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Structural characteristics of organic dairy farms in four European countries and their association with the implementation of animal health plans

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Abstract

The aim of the present study was to classify the diversity of organic dairy farms in four European countries according to their structural characteristics and investigate the association of these farm types with implementation of herd health plans. A Multiple Correspondence Analysis (MCA), followed by Agglomerative Hierarchical Clustering (AHC), was used to classify the farms. Data for the analysis came from a survey of 192 organic farms from France, Germany, Spain and Sweden and contained farm and farmer descriptions from which the typologies were derived. Herd health plans was agreed for each farm, via a participatory approach involving the farmers, their veterinarians and other advisors (e.g. dairy advisors) by the use of an impact matrix. The MCA yielded two principal component axes explaining 51.3% of variance. Three farm groups were identified by AHC using the factor scores derived from the MCA. Cluster 1, the most numerous group (56.7% of the sample), had medium herd sizes with moderate use of pasture and moderate intensity of input use. Cluster 2, representing 17.7% of the sample, were the most extensive system and mainly of very small farm size. Cluster 3 (25.5% of the sample and only found in Sweden), had an intensive management approach, but relatively low stocking rate. The analysis also showed that organic dairy farms adopted differentiated strategies towards economic assets and animal health status, according to group membership. The typology therefore provides insights into the potential for advisory strategies relating to husbandry practices, different housing, pasture management and intensity, etc. adapted to different groups of farms. Regarding herd health plan implementation, Cluster 1 was the group with most implemented actions and Cluster 2 with lowest rate of implemented actions. These results may be used as background for directing (tailored) advice strategies, i.e. different types of organic dairy farms (clusters) may require different types of advisory services and recommendations adapted to the specific farm situation in order to deliver future improvements in animal health.

Key words: organic dairy system; animal health, farm typologies; Multiple Correspondence

Analysis; Cluster analysis; tailored advisory services

1. Introduction

It is well known that the prevalence of production diseases in conventionally managed dairy cows varies considerably between farms and countries. A recent survey of organic dairy farms showed similar variation in the prevalence of production diseases, implying that a considerable proportion of farms are at risk of not meeting the expectations of consumers, i.e. expectations of high levels of animal health and welfare (Krieger et al., 2017). The presence of this variation suggests that production diseases are primarily determined by management factors (Nir Markusfeld, 2003), which are not impacted by statutory and certification requirements and so can vary between organic farms despite existence of these common standards.

One of the characteristics requirements of certified organic livestock systems is the design and implementation of health plans for farm animals, which describe the management practices to be used. The primary aim of these health plans is the identification of both the prevailing health problems and the solutions to these. As noted by previous studies, the likelihood of success in delivering on these solutions to health problems is, however, highly dependent on the preparedness of the farm management (farmer motivation) to undertake the actions identified in the plans by advisors, and the availability and quality of farm resources (Vaarst et al., 2007; Bennedsgaard et al., 2010; Vaarst et al., 2011; Ivemeyer et al., 2012).

Both farm and farmer characteristics therefore play an important role in the way farm management practices are carried out. For example, Barkema et al. (1999) demonstrated that, in addition to the rearing environment, the specific combination of farmer objectives and motivation have a significant influence on the implementation of actions to prevent disease. This fact provides a major challenge to the advisory network, because it suggests that for animal health advisors to provide better advice, they must take greater account of both the farm structure and the characteristics of the farmer, and adapt their approach in light of the states of these factors (Jansen et al., 2010; Derks et al., 2013).

There is very little information available on the extent of variation in these factors across the organic dairy sector in Europe, and only three studies generate descriptions of the structure and management approaches of national organic dairy sectors (Perea et al., 2010; Ivemeyer et al., 2017; Wallenbeck et al., 2018). However, few studies have been identified that attempt to systematize the observed variation in these sectors, either using clustering or other approaches, especially at a cross-country scale. As a consequence, it is not known whether this variation in structure and management approaches is stochastic, or whether there are systematic variations across the community of farms, i.e. meaning that farm typologies can be identified.

If a typology of organic dairy farms exists, and if this can be shown to be a predictor of herd health decision making, then the elaboration of these relationships would provide greater insight into the role of farm and farmer characteristics as drivers of and barriers to health management.

The first objective of this survey was, therefore, to explore the possibility of identifying meaningful typologies across the community of organic dairy farms in four European countries, based on a battery of farm and farmer descriptors. The second objective was to evaluate whether such farm typologies may be identifiable with significant variation in the rate of implementation of actions to improve herd health.

2. Materials and Methods

2.1. Location of the study areas

The study reported here was undertaken as part of an EU-funded research project (No. 311824) called IMPRO (http://www.impro-dairy.eu/). The study sought to identify and overcome weak points in current health management strategies on organic dairy farms and identify novel strategies to increase the implementation of evidence-based actions to improve health management practice.

As a means to achieving this, data were collected from 192 organic dairy farms (from 218 contacted) in France (51), Germany (60), Spain (27) and Sweden (53). Farms were selected on the basis of certain inclusion criteria to ensure that the sample was representative of organic dairy production in each country, i.e.: (1) time under organic conversion (a minimum of 1 year); (2) availability of official milk recording scheme records; (3) intention to continue in organic production for at least five years; and (4) a herd size typical of the country of residence. In addition, differences in infrastructure and other characteristics were purposively taken into account in the selection of farms to reflect the participating countries (i.e. geographic representative regions). The surveyed farms accounted for between 10% (Sweden) and 33% (Spain) of the population of organic farms in the study countries.

The study farms were located in 14 regions across the study countries (see Figure 1). This included the French regions of Morbihan, Loire Atlantique, Lorraine; Northern Germany (Schleswig-Holstein, Mecklenburg-Vorpommern and Lower Saxony), Central Germany (Hesse and Northern Bavaria), and South of Germany (Lower Bavaria and Baden-Württemberg); in Spain, the North (Asturias, Basque Country, Cantabria, Catalonia and Galicia), and Centre (Madrid); the Swedish regions of Gävleborgs, and Värmlands län, Uppsala and Västmanlands län, Stockholms and Östergötlands län and Västra götalands län. The climatic conditions of these regions, as classified using the KÖPPEN-GEIGER climate classification (http://koeppen-geiger.vu-wien.ac.at), is warm temperate, but with some diversity within this classification, i.e. with precipitation ranging from fully humid to winter dry, and temperatures ranging from cool to hot summer.

Figure 1. Map showing the location of the participant farms in the four study countries.

2.2. Farm data collection

The data used in the study were collected on four occasions during the two year period March 2013 – April 2015 and were drawn from five separate sources, i.e. four specially-designed surveys and one pre-existing secondary dataset (French Ministry of Agriculture and France Genetique Elevage (FGE), the German federal milk recording organisations (LKV) and Vereinigte Informationssysteme Tierhaltung (VIT), the Spanish Holstein Association (CONAFE) and the Spanish Ministry of Agriculture, Food and Environment, and Växa Sverige AB). Survey instruments (i.e. questionnaires and interview schedules) were designed collectively by the multi-national research team (6 countries, 15 researchers) in English. These were then translated into local languages, for use in each of the study countries, by the national research teams.

In the first round of data collection, basic farm structural information were obtained by means of face-to-face interviews, guided by an interview schedule. These on-farm interviews were conducted by 5 members of the research team, between March and August 2013, and lasted between 3 and 5 hours. This data was supplemented by milk recording data for each farm for the most recent full year, i.e. 2012. The farm structure surveys obtained data on the characteristics of the respondent, e.g. his/her education and livestock association membership, and the farm: reproductive management, milking system, housing and husbandry practices, feeding regime, grazing management, herd health status and health management (i.e. disease prevention and control programs - for further information see Supplementary Material 1).

