



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

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2 **association with the implementation of animal health plans**

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22

23 **Abstract**

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

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

50 Analysis; Cluster analysis; tailored advisory services

## 51 **1. Introduction**

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

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

70 Both farm and farmer characteristics therefore play an important role in the way farm  
71 management practices are carried out. For example, Barkema et al. (1999) demonstrated  
72 that, in addition to the rearing environment, the specific combination of farmer objectives and  
73 motivation have a significant influence on the implementation of actions to prevent disease.  
74 This fact provides a major challenge to the advisory network, because it suggests that for  
75 animal health advisors to provide better advice, they must take greater account of both the

76 farm structure and the characteristics of the farmer, and adapt their approach in light of the  
77 states of these factors (Jansen et al., 2010; Derks et al., 2013).

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

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

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

## 96 **2. Materials and Methods**

### 97 **2.1. Location of the study areas**

98 The study reported here was undertaken as part of an EU-funded research project (No.  
99 311824) called IMPRO (<http://www.impro-dairy.eu/>). The study sought to identify and  
100 overcome weak points in current health management strategies on organic dairy farms and  
101 identify novel strategies to increase the implementation of evidence-based actions to

102 improve health management practice.

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

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

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



125

## 126 **2.2. Farm data collection**

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

137 In the first round of data collection, basic farm structural information were obtained by means  
138 of face-to-face interviews, guided by an interview schedule. These on-farm interviews were  
139 conducted by 5 members of the research team, between March and August 2013, and



140 lasted between 3 and 5 hours. This data was supplemented by milk recording data for each  
141 farm for the most recent full year, i.e. 2012. The farm structure surveys obtained data on the  
142 characteristics of the respondent, e.g. his/her education and livestock association  
143 membership, and the farm: reproductive management, milking system, housing and  
144 husbandry practices, feeding regime, grazing management, herd health status and health  
145 management (i.e. disease prevention and control programs - for further information see  
146 Supplementary Material 1).

147 A second round of on-farm interviews was undertaken during the period September 2013 to  
148 April 2014 by members of the research team who previously received training on  
149 moderation. Three types of activities were undertaken. First, farmers were required to supply  
150 data (for the financial year 2012) for use (by the interviewer) in an economic analysis tool,  
151 which assessed the economic costs (failure costs) associated with extant levels of four of the  
152 most important production diseases on the farms, i.e. mastitis, lameness, ketosis and  
153 metritis. Second, by means of a participatory process involving the farmer, their herd  
154 veterinarian and other advisors, plus the project researcher in a joint dialogue, a set of  
155 management actions were agreed, to further control production diseases on the farm. The  
156 process on each farm was documented in a "recording booklet" where the researcher noted  
157 interim results and key observations. In addition, different passages of the process were  
158 tape-recorded, which provided possibilities for double checking of records. The booklet  
159 served as a basis for a written report that was subsequently sent to all farmers. The main  
160 outcomes from the farmer perspective were the identification of the farm-specific key  
161 variables relevant for disease management, the identification of areas with room for  
162 improvement and a set of farm-individual health actions. Finally, data was supplied by the  
163 farmer, by means of a pre-supplied questionnaire, on their attitudes towards adoption of  
164 these health actions. Direct attitude towards the outcome of the actions as a package was  
165 constructed in the form of a composite variable aggregating over individual direct outcomes  
166 attitudes i.e., towards taking additional preventative measures to improve herd health (for

167 more details see Jones et al., 2016). The advice and actions could be general, such as  
168 seeking more knowledge, or very specific, such as providing straw when drying off, written  
169 instructions for staff or reconstruction work, for more details see Emanuelson (2014).

