Investing in health to improve the sustainability of cattle production in the United Kingdom: a narrative review

by Capper, J.L. and Williams, P.

DOI link to the version of record on the publisher's site

Capper, J.L. and Williams, P. (2023) 'Investing in health to improve the sustainability of cattle production in the United Kingdom: a narrative review', *The Veterinary Journal*, 296-297, article number 105988.

The Veterinary Journal 296-297 (2023) 105988

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Invited review

Investing in health to improve the sustainability of cattle production in the United Kingdom: A narrative review

Judith L. Capper [a,*], Paul Williams [b]

[a] Agriculture and Environment Department, Harper Adams University, Newport, Shropshire TF10 8NB, UK
[b] MSD Animal Health, Walton, Milton Keynes, Buckinghamshire MK7 7AJ, UK

ARTICLE INFO

Keywords:
Disease
Greenhouse gas emissions
Health
Technologies
Vaccines

ABSTRACT

Livestock health is a key concern for all food system stakeholders and has considerable impacts upon sustainable food production. Improving productivity means that a set quantity of milk or meat may be produced at a lower economic cost, using fewer resources and with reduced greenhouse gas emissions (GHGe); however, diseases that reduce yield, growth or fertility have the opposite effect. The purpose of this narrative review was to assess the breadth of economic and environmental sustainability information relating to cattle health within the literature and to discuss related knowledge gaps within the literature. The mechanisms by which improved awareness and investment can lead to improved cattle health both on-farm and across the wider cattle industry are also appraised; concluding with the opportunities and challenges still outstanding in improving sustainability through livestock health. The economic and environmental impacts of cattle health have not been sufficiently quantified in the literature to draw valid conclusions regarding the sustainability impact of different diseases. Where available, economic data tended to be dated or extremely variable. Furthermore, environmental analyses did not use consistent methodologies and principally focused on GHGe, with little attention paid to other metrics. Although reducing disease severity or occurrence reduced GHGe, published impacts of disease varied from 1% to 40% with little apparent association between GHGe and industry-wide economic cost. An urgent need therefore exists to standardise methodologies and quantify disease impacts using a common baseline with up-to-date data inputs. Given the threat of antimicrobial resistance, improving cattle health through technology adoption and vaccine use would be expected to have positive impacts on social acceptability, especially if these improvements rendered milk and meat more affordable to the consumer. Therefore, it is important for cattle producers and allied industry to take a proactive approach to improving cattle health and welfare, with particular focus on diseases that have the greatest implications for sustainability.

1. Introduction

The world population currently stands at over 7.2 billion people and, by 2050, is predicted by the United Nations[1] to rise to 9.6 billion people, of which the majority will live in the developing world and will have a considerable increase in income per capita compared to the present day. The demand for animal-source foods (milk, meat and eggs) increases linearly with household income, thus the Food and Agriculture Organization (FAO) of the United Nations predicts a 48.6% increase in food requirements to fulfil global demands in 2050.[2] Projected population gains will also intensify competition for resources (land, water, energy), therefore the livestock industry faces a substantial challenge in concurrently increasing food production, reducing environmental impacts and improving animal health and welfare (Buller et al., 2018).

Sustainability is commonly defined as a balance between three pillars: environmental responsibility, economic viability and social acceptability (de Wit et al., 1995; United Nations[3]). All three factors are interdependent, varying in importance according to temporal challenges

* Corresponding author.
E-mail address: jcapper@harper-adams.ac.uk (J.L. Capper).

[1] See: United Nations, 2017. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.248. https://population.un.org/wpp/publications/files/wpp2017_keyfindings.pdf (accessed 2 May 2023).
[2] See: FAO, 2017. The Future of Food and Agriculture. https://www.fao.org/3/i6583e/i6583e.pdf (accessed 2 May 2023).
[3] See: United Nations, 2005. 2005 World Summit Outcome. https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_60_1.pdf (accessed 2 May 2023).

https://doi.org/10.1016/j.tvjl.2023.105988
Received 3 October 2022; Received in revised form 2 May 2023; Accepted 3 May 2023
Available online 5 May 2023
1090-0233/

arising from markets, government, climate or resource use. For example, without financial security and the ability to secure adequate return on investment, few farming operations will succeed. However, failing to take responsibility for environmental impacts of livestock production may have direct (e.g. penalties for pollution incidents) or indirect (e.g. reductions in animal or crop performance) economic consequences, in addition to reducing consumer confidence and therefore social acceptability of the production system.

Excellent animal health is the foundation of successful, sustainable livestock farming systems as defined by the three pillars. Diseased livestock do not perform as well as their healthy cohorts, leading to important consequences for herd or flock efficiency, either through subtle sub-clinical diseases that may have insidious productivity impacts, or clinical diseases with visible short or long-term effects on growth, yield, reproduction or mortality. However, as cited by the OIE,[4] over 20% of global animal protein is lost to disease. This efficiency loss increases resource use (feed, water, land, crop inputs), greenhouse gas emissions (GHGe) and the economic cost per unit of food produced (Capper and Bauman, 2013). The effects of poor livestock health may further impact on social acceptability through consumer concerns and perceptions regarding antimicrobial resistance (AMR), zoonotic disease and other public health concerns. Although sustainability is an important issue for all food production stakeholders, the specific impacts of livestock health have seldom been discussed in any detail.

The purpose of this narrative review was to assess the breadth of economic and environmental sustainability information relating to cattle health within the literature and to discuss the current knowledge gaps within the literature. The mechanisms by which improved awareness and investment can lead to improved cattle health both on-farm and across the wider cattle industry are also appraised; concluding with the opportunities and challenges still outstanding in improving sustainability through livestock health.

