); higher prevalence was found in loose housing than in tie-stalls (Popescu et al., 2013); and more lameness was detected in free stalls than straw yards (Haskell et al., 2006). Being outdoors also carries some risks. Interdigital skin softening and trauma caused by poor outdoor conditions, poorly designed outdoor pens, concrete roads and poorly maintained outdoor walking tracks can increase lameness due to foot injuries or diseases (digital dermatitis or interdigital necrobacillosis) (Chesterton et al., 1989; Clarkson and Ward, 1991; Tranter and Morris, 1991; Alban, 1995; Alban et al., 1996; Fabian et al., 2014; Holzhauer et al., 2006; O'Driscoll et al., 2008a; O'Driscoll et al., 2009; Barker et al., 2009; Burow et al., 2014). Heath stress may also increase the probability of lameness in outdoor settings by altering feeding (predisposing to subclinical ruminal acidosis) and behavioural changes (increased standing time) (Somers et al., 2005). In addition, more lame cows were seen when grazing with sheep (Barker et al., 2010)

Risk factor	Lameness
Nutrition: concentrate input, use of forage, concentrate–fibre ratio	Very intensive or unbalanced diets (high concentrates–forage ratio, high concentrate amount or high dietary protein intake) and errors in feeding management leading to ruminal acidosis are associated with higher incidence of laminitis (Livesey and Fleming, 1984; Manson and Leaver, 1987; Manson and Leaver, 1988a, b; Nocek, 1997; Bergsten, 2003; Kleen et al., 2003; Cook et al., 2004; Thoefner et al., 2004; Nielsen et al., 2013). Transition diets with low fibre, short duration of fibre intake and restricted forage intake near calving increases laminitis and lameness prevalence (DeChant et al., 1998; Donovan et al., 2004). Cows eating wet fermented diets had more hoof problems than those with a dry diet (Leach et al., 2005). Ruminal acidosis and laminitis in pasture-fed cattle should be taken into account in pastures with low levels of effective fibre, rapid rates of fibre degradation, high water content and high concentrations of rumen-degradable protein, particularly when supplemented with concentrate (Westwood et al., 2003)
Output: milk yield per cow	Many studies have found a correlation between hoof lesions (sole ulcers and white line disease) or diseases (interdigital necrobacillosis) and high average milk production (Alban et al., 1995, 1996; Bergsten, 2003; Mulligan et al., 2006; Amory et al., 2008; Onyiro et al., 2008; Rutherford et al., 2009; Brenninkmeyer et al., 2013; Richert et al., 2013b). Mineral deficiencies and negative energy balance that may lead to a thinner digital cushion occur frequently, predisposing cows with high production to foot lesions (Collard et al., 2000; Bicalho et al., 2009; Trevisi et al., 2012; Nielsen et al., 2013). Longer standing time and more frequent lying bouts may predispose high-yielding cows to foot lesions (Navarro et al., 2013). Once-a-day milking resulted in improvements to hoof health and locomotion ability (O'Driscoll et al., 2010). No correlation with production was found for digital dermatitis (Amory et al., 2008). In contrast, several studies did not find a close relationship between production and lameness, showing, once more, that good management and husbandry conditions can help control some risk factors (Haskell et al., 2006; Kujala et al., 2010)
Human factor: management, human–animal relationship	Experience, knowledge, empathy, motivation, income and overall farmers' attitude were found to be closely related to lameness prevalence in a herd (Faye and Lescourret, 1989; Alban, 1995; Rouha-Mülleder et al., 2009; Leach et al., 2010; Lean et al., 2013a; Becker et al., 2014b, c). Early diagnosis, longer times checking cows and regular trimming reduces lameness prevalence, severity and recovery time (Mill and Ward, 1994; Clarkson et al., 1996; Ward, 1999; Fjeldaas et al., 2006; Barker et al., 2007; Smith et al., 2007; Espejo and Endres, 2007; Hernandez et al., 2007; Groenevelt et al., 2014; Lean et al., 2013b). In animals grazing, the patience shown by stockmen when driving cattle was associated with the prevalence of lameness (Clarkson and Ward, 1991). Prevalence is lower when claw trimming is done by the farm stockperson. Outsourcing (e.g. hoof trimmers) has biosecurity risks (Sullivan et al., 2014)
Breed	Reduced occurrence of foot lesions and higher longevity in more rustic breeds has been found (Gandini et al., 2007; Becker et al., 2014b). Lameness was found to be more prevalent in Holstein cows than in some other dairy breeds (Ayrshire, Jersey, Simmental, Meuse Rhine Ijssel, Italian Bruna, Pezzata Rossa Italiana, Grigia Alpina and Pezzata Rossa d'Oropa) (Huang et al., 1995; Holzhauer et al., 2006; Baird et al., 2009; Kujala et al., 2009; Mattiello et al., 2011; Brenninkmeyer et al., 2013; Sarjokari et al., 2013). Brown Swiss and Guernsey breeds have shown higher susceptibility to sole ulcers (Huang et al., 1995). Danish Black and White, Red Danish or Danish Red and White breeds have an increased risk of developing lameness compared with Danish Jersey (Alban, 1995; Alban et al., 1995)

3.4.3.2. Risk factors for mastitis

Table 14 reports the results from the literature review about risk factors for mastitis.

