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1 **Structural characteristics of organic dairy farms in four European countries and their**

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

3 **Authors**

4 Isabel Blanco-Penedo[a,b*], Karin Sjöström[a], Philip Jones[c], Margret Krieger[d], Julie Duval[e], Felix

5 van Soest[f], Albert Sundrum[d], Ulf Emanuelson[a]

6

7 [a] *Swedish University of Agricultural Sciences, Department of Clinical Sciences, SE-750 07*

8 *Uppsala, Sweden.* Isabel Blanco-Penedo: isabel.blanco.penedo@slu.se; Karin Sjöström

9 karin.sjostrom@slu.se; Ulf Emanuelson: Ulf.Emanuelson@slu.se

10 [b] *Former Institution: IRTA, Animal Welfare Subprogram, ES-17121 Monells, Girona, Spain*

11 [c] *School of Agriculture, Policy and Development, University of Reading, Whiteknights, PO*

12 *Box 237, Reading, RG6 6AR, UK. p.j.jones@reading.ac.uk*

13 [d] *University of Kassel, Department of Animal Nutrition and Animal health,*

14 *Nordbahnhofstrasse 1a, D-37213 Witzenhausen, Germany.* Margret Krieger:

15 margret.krieger@uni-kassel.de*; Albert Sundrum:* sundrum@uni-kassel.de

16 [e] *BIOEPAR, INRA, Oniris, La Chantrerie, 44307 Nantes, France.* Julie Duval:

17 julie.duval@oniris-nantes.fr

18 [f] *Business Economics group, Wageningen University, Hollandseweg 1, 6706 KN*

19 *Wageningen, The Netherlands. felix.vansoest@gmail.com*

20

21 [*] Corresponding author: Isabel Blanco-Penedo. Email: isabel.blanco.penedo@slu.se

22

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

50   Analysis; Cluster analysis; tailored advisory services

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 götalands

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

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).

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

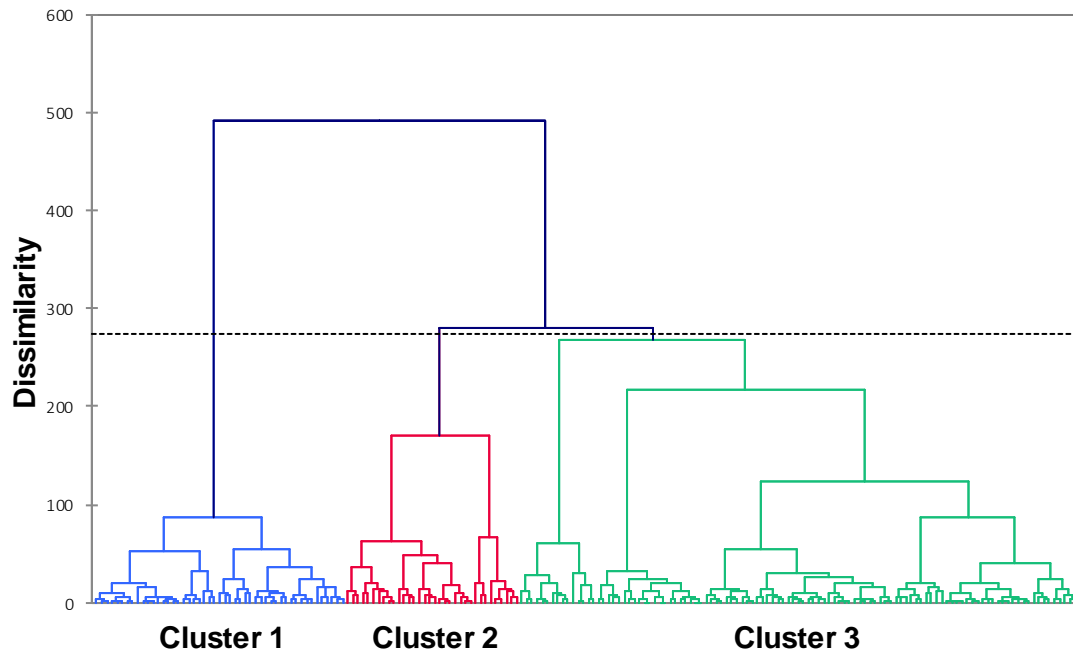182 grouped using AHC according to the factor scores derived from the MCA.