2. The evidence basis for improving health as a mechanism to enhance sustainability

2.1. Productivity and the dilution of maintenance concept

Multiple studies have described the role of improved cattle productivity in improving economic or environmental sustainability via the ‘dilution of maintenance’ effect (Capper, 2011; Capper, 2012; White and Capper, 2014; Hyland et al., 2016; Capper and Cady, 2020; Capper et al., 2021). In brief, the daily maintenance nutrient requirement of an individual animal or entire herd can be considered one of the ‘fixed’ costs of livestock production, in that it must be met before nutrients can be partitioned into lactation or growth. If productivity (milk yield or liveweight gain) improves, the daily nutrient requirement increases accordingly, but the proportion of nutrients apportioned to maintenance are diluted out over a greater number of production units. If a dairy cow, for example, increases milk yield per day from 15 L to 45 L, the total daily energy cost rises from 140 MJ/day to 282 MJ/day, yet the energy needed per unit of milk decreases from 9.4 MJ/L milk to 6.3 MJ/L milk. We can apply the same dilution concept to both resource use and GHGe per L of milk, all of which have an economic and environmental cost.

As shown in Table 1, cattle diseases may decrease milk or meat yields; reduce liveweight gains (therefore requiring more time to reach puberty, slaughter or mature weight), delay conception or parturition; increase abortion/stillbirth; cause premature culling or mortality; reduce feed efficiency; or result in condemnation of organs and carcasses. These may all be regarded as operational economic losses, yet also have considerable impacts on resource use and GHGe, as either more animals or a greater amount of time is required to maintain production (Wall et al., 2010; Wall et al., 2012). For example, calving rate (the proportion of cows producing a live calf) is a key beef productivity metric, which may be substantially affected by diseases that affect fertility or cause abortion (e.g. neosporosis). In an ideal system, with perfect reproductive health, nutrition and management, cows would calve every twelve months, weaning a live calf each year. However, in reality, beef calving rate varies considerably across global regions and may be as low as 60% in extensive beef systems. Capper (2013) reported that improving calving rate from the U.S. average of 90–100% reduced economic costs and GHGe per kg of beef by 5.3% and 6.5%, respectively; whereas a calving rate of 60% conferred a 36.2% increase in economic cost and a 45.5% increase in GHGe per kg of beef compared to the ideal. Indeed, Skuce et al.[5] calculated that eliminating neosporosis from a beef herd with a 10% prevalence would reduce GHGe by 2.2%. There are therefore considerable economic and environmental opportunities associated with ensuring that a high proportion of cattle produce a calf each year.

Table 1
Potential economic and environmental effects of performance impacts imposed by cattle diseases.

Performance impact	Potential economic and environmental effects
Reduced milk yield or carcase weight	Resources and GHGe divided over fewer units of production
Failure to conceive	Proportion of non-productive time within lifespan increased, thereby increasing resource use and GHGe
Abortion or stillbirth	Resources and GHGe invested in conception and pregnancy not recouped by producing viable offspring, therefore divided over fewer units of production
Reduced growth rates	Greater time to reach puberty or target weight with consummate increases in resources and GHGe
Increased mortality	Resources and GHGe invested are not recouped by milk or meat output
Milk residue failures, condemned organs or carcases	Resources and GHGe invested are not recouped by milk or meat output
Reduced feed efficiency	Increased resources required to maintain output

GHGe, Greenhouse gas emissions

2.2. The impacts of specific diseases on economic costs and environmental impact

The impacts of livestock disease on economic viability are important concerns for the producer, yet the literature relating to the economic or environmental consequences of cattle diseases is sparse, and often dated. For example, the economic costs of endemic livestock diseases in the UK were calculated by Bennett (2003), who reported that mastitis, lameness, fasciolosis and bovine viral diarrhoea virus (BVD) had the most substantial economic impacts (at £121 million,[6] £48 million[6], £29 million[6] and £18 million[6] annual cost to the industry, respectively, at 1996 values) with lesser impacts attributed to leptospirosis (£12 million[6]), summer mastitis (£10 million[6]), parasitic bronchitis (£8 million[6]) and infectious bovine keratoconjunctivitis (£6 million[6]). This provides a useful ranking by which to compare diseases, however, given the time elapsed since the analysis was conducted, does not account for advances and improvements in animal health over the past two decades. Even when current, economic analyses of livestock health within the literature tend to focus on short-term direct impacts (e.g. reduced sales,

[4] See: OIE, 2015. Animal Health - A Multifaceted Challenge. https://www.oie.int/fileadmin/Home/eng/Media_Center/docs/pdf/Key_Documents/ANIMAL-HEALTH-EN-FINAL.pdf (accessed 2 May 2023).

[5] See: Skuce, P.J., Bartley, D.J., Zadoks, R.N., MacLeod, M., 2016. Livestock Health and Greenhouse Gas Emissions. https://www.climatexchange.org.uk/media/2031/livestock_health_and_ghg.pdf (accessed 2 May 2023).

[6] £ 1 = Approximately US$1.25, €1.14 at 2 May 2023.

need for more replacement animals) rather than considering the wider implications of disease on consumer price, trade and indirect costs. As a rare exception, Barratt et al. (2019) estimated the indirect costs of cattle disease control strategies, using a large foot and mouth disease (FMD) outbreak in Scotland as an example, and demonstrated that when the economic analysis was extended beyond direct costs to effects on international trade and other commodity sectors, FMD vaccination provided a more cost-effective strategy than culling.