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

### 175 **2.3. Data management and statistical analysis**

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

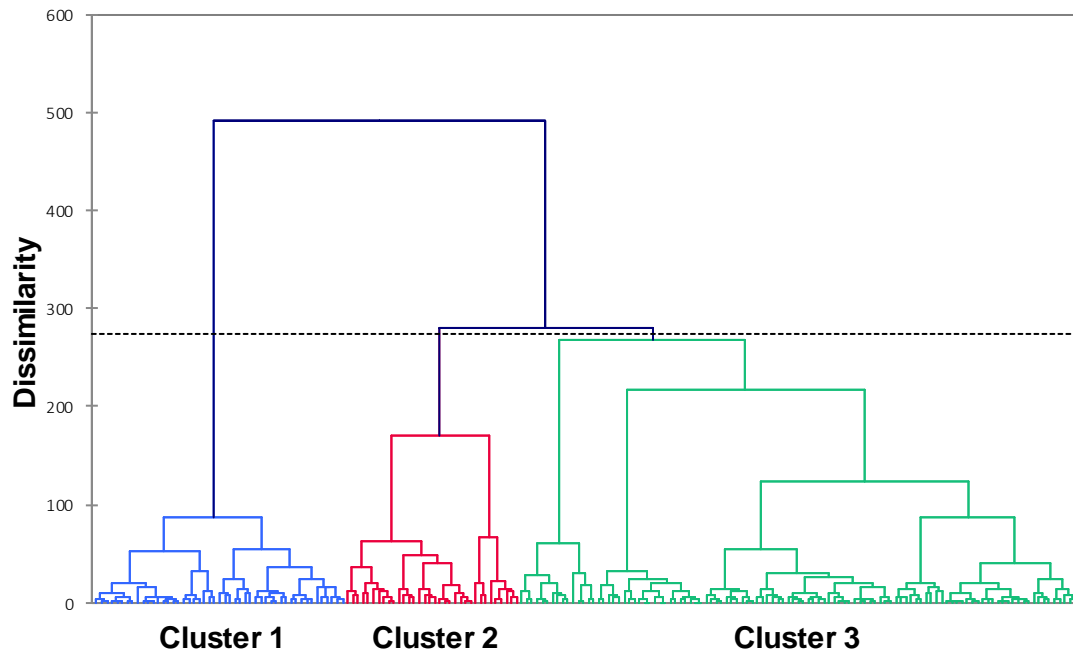
183 In Stage 1, 114 farm structure variables were entered into an Excel-matrix and screened for  
184 missing and abnormal values using procedures exemplified by Prunier et al. (2013) and De  
185 Boyer des Roches et al. (2016) in studies linking animal health outcomes to structural  
186 factors. Approximately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

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

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

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

214



215

216

217 Once the clusters were identified, Kruskal-Wallis and Chi<sup>2</sup> tests for homogeneity were  
218 undertaken to determine whether there were significant differences between them in terms  
219 of farm structure, production factors and disease costs. In addition, a composite attitude  
220 variable, created by combining five original attitude variables as described by Jones et al.  
221 (2016), was also compared between clusters. This was done to determine whether farm  
222 cluster group membership was associated with particular attitudes (beliefs) and intention to  
223 undertake additional health actions identified in the health plan. The associations between  
224 farm cluster membership and the proportion of actions that had been implemented and the  
225 stated reasons for discarding agreed actions, were studied using descriptive statistics.