A second round of on-farm interviews was undertaken during the period September 2013 to April 2014 by members of the research team who previously received training on moderation. Three types of activities were undertaken. First, farmers were required to supply data (for the financial year 2012) for use (by the interviewer) in an economic analysis tool, which assessed the economic costs (failure costs) associated with extant levels of four of the most important production diseases on the farms, i.e. mastitis, lameness, ketosis and metritis. Second, by means of a participatory process involving the farmer, their herd veterinarian and other advisors, plus the project researcher in a joint dialogue, a set of management actions were agreed, to further control production diseases on the farm. The process on each farm was documented in a “recording booklet” where the researcher noted interim results and key observations. In addition, different passages of the process were tape-recorded, which provided possibilities for double checking of records. The booklet served as a basis for a written report that was subsequently sent to all farmers. The main outcomes from the farmer perspective were the identification of the farm-specific key variables relevant for disease management, the identification of areas with room for improvement and a set of farm-individual health actions. Finally, data was supplied by the farmer, by means of a pre-supplied questionnaire, on their attitudes towards adoption of these health actions. Direct attitude towards the outcome of the actions as a package was constructed in the form of a composite variable aggregating over individual direct outcomes attitudes i.e., towards taking additional preventative measures to improve herd health (for more details see Jones et al., 2016). The advice and actions could be general, such as seeking more knowledge, or very specific, such as providing straw when drying off, written instructions for staff or reconstruction work, for more details see Emanuelson (2014).

Finally, after one year (i.e. in 2015), a follow-up questionnaire was used to assess the degree of farmer uptake of the set of farm-specific animal health management actions agreed during the second farm visit. Where there was non-implementation, the reasons for this were elicited and categorised into seven broad groups. For more detail on these data collection activities, see Jones et al. (2016), Krieger et al. (2017), and Sjöström et al. (2018).

2.3. Data management and statistical analysis

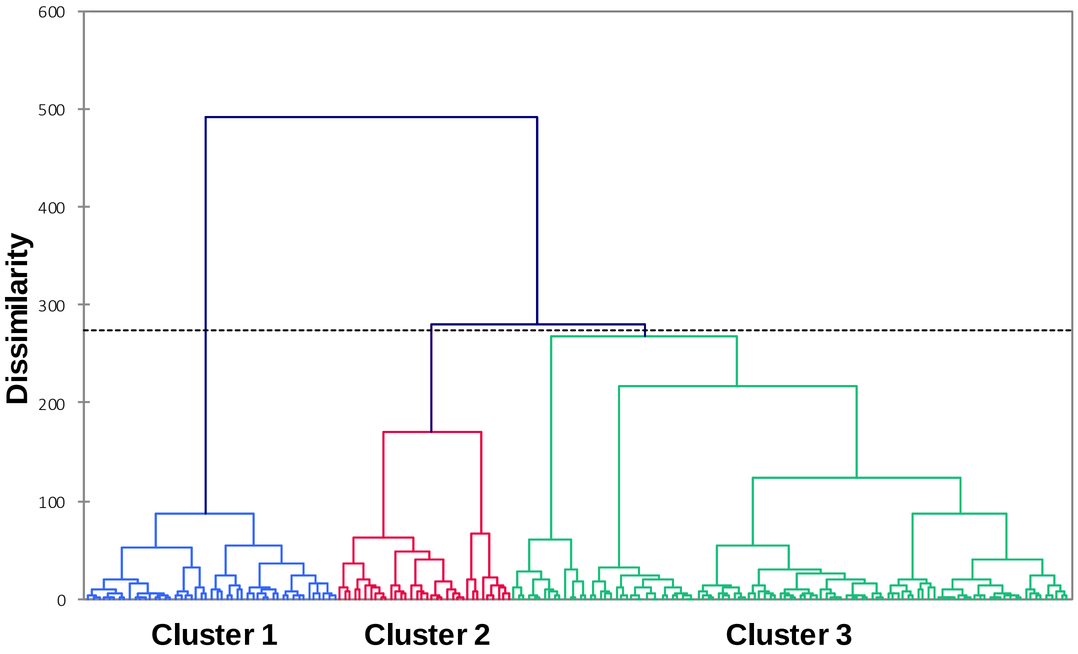
The characterization of farms into typologies, based on the farm structure data derived from the first farm visit plus milk recording data, was carried out in three stages: (1) review and selection of variables; (2) Multiple Correspondence Analysis (MCA); and (3) Agglomerative Hierarchical Clustering (AHC). MCA provides a correspondence analysis of the cross-tabulation of a matrix of variables. The MCA was selected as the most suitable technique to undertake this analysis, since most of the available data were qualitative. Farms were grouped using AHC according to the factor scores derived from the MCA.

In Stage 1, 114 farm structure variables were entered into an Excel-matrix and screened for missing and abnormal values using procedures exemplified by Prunier et al. (2013) and De Boyer des Roches et al. (2016) in studies linking animal health outcomes to structural factors. Approximately 20% of the variables were transformed into binary scales using the median as the status threshold. Variables with greater than 50% missing values, uninformative variables (i.e. coefficient of variation less than 50%), and variables that provided redundant information (highly correlated with other variables, i.e. Rho ≥0.90) were discarded. This process resulted in 31 variables (presented in Table 1 and Table 2) relating to farmer profile, animal housing and management characteristics, which were retained for further analysis (i.e. Stage 2).

In Stage 2, MCA was used to reduce the dimensionality of the data, i.e. reduce the number of categorical variables to fewer continuous variables (principal components) capturing the most variability. The MCA analysis was run using STATA (Stata Corporation, College Station, TX, USA) and the AHC was performed in XLSTAT© software (Addinsoft, 2017).The two principal components identified by the MCA which explained the most variation displayed significant contributions from 16 main variables These variables (used to construct the MCA) are underlined in Table 1 and Table 2.

In Stage 3, AHC was used with the principal components derived from the MCA, to identify homogenous groups of farms. The AHC used the approach suggested by Ward (1963) to produce homogeneous groups using the squared Euclidean distance as a clustering measure. Variation within farm cluster and variance decomposition within-class was also considered when running the AHC. The optimal number of clusters was determined from the dendogram (see Figure 2) using a 'cutting height' of 270, following the method used in previous studies that created farm typologies (Köbrich et al., 2003; Riveiro et al., 2013). The cutting height of 270 accounted for the number of relevant clusters for each cut and the total number of farms included in clusters (accounting for the largest reduction in the number of groups at minimum height on the dissimilarity axis). The resulting clusters were selected to conform best to the real situation and to the goals of the research, as proposed by other studies performed for other livestock sectors (Riveiro et al., 2013).

Figure 2. Dendrogram for Hierarchical Clustering using Ward's method and the squared Euclidean distance measure and the cutting line. Each color represent a cluster of farms.



Dissimilarity
600
500
400
300
200
100
0
Cluster 1
Cluster 2
Cluster 3

215

216

Once the clusters were identified, Kruskal-Wallis and Chi² tests for homogeneity were undertaken to determine whether there were significant differences between them in terms of farm structure, production factors and disease costs. In addition, a composite attitude variable, created by combining five original attitude variables as described by Jones et al. (2016), was also compared between clusters. This was done to determine whether farm cluster group membership was associated with particular attitudes (beliefs) and intention to undertake additional health actions identified in the health plan. The associations between farm cluster membership and the proportion of actions that had been implemented and the stated reasons for discarding agreed actions, were studied using descriptive statistics.