Table 14: Risk factors for mastitis from the literature review

Risk factor	Mastitis
Multifactorial effect: type of farm	Only half of the variability of high SCC is explained at the herd level (Madouasse et al., 2012; Piepers et al., 2012). Severe mastitis was more frequent in most intensive systems and subclinical mastitis was more frequent in less intensive farms. Mastitis with only local signs (udder and milk changes) did not differ between systems (Fourichon et al., 2001). There is higher incidence of clinical mastitis in conventional than in organic herds, but signs to detect and define mastitis differed widely between farmers (Richert et al., 2013c). Other studies have shown similar SCC and clinical mastitis prevalence between organic and conventional herds (Fall et al., 2008; Fall and Emanuelson, 2009; Haskell et al., 2009; Cicconi-Hogan et al., 2013a). Factors associated with SCC differ between organic herds and conventional herds (Cicconi-Hogan et al., 2013a). However, *Staphylococcus aureus* was more frequently isolated in bulk tank milk in organic herds than in conventional (Cicconi-Hogan et al., 2013b). In Brazil, organic farms used less drugs and had lower productivity, but had similar health situations (Honorato et al., 2014)
Herd size	Only severe mastitis was more frequent in the largest herds in France (Fourichon et al., 2001). In contrast, SCC increased in smaller size farms in the same population and also in the USA (Fourichon et al., 2001; Cicconi-Hogan et al., 2013a). However, Simensen et al. (2010) found lower bulk milk SCC but higher incidence of clinical mastitis in smaller herds in Norway
Nutrition: concentrate input, use of forage, concentrate–fibre ratio	In Switzerland, lower herd SCC in organic farms was not associated with any feeding factors (Ivemeyer et al., 2009). In the USA, feeding factors varied between systems: a decrease in SCC was associated with the amount of grain fed and with higher use of external input (for feed, advice, reproduction and vaccination). In organic herds only, use of anionic salts in transition cow diets was associated with decreased SCC (Cicconi-Hogan et al., 2013a)
Output: milk yield per cow	Milk yield is a well-known risk factor for mastitis, as demonstrated by a large number of studies. However, some high-yielding herds manage to cope with that risk and have low incidence of mastitis (Fourichon et al., 2001)
Housing type: pastures use and exercise	A higher incidence of clinical mastitis in herds in tie-stall than in free-stall housing was found, but, in contrast, the proportion of udder composite milk test day records with SCC > 200 000 cells/mL was lower (Gordon et al., 2013). In herds of 50 cows, the incidence of clinical mastitis was lower in free-stalls than in tie-stalls, whereas, in smaller herds (20 cows), there was no difference (Simensen et al., 2010). Soft flooring materials in free stalls (rubber mats, multilayer mats or mattresses) were associated with lower incidence of clinical mastitis (Ruud et al., 2010). However, substantial differences in risk factors for clinical mastitis and for high SCC in herds were found in tie-stall or free-stall housing systems. The association between housing system and housing characteristics (bedding, stall base, stall length) and intramammary infection with *Staphylococcus aureus* differed for cows in different parities in the same herds. Similarly, the association of stocking density with elimination of infection depended on days in milk (Dufour et al., 2012). In Switzerland, lower herd SCC was described in organic farms with Alpine summer pasturing, while there was no effect of housing (except soft bedding) (Ivemeyer et al., 2009). In the Netherlands, the incidence of subclinical mastitis in first-parity cows was lower in herds with day and night grazing (Santman-Berends et al., 2012). In Brazil, there was no difference in the percentage of cows with high SCC between small size farms and extensive, pasture-based and semi-intensive farming systems (Costa et al., 2013). Herds sending lactating cows to seasonal communal grazing were at higher risk of being infected with contagious genotype strains of *Staphylococcus aureus* (Berchtold et al., 2014). Cleanliness of the cows kept outdoors (in pens or paddocks) was associated with SCC and varied with season with a higher proportion of dirty cows in rainy months in Brazil (Sant'anna and Paranhos da Costa, 2011). However, others studies found no difference in SCC or *Staphylococcus aureus* in bulk tank milk between grazing and non-grazing conventional herds (Cicconi-Hogan et al., 2013b). These results show the complexity of multifactorial associations (Gordon et al., 2013)

Risk factor	Mastitis
Breed	Holstein are considered to be at a higher risk of mastitis than other breeds and differences can be observed in comparison with Normande (Fourichon et al., 2001) and Swedish Red (Nyman et al., 2009). In organic farms in Switzerland, lower herd SCC was described in Alpine Fleckvieh cows than in other breeds (Ivemeyer et al., 2009). In the Netherlands, the Red and White cattle (Meuse-Rhine-Yssel) showed a higher rate of clinical mastitis caused by *Staphylococcus aureus* than other breeds (Elbers et al., 1998)
Human factor	The human factor is paramount in the causal pathway of mastitis. This probably explains why mastitis prevalence varies to a very large extent even between similar farming systems. Many risk factors result from inadequate management resulting in increased exposure of the udder to pathogens (e.g. poor hygiene, milking technique, milking parlour equipment maintenance, housing conditions), or in decreased ability of the cow to control the infection (e.g. teat lesions, poor feeding, stress)

3.4.3.3. Risk factors for metabolic diseases

Table 15 reports the results from the literature review about risk factors for metabolic diseases.