### 226 **3. Results**

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

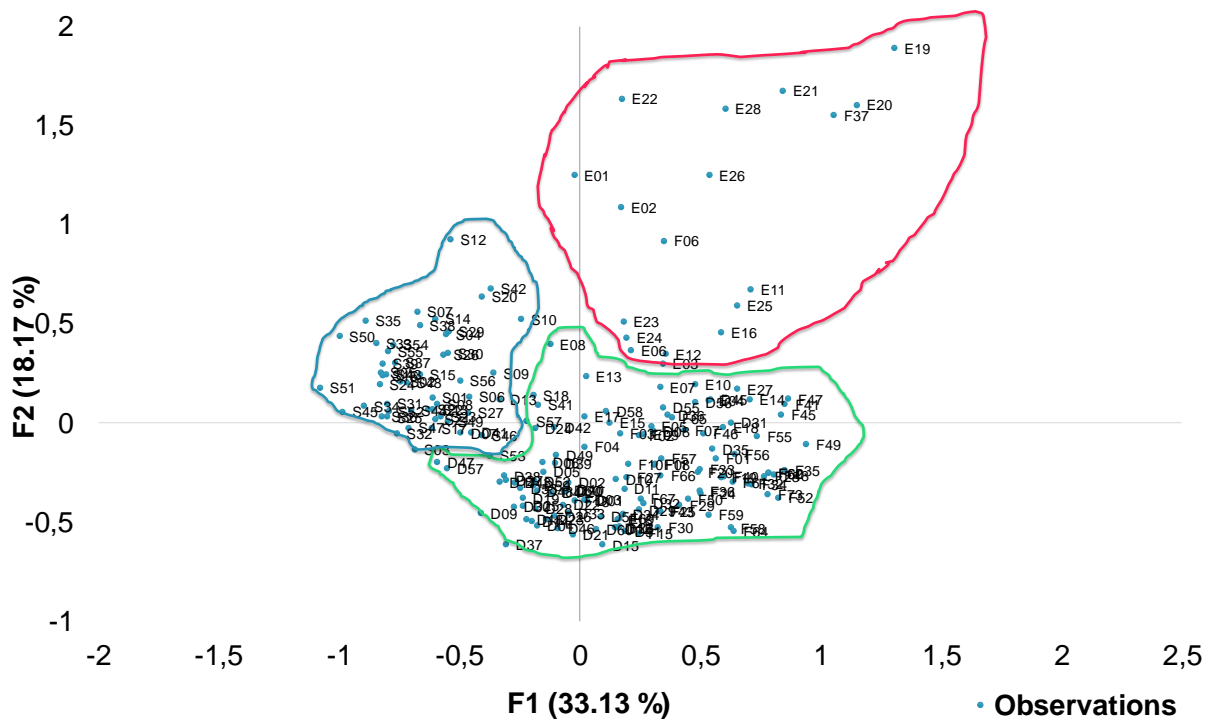
#### 232 **3.1. Farm clusters**

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

241 There was significant variation in most farm and farmer characteristics between the Clusters  
242 (Tables 1 and 2). However, variation within farm clusters, as measured by within-class

243 variance decomposition, was larger (68.6%) than between cluster classes (31.4%). The  
244 optimal number of clusters was therefore determined, resulting in a cutting height on the  
245 dendrogram dissimilarity axis of 270 (Figure 2).

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



249 3.1.1. Description of the farm clusters for housing and building.

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

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

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

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

<b>Variables</b>	<b>Cluster 1 (n=109)</b>	<b>Cluster 2 (n=34)</b>	<b>Cluster 3 (n=49)</b>	<b>p- value<sup>#</sup></b>
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%	
<u>Type of milking system</u>				<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 <sup>1</sup>	2.8%	26.5%	20.4%	
<hr/>				
<u>Lactating cows' type of housing</u>				<0.001
Loose stall	100%	70.6%	83.7%	
Tie-stall	0%	14.7%	16.3%	
Always outside	0%	14.7%	0%	
<hr/>				
<u>Lactating cows' type of floor in housing<sup>2</sup></u>				<0.001
Solid	58.8%	62.8%	81.6%	
Slatted (up to 50%)	29.4%	12.8%	7.9%	
Slatted (> 50%)	11.8%	20.9%	10.5%	
N.A.	0%	3.5%	0%	
<hr/>				
<u>Lactating cows' type of building</u>				<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%	
<hr/>				
<u>Lactating cows' type of lying space</u>				<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%	
<hr/>				
<u>Lactating cows' type of bedding</u>				<0.001
Sand	0.91%	2.9%	0%	
Wood shavings	2.8%	2.9%	30.6%	
<hr/>				