The literature relating to the sustainability impacts of cattle diseases is sparse, yet it's worth examining the economic and environmental data relating to some of the most important cattle diseases endemic in the UK (Table 2). According to a recent report from the Moredun Research Institute (2022), effective control of the following diseases or syndromes confers important opportunities to mitigate methane emissions: bovine tuberculosis, BVD, Johne's disease, bovine respiratory disease, infectious bovine rhinotracheitis (IBR) and dairy cow lameness. It's notable that this list does not include mastitis. As one of the most common disease issues on dairy farms (and to a lesser extent, in beef herds), with an average incidence of 59.5 (18–164 range) clinical cases per 100 dairy cows (Down et al., 2016), mastitis-induced yield reductions are associated with an inevitable economic cost. This cost is highly variable however, with estimates ranging from £ 111[6] to £ 341[6] per clinical case according to Down et al. (2013). This variation may partially be explained by the range in milk loss per cases, cited by Wapenaar et al. (2017) as ranging from a negligible amount to 1050 kg.

Given the importance of this disease to dairy producers, the impacts on GHGe are surprisingly modest, hence mastitis not being included in the list within the Moredun Research Institute (2022) report, yet this should not be an unexpected finding, as the clinical effects of mastitis are relatively minor and short-lived compared to other diseases. Statham et al.[7] reported that mitigating mastitis in the average UK dairy herd could reduce GHGe by 6%, although a greater effect (12%) was revealed by implementing health improvement measures in the worst 10% of herds. Hospido and Sonesson (2005) showed that reducing the incidence of clinical mastitis from 25% to 18% and reducing sub-clinical mastitis incidence from 33% to 18%, cut GHGe by 2.5% per kg of farm output (milk and meat). Similarly, Özkan et al. (2015) modelled the effects of reduced mastitis occurrence (11% vs. 18%), lower somatic cell count (SCC; 86,000 cells/mL vs. 217,000 cells/mL) and increased milk yield (27.8 kg/day vs. 25 kg/day). In that scenario, dairy producers could realise an increased gross margin per year equal to £ 253[6]/cow or £ 0.014[6]/kg energy-corrected milk (ECM), an 11% reduction in involuntary culling and 0.02 kg (5.0%) decrease in GHGe per kg ECM. Using a complex dynamic simulation model, Mostert et al. (2019) reported that, on average, clinical mastitis increased GHGe per kg of fat-and-protein-corrected milk (FPCM) by 6.2%, primarily resulting from disease impacts on culling, yield losses and discarded milk. Within a single lactation however, GHGe per kg FPCM increased by 5.2% in cows with one case of clinical mastitis, to 7.5% and 10.0% in cows with two or three cases, respectively, showing the relative importance of repeated cases.

One of the most often investigated cattle diseases is the highly contagious pestivirus BVD, which is shed by persistently infected cattle throughout their lifetime, increasing both morbidity and mortality (Richter et al., 2017). Control schemes have been implemented in various countries where the disease is endemic, however, in one study of non-vaccinated herds in Northern Ireland, Cowley et al. (2014) reported that the herd-level prevalence of BVD was 98.5% in dairy herds and 98.3% in beef herds. Yarnall and Thrusfield (2017) suggested that BVD costs up to £ 252[6] per cow (with an average of £46.50[6] per cow), which would be equivalent to an annual total cost of £ 162[6] million to the UK cattle industry, yet, as discussed by Stott et al. (2010), the impact of secondary infection from immune suppression may substantially increase this cost. Indeed, in a systematic review of economic impacts of BVD, Richter et al. (2017) reported that the direct costs varied from £ 1.93[6]-£ 578[6] per animal across regions – a huge range. The importance of accurate economic data on disease control was highlighted specifically by Pinior and Firth (2017), who commented that countries that had economically assessed the impact of BVD were up to 10 times more likely to implement an eradication programme. Chatterton et al. (2015) showed that BVD could increase the GHGe per kg of beef by 12.9%, a 2.2 kg increase compared to the baseline (17.1 kg CO_2e per kg beef carcass), although this impact was not adjusted for disease prevalence. Furthermore, in a pilot project examining the effects of dairy cattle disease on GHGe, Statham et al.[7] reported that eradicating BVD would cut GHGe by 4% in average UK herds, but 11% in the worst 10% of herds. In a comparative study published by ADAS,[8] BVD did not have the greatest impacts on GHGe of the cattle diseases studied, however, its relatively high prevalence in English herds (Prosser et al., 2022) indicates that its elimination would have considerable benefits. This may be achieved, in part through implementation of government policy. For example, Scotland's BVD eradication scheme, which began as a voluntary programme in 2010 before becoming mandatory in 2013, has, to date, resulted in 91% of Scottish herds being classified as BVD-negative though a stringent screening programme.[9] Extension of the current BVDFree England[10] programme to become mandatory, potentially in conjunction with the Animal Health and Welfare Pathway,[11] could therefore mitigate the impacts of the disease.