Table 15: Risk factors for metabolic diseases from the literature review

Risk factor	Metabolic diseases
Multifactorial effect: type of farm	Ketosis was found to be higher in cold versus warm seasons, and in older cows versus younger cows (Berge and Vertenten, 2014). The prevalence of subclinical ketosis in certain European countries was 21.8 % (Suthar et al., 2013), and was higher in organic farms (Abuelo et al., 2014)
Herd size	Large herds were found to be at a low risk of ketosis (Berge and Vertenten, 2014), but at a high risk of displaced abomasums or clinical ketosis (Stengärde et al., 2012). Herds in small free stall and tie-stall barns were similar in both performance and health (Simensen et al., 2010).
Nutrition: concentrate input, use of forage, concentrate–fibre ratio	Transition cows were found to have negative energy balance and/or perturbed energy metabolism (fatty liver, ketosis, subacute, acute ruminal acidosis); disturbed mineral utilisation (milk fever, subclinical hypocalcaemia); and perturbed immune function (retained placenta, metritis, mastitis) (Esposito et al., 2014). High concentrate diets lead to a high risk of ketosis in small organic and conventional farms (Richert et al., 2013). Reducing concentrates in organic farms had no negative effects on health and fertility of cows (Notz et al., 2013). Feeding in the morning only during the summer is a risk factor for proper metabolic and physiological functioning of the cows (Calamari et al., 2013). There was a risk of ruminal acidosis with fine maize particles (De Nardi et al., 2014); short eating time and increased eating rate (Nasrollahi et al., 2014); total mixed ration with small particle size and thoroughly mixed (Kmicikewycz and Heinrichs, 2014; Golder et al., 2014); and only one diet offered without the possibility for cows to select the diet (Moya et al., 2014). The subacute ruminal acidosis risk increased when high-grain diets (Gao and Oba, 2014). Recovery was demonstrated after 72 hours when cows were fed appropriate diets (Maulfair et al., 2013). A reduced risk was demonstrated when ground maize was substituted with beet pulp (Guo et al., 2013), and when fed active dried and killed dried yeast (Vyas et al., 2014). Hypocalcaemia and milk fever are associated with metabolic alkalosis due to high dietary cation–anion difference diets (Goff et al., 2014). Control of the zinc and iron status of cows should be included in the prevention and therapy of milk fever (Heilig et al., 2014). Anionic minerals did not prevent hypocalcaemia (Greghi et al., 2014). Total mixed ration particle size had a significant effect on incidence of displaced abomasums (Simoes et al., 2013). Lower serum alpha-tocopherol concentration was a potential early indicator for displaced abomasum in multiparous cows (Qu et al., 2013). Lower BCS during the lactation was genetically associated with mastitis and metabolic disease (Loker et al., 2012)
Output: milk yield per cow	High maximum daily milk yield was a risk factor for displaced abomasum or clinical ketosis (Stengärde et al., 2012)

Risk factor	Metabolic diseases
Housing type: pastures use and exercise	There is low prevalence of bloat and ketosis in intensive pasture-based systems, while acidosis has a high point prevalence (Lean et al., 2008). Mean herd-level prevalence of subclinical ketosis in New Zealand was 14.3 and 2.6 % at 7–12 and 35–40 days post calving, respectively (Compton et al., 2014), and in a grazing production system was 10.3 % between 4 and 19 days in milk (Garro et al., 2014). Stall barn confinement in small conventional and organic farms results in a high risk of ketosis (Richert et al., 2013c). Increased pasture in diet increased the risk of diarrhoea in Australian dairy herds (Bramley et al., 2013). Oat and perennial ryegrass pasture diets in winter increase non-parturient hypocalcaemia (Coneglian et al., 2014)
Breed	Holsteins were found to differ in health and production compared with Jerseys owing to different hormones and metabolites concentrations (Brown et al., 2012). Lipolysis and ketogenesis in Czech Fleckvieh dairy cows show high metabolism adaptation in the perinatal period (Kupczyński et al., 2011)
Human factor	Both shortening and omitting the dry period reduce the ketosis risk in the next lactation (van Knegsel et al., 2013; Koepf et al., 2014; Shoshani et al., 2014). Keeping dry cows in one group and not cleaning the feeding platform daily are risk factors for displaced abomasum or clinical ketosis (Stengärde et al., 2012)

3.4.3.4. Risk factors for reproductive disorders

Table 16 reports the results from the literature review about risk factors for reproductive disorders.

Table 16: Risk factors for reproductive disorders from the literature review

Risk factor	Dystocia	Metritis
Multifactorial effect: type of farm	The primary risks are primiparity, twin calves, male calves and a high weight of calves at birth (Atashi et al., 2012)	Proximate risks related to animal include dystocia, twin calves, retained placenta (Benzaquen et al., 2007; Dubuc et al., 2010; Hossein-Zadeh and Ardalan, 2011), stillbirth, abortion, prolapsed uterus (Galvao, 2012) and ketosis (Berge and Vertenten, 2014). In Wisconsin, USA, metritis incidence is lower in organic (average herd size 200 cows) than in conventional farms (average herd size 75 cows) (Pol and Ruegg, 2007). There is also low incidence (3 %) for organic Brown Swiss cows in Switzerland (Yin et al., 2014)
Herd size	No association between herd size and risk of dystocia has been found (Fourichon et al., 2001 (64 cows); Mee et al., 2011 (pasture-based systems)). However, increased herd size results in less attention to cows at calving, increasing unattended difficult calvings (Mee, 2008; Stafford, 2011)	While Fourichon et al. (2001) and Bruun et al. (2002) found no effect of herd size (average number of cows approximately 60), metritis risk increased with herd size in the studies of Kaneene and Miller (1995) and Garcia et al. (2005) (both studies up to more than 200 cows). No effect of herd size was found in small-scale farms (Fourichon et al., 2001; Bruun et al., 2002) and the risk increases with herd size (Kaneene and Miller, 1995; Garcia et al., 2005)
Nutrition: concentrate input, use of forage, concentrate–fibre ratio		

Risk factor	Dystocia	Metritis
Output: milk yield per cow	There is little evidence for an effect of high milk yield on the risk of dystocia (review: Ingvartsen et al., 2003). In Holstein systems, the highest median incidences for 9 out of 14 disorders including dystocia and metritis were found in the very intensive group (i.e. low age at first calving, high level of concentrates, high proportion of maize in the total fodder crop area and high average milk yield) (Fourichon et al., 2001)	
Housing type: pastures use and exercise	Dystocia was found to be lower in loose housed than in tethered cows (Mee et al., 2014) and the risk was lower when cows were kept on pasture during the summer (Bendixen et al., 1986; Mee et al., 2014), but stillbirth was higher (Mee et al., 2014). There was an increased risk with autumn–winter calvings (Erb and Martin, 1980). Dystocia incidences in pasture-based systems (Stevenson, 2000; Mee et al., 2011; Stafford, 2011; Ribeiro et al., 2013) are similar to other production systems (Mee, 2008; Coignard et al., 2013)	No effect of housing (Coleman et al., 1985) or housing system and type of bedding on metritis was found (Bruun et al., 2002). Housing conditions (cow comfort) were shown to play a role in the prevention of metritis and ketosis (Galvao, 2013). There was a higher risk of early metritis in autumn–winter calving cows (Gröhn et al., 1990) and a lower risk for summer calvings or for cows that have access to pasture in summer (Bruun et al., 2002)
Breed	Non-Holstein, mostly dual-purpose breeds showed higher rates of dystocia in France (Fourichon et al., 2001). There was a lower risk of dystocia in Jerseys than in Holsteins (Olson, 2009). Increasing dystocia was found in Sweden, Canada and the USA due to “holsteinisation” (Mee, 2008)	Jerseys developed less metritis than large breeds (Bruun et al., 2002)
Human factor		Metritis risk decreased with the routine use of veterinarians for disease investigation (Kaneene and Miller, 1995)