3. Results

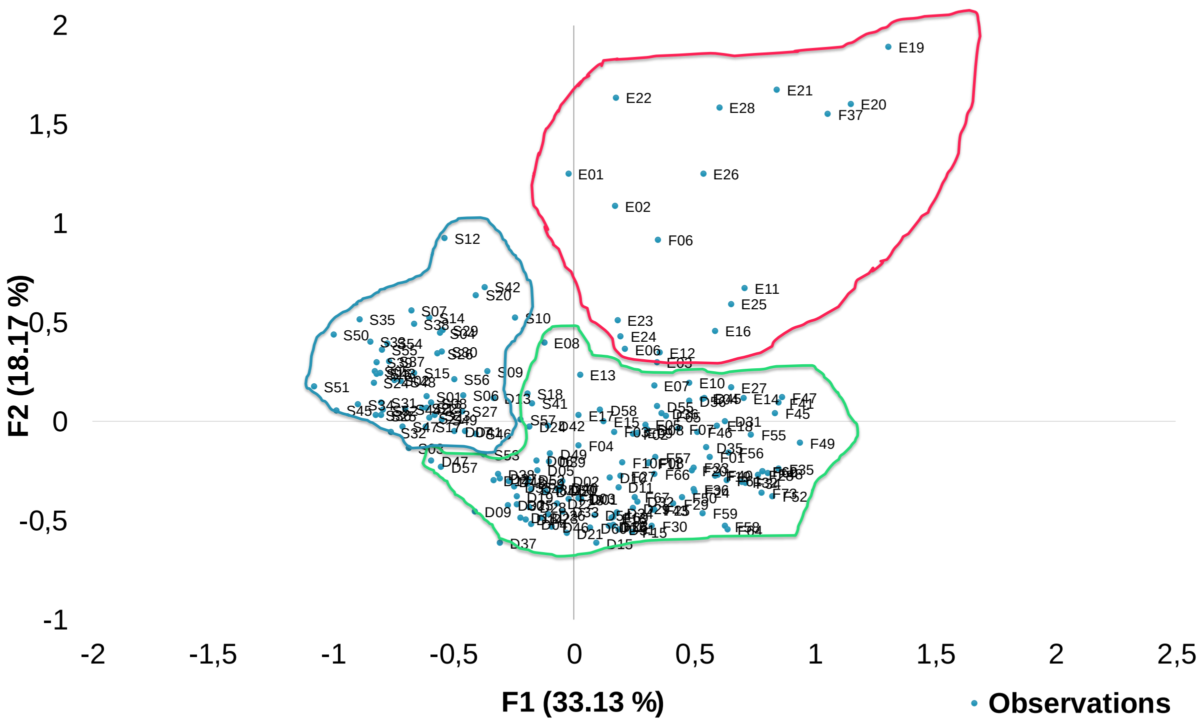
The 192 sample herds kept a total of 11,932 dairy cows, with an average herd size of 73.6 (range, 7.4- 376.5) with Holstein-Friesian as the predominant breed (found on 48.9% of the farms), and an average milk yield per cow of 7,135 kg on an average 305-day lactation (range: 3,317-10,880 kg). The average daily milk yield was 26.9 kg (range: 4.2-65.1 kg) per day.

3.1. Farm clusters

Three farm clusters were identified through the MCA and subsequent AHC, i.e. Cluster 1 (54 German, 41 French, 12 Spanish and 2 Swedish farms), Cluster 2 (6 German, 10 French, 16 Spanish and 2 Swedish farms) and Cluster 3 (49 Swedish farms). The spatial localization of the farms, according to the two principal components obtained from the MCA, is presented in Figure 3. The MCA yielded two principal components axes – the first, corresponding to the ordinate, explaining 33.1% of the variance, the second component, corresponding to the abscissa, capturing 18.2% of the variance (i.e. 51.3% of variance combined). The third and fourth dimensions explained only 8.3% and 7.5% of variance, respectively.

There was significant variation in most farm and farmer characteristics between the Clusters (Tables 1 and 2). However, variation within farm clusters, as measured by within-class variance decomposition, was larger (68.6%) than between cluster classes (31.4%). The optimal number of clusters was therefore determined, resulting in a cutting height on the dendrogram dissimilarity axis of 270 (Figure 2).

Figure 3. Plot of farms showing the spatial localization of the farm clusters in relation to Factor 1 and Factor 2 of the Multiple Correspondence Analysis. Numbers in brackets on axes indicate percentage variation explained by the dimension.



3.1.1. Description of the farm clusters for housing and building.

Across the clusters, the characteristics of buildings and facilities for lactating and dry cows followed local (climate) patterns and herd size. Milking systems provided the biggest source of diversity among clusters, where automatic milking systems (AMS) were predominantly found only in Cluster 3.

A tendency could be seen that Cluster 1 had younger farmers, while Cluster 2 was characterized by having older farmers and Cluster 3 these were equal distributed. Farms in Cluster 1 had medium sized herds and land areas, medium days on pasture per year, and the highest use of home-grown concentrate. The 39 farms in Cluster 2 were low-input, low output, small scale farms with the highest level of access to grazing. Farms of Cluster 3 were entirely confined to Sweden. These were the largest farms with the largest average herd sizes (compared to the average of all clusters), the highest concentrate input, lowest stocking rate, highest milk yields, lowest level of access to grazing across the year, and most equal distribution of gender among the farmers.

Table 1. General farm and farmer characteristics of each of three farm clusters based

on the distribution of cases for each qualitative variable used in the Multiple Correspondence Analysis and Agglomerative Hierarchical Clustering, plus Chi^2 test of homogeneity (in total 192 farms). The underlined variables were the variables selected for the characterisation of the clusters.

Variables	**Cluster 1 (n=109)**	**Cluster 2 (n=34)**	**Cluster 3 (n=49)**	***p-value***[#]
Farmer's age				0.107
Less than 26 years	9.2%	2.9%	4.1%	
26 – 34	16.5%	8.8%	12.2%	
35 – 44	24.7%	35.3%	30.6%	
45 – 54	41.3%	38.2%	28.6%	
55 – 64	7.3%	11.8%	24.5%	
More than 64 years	0.92%	2.9%	0%	
Farmer's gender				0.014
Male	83.5%	76.5%	59.2%	
Female	18.7%	23.5%	40.8%	
Predominant breed				0.960
Non Holstein-Frisian	89.9%	88.2%	89.8%	
Holstein-Frisian	10.1%	11.8%	10.2%	
Type of milking system				<0.001
Side by side	6.4%	5.8%	0%	
Tandem	11%	14.7%	6.1%	
Herringbone	72.5%	50%	18.4%	
Rotatory	0.9%	2.9%	0%	
AMS	6.4%	0%	55.1%	

Others[1]	2.8%	26.5%	20.4%	
Lactating cows’ type of housing				<0.001
Loose stall	100%	70.6%	83.7%	
Tie-stall	0%	14.7%	16.3%	
Always outside	0%	14.7%	0%	
Lactating cows’ type of floor in				<0.001
housing[2]	58.8%	62.8%	81.6%	
Solid	29.4%	12.8%	7.9%	
Slatted (up to 50%)	11.8%	20.9%	10.5%	
Slatted (> 50%)	0%	3.5%	0%	
N.A.				
Lactating cows’ type of building				<0.001
Warm building	12.8%	44.1%	71.4%	
Outdoor climate (open)	16.5%	11.8%	10.2%	
Outdoor climate (semi-open)	60.6%	32.4%	2.0%	
Outdoor climate (closed)	10.1%	11.8%	16.3%	
Lactating cows’ type of lying space				<0.001
Cubicles	70.6%	52.9%	95.9%	
Deep litter	21.1%	11.8%	4.1%	
Frequently renewed litter	7.3%	17.6%	0%	
N.A.	0.91%	17.6%	0%	
Lactating cows’ type of bedding				<0.001
Sand	0.91%	2.9%	0%	
Wood shavings	2.8%	2.9%	30.6%	

