Climate change and cattle farming

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Issues raised by cattle farming in relation to climate change extend beyond discussion of greenhouse gas emissions and global warming. There are profound consequences for water availability, soil degradation, biodiversity and local ecology, as well as in terms of conflict for energy supplies. Although climate change impacts on cattle farming (through effects on water availability, heat stress and flooding, for example), this article focuses on how cattle farming impacts on climate change. It explores the issues in terms of the impact of cattle farming on the environment, and how to measure and reduce climate change impacts at farm level. Managing the complex and conflicting balance of factors required for sustainable food production offers an important role for the veterinary surgeon.

Climate change: where are we now?

‘Global warming’ and ‘climate change’ have become familiar household terms. However, much confusion prevails over these issues as a result of an incomplete scientific foundation and they are often influenced by politics as much as by science. Climate change has entered the public debate globally. Many climate scientists have speculated that it will have severe social, economic and environmental effects through rising sea levels, changing weather patterns and temperature rises that will challenge society through compromised food production and water availability. International policy aims to lower the greenhouse gas emissions that are thought to be responsible for climate change (IPCC 2014).

However, challenges exist in achieving binding transnational agreements. The Kyoto Protocol of 1992 committed industrialised countries to reduce their greenhouse gas emissions by at least 5 per cent below the levels recorded in 1990 by 2012. The USA refused to sign this commitment amid concerns about compromised competitiveness. Following the Copenhagen Summit in 2009, a last-minute ‘Copenhagen Accord’ was agreed by the USA, China, Brazil and South Africa, backed by the EU and the other 193 nations present. This accord recognised the goal of restricting global warming to 2°C to prevent ‘dangerous climate change’, but it did not actually endorse this restriction. Further progress was made at the Climate Conference in Cancun, Mexico, in 2010, but it was not until April 2016 that the 196 parties to the United Nations Framework Convention on Climate Change (UNFCCC) signed the 2015 Paris Agreement on Climate Change. Under this agreement, all countries pledged to work to limit the overall temperature rise to no more than 2°C, while aiming to keep the temperature rise below 1.5°C.

The UK Climate Change Act 2008 outlines one of the most ambitious national climate change programmes, with a target of reducing greenhouse gas emissions by 34 per cent by 2020 and by 80 per cent by 2050, compared to the levels recorded in 1990 (Statham and others 2012). The EU has committed to the ‘20-20-20 goals’. These are a reduction in EU greenhouse gas emissions of at least 20 per cent below 1990 levels, that 20 per cent of EU energy consumption is to come from renewable resources, and a 20 per cent reduction in primary energy use by 2020 (United Nations 1998).

Greenhouse gas emissions

The four principal greenhouse gases are carbon dioxide (CO₂), methane, nitrous oxide and ammonia. Five major sectors make up the total anthropogenic greenhouse gas emissions. These are:

- Energy
- Industry
- Waste
- Land use, land use change and forestry (LULUCF)
- Agriculture

Overall, livestock activities were originally postulated to contribute an estimated 18 per cent to these total greenhouse gas emissions (FAO 2006); however, this figure has been extensively challenged and subsequently revised downwards. Livestock were originally attributed a 50 per cent share of the last two categories (LULUCF and agriculture) and nearly an 80 per cent share of all agricultural emissions. In 2010, the FAO produced a ‘lifecycle assessment’ of the dairy sector, in which it was proposed that this sector contributed 4 per cent to the total global man-made greenhouse gas emissions, although this includes many assumptions (Box 1).

Livestock contribution to the four principal greenhouse gases

Carbon dioxide

Livestock were attributed 9 per cent of global anthropogenic CO₂ emissions (FAO 2004). There are considerable uncertainties in these estimates, which include deforestation for feedcrop land and pasture, as well as land degradation. Although less significant than LULUCF, intensification of livestock production is tending to increase fossil fuel use and hence CO₂ emissions.