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%
<u>Dry cows' type of housing</u>			<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%	
<u>Dry cows' type of building</u>			<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%
<u>Dry cows' type of floor</u>			<0.001
Solid	41.3%	47.1%	4.1%
Slatted	58.7%	52.9%	95.9%
<u>Dry cows' type of bedding</u>			<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%	
<u>Dry cows' type of lying space</u>				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%	
<u>Separation of cows into housing groups (and number)</u>				<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%	
<u>Different housing groups for lactating cows<sup>3</sup></u>				<0.001
No	94.5%	94.1%	85.7%	
Yes	5.5%	5.8%	14.3%	
<u>Separation of dry cows in feeding groups</u>				<0.001
No	17.4%	58.8%	4.1%	
Yes	82.6%	41.2%	95.9%	
<u>Feeding groups for lactating cows<sup>4</sup></u>				<0.001
No	82.6%	94.1%	6.1%	
Yes	17.4%	5.8%	93.9%	
<u>Milk delivery</u>				<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%

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

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

271 <sup>1</sup>Selection of different systems that included a permanently installed circular walk-

272 through system for pasture-based milking and abreast parlours.

273 <sup>2</sup>This question concerns standing areas only (such as walkways, feeding areas, waiting

274 area, and outside run) which are accessible at all times. All lying areas are excluded.

275 <sup>3</sup>Different housing groups for lactating cows refers to separation of cow groups on

276 housing.

277 <sup>4</sup> Different feeding groups refers to number of feeding groups that exist on the farm

278 regarding roughage and / or total mixed ration.

279 N.A. not applicable

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

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

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

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

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	<b>Cluster 1</b>	<b>Cluster 2</b>	<b>Cluster 3</b>	
<b>Variable</b>	<b>(n=109)</b>	<b>(n=34)</b>	<b>(n=49)</b>	<b><i>p-</i></b>
				<b><i>value</i><sup>#</sup></b>

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<u>Years certified organic</u>	8	6	7	0.722
Number of cows	62.7	38.5	68.4	<0.001
<hr/>				
Total area (ha) <sup>1</sup>	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
<hr/>				
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 <sup>2</sup>	2	1.9	1.5	0.010
Manpower dedicated to all agricultural activities <sup>3</sup>	2.5	2	3	<0.001
Stocking rate <sup>4</sup> (Livestock unit per ha)	0.63	0.51	0.32	<0.001
<u>Time on pasture (days/year)</u>	210	238	153	<0.001
<hr/>				
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
<hr/>				
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

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

303 \*variables related to total area (ha)

304 <sup>1</sup> Agricultural Area is defined as the area used for farming. It includes the land  
305 categories: arable land, permanent grassland, permanent crops, and other agricultural  
306 land such as kitchen gardens. The term does not include unused agricultural land,  
307 woodland and land occupied by buildings, farmyards, tracks, ponds, etc.

308 [http://epp.eurostat.ec.europa.eu/statistics\\_explained/index.php/Glossary:Agricultural\\_a](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Agricultural_area)  
309 [rea](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Agricultural_area) %28AA%29

310 <sup>2</sup> Full-time equivalent (FTE) consisting on 40 hours (= 1 FTE), and part-time worker employed for  
311 20 hours a week (=0.5 FTE).

312 [http://epp.eurostat.ec.europa.eu/statistics\\_explained/index.php/Glossary:Full-time\\_equivalent](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Full-time_equivalent)

313 <sup>3</sup> Relates only to manpower dedicated to the dairy cow herd. Manpower dedicated to milk  
314 processing is not included.

315 <sup>4</sup>Ratio of the total herbivores against the total fodder area.

316 [http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental\\_indicator\\_-](http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_livestock_patterns)  
317 [\\_livestock\\_patterns](http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_livestock_patterns)

### 318 3.2. Production disease costs

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

324 **Table 3.** Median (range) of losses (in Euro<sup>1</sup> per cow) due to lameness for the three  
325 farm clusters for the year 2012, p-values are given for Kruskal-Wallis tests (33 farms  
326 had missing values)

	Cluster 1	Cluster 2	Cluster 3	
Variables	(N=94)	(N=31)	(N=36)	<i>p-value</i> <sup>#</sup>
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

327 <sup>#</sup> If significant ( $P < 0.05$ ), clusters are deemed to be drawn from different populations.