Turf/compost	0.91%	0%	16.3%	
Straw	64.2%	44.1%	26.5%	
Chalk	16.5%	2.9%	8.2%	
Other	14.7%	35.3%	18.4%	
N.A.	0%	11.8%	0%	
Dry cows' type of housing				<0.001
Loose stall	75.2%	52.9%	87.8%	
Tie-stall	1.8%	11.8%	12.2%	
Always outside	21.1%	20.6%	0%	
N.A.	1.8%	14.7%		
Dry cows' type of building				<0.001
Warm building	11%	26.5%	44.9%	
Outdoor climate (semi-open)	20.2%	5.9%	30.6%	
Outdoor climate (open)	38.5%	23.5%	8.16%	
Outdoor climate (closed)	9.2%	11.8%	16.3%	
N.A.	21.1%	32.4%	0%	
Dry cows' type of floor				<0.001
Solid	41.3%	47.1%	4.1%	
Slatted	58.7%	52.9%	95.9%	
Dry cows' type of bedding				<0.001
Sand	0.9%	2.9%	0%	
Wood shavings	2.8%	5.8%	24.5%	
Turf/compost	0.9%	0%	14.3%	
Straw	61.5%	38.2%	42.9%	
Chalk	7.3%	2.94%	6.1%	
Other	6.4%	17.6%	12.2%	

N.A.	20.2%	32.4%	0%	
Dry cows' type of lying space				0.682
Deep litter	33.9%	29.4%	65.3%	
Frequently renewed litter	36.7%	20.6%	32.7%	
Cubicles	8.3%	14.7%	2.1%	
N.A.	21.1%	35.3%	0%	
Separation of cows into housing groups (and number)				<0.001
Lactating with dry cows	2.75%	14.7%	6.1%	
Lactating and dry cows separate	81.7%	85.3%	57.1%	
Lactating cows in 2 groups	10.1%	0%	24.5%	
Lactating cows in 3 or more groups	5.5%	0%	12.2%	
Different housing groups for lactating cows [3]				<0.001
No	94.5%	94.1%	85.7%	
Yes	5.5%	5.8%	14.3%	
Separation of dry cows in feeding groups				<0.001
No	17.4%	58.8%	4.1%	
Yes	82.6%	41.2%	95.9%	
Feeding groups for lactating cows [4]				<0.001
No	82.6%	94.1%	6.1%	
Yes	17.4%	5.8%	93.9%	
Milk delivery				<0.001
Private dairy company	31.2%	38.2%	4.1%	
Cooperative dairy company	53.2%	32.4%	93.9%	

Shop/retailer	4.6%	5.8%	0%	
Other	11.0%	23.5%	2.1%	
<u>Region</u>				<0.001
Morbihan	11.9%	14.7%	0%	
Loire Atlantique	7.3%	35.3%	0%	
Lorraine	13.8%	23.5%	0%	
Northern Germany	10.1%	0%	0%	
Central Germany	22.0%	11.8%	0%	
South of Germany	17.4%	5.8%	0%	
Gävleborg and Värmlands län	0%	2.9%	24.5%	
Uppsala and Västmanlands län	0.91%	0%	18.4%	
Stockholms and Östergötlands län	1.8%	0%	46.9%	
Västra götalands län	0%	2.9%	10.2%	
North-West Spain	8.3%	5.8%	0%	
North-Central Spain	1.8%	35.3%	0%	
North-East Spain	0%	5.8%	0%	
Central Spain	2.9%	0%	0%	

Note: Underlined variables were those factors of MCA used for the creation of the clusters.

[#]If significant ($P < 0.05$), clusters are deemed to be drawn from different populations.

[1]Selection of different systems that included a permanently installed circular walk-through system for pasture-based milking and abreast parlours.

[2]This question concerns standing areas only (such as walkways, feeding areas, waiting area, and outside run) which are accessible at all times. All lying areas are excluded.

[3] Different housing groups for lactating cows refers to separation of cow groups on housing.

[4] Different feeding groups refers to number of feeding groups that exist on the farm regarding roughage and / or total mixed ration.

N.A. not applicable

There was significant variation between clusters in terms of days on pasture, with Cluster 2 hosting the most extensive production systems. Clusters 1 and 2 had equal share of land devoted to permanent pasture. Milk yield and stocking rates was very heterogeneous among the three farm clusters. Manpower dedicated to dairy husbandry was significantly different among the three farm clusters, where Cluster 1 had the highest dairy manpower allocation. Cluster 3 had the lowest stocking rate and labour use per dairy cow. Stocking rates depended markedly on the farm area, showing differences in input use intensity of the clusters.

There was a negative correlation of number of cows with manpower dedicated to cows, but a positive correlation of number of cows with the manpower dedicated to general agricultural activities.

There were large differences in concentrate feeding (Table 2) between the clusters, notably Cluster 3 used three times the average amount of concentrate per cow than did Cluster 2. Consistent with these differences in the intensity of the production systems, there were also differences in terms of reproductive management, where significant differences were found for age of first calving (Table 2).

Table 2. General characteristics (medians) related to farmer profile and management of organic farms for each quantitative variable used in the Multiple Correspondence Analysis and Agglomerative Hierarchical Clustering and comparison among farm clusters (in total 192 farms), *p-values* are given for the Kruskal-Wallis tests. The underlined variables were the variables selected for the characterisation of clusters

Variable	**Cluster 1 (n=109)**	**Cluster 2 (n=34)**	**Cluster 3 (n=49)**	***p-value*#**

Years certified organic	8	6	7	0.722
Number of cows	62.7	38.5	68.4	<0.001
Total area (ha) [1]	99.5	67	204	<0.001
Permanent grass & legumes	40	26	25	0.413
Non-permanent grass & legumes	31	14	110	<0.001
Corn silage	3	0	0	<0.001
Whole-plant silage (except corn)	0	0	10	<0.001
Cereal crops	10.7	0	40	<0.001
Grain legumes	0	0	0	0.098
Other	0	0	0	0.173
Milk yield (kg/cow and year)	6552	5562	8896	<0.001
Milk/concentrate (kg/kg)	5.9	5.8	3.6	<0.001
Productivity per ha and year (kg milk/ha)[*]	61.3	87.9	44.9	<0.001
Concentrate per ha and year (kg/ha)[*]	0.12	0.20	0.13	0.092
Manpower dedicated to dairy cows[2]	2	1.9	1.5	0.010
Manpower dedicated to all agricultural activities[3]	2.5	2	3	<0.001
Stocking rate[4] (Livestock unit per ha)	0.63	0.51	0.32	<0.001
Time on pasture (days/year)	210	238	153	<0.001
Feeding management				
Use of home-grown concentrate (%)	80	40	60	0.185
Concentrate use (100 kg/cow/year)	10	7.5	24.5	<0.001
Reproductive management				
Target voluntary waiting period (days)	50	55	50	0.456
Target age at first calving (months)	28	29	24	<0.001
Median calving interval (days)	388	403	390	0.069

Note: Underlined variables were those factors of MCA used for the creation of the clusters.

