152. Developing precision livestock farming in practice: using sensor time series data for breeding decision support systems

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Abstract

The objective of GenTORE is to develop innovative genome-enabled selection and management tools to optimise cattle resilience and efficiency in widely varying environments. These tools incorporate both genetic and non-genetic variables, aiming to increase the economic, environmental and social sustainability of European cattle meat and milk production systems. Using available on-farm technology allows large-scale phenotyping of resilience and efficiency that can be applied to evidence-based management, breeding and culling decisions. Veterinarians and other farm advisors are engaged with farm business drivers that are influenced by consumer and societal demands including the environment, human health concerns regarding antimicrobial resistance and animal welfare. Conflicts exist in balancing these factors. Evidence-based tools to support herd-level strategy are lacking. This work describes how multiple streams of sensor data can be combined to inform herd-level strategy in a time-efficient, automated and objective system to support advisor input to herd health.

Introduction

The GenTORE project aims to develop innovative genome-enabled selection management tools to optimise cattle resilience and efficiency in widely varying environments.

Current decision tools for breeding often fail because they ignore the complex interactions between production, health, genotypic predisposition, and reproduction performance at a specific herd population level; they also require significant time and are not user friendly for advisors or at farm level.

This paper outlines how the management tools developed through GenTORE can help farmers, veterinarians and other advisors to balance the four key drivers in sustainable dairy and beef farming (Figure 1).

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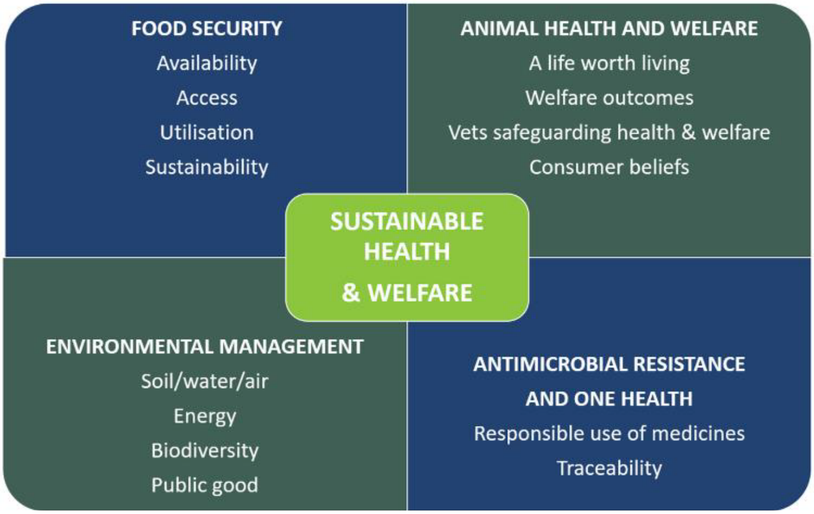

Figure 1. The sustainable herd health balance for farm advisors.

Balancing the drivers for evidence-based herd decision-making

Veterinarians and other farm advisors are engaged with the farm business drivers described below that are influenced by consumer and societal demands. Conflicts exist in balancing these factors. Precision Livestock Farming (PLF) offers opportunities for innovation in evidence-based decision-making for farmers, veterinarians and advisors. A balance must be achieved in sustainable dairy and beef farming between four key drivers (Figure 1):

1. 'One Health';
2. environmental impact;
3. animal health and welfare;
4. food security.

'One Health'. The concept of 'One Health' encompasses animal health, human health and the environment. One Health is ever present in the global fight against the development of antimicrobial resistance. It is already the cause of 700,000 human deaths every year (O'Neill 2016). Decisions to administer antimicrobials to cattle are critically important, but often highly subjective and not risk-based.

Environmental impact. The importance of mitigation of the impacts of dairy farming on the environment are increasingly recognised (Statham *et al.* 2017; Statham *et al.* 2020). In 2010 the Food and Agriculture Organization of the United Nations (FAO) produced a 'lifecycle assessment' of the dairy sector which was proposed to contribute 4% to the total global man-made greenhouse gas emissions. Improved efficiency of milk production will reduce negative environmental effects; if fewer cows (and replacements) are required and there are fewer 'lost' litres of milk and a reduction in greenhouse gases and resources per litre of saleable milk. 'Lost' milk here includes milk that does not enter the food chain following animal treatment or a reduction in yield that occurs following clinical or subclinical disease or poor reproductive performance. The difference in environmental impact between the best and poorest performing herds in terms of health and fertility is likely to be very large; in terms of fertility alone reductions in methane emissions of the order of 25% appear to be possible between the best and poorest herds (Garnsworthy 2004; ADAS 2013).

Animal health and welfare. It is important that the connections are clearly made for welfare as well as health in managing the sustainability of food production (Broom *et al.* 2013).