328 <sup>1</sup>Costs estimations for Sweden were made in Swedish Krona (SEK) and converted to  
329 Euro at the rate of 1SEK=€ 0.11

330 **Table 4.** Median (range) of losses (in Euro<sup>1</sup> per cow) due to udder disorders for the  
331 three farm clusters (n=165), p-values are given for Kruskal-Wallis tests (33 farms had  
332 missing values)

	Cluster 1	Cluster 2	Cluster 3	
Variable	(N=94)	(N=31)	(N=36)	<i>p-value</i> <sup>#</sup>



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

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

334 <sup>1</sup>Costs estimations for Sweden were made in Swedish Krona (SEK) and converted to  
335 Euro at the rate of 1SEK=€ 0.11.

336 The assessment of certain health indicators, thoroughly analyzed in Krieger et al.

337 (2017) showed significant differences among the clusters.

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

	<b>Cluster 1</b>	<b>Cluster 2</b>	<b>Cluster 3</b>	<b>sign</b>
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 <sup>a</sup> , %	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
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341 <sup>a</sup>SCC=somatic cell counts.

### 342 **3.3. Actions to improve herd health**

343 The number of health management actions identified for each farm ranged from 0 to  
344 22, while the proportion of implemented measures per farm varied between 0 and  
345 100% (median 67%) (see Sjöström et al., 2018). The levels of implementation and non-  
346 implementation of additional herd health management actions after performing the  
347 impact matrix as part of a participatory process is presented in Table 6. Reasons for  
348 not implementing all management measures specified in the action plan were indicated  
349 in 78 (76%) of the questionnaires. The most frequent reasons were constraints related  
350 to housing and / or construction (36% of the farmers), followed by time limitations  
351 (31%), costs / financial limitations (26%) and that the farmers were no longer  
352 convinced that the measures would produce a positive outcome (26%). It was also  
353 quite common that other measures than those agreed were implemented instead  
354 (23%) or that farmers did not see the need of a planned measure anymore due to  
355 absence of the initial health problem (24%).

356 Direct attitude towards the action (i.e. intention to adopt health actions) was not  
357 significantly different between the clusters (P=0.147). However, farm clusters differed  
358 on the number of actions that were agreed to implement, with double the number of  
359 actions on Cluster 3 farms than on farms in Clusters 1 and 2. The rate of  
360 implementation of actions was significantly higher in Clusters 1 and 3 than in Cluster 2.  
361 In terms of the stated reasons for failure to take up actions, the most important  
362 connected with the farm style structure in absolute terms was prohibitive time and cost  
363 requirements, followed by limitations to housing construction and design. However,  
364 these barriers were fairly common in all three clusters. In terms of barriers to uptake,

365 where clusters differed was in the role of skills and access to expertise, which were  
 366 seen very much as a barrier to uptake in Cluster 2, but not to any significant extent in  
 367 the clusters representing larger and more intensive farms.

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

<b>Variable</b>	<b>Cluster 1 (n=109)</b>	<b>Cluster 2 (n=34)</b>	<b>Cluster 3 (n=49)</b>	<b>p-value<sup>#</sup></b>
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

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

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

#### 375 **4. Discussion**

376 Three major organic dairy farm clusters were identified across Germany, France, Spain  
377 and Sweden. At the heart of each cluster is a meaningful farm typology that differs from  
378 the types found in the other clusters. Two of the typologies generated here appear in  
379 all countries, in spite of the fact that the countries have very different topography,  
380 climate, organic farming traditions and rates of organic market growth (Sanders et al.,  
381 2016). It is interesting that these two organic typologies are coherent and yet transcend  
382 national boundaries, when the national differences listed above are known to shape the  
383 development of different production structures.