Johne's disease causes a protein-losing enteropathy, thus impacting milk yield and liveweight gain (van Schaik et al., 1996). The prevalence and economic impacts of Johne's are difficult to quantify, nonetheless, Garcia and Shalloo (2015) suggested that for every clinically-infected cow within a herd, another 25 cows may be infected. If the costs of clinical cases, estimated by Gunn et al. (2004), were correct (albeit extremely dated) at £ 26[6] per dairy cow and £ 17[6] per beef cow, this could be equivalent to an annual cost of £ 2.8[6] million to the English cattle industry, adjusted for a 45% increase in inflation between 2004 and 2017. ADAS[8] reported that the presence of Johne's disease increased GHGe by 25% per kg of milk and up to 40% per kg of beef – the greatest impacts of any endemic diseases investigated. The seeming disparity between the economic costs and GHGe in this case highlight the importance of assessing disease impacts at the appropriate level. Johne's may cause devastating impacts in the short-term at the farm level if a test and cull strategy is employed and therefore have a substantial effect on GHGe, yet may be diluted out at the industry level due to the numbers of farms with a low prevalence or risk.

The viral disease IBR has persistent effects throughout the animal's lifetime, with respiratory and eye symptoms, reduced milk yields and abortion, increased mortality, and reduced liveweight gain (Nettleton and Russell, 2017). Although effective vaccination protocols allow IBR

[7] See: Statham, J., Scott, H., Statham, S., Acton, J., Williams, A., Sandars, D., 2020. Dairy Cattle Health and Greenhouse Gas Emissions Pilot Study: Chile, Kenya and the UK. https://dairysustainabilityframework.org/wp-content/uploads/2020/10/Dairy-Cattle-Health-and-GHG-Emissions-Pilot-Study-Report.pdf (accessed 2 May 2023).

[8] See: ADAS, 2015. Study to Model the Impact of Controlling Endemic Cattle Diseases and Conditions on National Cattle Productivity, Agricultural Performance and Greenhouse Gas Emissions. https://randd.defra.gov.uk/ProjectDetails?ProjectID= 17791&FromSearch=Y&Publisher= 1&SearchText=AC0120&SortString=ProjectCode&SortOrder=Asc&Paging= 10#Description (accessed 2 May 2023).

[9] See: Centre of Expertise on Animal Disease Outbreaks, 2023. BVD Monthly Summary Report: Monthly Update. https://www.epicscotland.org/resources/bvd-monthly-summary-report-monthly-update/ (accessed 2 May 2023).

[10] See: BVDFRee, 2023. What is the BVDFree Scheme? https://bvdfree.org.uk/ (accessed 2 May 2023).

[11] See: DEFRA, 2022. Policy Paper: Animal Health and Welfare Pathway. https://www.gov.uk/government/publications/animal-health-and-welfare-pathway/animal-health-and-welfare-pathway (accessed 2 May 2023).

Table 2
Impacts of cattle diseases on economic cost, key performance indicators and greenhouse gas emissions.

Disease	Economic cost (£/year)[a]	Milk yield	Fertility	Growth rate	Mortality	Potential effect on GHGe[b]
Mastitis	£ 125–384 million to the industry[c]	Reduced	Reduced	N/A	Major cause of culling	Moderate
Bovine viral diarrhoea virus	£ 162 million to the industry[d]	Reduced	Reduced	Reduced	Increased (calves)	Moderate
Johne's disease	£ 2.8 million to the industry[e]	Reduced	Reduced	Reduced	Major cause of culling	High
Infectious bovine rhinotracheitis	£ 200 per sub-clinically infected cow[f]	Reduced	Reduced	Reduced	Increased (calves and fattening cattle)	High
Lameness	£ 155–280 per case[g]	Reduced	Reduced	N/A	Major cause of culling	Moderate
Bovine respiratory disease	£ 60 million to the industry[h]	N/A	N/A	Reduced	Increased (calves)	Low

GHGe, Greenhouse gas emissions
[a] £ 1 = Approximately US$1.25, €1.14 at 2 May 2023.
[b] Low = <4%, Moderate = 4–8%, High = >8%; all per unit of milk or meat produced
[c] Calculated from data published by Down et al. (2013)
[d] Calculated from data published by Yarnall and Thrusfield (2017) and AHDB[12]
[e] Calculated from data published by Gunn et al. (2004) adjusted for prevalence and increase in inflation over time
[f] Statham et al., 2015
[g] Liang et al., 2017
[h] Calculated from data published by Statham, 2018

to be eradicated, subclinical infection may cost up to £ 200[6] per infected cow annually as a consequence of a 2.6 kg/day (up to 1000 kg per lactation) reduction in milk yield (Statham et al., 2015). At the herd level, ADAS[8] showed that IBR increased GHGe per kg of ECM by 8% and per kg of beef by 20%; and at the industry level, Skuce et al.[5] reported that eradicating IBR within the Scottish cattle herd would reduce GHGe from cattle production by 1.5–3.0%.

Given the relatively high lameness rates within UK dairy herds (Griffiths et al., 2018; Randall et al., 2019) and the negative effects of lameness on milk yield, fertility, feed intake and growth, it is surprising to note that no current, UK-specific, peer-reviewed economic data appears to exist, and only two papers have discussed the impacts of dairy cattle lameness on GHGe. Although not directly applicable to UK systems, Charfeddine and Pérez-Cabal (2017) reported that the annual economic cost of claw disorders in Spanish dairy herds varied from £ 45[6] to £ 523[6] per affected cow. Similar ranges were published by Liang et al. (2017), who used a modelling simulation to quantify total lameness costs of £ 155[6] in primiparous cows and £ 280[6] in multiparous cows. Mostert et al. (2018) modelled the GHG impacts of lameness due to foot lesions, reporting that GHGe were increased by 1.5% per kg of FPCM with a lesser impact per case of digital dermatitis (0.4% increase) than sole ulcers (3.6%) or white line disease (4.3% increase); with the majority of the GHG impact being due to increased culling. Chen et al. (2016) quantified the effect of lameness in cattle within a grazed dairy operation using life cycle assessment, reporting that baseline GHGe could be increased by up to 7.8% if the lameness rate increased from a baseline 15%, to 70%, with a milk loss per cow of 1.80 kg/day. Furthermore, the on-farm impacts of implementing measures to reduce lameness incidence or severity are seldom considered. Herzog et al. (2020), reported that introducing rubber mats to alleyways in Austrian dairy systems increased GHGe, as although productivity improved, it was outweighed by the environmental cost of mat procurement, installation and disposal. This shows that although the relative lack of literature on the impacts of lameness on GHGe is an important knowledge gap, the mitigation potential of interventions also warrants further investigation. Lameness also has potentially important social acceptability consequences, as many consumers only see cattle when they are being moved on the road, with the lame animals inevitably at the back of the herd. Lameness mitigation through proactive prevention and prompt treatment therefore offers opportunities for a trifold sustainability benefit.