In 2007, the dairy sector emitted 1949 million tonnes of CO₂-equivalent emissions (1.26 per cent), of which 1328 million tonnes were attributed to milk, 151 million tonnes to meat from culled animals, and 490 million tonnes to meat from fattened calves (FAO 2010).
Box 1: FAO’s lifecycle assessment

In 2010, the FAO produced a ‘lifecycle assessment of the dairy sector, suggesting that this sector contributed to 4 per cent of global man-made greenhouse gas emissions. This includes many assumptions:

The average global emissions from milk production, processing and transport is estimated to be 2.4 kg of CO₂-equivalent emissions per kg of fat and protein-corrected milk (FPCM) at farm gate, but the variation regionally is very significant. Average regional emissions, per kg of FPCM at farm gate, range from 1.3 kg to 7.5 kg of CO₂-equivalent emissions (± 26 per cent). The highest emissions were found in developing regions, with sub-Saharan Africa, South Asia and North Africa and the Near East having an average of 7.5 kg, 4.6 kg and 3.7 kg of CO₂-equivalent emissions per kg of FPCM, respectively. Industrialised regions, such as Europe and North America, had the lowest emissions per kg of FPCM.

Other assumptions are that the level of greenhouse gas emissions, per kg of FPCM, is higher in grazing systems than in mixed systems. Grassland systems contribute about 2.72 kg of CO₂-equivalent emissions per kg of FPCM, compared to mixed systems, which on average contribute 1.78 kg. Along the entire dairy food chain, ‘cradle-to-farm gate’ emissions (i.e., from young calf to adult milking cow on farm) contribute the highest proportion of emissions (93 per cent on average). In industrialised countries, the relative contribution ranges between 78 and 83 per cent (i.e., 20 per cent of emissions occur after the milk has left the farm), while in developing regions the contribution ranged between 90 and 99 per cent of total emissions. However, the assumptions and uncertainty in these life cycle assessments demands significant care in interpretation (FAO 2010).

Methane

Livestock were attributed 35 to 40 per cent of global anthropogenic methane emissions (FAO 2006). Eighty per cent of agricultural methane emissions were due to enteric fermentation and manure. Methane contributes most to the global warming impact of milk production: 52 per cent of greenhouse gas emissions from both developing and developed countries are attributable to methane (FAO 2010).

Nitrous oxide

Livestock were attributed 65 per cent of global anthropogenic nitrous oxide emissions (FAO 2006), the most potent of the four major greenhouse gases. This represents 75 to 80 per cent of all agricultural emissions (FAO 2010).

Ammonia

Livestock were attributed 64 per cent of global anthropogenic ammonia emissions (FAO 2006), even though the resulting air and water pollution have generally been regarded more for their local impact than their effect on global warming.

Impact of cattle farming on the environment

At a global level, livestock farming accounts for 40 per cent of agricultural gross domestic product (GDP), employs 1.3 billion people and supplies approximately one third of the protein consumed by the human population. Global production of meat is projected to more than double from the 229 million tonnes produced in 1999/2001 to 465 million tonnes by 2050, and global milk production to almost double from 580 million tonnes to 1043 million tonnes (FAO 2010). The environmental effects of each unit of livestock production must consequently halve in this time period to prevent increased impact.

Cattle farming activities are socially and politically highly significant and impact on virtually all aspects of the environment. This impact may be direct, for example, through emission of greenhouse gases, or indirect, for example through expansion of soybean production for feed replacing forests in South America. However, the idea that ruminant agricultural systems are inherently inefficient methods of food production needs challenging; 70 per cent of the world’s agricultural area is grassland and much of this could not be converted to cereal production, mainly for climatic reasons, but also due to the risk of damage to ecosystems. In these areas, ruminants can convert the grassland energy and protein (much of which is fibre-bound or present as a non-protein nitrogen source) into food for people. Furthermore, in countries with large food-processing industries, the disposal of food residue is a significant issue and this residue can often be converted to milk or meat by ruminants.

However, the livestock sector does still emerge as one of the top two or three most important influences on the environment, both at local and global levels (Table 1).