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

395 Even though the basis of production rules for organic operations in Europe is the same,  
396 organic milk production conditions vary greatly throughout Europe which respect to  
397 factors such as access to grazing and housing. Pasture is at the heart of organic

398 livestock management and this is seen as a key part of the feeding and husbandry  
399 approach that promotes positive health outcomes (EC 834/2007; EFSA, 2009). For  
400 instance, Sjöström et al. (2018) studied the prevalence of lameness in the same herds  
401 as were used the present study and found zero-grazing herds (found only in Germany).  
402 These zero grazing farms had a higher likelihood of lameness than German organic  
403 grazing herds in the sample. Unexpectedly, some farms in our own study were also  
404 found to be in breach of organic regulations, i.e. they continued to use slatted floors in  
405 housing (more than 50% of the total surface floor). Similar breaches of organic  
406 standards were found by Schmid and Knutti (2009) who compared the main  
407 requirements of EU organic production rules with other welfare standards and found  
408 differences related to observance of the prohibition of certain housing systems.

409 The amount of time that dairy cows are allowed access to grazing varies widely across  
410 the four European countries, although there is an increasing trend towards  
411 intensification as historically observed (van Arendonk and Liinamo, 2003), with an  
412 increase in the number of high yielding cows requiring more energy and protein dense  
413 rations. This is confirmed in the farms in Cluster 3, with the highest proportion of their  
414 land areas as temporary grass and legumes (roughage and feed based systems),  
415 which is generally more intensively managed and higher yielding than permanent  
416 pastures. This trend is leading to decreasing use of traditional grazing systems (EFSA,  
417 2015) and more use of indoor rearing and use of concentrates and ensiled forage. The  
418 literature describes a broad range of rates of concentrate use in organic dairy herds,  
419 with variation often related to geographical and husbandry differences. To illustrate, in  
420 the SOLID project (Horn et al., 2014), concentrate levels for the group defined as 'low  
421 input' were estimated to be 286 kg/cow/lactation in Austria, 717 kg/cow/lactation in  
422 Northern Ireland and 1,359 kg/cow/lactation in Finland. Even lower levels of  
423 concentrate feeds have been found in Germany, i.e. 200 kg dry matter of concentrates  
424 per cow per year leading to a milk yield of 6 000 kg (Müller-Lindenlauf, 2008). In the

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

432 In the farm typology found in Cluster 3, concentrate use of 2,446 Kg/cow/year might be  
433 deemed excessive, based on the ranges listed above, although use of forage was also  
434 very high in this case. The fact of Cluster 3 also had a low milk/concentrate ratio  
435 compared to others Clusters, suggests the use of more intensive indoor rearing; yet  
436 this ratio needs further research across the year since the use of forage in this farm  
437 typology might vary according to the seasons. Cluster 3 also had more land available  
438 for feeding (non-permanent grass and legumes), probably as a result of the climate in  
439 Sweden, implying less time available for grazing and more use of conserved forage in  
440 the cold season. In terms of the rates of implementation of health management actions,  
441 there was considerable variation between the clusters. Farmers in Cluster 2 had the  
442 lowest rate of implementation of actions (44 %). This cluster 2 has the most extensive  
443 management systems, the smallest farmed area and lowest use of inputs and  
444 resources of any of the clusters. Milk yields were also low, and this more than offsets  
445 the low input use. Production methods have specific strengths and weaknesses. It has  
446 been globally debated whether the most extensive systems can reach a satisfactory  
447 level of profitability without intensification (i.e. Hanrahan et al. 2018). The limitation of  
448 intensification management is also one precondition for better health in dairy cattle  
449 (Hultgren, 2016). However, if extensive use of resources is the basis of its distinctive  
450 production, it might be a sign of the farming style, captured in a marketing strategy,  
451 with a remarkable impact on their profitability (van der Ploeg and Ventura, 2014). The

452 relationship between the economic and social sustainability of extensive farming  
453 systems and their feeding management regimes is very important. Grazing has been  
454 found to be associated with lower production costs, and lower use of concentrate,  
455 since well-maintained pasture is a highly nutritious feed source. However, conclusions  
456 about farm profitability have to be more cautious since the margin per liter of milk  
457 produced is a more relevant performance measure in the case of smallholder farms  
458 (Nemes, 2009).