3. How can producers be encouraged to invest in cattle health and sustainability?

To our knowledge, only ADAS[8] and Statham et al.[7] have compared the relative benefits of cattle disease mitigation using a common methodology, although both studies were limited to a small selection of diseases and the ADAS[8] study appeared to show only a tenuous relationship between the economic cost of disease mitigation and associated changes in GHGe. However, ADAS[8] did identify three major barriers to reducing the incidence of disease issues within cattle operations: 1) producers lacked awareness of the economic opportunities forgone by disease losses (e.g. being unable to accurately value the cost of a case of mastitis); 2) there was often a lack of capacity to address the disease/condition (e.g. vaccines or medicines being stored or used incorrectly) and 3) there may be an unwillingness to change practices or invest in infrastructure, veterinary advice or medicines.

Reducing the incidence and severity of cattle diseases should improve both profitability and GHGe, yet considerable variation in economic consequences and relatively low GHG impacts make these benefits relatively difficult to justify to producers. For example, although liver fluke is a considerable concern within UK livestock production, Jonsson et al. (2022) reported that the GHGe from a beef herd with no fluke were only ~1.5% lower than those of an uninfected herd, therefore producers would be unlikely to implement preventative measures based on GHGe alone. Moreover, as noted by Bartley et al. (2016), many diseases co-exist and interact on-farm, therefore it is difficult to quantify the effects of implementing a prevention or control strategy. The relationship between resource use, GHGe and livestock health appears clear, yet the association with economic parameters may more complex, as excellent livestock health cannot be achieved without some degree of economic investment, whether overt (e.g. medicines) or less tangible (e.g. time invested in surveillance and data recording). Given the risk of AMR, a strong argument can be made for the adoption of vaccines, wherever possible, to safeguard animal, human and ecosystem health. However, the real problem is that most producers do not measure or monitor disease levels on farm so they cannot attribute the true economic cost to their herd and therefore quantify the cost-benefit of preventative health measures. Moreover, the costs of sub-clinical infection and failure to reach optimal performance are largely ignored. In the short term, it might therefore seem economically advantageous to use an antimicrobial in a small proportion of animals at a relatively lower cost than vaccinating the entire population. However, vaccination is accompanied by the assurance that future disease incidence should be considerably lower, thus reducing the need for further AMU – a clear economic and AMR benefit (Jansen et al., 2018).

The poultry and aquaculture industries display progressive attitudes to disease prevention. This is evidenced by the concerted efforts of the poultry industry in implementing the national salmonella reduction programme (a combination of routine testing, vaccination and welfare and husbandry improvements) such that over 90% of UK eggs are now produced under the Red Lion code. Sustainability benefits could be gained from the ruminant sector adopting a similar approach to reduce endemic disease. This approach may partially be implemented by shifting the emphasis from a reactive therapeutic approach to disease control to focus on prevention. This encompasses changes in management practice, biosecurity, surveillance and prophylaxis – vaccines have a critical role to play in this strategy. However, although vaccines are available to aid the control of many endemic diseases, their uptake in the ruminant sector remains comparatively low. In the UK, Bovine Herpes Virus Type 1 (BoHV-1; the causative agent of IBR) is estimated to be present in over 70% of herds (Nettleton and Russell, 2017), yet only 30% of cattle are estimated to have been vaccinated.[12]

Most vaccines are administered by producers, on-farm studies reported that vaccines are often stored and used incorrectly, which might compromise efficacy (Meadows, 2010; Rees et al., 2018; Williams and Paixão, 2018). This could be rectified at the producer level by incorporating vaccine-specific training into apprenticeships and educational courses, as well as Red Tractor and other relevant standards. The relatively new veterinary technician apprenticeship standard could also increase the capacity of vet-led teams to vaccinate greater numbers of cattle, which could help address the shortage of the relevant skills and labour on many farms.

4. How can the wider industry be encouraged to invest in cattle health and sustainability?

One of the biggest barriers to the animal health industry investing in sustainability is that understanding the true impact of animal health on GHGe is hampered by a lack of substantial, joined-up data. Although modelled data relating to mortality or culling are often available, the impact of morbidity, and particularly sub-clinical disease, is very limited, especially when relating to real-time impacts rather than modelled simulations (Macleod and Moran, 2017). This means that true disease prevalence and therefore performance and sustainability impacts, are underestimated at farm and population level. Investment in improved disease surveillance, detection and recording would help establish a reliable benchmark from which to track and monitor improvements in health and the associated reduction in GHG. However, many existing GHG assessment models and tools do not have the capacity to assess the implications of livestock disease, and require further model development (Özkan et al., 2016; Kipling et al., 2021).