Food security. Food security is not limited solely to the quantitative aspects of food supply. Three fundamental dimensions are applicable to products of animal origin: availability of food, access to food, and effective and safe utilisation of food (Bonnet *et al.* 2011). Sustainability refers to the capacity for sustainably maintaining agricultural production (including animal production), national and international trade, storage and supply and food consumption that will meet the demand in the long term and even in the context of new constraints.

Herd level breeding and health decisions can be supported by on-farm sensor time series data presented as proxies of resilience and efficiency

Evidence-based tools to support herd-level strategy setting are lacking. However multiple streams of sensor data can be combined in a time-efficient, automated and objective system to support advisor input to herd health. Climate change, with its increasing frequency of environmental disturbances puts pressures on the livestock sector (Hansen *et al.* 2012). More complex traits such as resilience must be considered in our management strategies and breeding programs (Friggens *et al.* 2022). Resilient animals respond well to environmental challenges, are more likely to overcome them without assistance and therefore have better health and welfare. In practice there remains a lack of operational measures of resilience that can be deployed at large scale across different farm types and livestock species. Such measures are needed to provide more precise phenotypes of resilience for use in farm management and animal breeding decisions. Decisions can be made at individual animal level, but when combined can inform critical changes in herd level policies and protocols.

Cow resilience and efficiency are two key traits that can be used for decision making. Sensor-based proxies for phenotypes offer an important dimension to application of genomics data. Novel proxies for complex phenotypes were developed in Horizon 20-20 project 'GenTORE' for resilience using already existing at-market technology. Definitions and ways to calculate resilience outcomes were lacking; methodology had to be objective and valid so appropriate ranking of the cows for these traits on farm was possible (Adriaens *et al.* 2020). For resilience, a combination of longevity, health, robustness, production, and reproduction performance had to be considered. This resulted in the following definition for ranking cows: 'resilience is the cumulative result of a cow's ability to re-calve' (and thus extend her productive lifespan), supplemented with secondary corrections for age at first calving, calving intervals, 305-day milk yield, health events and number of inseminations. Different weightings of the included variables were proposed and cross-validated to produce a common equation to calculate the resilience scores. The highest weight was given to the number of parities. One of the main challenges in this work was the availability, completeness and reliability of the data (Adriaens *et al.* 2020).

Sensor technologies record parameters reflecting animals' performance, behaviours and physiological state. Besides the classical use for event detection and 'alerts', time series data from sensors can be characterized to provide information on how animals have performed over time. Two types of sensor features were defined. Type A sensor features generally characterize the sensor measurements relative to the herd peers, and include milk yield, body weight, rumination and activity. Type B sensor features specifically target the identification of dynamics in the time series indicating certain health or fertility events. Several primary algorithms to predict the resilience and efficiency rankings from the sensor features were tested. These algorithms were deployed to design software that could signal herd level change in resilience and thus provide an evidence base for practical changes in herd management policies.

Combining individual level data from multiple technologies in a form that is useable in real world situations in real time requires an additional integration step to deal with issues such as synchrony of multiple proxy indications at animal level. Statistical methods to deal with these issues and combine proxies into one reliable indicator have been proposed (Adriaens *et al.*, 2020). GenTORE partner 'Noldus' have developed a demonstration web framework using the software Blazor (https://demos.telerik.com/blazor-ui/; Microsoft, Redmond, USA) that outlines the potential of this combination of time-series sensor data as herd level resilience and efficiency based tools: Comparing herd resilience and efficiency score against a group benchmark; Visualization of four main component scores (Health, Fertility, Production and Herd Inventory) and a detailed view of underlying data for farm advisor or researcher.

Developing an advanced dairy cow decision-support tool prototype to optimize breeding decisions for dairy cows is a vital missing link in the industry today. So many PLF technologies operate in separate silos; opportunities to make evidence based breeding or culling decisions are essentially missed on many farms. GenTORE looks to integrate multiple sources of information including PLF sensor data, genomics and germplasm quality data (Spilman *et al.* 2017) to drive an opportunity to realise the wasted potential in commercial herds by targeting scarce resources and optimizing herd management decisions. The aim is to establish a practical approach to how the genetic potential offered by genomics can be optimally exploited in each individual herd environment.

Conclusions

Sustainable herd health would be supported by objective advice. Current decision tools for breeding often fail because: (1) they ignore the complex interactions between production, health, genotypic predisposition and reproduction performance at a specific herd population level; and (2) they require significant time and are not easy to use at farm level or for advisors. GenTORE aims to integrate multiple sources of information including PLF sensor data and genetics in order to deliver a herd level advisory tool that can inform a balanced herd sustainable management strategy.

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