[#] If significant (P < 0.05), clusters are deemed to be drawn from different populations.

[*]variables related to total area (ha)

[1] Agricultural Area is defined as the area used for farming. It includes the land categories: arable land, permanent grassland, permanent crops, and other agricultural land such as kitchen gardens. The term does not include unused agricultural land, woodland and land occupied by buildings, farmyards, tracks, ponds, etc. http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Agricultural_area_%28AA%29

[2] Full-time equivalent (FTE) consisting on 40 hours (= 1 FTE), and part-time worker employed for 20 hours a week (=0.5 FTE). http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Full-time_equivalent

[3] Relates only to manpower dedicated to the dairy cow herd. Manpower dedicated to milk processing is not included.

[4]Ratio of the total herbivores against the total fodder area. http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_livestock_patterns

3.2. Production disease costs

Regarding the major production disease costs, significant differences were found in the costs of lameness across the three clusters, with costs being much higher in Cluster 3 than in 1 and 2 (see Table 3), primarily due to elevated costs of culling. However, failure costs for mastitis (Table 4) were broadly similar across the three clusters at about 120 Euros per cow, although costs were slightly higher in Clusters 2 and 3.

Table 3. Median (range) of losses (in Euro[1] per cow) due to lameness for the three farm clusters for the year 2012, p-values are given for Kruskal-Wallis tests (33 farms had missing values)

Variables	Cluster 1 (N=94)	Cluster 2 (N=31)	Cluster 3 (N=36)	***p-value***#
Milk production losses	14.4 (0-143)	8.2 (0-41.5)	32.2 (0-258)	<0.001
Costs of labour (clinical lameness)	0.25 (0- 5.6)	0 (0-1.3)	0 (0-5.9)	<0.001
Costs of labour (veterinarian)	0.19 (0-3.4)	0 (0-0.78)	0 (0-1.6)	<0.001
Medication (for the treatment of clinical lameness only)	0.48 (0-18.0)	0.30 (0-11.5)	6.20 (0-47.8)	<0.001
Costs of discarded milk (due to antibiotic treatment)	4.85 (0-75.8)	4.18 (0-61.4)	34.3 (0-225)	<0.001
Costs of culling and destruction	8.6 (-1.5-169)	0 (0- 78.6)	138 (-55.9-763)	<0.001
Estimated total costs of foot health failures	43.7 (-1.4-306)	19.3 (0-114)	264 (-56-925)	<0.001

If significant (P < 0.05), clusters are deemed to be drawn from different populations.

[1]Costs estimations for Sweden were made in Swedish Krona (SEK) and converted to Euro at the rate of 1SEK=€ 0.11

Table 4. Median (range) of losses (in Euro[1] per cow) due to udder disorders for the three farm clusters (n=165), p-values are given for Kruskal-Wallis tests (33 farms had missing values)

Variable	Cluster 1 (N=94)	Cluster 2 (N=31)	Cluster 3 (N=36)	***p-value***#

Milk production losses	32.1 (11.5-316)	44.4 (18.4-98.6)	41.2 (20.4-84.3)	<0.001
Costs of labour (clinical cases)	2.5 (0.28-10.3)	4.5 (1.1-16.2)	1.41 (0-4.7)	<0.001
Cost of the veterinarian	0.22 (0.02-0.93)	0.44 (0.12-1.2)	0.30 (0-0.95)	<0.001
Medication (for the treatment of clinical cases only)	3.30 (0-25.2)	5.26 (0-51.4)	3.70 (0-106)	0.246
Costs of discarded milk (due to antibiotic treatment)	9.7 (0-65.0)	12.5 (0-50.9)	7.6 (0- 31.0)	0.227
Costs of culling and destruction	18.8 (-4.2-211)	0 (0-314)	43.5 (-18.5-259)	<0.001
Total costs of Clinical cases	62.6 (5.9-252)	71.4 (17.6-335)	72.8 (9.3-319)	0.367
Total costs of Subclinical cases	32.1 (11.5-316)	44.4 (10.6-404)	41.2 (185-766)	<0.001
Total costs of udder disorders	104 (31.8-462)	120 (48.7-395)	121.3 (44.9-361)	0.0624

[#] If significant (P < 0.05), clusters are deemed to be drawn from different populations.

[1]Costs estimations for Sweden were made in Swedish Krona (SEK) and converted to Euro at the rate of 1SEK=€ 0.11.

The assessment of certain health indicators, thoroughly analyzed in Krieger et al. (2017) showed significant differences among the clusters.

Table 5. Median of animal health indicators for year 2012 for organic herds in Cluster 1 (n=95), Cluster 2 (n=30), and Cluster 3 (n=49) p-values are given for Kruskal-Wallis tests

	Cluster 1	**Cluster 2**	**Cluster 3**	**sign**
Prevalence of not lame cows, %	79.4	87.2	95.7	<0.001
Prevalence of lame (score 1) cows, %	15.9	10.3	3.6	<0.001
Prevalence of lame (score 2) cows, %	3.9	2.5	0	<0.001
Prevalence of lame (score 1 and 2) cows, %	20.5	12.5	4.3	<0.001
Prevalence of high SCC[a], %	0.29	0.39	0.26	<0.001
Prevalence of increased risk of ketosis, %	11	9.2	9	0.029
Prolonged calving intervals	42	52.9	38.9	0.0292
Age average of 1st calvers	29.0	32.2	27.3	<0.001
Replacement, %	26.4	26.7	36.4	<0.001
On-farm mortality of cows, deaths per month	0.021	0.026	0.041	0.011

Calf mortality, deaths per month	0.022	0.042	0.011	<0.001

[a]SCC=somatic cell counts.

3.3. Actions to improve herd health

The number of health management actions identified for each farm ranged from 0 to 22, while the proportion of implemented measures per farm varied between 0 and 100% (median 67%) (see Sjöström et al., 2018). The levels of implementation and non-implementation of additional herd health management actions after performing the impact matrix as part of a participatory process is presented in Table 6. Reasons for not implementing all management measures specified in the action plan were indicated in 78 (76%) of the questionnaires. The most frequent reasons were constraints related to housing and / or construction (36% of the farmers), followed by time limitations (31%), costs / financial limitations (26%) and that the farmers were no longer convinced that the measures would produce a positive outcome (26%). It was also quite common that other measures than those agreed were implemented instead (23%) or that farmers did not see the need of a planned measure anymore due to absence of the initial health problem (24%).

Direct attitude towards the action (i.e. intention to adopt health actions) was not significantly different between the clusters (P=0.147). However, farm clusters differed on the number of actions that were agreed to implement, with double the number of actions on Cluster 3 farms than on farms in Clusters 1 and 2. The rate of implementation of actions was significantly higher in Clusters 1 and 3 than in Cluster 2. In terms of the stated reasons for failure to take up actions, the most important connected with the farm style structure in absolute terms was prohibitive time and cost requirements, followed by limitations to housing construction and design. However, these barriers were fairly common in all three clusters. In terms of barriers to uptake, where clusters differed was in the role of skills and access to expertise, which were seen very much as a barrier to uptake in Cluster 2, but not to any significant extent in the clusters representing larger and more intensive farms.

Table 6. Proportion of actions implemented and rejected, plus attitude towards the action, for the three farm clusters, plus principal reasons for rejection of actions (n=167), p values are given for Chi^2 test of homogeneity (qualitative variables) and Kruskal-Wallis tests (quantitative variables).