The data collection issue may be partially facilitated by advances in sensor and digital technology that enable precision livestock farming (PLF), which has considerable sustainability benefits for the livestock producers in terms of easier, data-driven health management and monitoring, as reviewed by Lovarelli et al. (2020). A wide array of different technologies are available, from sensors such as collars, ear-tags, pedometers and rumen boluses through to remote camera and neural programming systems, with each system tracking different parameters linked to animal health. This allows daily health monitoring to be linked to data-driven insights for the whole herd, leading to more efficient and timely decision making and subsequently improved animal health. Opportunities for PLF offered by a combination of sensor data collection, data integration and analysis, machine learning and event detection were comprehensively discussed by Niloofar et al. (2021), who concluded that PLF was a viable mechanism for improving productivity, reducing GHGe and improving marketing. However, at present, the uptake of these technologies may be limited by producer concerns that technology may replace contact with and understanding of livestock, in tandem with the financial investment required for an integrated system (Abeni et al., 2019). Furthermore, many existing apps or systems do not communicate across platforms, leading to repetitive data entry and individual data set interrogation. According to Tedeschi et al. (2021), artificial intelligence may play a considerable role in overcoming this barrier, yet more research is required to assess the factors that influence farmer adoption of new PLF technologies and therefore encourage behavioural change.

5. Unanswered questions

Cattle diseases have clear and profound impacts upon sustainability, however, understanding these impacts is only one point of leverage for improving animal health – attention must also be paid to the underlying mechanisms behind this variation. For example, producer perceptions and behaviours that impact prophylactic vs. therapeutic medicines use (e.g. the perception that vaccines are more expensive or less effective than antimicrobials or that the veterinarian shares the producer's values) may have a substantial impact on the observed effects of diseases on productivity (Bard et al., 2019). Furthermore, although controlling or eliminating endemic diseases would be a logical utopian desire, the degree to which this might occur will, in reality, be influenced by multiple factors, with some diseases being more tractable than others. Further research into the potential variation in disease control and elimination and therefore the potential for environmental and economic costs to be mitigated would therefore be extremely valuable.

Aside from consumers' obvious desire for livestock to be healthy and kept in high welfare systems, there is little published literature relating to the social sustainability impacts of cattle disease. Although consumer trust is imperative for livestock system resilience, the social acceptability of livestock products is not unwavering – the impact of a sudden disease outbreak may have critical impacts upon consumer acceptance, regardless of the relative risk to human health, as evidenced by the British BSE Crisis (Ashworth and Mainland, 1995). These crises of confidence may partially be mitigated by placing a greater focus on new and emerging diseases, especially zoonoses, and diseases that result in considerable changes in food security (e.g. the impacts of recent outbreaks of African swine fever on global pork production) and focusing on effective communication. Examining the impacts of diseases using a One Health approach and using the same lens to assess current and future management practices and production systems with a view to improving animal, human and ecosystem health should improve sustainability. This will only be successful however, if the importance of improving cattle health as a means to enhance sustainability is effectively communicated to all stakeholders.

6. Conclusions

Sustainable livestock production can only be achieved in tandem with excellent animal health and welfare. An urgent need therefore exists to accurately quantify the sustainability impacts of animal health, to benchmark performance and to implement a culture of continuous improvement. At the farm level, the impacts of a specific disease vary widely, affected by myriad animal, climatic and human factors. Future research should therefore concentrate on consistent methodologies and comparative studies that can attempt to assess relative disease impacts within and across systems. This will allow producers, veterinarians, animal health companies and policy makers to focus their efforts on those diseases that have the greatest implications for both animal welfare and economic and environmental sustainability.

Conflict of interest statement

Judith Capper reports relationships with MSD Animal Health, Health for Animals, Zoetis Inc., Merck Animal Health that include funding or grants; and with MSD Animal Health and Elanco Animal Health Inc that include speaking and lecture fees. Paul Williams reports a relationship with MSD Animal Health that includes employment.

[12] See: AHDB, 2020. Vaccine uptake report for cattle and sheep. https://ahdb.org.uk/knowledge-library/vaccine-uptake-report-for-cattle-and-sheep (accessed 2 May 2023).

References

Abeni, F., Petrera, F., Galli, A., 2019. A survey of Italian dairy farmers' propensity for precision livestock farming tools. Animals 9, 202.

Ashworth, S.W., Mainland, D.D., 1995. The economic impact of BSE on the UK beef industry. Outlook on Agriculture 24, 151–154.

Bard, A.M., Main, D., Roe, E., Haase, A., Whay, H.R., Reyher, K.K., 2019. To change or not to change? Veterinarian and farmer perceptions of relational factors influencing the enactment of veterinary advice on dairy farms in the United Kingdom. Journal of Dairy Science 102, 10379–10394.

Barratt, A.S., Rich, K.M., Eze, J.I., Porphyre, T., Gunn, G.J., Stott, A.W., 2019. Framework for estimating indirect costs in animal health using time series analysis. Frontiers in Veterinary Science 6, 190.

Bartley, D.J., Skuce, P.J., Zadoks, R.N., MacLeod, M., 2016. Endemic sheep and cattle diseases and greenhouse gas emissions. Advances in Animal Biosciences 7, 253–255.

Bennett, R., 2003. The 'direct costs' of livestock disease: The development of a system of models for the analysis of 30 endemic livestock diseases in Great Britain. Journal of Agricultural Economics 54, 55–71.

Buller, H., Blokhuis, H., Jensen, P., Keeling, L., 2018. Towards farm animal welfare and sustainability. Animals 8, 81.

