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Capturing systemic interrelationships by an impact analysis to help reduce production diseases in dairy farms

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ABSTRACT

Production diseases, such as metabolic and reproductive disorders, mastitis, and lameness, emerge from complex interactions between numerous factors (or variables) but can be controlled by the right management decisions. Since animal husbandry systems in practice are very diverse, it is difficult to identify the most influential components in the individual farm context. However, it is necessary to do this to control disease, since farmers are severely limited in their access to resources, and need to invest in management measures most likely to have an effect. In this study, systemic impact analyses were conducted on 192 organic dairy farms in France, Germany, Spain, and Sweden in the context of reducing the prevalence of production diseases. The impact analyses were designed to evaluate the interrelationships between farm variables and determine the systemic roles of these variables. In particular, the aim was to identify the most influential variables on each farm. The impact analysis consisted of a stepwise process: (i) in a participatory process 13 relevant system variables affecting the emergence of production diseases on organic dairy farms were defined; (ii) the interrelationships between these variables were evaluated by means of an impact matrix on the farm-level, involving the perspectives of the farmer, an advisor and the farm veterinarian; and (iii) the results were then used to identify general system behaviour and to classify variables by their level of influence on other system variables and their susceptibility to influence. Variables were either active (high influence, low susceptibility), reactive (low influence, high susceptibility), critical (both high), or buffering (both low). An overall active tendency was found for feeding regime, housing conditions, herd health monitoring, and knowledge and skills, while milk performance and financial resources tended to be reactive. Production diseases and labour capacity had a tendency for being critical while reproduction management, dry cow management, calf and heifer management, hygiene and treatment tended to have a buffering capacity. While generalised tendencies for variables emerged, the specific role of variables could vary widely between farms. The strength of this participatory impact assessment approach is its ability, through filling in the matrix and discussion of the output between farmer, advisor and veterinarian, to explicitly identify deviations from general expectations, thereby supporting a farm-specific selection of health management strategies and measures.

"*Every good regulator of a system must be a model of that system.*" (Conant and Ashby, 1970)

1. Introduction

Multifactorial diseases, such as metabolic and reproductive disorders, mastitis, and lameness, by causing economic losses and impairing the health and welfare of animals, represent serious problems in both conventional and organic dairy farming (Thamsborg et al., 2004). They have in common that all of them arise from complex interactions between a large number of risk factors, where each, in itself, would not necessarily lead to disease. Risk factors for the emergence of these diseases are mainly related to deficits in farm management, preventing animals from being able to cope with given living conditions. This is why they are called production diseases, because their prevalence and severity is impacted by management decisions (Nir, 2003). It is understood that production disease is an emergent property of the farm, arising

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from the functioning of the component parts of the system (Sundrum, 2012). Animal husbandry systems are, in practice, so diverse, that it is difficult to identify the most influential component in the individual farm context. This, however, is necessary to prevent disease, since farmers are severely limited in their access to resources, and therefore need to invest in management measures most likely to have a greatest beneficial effect (Sundrum, 2014).

With challenges on many fronts to contend with such as impacts on landscape and ecosystems, pollution, health risks, and animal welfare, livestock farming is hard-pressed to change in order to meet societal demands (Gibon et al., 1999). This is especially true for organic livestock farming, where consumer willingness to pay premium prices is tied up with their trust in the delivery of additional credence values. Organic farming has the stated aim of good animal health and welfare and seeks to achieve that aim by means of stricter production rules and use of extensive advisory services. These requirements, however, have not led to outstanding results in a considerable proportion of organic farms, e.g. with regard to prevalence of production diseases (Hovi et al., 2003; Krieger et al., 2016). Poor animal health is to the detriment of the animals, by causing pain and distress, as well as the farmers, by leading to unfair competition and threatening consumer confidence in product and process quality. It follows that livestock farming in general, and organic systems in particular, are in need of approaches that support the identification of management measures that are prospective for improving animal health. Involvement of advisors and veterinarians in the context of health management can be highly beneficial. Their expertise is essential for proper diagnoses and they provide relevant knowledge that may be used for problem solving. The value of external knowledge, however, heavily depends on the bearers' capacity to tailor advice on the basis of the farm context, to ensure it is applicable and useful. Due to the high complexity (non-linear dynamic relationships) in livestock systems, one-size-fits-all solutions to problems, based on ceteris paribus assumptions and one single perspective is insufficient. Instead, systemic approaches must be developed and tested that take into account the specific context of each farm and also which simplify complexity without reducing it to simple cause-effect relationships, and involve relevant stakeholders.