Atmosphere

In the UK, livestock farming is responsible for around 3.5 per cent of the total greenhouse gas emissions. As such, this sector has an obligation to reduce emissions in line with national and international agreements. A failure to reduce emissions would require larger cuts to be made in other areas, which is unlikely to be acceptable to governments and the other industries involved.

Cattle farming results in the production of three of the principal gases with global warming potential: CO₂, methane and nitrous oxide. Although CO₂ is the most important greenhouse gas overall (because of the quantities produced across all five of the main sectors listed above), methane and nitrous oxide make significant contributions. The term ‘CO₂-equivalent emission’ is used to standardise the global warming potential of different gases; methane and nitrous oxide have 23 times and 296 times the global warming potential of CO₂, respectively.

The most significant sources of greenhouse gases by cattle farming are the methane produced during enteric fermentation, which is released when animals eructate, and the methane and nitrous oxide released from mineral fertilisers, slurry (Fig 1) and manure (both when stored and spread). However, emissions are also generated from fuel and electricity produced from fossil fuels used for equipment and machinery on farm, and the production and transport of inputs and milk and milk products.

Soil

The banks of water courses, ponds, lakes and canals become poached and eroded over time if animals are allowed access. This reduces water quality by adding silt and faecal contamination and has the potential to increase phosphorus levels. Land degradation involves similar poaching of grazing land, feeding areas, gateways and tracks (Fig 2). Consequences include loss of organic matter, nutrient leakage, reduced fertility and erosion. Widespread logging in South America and South East Asia to produce grazing land for beef cattle and to grow feed crops is an example of a change in land use which can compromise greenhouse gas control and degrade water quality, land and biodiversity.

Water

Both ground and surface water may become contaminated either by a single event (eg, slurry discharging into a river), or from the cumulative result of agricultural activity over...
a prolonged time period. A range of different pollutants can contaminate water, most commonly nitrogen and phosphorus, but also agrochemicals such as veterinary medicines, dairy chemicals, disinfectants, pesticides, herbicides and fuels.

Nitrogen
About 60 per cent of the nitrates in English rivers come from agriculture. Chemical fertilisers and organic animal waste can cause nitrate pollution. Elevated nitrate levels can lead to eutrophication and algal bloom and, in drinking water, pose a risk to human health from methaemoglobinaemia through nitrate consumption.

Within Europe, the Nitrates Directive 1991 aims to protect water quality by promoting and legislating for good farming practices (Defra 2009). Member states are required to:
- Designate as Nitrate Vulnerable Zones (NVZs) all land draining to waters that are affected by nitrate pollution.
- Establish a voluntary code of good agricultural practice to be followed by all farmers.
- Establish a mandatory action programme of measures for the purposes of tackling nitrate loss from agriculture.
- Review the extent of their NVZs and the effectiveness of their action programmes at least every four years and make amendments if necessary.

Phosphorus
Phosphorus is a component of chemical fertilisers and organic animal waste; however, it is largely insoluble and not prone to leaching. Phosphorus pollution is less stringently controlled than nitrogen pollution within Europe, although other parts of the world are subject to stringent control measures.

Slurry, manure and other organic materials
Slurry, manure, silage effluent and other organic materials, such as milk and animal carcases, can cause substantial damage if they escape into water courses.

Table 1: Areas of the environment potentially harmed by cattle farming (Green and others 2011)