Conclusions and recommendations

Conclusions

Conclusions related to ToR1: a review of the available descriptions and categorisations of small-scale/non-conventional farms

- Without further specifications, the term “small-scale dairy farms” may be perceived in different ways, as no standardised information is available. It can be associated with herd size only, but, according to the mandate, this opinion interprets small-scale farms not only in relation to herd size, but also as encompassing other aspects of interest for the consumers about the production process, and so is related to non-conventional farming as well.
- Information on the distribution of farms by size is available, but other data describing small-scale farms from the literature and from umbrella organisations of dairy farmers in Europe are scarce.
- For the purpose of this mandate, in addition to herd size (up to 75 cows), non-exclusive criteria proposed to define small-scale farms related to non-conventional farming comprised the source of the workforce (family based), level of input (concentrate use, reflecting high use of forage), use of indigenous breeds and type of production (certification schemes).

- To cover a broad spectrum of small-scale farms, it was considered reasonable that farms meeting at least two of these criteria be considered non-conventional.
- The category of partial pasture use defined by the terms of reference can be further split into the categories of "restricted grazing" (less than 120 days on pasture) and "extended grazing" (between 120 and 300 days on pasture).
- In addition to the criteria used for the definition, many others were identified to further describe small-scale farms (e.g. land use, economic size).
- There is high variability in herd size across Europe in small-scale farms with up to 75 cows, as demonstrated by all data sources analysed in this opinion.
- A high variety of small-scale farms across Europe was found as regards all data sources analysed in this opinion for the criteria used for description and categorisation.
- Simple categorisation of small-scale/non-conventional farms taking into account the sizes and types of farming systems and husbandry practices was not possible because of the high variety of systems across Europe. The proposed criteria for definition of small-scale farms can be applied successfully in different EU countries.
- The criteria proposed for the definition and description of small-scale farms (e.g. herd size, source of work) are largely independent from each other and they all provide separate information to characterise a farming system.

Conclusions related to ToR2a: the main factors and welfare consequences under the above-classified farming systems and risk assessment methodology for risk ranking

- The same risk factors identified in the EFSA opinion of 2009 for intensive farming systems were also relevant for the systems addressed in this opinion. In addition, some factors were considered more likely to be present in small-scale systems related to resources provided on pasture (e.g. shelter), management of pasture (e.g. mixing herds) and management of the cows (e.g. use of local breeds).
- Based on the on-farm survey outcomes, risk factors do not differ among categories of farms divided by time spent on pasture.
- However, distinct clusters of farms were identified related to shared risk factors. The major factors differentiating clusters relate to pasture management (e.g. water provision, mixing of different herds during the summer), housing related to lying and feeding area, procedures used for disbudding of calves and cleanliness of the animals (as a risk factor for mastitis, for example), indicating that the majority of these factors are not related to the criteria used for the categorisation of small-scale farms.
- As shown by the risk ranking, some risk factors that can be present in small-scale farms (e.g. stocking density at feeding, herd milk yield, overgrown claws, stocking density at pasture, amount of concentrate fed at peak lactation) have been shown to be associated with lameness prevalence. No ranking of risk factors could be obtained for mortality, prevalence of very lean animals and prevalence of animals with skin lesions or swellings. The ranking outcomes are specific to the sample taken.
- The welfare consequences, as measured by the corresponding animal-based measures, identified for intensive farming systems were also considered relevant for the systems addressed in this opinion.
- The modified Welfare Quality assessment protocol applied in this opinion allowed efficient collection of data on a large number of animal-based measures in small-scale farms.
- Other animal-based measures gave useful information and showed variation between farms: (1) age at culling reflecting longevity, (2) rising behaviour, (3) claw conditions and (4) clinical mastitis.

- The distribution of risk factors and animal-based measures varied across the full range in the study farms. There were almost no farms that consistently displayed a low level of risks or a high level of welfare.
- Related to the on-farm risk factor identification, there is little potential to reduce the protocol because only a few risk factors provide redundant information.

Conclusions related to ToR2b: the suitability of animal-based measures for dairy cows, identified by the 2012 EFSA scientific opinion, for assessing animal welfare in the above-classified farming systems

- Animal-based measures identified in the EFSA opinion of 2012 for intensive farming are well suited for application in small-scale dairy farms.
- The difficulties in recording animal-based measures are similar in small-scale farms and in intensive farms. However, there are a few specific difficulties (e.g. longer time needed to achieve sufficient sample size for behaviour measures).
- Milk SCC data are often not available. Electronic records are missing in most of the farms, so assessment has to rely on records other than electronic ones (e.g. written records) and/or farmer estimates.
- The assessment of a limited number of resource/management-based measures (e.g. provision of water, procedures used for disbudding of calves) appears to be feasible where no animal-based measure is available.
- Prevalence measures may be difficult to interpret for very small herd sizes (i.e. impact of single animals on prevalence at herd level).
- The vast majority of animal-based measures provide independent information on the welfare status of a herd. There is very little potential to reduce the number of animal-based measures for an on-farm welfare assessment. Moreover, omitting single measures often does not lead to a significant reduction in the time needed to perform the assessment, as groups of measures are jointly assessed in the same sample of animals.
- Some of the animal-based measures may exhibit low feasibility and reliability if assessed when cows are on pasture (e.g. avoidance distance, behaviour around resting).