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

470 This survey confirms the findings of others, that organic dairy farming in Europe is  
471 largely constituted by small-scale family farms (Sanders et al., 2016). A similar trend  
472 was found by Prunier et al. (2013) for organic pig farms. Resource demands (e.g.  
473 labour, investments) in one field of farm management (i.e. animal health) may provoke  
474 conflicts with management actions in other fields, requiring farmers to allocate  
475 resources to those management areas which are preferred most, given the specific  
476 farming situation. These resource conflicts would be much greater on smaller farms,  
477 such as those in Cluster 2, where resources, especially of land, labour and capital, are  
478 most limited. Each farmer can have positive effects on most health aspects through



479 their management strategy. Each action is based on particular driving forces where the  
480 farmer has to involve the mobilization of resources where a specific organization of the  
481 labour process is needed. It would be expected therefore, that the rate of uptake of  
482 herd health recommendations would be lowest in Cluster 2 due to the extent of  
483 resource conflicts. The benefits of participatory approaches to the design of health  
484 management plans was more welcomed by Cluster 1, maybe more willing to  
485 reconfigure their farm business. The ratio of implementation was similar in Cluster 1  
486 and 3 but the main divergence between the farms in both clusters may be due to the  
487 specialization of the farms in Cluster 3 and the lower age of farmers in Cluster 1.

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

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

504 The results of this study suggest that veterinarians and other health advisors, when

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

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

## 522 **5. Conclusions**

523 From amongst the matrix of organic farms that exist across European countries, three  
524 major farm clusters have been identified, each with a relatively homogenous set of  
525 structural and management characteristics. The different socio-demographic, structural  
526 conditions and prevalence of diseases observed in these clusters have been shown to  
527 at least partially explain differences in the likelihood of adoption of agreed actions to  
528 improve animal health status. It is relatively safe to assume from this, therefore, that  
529 organic farm typology would be a useful basis on which to adapt (tailor) animal health  
530 advice to yield additional improvements in animal health status. In short, different types

531 of organic dairy farms (clusters) require different types of advisory services (i.e.  
532 approach and formulation of new support mechanisms). At the very least, the results  
533 suggest that there would be merit in conducting further research to gain a deeper  
534 understanding of the typologies that exist in the organic dairy farming community and  
535 to identify with each of these, their unique set of barriers to the uptake of different types  
536 of health management actions.

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### 544 **References**

545 Barkema, H.W., Van der Ploeg, J.D., Schukken, Y.H., Lam, T.J., Benedictus, G.,  
546 Brand, A., 1999. Management style and its association with bulk milk somatic cell  
547 count and incidence rate of clinical mastitis. *J. Dairy Sci.* 82, 1655–  
548 1663. [https://doi.org/10.3168/jds.S0022-0302\(99\)75394-4](https://doi.org/10.3168/jds.S0022-0302(99)75394-4)

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

552 Blanco-Penedo, I., Jones, P.J., Tranter, R.B., Velarde, A., 2014. Professional profile of  
553 the advisor of organic dairy farming. XI Congreso de la Sociedad Española de  
554 Agricultura Ecológica (SEAE) 1. - 4. October 2014. pp. 924.  
555 <http://www.agroecologia.net/recursos/publicaciones/actas/cd-actas->

556 xicongresoseae/actas/comunicaciones/92-perfil-tecnico-bovino-blanco-resumen.pdf

557 Burke, J., Roderick, S., 2006. Examination of the impact and effectiveness of herd  
558 health and welfare assessment in improving animal welfare on organic dairy farms,  
559 using qualitative interviews. Joint Organic Congress, Odense, Denmark, May 30-31  
560 2006.