Knowledge on the functional relationships between components is the basis for understanding the behaviour and attributes of systems and is necessary to achieve significant improvements in the performance of systems (Conway, 1985). In order to assess and analyse the interrelationships at work in systems, Vester and Hesler (1980) developed the Sensitivity Model; a method which uses cybernetic principles for system analysis and which is based on fuzzy logic (Zadeh, 1997), i.e. it uses imprecise knowledge of real experience. Within their 'network thinking method', representation of reality is achieved by the following steps: correctly identifying and selecting key system components; understanding how these inter-relate; and joining up the pattern in an 'impact matrix', all within a participatory framework. Impact matrices were initially developed and used for forecasting purposes (Godet, 1979; Gordon and Hayward, 1968) and have since been applied in a diversity of research contexts, e.g. identification of sustainability values (Cole et al., 2007), optimisation of management processes (Fried, 2010; Gausemeier, 1998; Schianetz and Kavanagh, 2008), cost benefit analysis (Wenzel and Igenbergs, 2001), improvement of slash and burn cultivation systems (Messerli, 2000), management of ecological reserves (Iron Curtain Consortium, 2004) and city regions (Wiek and Binder, 2005) as well as transport (OECD Environment Directorate, 2000), traffic (Vester, 2007), and settlement planning (Coplak and Raksanyi, 2003). Studying organic pig farms in Germany, Hoischen-Taubner and Sundrum (2012) were the first to use the impact matrix approach in the context of improving animal health.

The rationale for this study is the unsatisfactory animal health status in organic dairy farms, as demonstrated by Krieger et al. (2016), and the relative ineffectiveness of traditional herd health planning and management to improve this situation over many years. Systemic impact analyses were therefore conducted on European organic dairy farms which captured the complexity of individual farms and identified farm-level levers for driving desirable change. The overall objective of the study was to show the potentialities of using an impact analysis for reducing production diseases on (organic) dairy farms. The specific objectives were to evaluate the interrelationships between farm factors, determine the systemic roles of variables in driving herd health and identify the most influential variables in each farm context.

2. Material and methods

2.1. Farms

Impact analyses were performed during farm visits in four European countries. Farms were recruited to the study by phone or mail in Spain and Sweden, and through advisors involved in the project in Germany and France. A total of 192 organic dairy farms in France (51), Germany (60), Spain (28) and Sweden (53) were recruited and visited by 6 different researchers, 58 agricultural advisors and 143 veterinarians during a period of 6 months (from November 2013 until April 2014). Country differences in sample sizes are primarily due to level of sector development, for example, the sector is less developed in Spain than in the other countries (MAGRAMA, 2014). Farms had been in organic production from 1 to 29 years. Herd size ranged from 7.4 to 376.5 cow-years (calculated by adding all the cow-days per farm in the year of survey and dividing the product by 365). Herds were smallest in Spain (median 29.7 cow-years) and largest in Sweden (median 68.1 cow-years). Although stratification was not used in sample selection, the final sample does cover the size range and system diversity found in organic dairy farms in Europe.

2.2. Definition of system variables

Identification of relevant system variables was undertaken before the farm visits to ensure that all key factors that play a role in the way the system behaves were captured. This step involved the definition of system boundaries, i.e. the organic dairy farm, and goal-setting, i.e. reducing the prevalence of production diseases. These choices then determined who should be involved in the subsequent variable selection process, namely, stakeholders affected by, or affecting, farm animal health management. To facilitate the identification of relevant system variables, five regional workshops were conducted in France (2), Germany (1), Spain (1), and Sweden (1). The workshops were held within a multidisciplinary framework and attended by a total of 80 experts in animal health on organic dairy farms: farmers, advisors, veterinarians, researchers, dairy processers and traders, and members of dairy associations. The list of variables identified, which was collected in a participatory process, was structured, and reduced to a set of essential components, resulting in four national lists containing a total of 81 variables. Using these lists a multinational team of researchers then established a pan-European set of 20 variables applicable to a wide range of farms (Duval et al., 2013). In pilot visits to two organic dairy farms, impact analyses were performed using these 20 variables. To reduce the time needed to undertake the task, this set was further aggregated to 13 variables (Table 1). As proposed by Vester (2007), the final set of variables was then screened to bio-cybernetic criteria, in a so-called 'criteria matrix', to make sure it sufficiently represents the system. During this validation exercise variables are assigned to 18 criteria in four categories (areas of life, physical, dynamic and system-relatedness). A variable set is regarded valid, if it is balanced and no aspect is neglected. The final set of 13 variables was found to cover all aspects, with a slight overhang of 'activities' and variables that are 'controllable from the inside' (data not shown).