Capper, J.L., 2011. The environmental impact of beef production in the United States: 1977 compared with 2007. Journal of Animal Science 89, 4249–4261.

Capper, J.L., 2012. Is the grass always greener? Comparing resource use and carbon footprints of conventional, natural and grass-fed beef production systems. Animals 2, 127–143.

Capper, J.L., 2013. The environmental and economic impact of calving rate within U.S. beef production. In: Proceedings of the ADSA-ASAS Joint Annual Meeting, Indianapolis, IN, USA, July 8–12, 2013 p. 599.

Capper, J.L., Bauman, D.E., 2013. The role of productivity in improving the environmental sustainability of ruminant production systems. Annual Review of Animal and Veterinary Biosciences 1, 469–489.

Capper, J.L., Cady, R.A., 2020. The effects of improved performance in the U.S. dairy cattle industry on environmental impacts between 2007 and 2017. Journal of Animal Science 98, skz2 91..

Capper, J.L., De Carvalho, T.B., Hancock, A.S., Sá Filho, O.G., Odeyemi, I., Bartram, D.J., 2021. Modeling the effects of steroid implant use on the environmental and economic sustainability of Brazilian beef production. Translational Animal Science 5, 1–21.

Charfeddine, N., Pérez-Cabal, M.A., 2017. Effect of claw disorders on milk production, fertility, and longevity, and their economic impact in Spanish Holstein cows. Journal of Dairy Science 100, 653–665.

Chatterton, J., Graves, A., Audsley, E., Morris, J., Williams, A., 2015. Using systems-based life cycle assessment to investigate the environmental and economic impacts and benefits of the livestock sector in the UK. Journal of Cleaner Production 86, 1–8.

Chen, W., White, E., Holden, N.M., 2016. The effect of lameness on the environmental performance of milk production by rotational grazing. Journal of Environmental Management 172, 143–150.

Cowley, D.J.B., Graham, D.A., Guelbenzu, M., Doherty, M.L., More, S.J., 2014. Aspects of bovine herpesvirus 1 and bovine viral diarrhoea virus herd-level seroprevalence and vaccination in dairy and beef herds in Northern Ireland. Irish Veterinary Journal 67, 1–5.

Down, P.M., Green, M.J., Hudson, C.D., 2013. Rate of transmission: A major determinant of the cost of clinical mastitis. Journal of Dairy Science 96, 6301–6314.

Down, P.M., Bradley, A.J., Breen, J.E., Browne, W.J., Kypraios, T., Green, M.J., 2016. A Bayesian micro-simulation to evaluate the cost-effectiveness of interventions for mastitis control during the dry period in UK dairy herds. Preventative Veterinary Medicine 133, 64–72.

Garcia, A.B., Shalloo, L., 2015. Invited review: The economic impact and control of paratuberculosis in cattle. Journal of Dairy Science 98, 5019–5039.

Griffiths, B.E., Grove White, D., Oikonomou, G., 2018. A cross-sectional study Into the prevalence of dairy cattle lameness and associated herd-level risk factors in England and Wales. Frontiers in Veterinary Science 5, 65.

Gunn, G.J., Humphry, R.W., Stott, A., 2004. Comparison of the modelled effects and consequential losses due to Johne's disease outbreaks for beef and dairy herds in Great Britain. Cattle Practice 12, 1–10.

Herzog, A., Hörtenhuber, S., Winckler, C., Kral, I., Zollitsch, W., 2020. Welfare intervention and environmental impacts of milk production – cradle-to-farm-gate effects of implementing rubber mats in Austrian dairy farms. Journal of Cleaner Production 277, 123953.

Hospido, A., Sonesson, U., 2005. The environmental impact of mastitis: a case study of dairy herds. Science of the Total Environment 343, 71–82.

Hyland, J.J., Styles, D., Jones, D.L., Williams, A.P., 2016. Improving livestock production efficiencies presents a major opportunity to reduce sectoral greenhouse gas emissions. Agricultural Systems 147, 123–131.

Jansen, K.U., Knirsch, C., Anderson, A.S., 2018. The role of vaccines in preventing bacterial antimicrobial resistance. Nature Medicine 24, 10–20.

Jonsson, N.N., MacLeod, M., Hayward, A., McNeilly, T., Ferguson, K.D., Skuce, P.J., 2022. Liver fluke in beef cattle – impact on production efficiency and associated greenhouse gas emissions estimated using causal inference methods. Preventive Veterinary Medicine 200, 105579.

Kipling, R.P., Bannink, A., Bartley, D.J., Blanco-Penedo, I., Faverdin, P., Graux, A.I., Hutchings, N.J., Kyriazakis, I., Macleod, M., Østergaard, S., et al., 2021. Short communication: Identifying key parameters for modelling the impacts of livestock health conditions on greenhouse gas emissions. Animal 15, 100023.

Liang, D., Arnold, L.M., Stowe, C.J., Harmon, R.J., Bewley, J.M., 2017. Estimating US dairy clinical disease costs with a stochastic simulation model. Journal of Dairy Science 100, 1472–1486.

Lovarelli, D., Bacenetti, J., Guarino, M., 2020. A review on dairy cattle farming: Is precision livestock farming the compromise for an environmental, economic and social sustainable production? Journal of Cleaner Production 262, 121409.

Macleod, M., Moran, D., 2017. Integrating livestock health measures into marginal abatement cost curves. Scientific and Technical Review of the Office International des Epizooties 36, 97–104.

Meadows, D., 2010. A study to investigate the use and application of BVDV vaccine in UK cattle. Cattle Practice 18, 202–209.