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

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

569 EC No. 1804/1999. Council Regulation (EC) No 1804/1999 of 19 July 1999  
570 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural  
571 products and indications referring thereto on agricultural products and foodstuffs to  
572 include livestock production. OJ: JO L\_221, 24.8.1999, p. 1-28.

573 EC No. 834/2007. Council Regulation (EC) No 834/2007 of 28 June 2007 on organic  
574 production and labelling of organic products and repealing Regulation (EEC)  
575 No 2092/91. OJ L 189, 20.7.2007, p. 1–23.

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

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

580 EFSA, 2009. Scientific report on the effects of farming systems on dairy cow welfare

581 and disease. Annex to the EFSA Journal 1143, 1–284.

582 Emanuelson, U., 2014. IMPRO D2.4 – Report on health plans. Retrieved on 28 May  
583 2018 from <http://www.impro-dairy.eu/index.php/outreach/deliverables>.

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

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

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

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

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

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

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

609 Jones, P.J., Sok J., Tranter, R.B., Blanco-Penedo, I., Fall, N., Fourichon, C.,  
610 Hogeveen, H., Krieger, M.C., Sundrum, A., 2016. Assessing, and understanding,  
611 European organic dairy farmers' intentions to improve herd health. Prev. Vet. Med.  
612 133, 84–96. <https://doi.org/10.1016/j.prevetmed.2016.08.005>

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

617 Krieger, M., Sjöström, K., Blanco-Penedo, I., Madouasse, A., Duval, J.E., Bareille, N.,  
618 Fourichon, C., Sundrum A., Emanuelson, U., 2017. Prevalence of production disease  
619 related indicators in organic dairy herds in four European countries. Livest. Sci. 198,  
620 104–108. <https://doi.org/10.1016/j.livsci.2017.02.015>

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

623 Leiber, F., Schenk, I. K., Maeschli, A. Ivemeyer, S., Zeitz, J. O., Moakes, S., Klocke,  
624 P., Staehli, P., Notz, C., Walkenhorst, M., 2017. Implications of feed concentrate  
625 reduction in organic grasslandbased dairy systems: a long-term on-farm study. Animal  
626 11 (11), 2051–2060.

627 Lund, V., Algers, B., 2003. Research on animal health and welfare in organic farming –  
628 a literature review. Livest. Sci. 80, 55–68. [https://doi.org/10.1016/S0301-](https://doi.org/10.1016/S0301-6226(02)00321-4)  
629 [6226\(02\)00321-4](https://doi.org/10.1016/S0301-6226(02)00321-4)

630 Martins, S.B., and Rushton, J., 2014. Cost-effectiveness analysis: adding value to

631 assessment of animal health, welfare and production. Rev. sci. tech. Off. int. Epiz.,  
632 2014, 33 (3), 681-689

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

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

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

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

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

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

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

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

656 Directorate-General for Agriculture and Rural Development. Available at:  
657 [https://ec.europa.eu/agriculture/external-studies/2016-organic-food-chain\\_en](https://ec.europa.eu/agriculture/external-studies/2016-organic-food-chain_en)  
658 (accessed 25.07.2017).

659 Schmid, O., Knutti S., 2009. Animal welfare in organic farming legislations and  
660 standards – analysis & proposal for a more outcome-oriented approach/tool.  
661 Agriculture and Forestry Research, Special Issue No 362 (Braunschweig, 2012) ISSN  
662 0376-0723.

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

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

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

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

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



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

685 Wallenbeck, A., Rousing, T., Sørensen, J. T., Bieber, A., Spengler Neff, A., Fuerst-  
686 Walzl, B., Winckler, C., Pfeiffer, C., Steininger, F., Simantke, C., March, S., Brinkmann,  
687 J., Walczak, J., Wójcik, P., Ribikauskas, V., Wilhelmsson, S., Skjerve, T., Ivmeyer, S.,  
688 2018. Characteristics of organic dairy major farm types in seven European countries.  
689 *Organic Agriculture.* <https://doi.org/10.1007/s13165-018-0230-1>.

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