Conclusions related to ToR2c: an assessment of the impact of production diseases on welfare

Impact of production diseases on welfare of dairy cows in general:

- The impact of diseases on the individual animal's welfare state does not depend on herd size or farming system.
- Welfare consequences of subclinical mastitis are not well known.
- Variability of incidence and prevalence of production diseases is high between farms.
- It is well documented that high-yielding cows are generally more likely to develop production diseases (e.g. ketosis). Proper management is especially important for fulfilling the needs of these cows independently of the system.

Impact of production diseases on welfare of dairy cows in small-scale farms:

- Very little of the literature addresses specifically the risk factors for the occurrence and welfare consequences of diseases in small-scale farms.
- Most diseases have a multifactorial origin not specific to a farming system. There are almost no risk factors for disease that are specific to small-scale farms.

- Generalisations of results from studies comparing production diseases between systems in a given country in a given time cannot be done without precautions because farming systems and husbandry practices show high variability among small-scale farms.
- Small-scale farms are more likely to provide access to pasture, thus reducing the incidence of some diseases (e.g. lameness). However, access to pasture can increase the incidence of other diseases (e.g. metabolic disorders, interdigital necrobacillosis).
- Organic or small-scale farms less frequently outsource technical and veterinary assistance because they tend to initiate therapy by themselves.

RECOMMENDATIONS

Recommendations related to ToR1: a review of the available descriptions and categorisations of small-scale/non-conventional farms

- In addition to herd size (up to 75 cows), farms meeting at least two of the following criteria can be considered non-conventional: more than 80 % of the workforce provided by family members (including partners and their families, e.g. cooperation of farms, neighbours and partner farms); less than 800 kg of concentrate per cow per year; at least 50 % of cows from indigenous breeds (local/regional protection scheme); holding one of the following certifications: organic/biodynamic production, protected designation of origin (PDO), protected geographical indication (PGI) or traditional specialities guaranteed (TSG).
- Although a median threshold for concentrate use of 800kg/cow/year was chosen for the production systems considered in this opinion, regional or national differences (e.g. climatic conditions more or less favourable to forage production) should be taken into account and the threshold may have to be adapted at national level.
- Beyond farm/herd size, better coordination in recording and sharing of some data is needed (e.g. level of access to pasture, breeds, marketing channels, certification schemes).
- In addition to the criteria used for the definition, many others may be used to further describe small-scale farms (e.g. land use, economic size). As the criteria proposed for the definition and description of small-scale farms are independent from each other, they should be considered separately for providing a detailed description of small-scale farms.

Recommendations related to ToR2a and ToR2b: the main factors and welfare consequences under the above-classified farming systems and risk assessment methodology for risk ranking

- Overall, it is recommended that the risk factors and animal-based measures proposed in this assessment be used with the suggested minor modifications.
- If the protocol is used when cows are on pasture, parameters have to be adapted (e.g. avoidance distance) or time points have to be defined of when assessment should be done (before and after milking, during pasture).

Recommendations related to ToR2c: an assessment of the impact of production diseases on welfare in small-scale dairy cow farming systems

- Small-scale farmers, who are less likely to rely on veterinary assistance, need to be provided with tools for checking cow health, such as specific animal-based measures.
- In addition to SCC, measures of clinical mastitis should be added to the animal-based measure collection protocol to assess welfare consequences of mastitis in dairy farms.

Recommendations for further research

- For enabling the identification of risk factors present in small-scale farms, there is a need for an extension of this pilot study to cover all seasonality differences (e.g. to include a better representation of pasture-related risk factors during the summer).
- For enabling the ranking of risk factors present in small-scale farms, there is a need for an extension of this pilot study to include a better representation of all small-scale farming systems in Europe.
- The effect on welfare of subclinical mastitis (demonstrated by increases in SCC without visible changes in the milk or the udder) should be further investigated.
- There is a need for further research addressing specifically the risk factors for the occurrence and welfare consequences of diseases in small-scale farms.

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APPENDICES

Appendix A. List of variables used as farm descriptors, including short name of the variable and results.

Continuous variables are reported in the first table, categorical variables in the second table.

Variable	Short name of the variable	Unit	Minimum	Mean	Median	Maximum	Std Dev	N Missing
Total number of cows for dairy production	nDairyCows	n	10	34	33	75	17	0
Age at culling during previous 12 months	AvAgeAtCulling	months	30	90	84	216	33	21
Percentage of income from dairy production	PIncDairyProd	%	15	81	90	100	22	2
Age of the milking parlour	aMilPar	years	0.16	15	14	45	10	14
Proportion of cows in first lactation	pCowsFL	%	0	22	22	50	9	1
Proportion of cows in second /third lactation	pCowsSecThrdLact	%	3	36	35	69	13	2
Proportion of cows in fourth/ fifth lactation	pCowsFouFifLact	%	0	23	24	56	11	7
Proportion of cows in sixth or more lactation	pCowsSixMoLact	%	0	15	13	63	12	7
Ratio of heifers on the number of cows	pHeifers	%	0	57	54	153	31	0
Number of bulls	nBulls	n	0	0.6	0.0	8.0	1.3	0
Proportion of disbudded/ dehorned cows	pDisDehNDehornAn	%	0	64	82	127*	41	12
Time the newborn calf is left with the mother after birth	LCalfKWMoth	hours	0	9	1	204	26	5
Average calving rate during previous 12month	avgCalvingRate	% (can be>100)	23	70	76	144	24	46
Calving interval during previous 12 months	calInt	days	335	388	390	468	26	26
Number of milkings per day	dMilkFreq	n/day	1	1.99	2	2.2	0.09	1
Proportion of direct sale of milk	propDirectSale	%	0	18	0	100	34	1
Percentage of heifers bought from outside the farm	ClosedHerd	%	0	6	0	100	16.6	0
Number of hours on pasture per year	AnnualHrsPasture	Hours/ year	0	2781	2160	8760	2452	0
Number of hours on Outdoor Loafing Area per year	AnnualHrOLA	Hours/ year	0	1034	0	8760	2517	1
Access to outdoor loafing area or pasture	OutdoorAccess	Hours/ year	0	2843	2180	8760	2416	0
Average number of functional trimmings	funcTrimYear	n/cow/ year	0	1.07	1	7	0.96	9
Milk yield at herd level during previous 12 months	hMYield	kg	2100	6125	6017	10709	1880	0
Amount of concentrates fed at beginning of dry period	kgConFeedDry	kg/ day	0	0.92	0	11.5*	1.6	0
Amount of concentrates fed to housed cows at peak lactation	kgConPeakLact	kg /day	0	6.63	5.5	31*	5.04	1