Moredun Research Institute, 2022. Acting on methane: opportunities for the UK cattle and sheep sectors. A report prepared by Moredun Research Institute on behalf of Ruminant Health and Welfare. Moredun Research Institute, Penicuik, UK.

Mostert, P.F., van Middelaar, C.E., de Boer, I.J.M., Bokkers, E.A.M., 2018. The impact of foot lesions in dairy cows on greenhouse gas emissions of milk production. Agricultural Systems 167, 206–212.

Mostert, P.F., Bokkers, E.A.M., de Boer, I.J.M., van Middelaar, C.E., 2019. Estimating the impact of clinical mastitis in dairy cows on greenhouse gas emissions using a dynamic stochastic simulation model: a case study. Animal 13, 2913–2921.

Nettleton, P., Russell, G., 2017. Update on infectious bovine rhinotracheitis. In Practice 39, 255–272.

Niloofar, P., Francis, D.P., Lazarova-Molnar, S., Vulpe, A., Vochin, M.-C., Suciu, G., Balanescu, M., Anestis, V., Bartzanas, T., 2021. Data-driven decision support in livestock farming for improved animal health, welfare and greenhouse gas emissions: Overview and challenges. Computers and Electronics in Agriculture 190, 106406.

Özkan, Ş., Østergaard, S., Strøm, T., 2015 of Conference. The relationship between level of somatic cell count and greenhouse gas emissions, In: MACSUR Science Conference 2015: Integrated Climate Risk Assessment in Agriculture and Food, Reading University, Reading, UK, 8–12 April 2015 pp. SP5-SP42.

Özkan, Ş., Vitali, A., Lacetera, N., Amon, B., Bannink, A., Bartley, D.J., Blanco-Penedo, I., de Haas, Y., Dufrasne, I., Elliott, J., et al., 2016. Challenges and priorities for modelling livestock health and pathogens in the context of climate change. Environmental Research 151, 130–144.

Pinior, B., Firth, C.L., 2017. The economics of bovine viral diarrhoea eradication. Veterinary Record 181, 300.

Prosser, N.S., Hill, E.M., Armstrong, D., Gow, L., Tildesley, M.J., Keeling, M.J., Kaler, J., Ferguson, E., Green, M.J., 2022. Descriptive analysis of national bovine viral diarrhoea test data in England (2016–2020). Veterinary Record 191, e1854.

Randall, L.V., Thomas, H.J., Remnant, J.G., Bollard, N.J., Huxley, J.N., 2019. Lameness prevalence in a random sample of UK dairy herds. Veterinary Record 184, 350.

Rees, G., Barrett, D.C., Buller, H., Mills, H.L., Reyher, K.K., 2018. Storage of prescription veterinary medicines on UK dairy farms: a cross-sectional study. Veterinary Record 184, 153–162.

Richter, V., Lebl, K., Baumgartner, W., Obritzhauser, W., Käsbohrer, A., Pinior, B., 2017. A systematic worldwide review of the direct monetary losses in cattle due to bovine viral diarrhoea virus infection. The Veterinary Journal 220, 80–87.

Statham, J., 2018. Respiratory disease in cattle — a practical approach. Livestock 23, 206–213.

Statham, J., Randall, L., Archer, S., 2015. Reduction in daily milk yield associated with subclinical bovine herpesvirus 1 infection. Veterinary Record 177, 339–342.

Stott, A.W., Humphry, R.W., Gunn, G.J., 2010. Modelling the effects of previous infection and re-infection on the costs of bovine viral diarrhoea outbreaks in beef herds. The Veterinary Journal 185, 138–143.

Tedeschi, L.O., Greenwood, P.L., Halachmi, I., 2021. Advancements in sensor technology and decision support intelligent tools to assist smart livestock farming. Journal of Animal Science 99, skab0 38..

van Schaik, G., Kalis, C.H.J., Benedictus, G., Dijkhuizen, A.A., Huirne, R.B.M., 1996. Cost-benefit analysis of vaccination against paratuberculosis in dairy cattle. Veterinary Record 139, 624–627.

Wall, E., Simm, G., Moran, D., 2010. Developing breeding schemes to assist mitigation of greenhouse gas emissions. Animal 4, 366–376.

Wall, E., Coffey, M.P., Pollott, G.E., 2012. The effect of lactation length on greenhouse gas emissions from the national dairy herd. Animal 6, 1857–1867.

Wapenaar, W., Archer, S., Remnant, J., Murphy, A., 2017. Control of infectious diseases in dairy cattle. In: Webster, J. (Ed.), Achieving Sustainable Production of Milk. Volume 3: Dairy Herd Management and Welfare. Burleigh-Dodds Science Publishing Ltd, Cambridge, UK.

White, R.R., Capper, J.L., 2014. An environmental, economic and social assessment of improving cattle finishing weight or average daily gain within United States beef production. Journal of Animal Science 91, 5801–5812.

Williams, P.D., Paixão, G., 2018. On-farm storage of livestock vaccines may be a risk to vaccine efficacy: a study of the performance of on-farm refrigerators to maintain the correct storage temperature. BMC Veterinary Research 14, 136.

de Wit, J., Oldenbroek, J.K., van Keulen, H., Zwart, D., 1995. Criteria for sustainable livestock production: a proposal for implementation. Agriculture, Ecosystems and Environment 53, 219–229.

Yarnall, M.J., Thrusfield, M.V., 2017. Engaging veterinarians and farmers in eradicating bovine viral diarrhoea: a systematic review of economic impact. Veterinary Record 181, 347–354.