| Area of environment | Subcategories | Items that harm the environment | Notes |
|---------------------|--------------|--------------------------------|-------|
| Atmosphere          | Emissions    | Methane, nitrous oxide, ammonia, CO₂ | Methane has 23 times and nitrous oxide 296 times the global warming potential of CO₂. Cows produce around 500 litres of methane per day. Most methane emissions are enteric, whereas most nitrous oxide and ammonia emissions are from fertiliser/manure application or manure storage. Approximately 60 per cent of greenhouse gas emissions come from methane and around 30 per cent from fertiliser/manure management. Methane production tends to be lower per litre of milk produced in high-input systems. Indirect emissions occur from energy use, which tends to be higher for high-input systems. |
| Soil                | Soil structure, pollution, ecological issues | Loss of organic matter, nutrient leakage, reduced soil fertility, erosion | Generally worse with intensive land management, reduced recycling of animal waste and mechanical overloading causing compaction. Nitrogen losses often worse as production level increases. |
| Water               | Chemical – surface or ground water pollution | Nitrogen, potassium, phosphorus, agrochemical pollution | Soil overload of manure or chemicals, dependent upon local conditions, leading to leakage in surface or ground water. This may be aggravated by a reduction in soil permeability or storage capacity. Suggests that a future global shortage of water could be compounded by dairy farming. |
|                     | Water shortages | High water usage by dairy farming (particularly more intensive systems) | |
| Energy consumption  | Gas emissions, use of resources | CO₂ loss of non-renewable resources | Although a less important contributor to gaseous emissions than methane, energy use is greater in high-input systems, particularly for concentrate feed production/processing (this can be mitigated by use of by-products that have not been pelleted, for example brewers grains and Trafford Gold) and the worldwide transportation of cattle feedstuffs. |
| Local ecology       | Landscape alteration and biodiversity | Loss of plant and animal species, reduced variation in rural environments, environmental degradation | Both intensification and neglect can threaten local landscapes and biodiversity, but the overall impact of dairy farming on biodiversity is uncertain. Cultivation of some feedstuffs (eg, soya in South America) has led to deforestation and can have deleterious effects on local ecosystems. |
Measuring climate change impacts at farm level

Quantitatively evaluating all components of a dairy or beef business that have an environmental impact is not trivial. Such a scoring system would need to include beneficial and detrimental effects of all aspects of the farm including the pathways of products brought onto and taken off farm. The weighting of different components is not clear cut and neither are the ‘environmental costs’ of changing to different systems. For example, if improved biodiversity is at the expense of increased greenhouse gas emissions, which is more valuable in an environmental context?

Carbon footprinting

One method currently employed is that of whole farm ‘carbon footprinting’ (Fig 3). This involves examining data from all aspects of the farming enterprise that cause production of methane, nitrous oxide and CO₂ and calculating the total CO₂-equivalents per litre of 4 per cent butterfat-corrected milk or kg of beef produced. There are several ways to break this down but the main categories and subcategories are:

- Livestock – purchased feed, bedding, enteric fermentation, manure management, purchase/contract rearing
- Cropping – fertiliser manufacture and spreading, manure spreading
- Fuel and energy – total usage

Quantitative models take a relative weighting of these different categories into account. For instance, artificial fertiliser production carries a high environmental cost due to the quantity used on farm and also the quantity of nitrous oxide produced in its manufacture.

Identifying low carbon pathways

The technical report ‘Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment’ (FAO 2010) is part of a wider FAO study aiming to identify low carbon pathways for the entire livestock sector. It focuses on the dairy food chain, encompassing the life cycle of dairy products from the production and transport of inputs (fertiliser, pesticide and feed), changes in land use (deforestation related to soybean production), milk transport (farm to dairy and from processor to retailer), processing (the production of packages), and the distribution of products to retailers. Emissions are reported in ‘per kg of fat and protein-corrected milk (FPCM)’ units and are summarised in Box 2.

Marginal abatement cost curves

Marginal abatement cost can be used to measure the cost of reducing a unit of pollution. There is potential for worthwhile ‘win-win’ outcomes for both farm profits and sustainable food production by cost-effectively reducing greenhouse gas emissions in the cattle sector through implementing measures to control endemic diseases and improve productivity. Marginal abatement cost curves (MACCs) have been developed across a number of sectors to identify the most economically efficient reductions in greenhouse gases. Specific MACCs for endemic cattle disease control have been proposed, as in Fig 4 (ADAS 2015).

Reducing the impact on climate change at farm level

There are essentially three main areas of opportunity to mitigate the impact of cattle farming on climate change.