Variable	**Cluster 1 (n=109)**	**Cluster 2 (n=34)**	**Cluster 3 (n=49)**	***p-value*[#]**
Direct attitudes towards the action	17	17	17	0.147
Number of agreed actions (median)	6	7	14.5	<0.001
Proportion of implemented actions(n=80)*	71.4%	44%	65%	0.003
Proportion of actions rejected due to time and cost (n=89)*	41.37%	43.75%	47.06%	0.821
Proportion of actions rejected due to lack of skills and access to expertise (n=89)*	1.72%	18.75%	5.88%	0.030
Proportion of actions rejected due to limitations of housing and construction (n=89)*	31.03%	37.5%	23.5%	0.684

If significant ($P < 0.05$), clusters are deemed to be drawn from different populations.

*The number between parentheses with the variables names corresponds to the frequency of responses provided by the farmers.

4. Discussion

Three major organic dairy farm clusters were identified across Germany, France, Spain and Sweden. At the heart of each cluster is a meaningful farm typology that differs from the types found in the other clusters. Two of the typologies generated here appear in all countries, in spite of the fact that the countries have very different topography, climate, organic farming traditions and rates of organic market growth (Sanders et al., 2016). It is interesting that these two organic typologies are coherent and yet transcend national boundaries, when the national differences listed above are known to shape the development of different production structures.

Averaged cross the three clusters, days spent at pasture per year were higher than reported elsewhere (Horn et al., 2014). However, significant differences exist between the clusters, suggesting differences in both the importance of grazing as a feed source and production intensity. This may be an important consideration because production intensity, particularly stocking rates and rate of use of concentrate feeds, could be an important determinant of the prevalence and severity of production diseases, with prevalence and severity tending to increase as production intensity increases. However, as reported by Krieger et al. (2017), the prevalence of production diseases were lower, while the productive lifespan was shorter and the estimated total costs of foot health failures are higher, in the Swedish herds (which are largely confined to Cluster 3), which had the most intensive production system in the sample.

Even though the basis of production rules for organic operations in Europe is the same, organic milk production conditions vary greatly throughout Europe which respect to factors such as access to grazing and housing. Pasture is at the heart of organic livestock management and this is seen as a key part of the feeding and husbandry approach that promotes positive health outcomes (EC 834/2007; EFSA, 2009). For instance, Sjöström et al. (2018) studied the prevalence of lameness in the same herds as were used the present study and found zero-grazing herds (found only in Germany). These zero grazing farms had a higher likelihood of lameness than German organic grazing herds in the sample. Unexpectedly, some farms in our own study were also found to be in breach of organic regulations, i.e. they continued to use slatted floors in housing (more than 50% of the total surface floor). Similar breaches of organic standards were found by Schmid and Knutti (2009) who compared the main requirements of EU organic production rules with other welfare standards and found differences related to observance of the prohibition of certain housing systems.

The amount of time that dairy cows are allowed access to grazing varies widely across the four European countries, although there is an increasing trend towards intensification as historically observed (van Arendonk and Liinamo, 2003), with an increase in the number of high yielding cows requiring more energy and protein dense rations. This is confirmed in the farms in Cluster 3, with the highest proportion of their land areas as temporary grass and legumes (roughage and feed based systems), which is generally more intensively managed and higher yielding than permanent pastures.This trend is leading to decreasing use of traditional grazing systems (EFSA, 2015) and more use of indoor rearing and use of concentrates and ensiled forage. The literature describes a broad range of rates of concentrate use in organic dairy herds, with variation often related to geographical and husbandry differences. To illustrate, in the SOLID project (Horn et al., 2014), concentrate levels for the group defined as 'low input' were estimated to be 286 kg/cow/lactation in Austria, 717 kg/cow/lactation in Northern Ireland and 1,359 kg/cow/lactation in Finland. Even lower levels of concentrate feeds have been found in Germany, i.e. 200 kg dry matter of concentrates per cow per year leading to a milk yield of 6 000 kg (Müller-Lindenlauf, 2008). In the

UK, Ferris (2014) considered 560 kg per cow per lactation as a low rate of concentrate use in organic dairy enterprises. The rates of concentrate feed use reported in the literature have no direct comparator in the present study as the present study did not estimate concentrate use on the basis of lactations. However, some ‘ball-park’ comparisons can be made. For example, rates of concentrate feeding in Cluster 2 and in lesser extent Cluster 1 could be ranged in the Horne et al (2014) “low input” category.

In the farm typology found in Cluster 3, concentrate use of 2,446 Kg/cow/year might be deemed excessive, based on the ranges listed above, although use of forage was also very high in this case. The fact of Cluster 3 also had a low milk/concentrate ratio compared to others Clusters, suggests the use of more intensive indoor rearing; yet this ratio needs further research across the year since the use of forage in this farm typology might vary according to the seasons. Cluster 3 also had more land available for feeding (non-permanent grass and legumes), probably as a result of the climate in Sweden, implying less time available for grazing and more use of conserved forage in the cold season. In terms of the rates of implementation of health management actions, there was considerable variation between the clusters. Farmers in Cluster 2 had the lowest rate of implementation of actions (44 %). This cluster 2 has the most extensive management systems, the smallest farmed area and lowest use of inputs and resources of any of the clusters. Milk yields were also low, and this more than offsets the low input use. Production methods have specific strengths and weaknesses. It has been globally debated whether the most extensive systems can reach a satisfactory level of profitability without intensification (i.e. Hanrahan et al. 2018). The limitation of intensification management is also one precondition for better health in dairy cattle (Hultgren, 2016). However, if extensive use of resources is the basis of its distinctive production, it might be a sign of the farming style, captured in a marketing strategy, with a remarkable impact on their profitability (van der Ploeg and Ventura, 2014). The relationship between the economic and social sustainability of extensive farming systems and their feeding management regimes is very important. Grazing has been found to be associated with lower production costs, and lower use of concentrate, since well-maintained pasture is a highly nutritious feed source. However, conclusions about farm profitability have to be more cautious since the margin per liter of milk produced is a more relevant performance measure in the case of smallholder farms (Nemes, 2009).

Systematic patterns of variation across the organic dairy community have been shown, to the extent that farm typologies can be identified. The possibility also exists that this typology explains some of the variation in actions related to health status, such as disease costs and the quality of health management. If the above is indeed the case, then the main actions to be considered to improve health in these farms are improvement of the core structure of the farm per se, such as organization and data control, since this is a crucial factor for improving animal health (Emanuelson, 2014). Such a typology may also explain levels of implementation of actions contained within farm health plans (van der Ploeg et al., 2009). This might explain why Cluster 2 has a significantly lower rate of implementation of actions compared to any other cluster, as this cluster has a distinct and internally consistent style of farming.

This survey confirms the findings of others, that organic dairy farming in Europe is largely constituted by small-scale family farms (Sanders et al., 2016). A similar trend was found by Prunier et al. (2013) for organic pig farms. Resource demands (e.g. labour, investments) in one field of farm management (i.e. animal health) may provoke conflicts with management actions in other fields, requiring farmers to allocate resources to those management areas which are preferred most, given the specific farming situation. These resource conflicts would be much greater on smaller farms, such as those in Cluster 2, where resources, especially of land, labour and capital, are most limited. Each farmer can have positive effects on most health aspects through their management strategy. Each action is based on particular driving forces where the farmer has to involve the mobilization of resources where a specific organization of the labour process is needed. It would be expected therefore, that the rate of uptake of herd health recommendations would be lowest in Cluster 2 due to the extent of resource conflicts. The benefits of participatory approaches to the design of health management plans was more welcomed by Cluster 1, maybe more willing to reconfigure their farm business. The ratio of implementation was similar in Cluster 1 and 3 but the main divergence between the farms in both clusters may be due to the specialization of the farms in Cluster 3 and the lower age of farmers in Cluster 1.