Variable	Short name of the variable	Unit	Minimum	Mean	Median	Maximum	Std Dev	N Missing
Amount of concentrates fed before calving	kgConFeedBCal	Kg/day	0	2.28	2	12	2.17	6
Amount of concentrates fed to dry cows on pasture	kgConPasDry	kg / year	0	40	0	1525	173	14
Amount of concentrates fed in farms with access to pasture	kgConPasLact	kg / cow/ year	0	756	300	5490	1261	15
Percentage of concentrate bought from outside the farm	perConBouOut	%	0	80	100	100	37	0
Percentage of forage bought from outside the farm	perForBouOut	%	0	25	10	100	32	0
Total forage area	totalForageArea	ha	0	29	25	120	23	1
Maximum distance of summer shelter from pasture	mDistanceSSPast	Km	0	1.97	0	40	7.78	78
Number of anti-frost drinkers	nAnti-frostDrinker	n	0	0.07	0	2	0.32	8
Number of bowls	nBowl	n	0	4.7	1.0	34.0	7.2	8
Number of bowls with reservoir	nBowlReservoir	n	0	0.3	0.0	16.0	1.6	8
Number of troughs/farm	nTrough	n	0	1.1	1.0	8.0	1.5	8
Number of all water points	nWaterPointsAll Types	n	1	8	4	40	9	8
Proportion of natural mating in the farm	propNatMating	%	0	21	0	100	37	1
Total pasture area	totalPastArea	ha	0.0	31.8	15.5	190.0	43.1	2
Proportion of cubicles facing cubicles	pCubACub	%	0.0	48.7	50.0	100.0	42.2	64
Proportion of cubicles facing the wall	pCubWall	%	0.0	49.8	46.2	100.0	42.9	64
Proportion of cross-bred cows at time of visit	pCross_breed	%	2.0	23	12	94	25	99
Proportion of Holstein cows	pHolstein	%	3	74	88	100	32	81
Proportion of not Holstein cows	pNotHolstein	%	0.0	69*	100*	105*	43	0
Number of employees working with dairy cows (n) *= improper value due to submitted data quality issues	workforce	%	0	0.2	0.0	2.2	0.5	0

Categorical Variables	Short name of the variable	Score	Number (farms)	Percentage for each value within the column
Change of milking system (or milker) during summer	chMilkSysDSum	missing	25	20.2
		0= no	92	74.2
		2= yes	7	5.7
Community (multi-herd) collection of milk	comColl	0= no	82	66.1
		2= yes	42	33.9
Type of milking system	mSyst	0 -manual milking	2	1.6
		1 - machine milking	119	96.0
		2 - robotic milking	3	2.4
Claw Trimming performed by farmer or by external personnel	clawTrimP	missing	18	14.5
		0 - performed by farmer	45	36.3
		2 - performed by personnel	61	49.2
Mixing with other herds during summer grazing	mixSummGra	missing	25	20.2
		0= no	86	69.4
		2= yes	13	10.5
Mixing with other species during summer grazing	mixSummGraOthSp	missing	25	20.2
		0= no	89	71.8
		2= yes	10	8.1
Seasonal calving	seasCal	0= no	101	81.5
		2= yes	23	18.6
Presence of other species in the same farm	othAnimal	0 = no	74	59.7
		1 = yes, farm species	2	1.6
		2 = yes, other species	48	38.7
Veterinary advice for vaccination plan (yes/no)	vetAdviceVP	missing	1	0.8
		0 = no	72	58.1
		2 = yes	51	41.1

Appendix B. List of variables used as risk factors, including short name of the variable and results (all risk factors are considered at the herd level).

Continuous variables are reported in the first table, categorical variables in the second table.

Variable	Unit	Short name of the variable	Minimum	Mean	Median	Maximum	Std Dev	N Missing
Number of dairy cows	n	nDairyCows	10	34	33	75	17	0
Percentage of heifers bought from outside the farm (closed herd)	%	ClosedHerd	0	6	0	100	17	0
How many days before calving do you start to give concentrate feed?	days	dayBefCalCon	0	17	14	70	19	28
Number of hours on pasture per year	(hours/ year)	annualHoursPasture	0	2781	2160	8760	2452	0
Number of hours on Outdoor Loafing Area per year (hours/year)	(hours/ year)	annualHoursOLA	0	1034	0	8760	2517	1
Milk Yield at herd level (During previous 12 month)	Kg	hMYield	2100	6125	6017	10709	1880	0
Kg of concentrate fed at the beginning of dry period	Kg	kgConFeedDry	0.0	0.9	0.0	11.5	1.6	0.0
Amount of concentrates fed for housed lactating cows at peak lactation	Kg	kgConPeakLact	0.0	6.6	5.5	31.0	5.0	1.0
Length of dry period	days	lengthDryPer	0	59	60	114	13	2
Maximum distance in Km of summer shelter from pasture	Km	mDistanceSSPast	0	2	0	40	8	78
Times/day food is pushed towards the cows	n	nFoodPushToCows	0	2.0	2.0	3.0	1.2	0.0
nMealsDay	n	nMealsDay	0.5	2.4	2.0	10.0	1.5	0.0
Number of Calving Pens	n	numCalPen	0	0.6	0.0	10.0	1.1	0.0
Area of Pasture Per Cow	ha	AreaPasturePerCow	0	1.2	0.6	13.6	1.9	2.0