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 ≥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   dendogram (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 Chi² 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
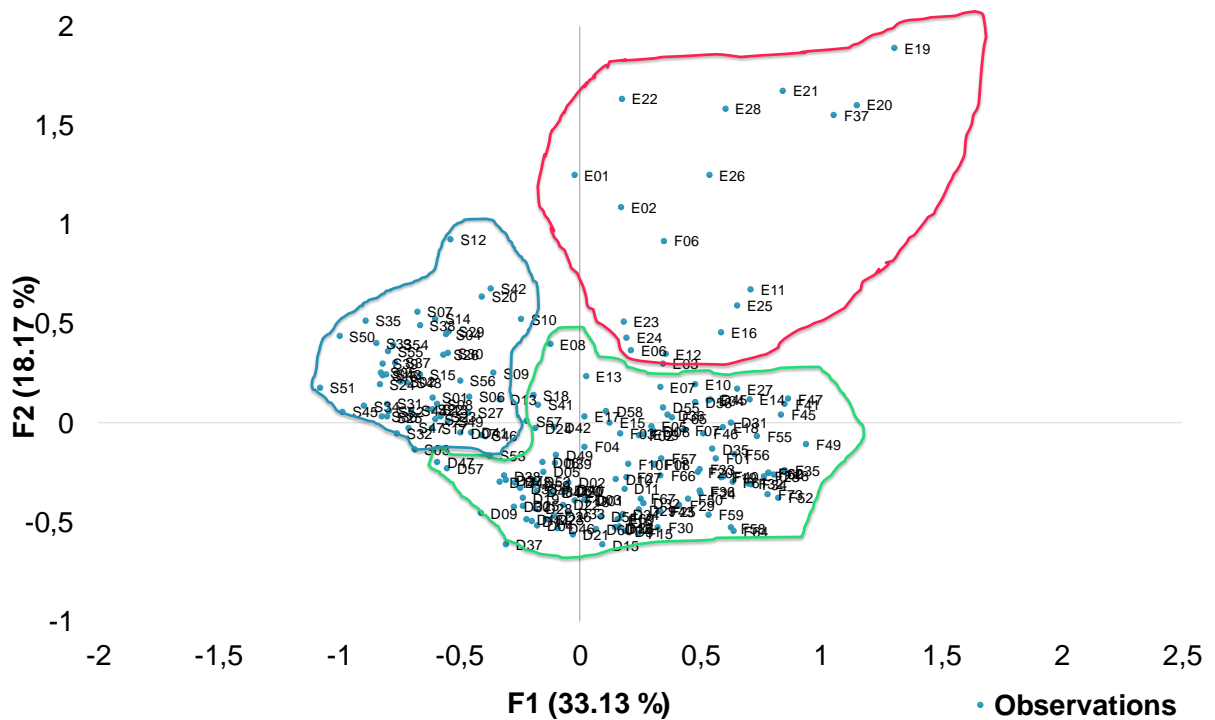
231 day.

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.

F2 (18.17 %) (vertical axis), **F1 (33.13 %)** (horizontal axis), • **Observations**

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

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%	

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   [1]Selection of different systems that included a permanently installed circular walk-

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

273   [2]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   [3] Different housing groups for lactating cows refers to separation of cow groups on

276   housing.

277   [4] 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

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

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

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

303 *variables related to total area (ha)

304 [1] 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

309 rea_%28AA%29

310 [2] 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

313 [3] Relates only to manpower dedicated to the dairy cow herd. Manpower dedicated to milk

314 processing is not included.

315 [4] Ratio of the total herbivores against the total fodder area.

316 http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-

317 _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[1] 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)

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

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

334 [1]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

	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 |

341 ^aSCC=somatic cell counts.

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^2 test of homogeneity (qualitative variables) and

371 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

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.

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

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

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.

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

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-

587 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., Steinwidder, 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.; Gratzer, 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

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

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-
629 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.agsy.2013.05.004

654   Sanders, J., Gambelli, D., Lernoud, J., Orsini, S., Padel, S., Stolze, M., Willer, H. and

655   Zanoli, 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

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 Waltl, B., Winckler, C., Pfeiffer, C., Steininger, F., Simantke, C., March, S., Brinkmann,

687 J., Walczak, J., Wójcik, P., Ribikauskas, V., Wilhelmsson, S., Skjerve, T., Ivemeyer, 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