It is acknowledged that organic livestock farms in Sweden have a culture of high management standards in the area of animal health and welfare. In view of this claim it is not unexpected that the rate of uptake of actions was also high in Cluster 3. On the other hand, the highest costs of e.g. discarded milk due to antibiotic treatments of lameness or the estimated total costs of foot health failures also belonged to Cluster 3. This finding is consistent with the finding of Krieger et al. (2017) that Sweden has a lower prevalence of production diseases than the other countries included in this study.

The reasons given for non-uptake of actions seen in Cluster 2, i.e. a lack of skills and expertise, strongly suggests that the level of specific training for organic production is an important determinant of animal health status, as well as business performance. It must also be acknowledged that underlying this lack of skills on these smaller farms may be a lack of resources, i.e. the lack of time and money to acquire additional skills through training, or purchase of input from expert professionals. The lack of professional skills in organic dairy farming observed in some previous studies lends weight to this hypothesis (Blanco-Penedo et al., 2014). To confirm this assumption, more studies in this area will be needed.

The results of this study suggest that veterinarians and other health advisors, when trying to identify appropriate actions to improve animal health and welfare, need to understand the structure of their client's farm system. They also need to understand the way this may impact, not just the prevalence of production diseases, but also the efficacy and likelihood of implementation of actions (because the best decision depends heavily on the internal logic and context-bound reality on each dairy farm (Kristensen and Jakobsen, 2011). The findings of the study also indicate that farms belonging to different typologies, may need different (advisory) approaches to achieve the goal of decreased prevalence of production diseases.

Increasing production costs and loss of consumer confidence in the credence value of high animal health and welfare standards in organic production are major threats to organic farming in Europe (Sanders et al., 2016). It is recognized that in terms of required actions to improve animal health status, those that require long-term action, and those that require more investment, have a lower likelihood of implementation (Martins and Rushton, 2014). The same can be said for actions that require management changes not supported by the farm structure (OECD, 2000) or that different types of farming households may need different kinds of support (van der Ploeg et al., 2009).

5. Conclusions

From amongst the matrix of organic farms that exist across European countries, three major farm clusters have been identified, each with a relatively homogenous set of structural and management characteristics. The different socio-demographic, structural conditions and prevalence of diseases observed in these clusters have been shown to at least partially explain differences in the likelihood of adoption of agreed actions to improve animal health status. It is relatively safe to assume from this, therefore, that organic farm typology would be a useful basis on which to adapt (tailor) animal health advice to yield additional improvements in animal health status. In short, different types of organic dairy farms (clusters) require different types of advisory services (i.e. approach and formulation of new support mechanisms). At the very least, the results suggest that there would be merit in conducting further research to gain a deeper understanding of the typologies that exist in the organic dairy farming community and to identify with each of these, their unique set of barriers to the uptake of different types of health management actions.

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References

Barkema, H.W., Van der Ploeg, J.D., Schukken, Y.H., Lam, T.J., Benedictus, G., Brand, A., 1999. Management style and its association with bulk milk somatic cell count and incidence rate of clinical mastitis. J. Dairy Sci. 82, 1655–1663. https://doi.org/10.3168/jds.S0022-0302(99)75394-4

Bennedsgaard, T. W., Klaas I. C, Vaarst M., 2010. Reducing use of antimicrobials—Experiences from an intervention study in organic dairy herds in Denmark. Livestock Science 131(2), 183-192. https://doi.org/10.1016/j.livsci.2010.03.018

Blanco-Penedo, I., Jones, P.J., Tranter, R.B., Velarde, A., 2014. Professional profile of the advisor of organic dairy farming. XI Congreso de la Sociedad Española de Agricultura Ecológica (SEAE) 1. - 4. October 2014. pp. 924. http://www.agroecologia.net/recursos/publicaciones/actas/cd-actasxicongresoseae/actas/comunicaciones/92-perfil-tecnico-bovino-blanco-resumen.pdf

Burke, J., Roderick, S., 2006. Examination of the impact and effectiveness of herd health and welfare assessment in improving animal welfare on organic dairy farms, using qualitative interviews. Joint Organic Congress, Odense, Denmark, May 30-31 2006.

de Boyer des Roches, A., Veissier, I., Boivin, X., Gilot-Fromont, E., Mounier, L., 2016. A prospective exploration of farm, farmer, and animal characteristics in human-animal relationships: An epidemiological survey. J. Dairy Sci. 99, 5573–5585. https://doi.org/10.3168/jds.2015-10633

Derks, M., van Werven, T., Hogeveen, H., Kremer, D.J., 2013. Veterinary herd health management programs on dairy farms in the Netherlands: Use, execution, and relations to farmers characteristics. J. Dairy Sci. 96, 1623–1637. https://doi.org/10.3168/jds.2012-6106.

EC No. 1804/1999. Council Regulation (EC) No 1804/1999 of 19 July 1999 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production. OJ: JO L_221, 24.8.1999, p. 1-28.

EC No. 834/2007. Council 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, 20.7.2007, p. 1–23.

EFSA, 2012. Scientific Opinion on the use of animal-based measures to assess welfare of dairy cows. EFSA Journal 2012; 10(1), 2554.

EFSA, 2015. Scientific Opinion on the assessment of dairy cow welfare in small-scale farming systems. EFSA Journal 2015; 13(6), 4137.

EFSA, 2009. Scientific report on the effects of farming systems on dairy cow welfare and disease. Annex to the EFSA Journal 1143, 1–284.

Emanuelson, U., 2014. IMPRO D2.4 – Report on health plans. Retrieved on 28 May 2018 from http://www.impro-dairy.eu/index.php/outreach/deliverables.

Ferris, C., 2014. AFBI compares concentrate inputs for spring calving milk production systems. Released archives 2014, Agri-Food and Biosciences Institute, Hillsborough. Published: Wed 11 Jun 2014. Available at: [http://www.afbini.gov.uk/index/news/news-releases/news-releases-archive 2014.htm?newsid=26408]

Hanrahan, L., McHugh, N., Hennessy, T., Moran, B., Kearney, R., Wallace, M., Shalloo, L. 2018. Factors associated with profitability in pasture-based systems of milk production. J Dairy Sci. 101(6):5474-5485. doi: 10.3168/jds.2017-13223.

Horn, M., Steinwidder, A., Pfister, R., Gasteiner, J., Vestergaard, M., Larsen, T., Zollitsch, W., 2014. Do different cow types respond differently to a reduction of concentrate supplementation in an Alpine low-input dairy system? Livest Sci. 170, 72–83. https://doi.org/10.1016/j.livsci.2014.10.006

Hultgren, J., 2017. Key issues in the welfare of dairy cattle. Volume 3: Dairy herd management and welfare. (ed. J. Webster, C. J. C. Phillips, J. Hultgren). Achieving sustainable production of milk. Burleigh Dodds. ID: 9781786760524-002.