Categorical variables	Score	Number (farms)	Percentage for each value within the column
Change of the milking system (or personnel) during summer	missing	20	25
	0 = no	74	92
	2 = yes	6	7
Availability of equipment for claw trimming	0 = no trimming	52	65
	1 = portable claw trimming chute shared with neighbours	13	16
	2 = own equipment on farm	35	43
Dairy cows have access to pasture	0 = no	22	27
	2 = yes	78	97

Categorical variables	Score	Number (farms)	Percentage for each value within the column
Dairy cows have access to outdoor loafing area/pasture	0 = no	78	97
	2 = yes	22	27
Presence of dead ends	missing	43	53
	0 = yes	46	57
	2 = no	11	14
FunctioningWaterPoints	missing	7	9
	0 = yes	82	102
	2 = no	10	13
Mixing with other herd during summer grazing	missing	20	25
	0 = no	69	86
	2 = yes	10	13
Water Availability at Pasture	missing	20	25
	0 = no	6	7
	2 = yes	74	92
Water points at pasture	missing	23	29
	0 = natural sources of water	20	25
	1 = drinker	35	44
	2 = mixed	21	26

Appendix C. List of animal-based measures, including short name of the variable and results

Variable	Unit	Number of farms	Number of missing	Minimum	Mean	Median	Maximum	S.E.M.	Lower Quartile	Upper Quartile
Average AgeAtCulling	Months	103	21	30	90	84	216	33	66	108
AvoidanceDistance100cm or more	%	110	14	0	11	3	100	17	0	18
AvoidanceDistance 50-99cm	%	110	14	0	11	10	48	11	0	17
AvoidanceDistance Closer50cm	%	110	14	0	40	40	88	17	30	50
AvoidanceDistance Touched (0cm)	%	110	14	8	63	61	100	21	50	79
BCS VeryFat animals	%	124	0	0	10	7	50	11	0	15
BCS VeryLean animals	%	124	0	0	8	6	80	11	0	12
Claw Condition2	%	123	1	0	18	8	100	24	0	30
Diarrhoea	%	124	0	0	3	0	67	9	0	0
DirtyHindQuarter	%	124	0	0	47	38	100	32	19	77
DirtyLegs	%	124	0	0	57	63	100	34	22	89
DirtyUdder	%	124	0	0	42	40	100	26	23	57
DownerCows	%	124	0	0	2	0	13	3	0	4
Dystocia	%	124	0	0	5	2	67	8	0	6
Collision with equipment when rising	%	113	11	0	23	17	100	26	0	40
HairlessBody	%	124	0	0	32	30	87	21	14	44
HairlessCarpus	%	124	0	0	23	16	94	26	3	38
HairlessLowerHindLeg	%	124	0	0	17	12	64	17	3	27
HairlessPatches	%	124	0	0	39	35	90	20	23	55
HamperedRespiration	%	124	0	0	0	0	8	1	0	0
Lameness1and2	%	124	0	0	20	16	89	19	7	31
Lameness2	%	124	0	0	11	10	61	12	0	15
LesionBody	%	124	0	0	9	7	44	9	0	14
LesionCarpus	%	124	0	0	1	0	31	3	0	0
LesionLowerHindLeg	%	124	0	0	3	0	27	5	0	4

ManureHindQuarter	%	124	0	0	46	38	100	32	18	75
ManureLegs	%	124	0	0	54	60	100	34	19	85
ManureTeat	%	124	0	0	28	25	89	22	10	40
ManureUdder	%	124	0	0	28	20	100	26	6	42
MilkSomaticCellCount	%	99	25	0	16	13	83	16	5	21
Mortality	%	124	0	0	4	2	56	8	0	5
MudHindQuarter	%	124	0	0	1	0	31	4	0	0
MudLegs	%	124	0	0	3	0	100	15	0	0
MudTeat	%	124	0	0	1	0	34	5	0	0
MudUdder	%	124	0	0	1	0	31	4	0	0
NasalDischarge	%	124	0	0	3	0	51	7	0	3
OcularDischarge	%	124	0	0	0	0	6	1	0	0
OutsideLyingArea	%	115	9	0	16	0	100	26	0	23
pMastitis12Month	%	121	3	0	0	0	1	0	0	0
QBA	score (0-100)	124	0	16	57	59	101	18	47	68
RisingScore3or4	%	114	10	0	24	22	100	24	0	40
RisingScore5	%	114	10	0	8	0	100	19	0	0
SwellingBody	%	124	0	0	2	0	29	4	0	3
SwellingCarpus	%	124	0	0	2	0	26	4	0	3
SwellingLowerHindLeg	%	124	0	0	3	0	25	5	0	4
SwellingOrLesion	%	124	0	0	17	13	75	14	7	25
VulvarDischarge	%	124	0	0	1	0	17	3	0	1

Appendix D. Results of the inter-observer reliability testing performed on-farm, from videos or from pictures and during a video retraining session (n= 9 observers)