Ivemeyer, S.; Smolders, E.A.A.; Brinkmann, J.; Gratzer, E.; Hansen, B.; Henriksen, B.I.F.; Huber, J.; Leeb, C.; March, S.; Mejdell, C.; Nicholas, P.; Roderick, S.; Stöger, E.; Vaarst, M.; Whistance, L.K.; Winckler, C.; Walkenhorst, M. 2012. Impact of animal health and welfare planning on medicine use, herd health and production in European organic dairy farms. Livest Sci. 145, 1-3. https://doi.org/10.1016/j.livsci.2011.12.023

Ivemeyer, S., Brinkmann, J., March, S., Simantke, C., Winckler, C., Knierim, U., 2017. Major organic dairy farm types in Germany and their farm, herd, and management characteristics. Org. Agr. 1–17. https://doi.org/10.1007/s13165-017-0189-3

Jansen J., Steuten C. D. M., Renes R. J., Aarts N., Lam T. J. G. M., 2010, Debunking the myth of the hard-to-reach farmer: Effective communication on udder health. J. Dairy Sci. 93, 1296-1306. https://doi: 10.3168/jds.2009-2794

Jones, P.J., Sok J., Tranter, R.B., Blanco-Penedo, I., Fall, N., Fourichon, C., Hogeveen, H., Krieger, M.C., Sundrum, A., 2016. Assessing, and understanding, European organic dairy farmers' intentions to improve herd health. Prev. Vet. Med. 133, 84–96. https://doi.org/10.1016/j.prevetmed.2016.08.005

Köbrich, C., Rehman, T., Khan, M., 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agric. Syst. 76, 141–157. https://doi.org/10.1016/S0308-521X(02)00013-6

Krieger, M., Sjöström, K., Blanco-Penedo, I., Madouasse, A., Duval, J.E., Bareille, N., Fourichon, C., Sundrum A., Emanuelson, U., 2017. Prevalence of production disease related indicators in organic dairy herds in four European countries. Livest. Sci. 198, 104–108. https://doi.org/10.1016/j.livsci.2017.02.015

Kristensen, E., Jakobsen, E.B., 2011. Challenging the myth of the irrational dairy farmer; understanding decision-making related to herd health. N Z Vet. J 59(1), 1-7.

Leiber, F., Schenk, I. K., Maeschli, A. Ivemeyer, S., Zeitz, J. O., Moakes, S., Klocke, P., Staehli, P., Notz, C., Walkenhorst, M., 2017. Implications of feed concentrate reduction in organic grasslandbased dairy systems: a long-term on-farm study. Animal 11 (11), 2051–2060.

Lund, V., Algers, B., 2003. Research on animal health and welfare in organic farming – a literature review. Livest. Sci. 80, 55–68. https://doi.org/10.1016/S0301-6226(02)00321-4

Martins, S.B., and Rushton, J., 2014. Cost-effectiveness analysis: adding value to assessment of animal health, welfare and production. Rev. sci. tech. Off. int. Epiz., 2014, 33 (3), 681-689

Müller-Lindenlauf, M., 2008. Umweltwirkungen ökologisch wirtschaftender Milchviehbetriebe unterschiedlicher Fütterungsintensität und Produktionsstruktur. Dissertation Universität Bonn. ISBN-13: 9783895747175.

Nemes, N., 2009. Comparative analysis of organic and non-organic farming systems. A critical assessment of farm profitability. Food and Agriculture Organization of the United Nations

Nir Markusfeld, O. 2003. What are production diseases, and how do we manage them? Acta Vet. Scand. Suppl. 98, 21–32.

OECD Workshop. Adoption of technologies for sustainable farming systems. Wageningen Workshop Proceedings. Available at: http://www.oecd.org/greengrowth/sustainable-agriculture/2739771.pdf

Perea, J., Mata, H., García, A., Castaldo, A., Gómez, G., Acero, R., 2010. Technical and Social Aspects of Organic Dairy Farms in Northwest Spain (*in Spanish*]. Revista Científica, FCV-LUZ 20(6), 633–639.

Prunier, A., Dippel, S., Bochicchio, D., Edwards, S., Leeb, C., Lindgren, K., Sundrum, A., Dietze, K., Bonde, M., 2013. Characteristics of organic pig farms in selected European countries and their possible influence on litter size and piglet mortality. Org. Agr. 4(2), 163–173. https://doi.org/10.1007/s13165-013-0040-4

Riveiro, J.A., Mantecón, A.R., Álvarez, C,J., Lavín, P., 2013. A typological characterization of dairy Assaf breed sheep farms at NW of Spain based on structural factor. Agric. Syst. 120, 27–37. https://doi.org/10.1016/j.agsy.2013.05.004

Sanders, J., Gambelli, D., Lernoud, J., Orsini, S., Padel, S., Stolze, M., Willer, H. and Zanoli, R., 2016. Distribution of the added value of the organic food chain Final Report.

Directorate-General for Agriculture and Rural Development. Available at: https://ec.europa.eu/agriculture/external-studies/2016-organic-food-chain_en (accessed 25.07.2017).

Schmid, O., Knutti S., 2009. Animal welfare in organic farming legislations and standards – analysis & proposal for a more outcome-oriented approach/tool. Agriculture and Forestry Research, Special Issue No 362 (Braunschweig, 2012) ISSN 0376-0723.

Sjöström, K., Fall, N., Blanco-Penedo, I., Duval, J., Krieger, M., Emanuelson, U. 2018. Lameness and risk factors in organic dairy herds in four European countries. Livestock Science 208, 44–50. https://doi.org/10.1016/j.livsci.2017.12.009

Sjöström, K., Sternberg-Lewerin, S., Blanco-Penedo, I., Duval, J. E., Krieger, M., Emanuelson, U., and Fall, N., 2018. Effects of a participatory approach, with systematic impact matrix analysis in herd health planning in organic dairy cattle herds. Animal, 1 – 9. https://doi.org/10.1017/S1751731118002008

Vaarst, M., Nissen, Østergaard T.B. S., Klaas, I.C., Bennedsgaard, T.W., Christensen, J., 2007. Danish Stable Schools for Experiential Common Learning in Groups of Organic Dairy Farmers. https://doi.org/10.3168/jds.2006-607

Vaarst, M., Winckler C., Roderick S., Smolders G., Ivemeyer S., Brinkmann J., Mejdell C. M., Whistance L. K., Nicholas P., Walkenhorst M., Leeb C., March S., Henriksen B. I.F., Stöger E., Gratzer E., Hansen B., and Huber, J., 2011. Animal Health and Welfare Planning in Organic Dairy Cattle Farms. https://doi.org/10.2174/1874318801105010019 Van der Ploeg, J.D., Ventura, F., 2014. Heterogeneity reconsidered. Curr Opin Environ Sustain. 8, 23-28. https://doi.org/10.1016/j.cosust.2014.07.001

Van Arendonk, J., Liinamo, A.L. 2003. Dairy cattle production in Europe. Theriogenology 59, 563-569. 33. PMID:12499004

Van der Ploeg, J.D., Laurent, C., Blondeau, F., Bonnafous, P., 2009. Farm diversity, classification schemes and multifunctionality. J Environ Manage. 90, S124–S131. https://doi.org/10.1016/j.jenvman.2008.11.022

Wallenbeck, A., Rousing, T., Sørensen, J. T., Bieber, A., Spengler Neff, A., Fuerst-Waltl, B., Winckler, C., Pfeiffer, C., Steininger, F., Simantke, C., March, S., Brinkmann, J., Walczak, J., Wójcik, P., Ribikauskas, V., Wilhelmsson, S., Skjerve, T., Ivemeyer, S., 2018. Characteristics of organic dairy major farm types in seven European countries. Organic Agriculture. https://doi.org/10.1007/s13165-018-0230-1.

Ward, J., 1963. Hierarchical grouping to optimise an objective function. J. Am. Stat. Assoc. 58, 236–244. https://doi.org/10.2307/2282967