	Median (min-max)						
Indicator	**Number of cows/observations**	**Gold standard prevalence (%)**	**Observer prevalence (%)**	**Percentage agreement (%)**	**Cohen's kappa**	**Gwet's AC1**	**Correlation coefficient**
On-farm assessment							
Body condition (3 scores)	29 (27–30)	Very lean: 7 Very fat: 23	Very lean: 10 (3–15) Very fat: 17 (11–31)	78 (62–87)	0.77 (0.61–0.87)	0.71 (0.48–0.83)	-
Cleanliness lower hindleg (0/1)	30 (29–30)	20	30 (17–53)	86 (67–93)	0.66 (0.36–0.76)	0.77 (0.38–0.90)	-
Cleanliness hindquarter (0/1)	30 (29–30)	40	30 (17–43)	77 (70–83)	0.49 (0.31–0.64)	0.57 (0.42–0.71)	-
Cleanliness udder (0/1)	30 (26–30)	7	7 (0–13)	93 (87–97)	0.35 (0.00–0.65)	0.92 (0.84–0.96)	-
Cleanliness teats (0/1)	30 (26–30)	50	63 (40–83)	60 (43–67)	0.20 (–0.13–0.33)	0.23 (–0.12–0.36)	-
Number of hairless patches (n)	29 (25–30)	83	58 (48–83)	55 (39–66)	-	-	0.47 (0.13–0.71)
Number of lesions/ Swellings (n)	29 (22–30)	53	43 (16–52)	50 (41–69)	-	-	0.31 (–0.09–0.97)
Presence of at least 1 hairless spot but no lesion/swelling (0/1)	29 (18–30)	40	31 (6–48)	67 (36–79)	0.20 (–0.39–0.56)	0.43 (–0.19–0.61)	-
Presence of at least 1 lesion or swelling (0/1)	29 (22–30)	53	43 (16–52)	76 (52–83)	0.52 (0.11–0.78)	0.52 (0.11–0.78)	-
Nasal discharge (0/1)	30 (29–30)	7	3 (0–20)	93 (79–97)	0.35 (–0.10–0.78)	0.93 (0.74–0.96)	-
Ocular discharge (0/1)	30 (29–30)	0	0 (0–0)	100 (100–100)	n.a.[1]	n.a.	-
Purulent ocular discharge (0/1)	30 (29–30)	0	0 (0–3)	100 (97–100)	n.a.	0.97 (0.97–0.97)	-

	Median (min-max)						
Indicator	**Number of cows/observations**	**Gold standard prevalence (%)**	**Observer prevalence (%)**	**Percentage agreement (%)**	**Cohen's kappa**	**Gwet's AC1**	**Correlation coefficient**
Hampered respiration (0/1)	30 (30–30)	0	0 (0–7)	100 (93–100)	n.a.	0.95 (0.93–0.97)	-
Signs of diarrhoea (0/1)	30 (29–30)	3	3 (0–20)	93 (77–97)	n.a.	0.93 (0.07–0.97)	-
Vulvar discharge (0/1)	30 (29–30)	0	0 (0–7)	100 (93–100)	n.a.	0.96 (0.93–0.97)	-
Overgrown claws (0/1)	29 (25–30)	17	4 (0–13)	83 (80–86)	0.21 (–0.07–0.35)	0.78 (0.76–0.84)	-
Lameness (3 scores)	29 (24–30)	Overall lame: 70 Slightly lame: 23 Severely lame: 47	Overall lame: 55 (34–87); Slightly lame: 24 (0–43); Severely lame: 22 (10–53)	50 (41–60)	0.19 (–0.02–0.38)	0.25 (–0.07–0.40)	-
Assessment from pictures							
Body condition (3 score)	32 (32–32)	Very lean: 13 Very fat: 31	Very lean: 23 (13–41) Very fat: 34 (25–47)	78 (56–88)	0.64 (0.34–0.80)	0.69 (0.36–0.82)	-
Video assessment							
Lameness (3 scores)	38 (38–38)	Overall lame: 56 Slightly lame: 21 Severely lame: 36	Overall lame: 64 (42–74); Slightly lame: 32 (24–37); Severely lame: 32 (18–42)	78 (58–89)	0.65 (0.36–0.84)	0.67 (0.37–0.84)	-
Lying partly/completely outside lying area (0/1)	78 (78–78)	28	25 (22–31)	95 (92–96)	0.87 (0.82–0.90)	0.91 (0.87–0.94)	-
Qualitative assessment of rising movement (5 scores)	28 (28–28)	-	-	64 (25–96)	0.54 (0.11–0.95)	0.56 (0.06–0.99)	0.84 (0.73–0.99)
QBA score	17 (17–17)	-	-	-	-	-	0.36[2]
Retesting (video assessment)							
Lameness (3 score)	40 (40–40)	Overall lame: 60 Slightly lame: 28 Severely lame: 33	Overall lame: 58 (48–80) Slightly lame: 28 (18–38) Severely lame: 33 (20–45)	78 (65–93)	0.65 (0.47–0.89)	0.67 (0.48–0.89)	-

1: n.a. = coefficient not calculable 2: Kendall W correlation coefficient for all 10 observers

Appendix E. Table on means and number of farms in each category for clusters of farms found considering risk factors that are having less than 50 % missingness and that the recorded values are not been represented by a single value for more than 50 % of the recorded values

Clustered item	Number of variables with less than 50 % missing values and less than 50 % non-constant recordings	Number of principle components explaining 70 % variability	Number of clusters proposed in the final dendrogram	Value of critical height	Number of clusters where the Rand index reached the maximum value (maximum median value reached)
Farm descriptors	38		34	0.36	34(1)
Risk factors	30		21	0.34	21(1)
Animal-based measures	39		33	0.40	33(1)
Farms using farm descriptor data	38	15	3	2.11	
Farms using risk factor data	30	12	3	2.61	
Farms using animal-based measure data	39	12	3	1.26	

ANNEX

The dataset including all mapped data from the on-farm data collection submitted by the contractor of the outsourced project is annexed to this scientific opinion but, due to size issue, is published separately on the EFSA webpage and is available for download.