Promoting and enforcing environmental protection

Schemes to promote and enforce protection of the environment are vital if national and international goals and targets are to be met. Approximately 70 per cent of England’s farmland is currently covered by environmental management or stewardship schemes. Within the UK, the Environment Agency, an executive non-departmental public body, has responsibility for water and pollution control. Until recently, two UK departments (the Department of Energy and Climate Change and the Department for Environment, Food and Rural Affairs) governed policy in this area, and having two or more departments governing can create conflict and limit optimal management.

Biodiversity

Farming practices may have a huge impact on biodiversity as, almost by definition, most agricultural practices are trying to selectively exclude growth of other plants and pests. Hedgerows may be removed and heath, moor and marshlands drained to create uniform pastures for grazing. Developments in plant science, herbicides, pesticides and fertilisers create near-perfect mono-cultures of forage crops and cereals for feed. In many parts of the world, ancient and complex ecosystems (eg, the rainforests of South America) are being destroyed to make way for intensive agriculture. The same is true in areas of the USA and Europe, where the ‘maize silage and soya’ system of dairying has started to predominate over the past 20 years. Maize is a nutrient-hungry and pesticide-dependent crop that is protein deficient for dairy cows and hence they require extra protein (often soya) to make up this deficiency.

Microorganisms in the environment that break down the organic matter that these materials contain deplete oxygen from water with serious, even catastrophic, consequences for the aquatic life present.

Fig 3: Heat exchange unit in a farm dairy – just one of the things that might be considered when assessing a farm’s carbon footprint.
These are:
- Resource efficiency and environmental management measures.
- Nutrition and modification of enteric fermentation.
- Improved health and productivity by reducing the waste caused by disease and reproductive inefficiency.

Ways of reducing environmental impacts are summarised in Table 2.

Resource efficiency and environmental management measures

Many environmental improvements can be made that have associated financial benefits. Methods to reduce potentially deleterious environmental impacts can be divided into:
- Improved efficiency; for example, variable demand precision fans or milk pumps.
- Reduced emissions; for example, using covers on slurry stores.

Some common areas that lead to significant financial savings are outlined in Box 3.

Periodically, grants have become available to help finance investments that contribute to improvements in areas of environmental concern. Solar panels, wind turbines and anaerobic digesters (Fig 5) have rapidly become established on cattle farms, offsetting the climate change impact through the generation of ‘green’ renewable energy.

Nutrition and modification of enteric fermentation

Enteric fermentation generally provides more significant greenhouse gas impact than manure management. Mitigation methods include changing management towards high milk output systems away from more extensive grazing systems, although debate still continues over the role of grassland and silvopastoral systems as ‘carbon sinks’ (Broom and others 2013). Other solutions are based more around dietary changes.

Dietary formulation to optimise carbohydrate use

Feeding more starch and less fibre (Figs 6, 7) means that relatively more propionate and relatively less acetate and butyrate are produced in the rumen, leading to reduced methane production. A herd producing 8000 litres of milk per year and which has a relatively high starch content in the diet will have approximately 5 per cent lower methane production per litre (assuming an equivalent feed rate) than a herd producing the same milk with a lower dietary...
Farm Animals

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CO2 emissions

Energy consumption/

Genetics

It may be possible to select for ‘low emission’ animals by making use of the relatively large between-animal variations that exists in emission characteristics. Selecting for more efficient and resilient animals may mitigate greenhouse gas production.

Diet

Effective use of feed improves performance and reduces inputs and waste per litre of milk produced. Current areas of research include high dry matter intakes, high-quality forage, high-sugar forage, use of clover, addition of specific oils or other feed addatives to reduce methane emissions.

Housing

More frequent slurry removal reduces ammonia emissions. Bolder and longer-term strategies could include scavenging greenhouse gases from negatively ventilated, sealed buildings. Collected gases (eg, methane) could be reused on farm.

Genetics

It may be possible to select for ‘low emission’ animals by making use of the relatively large between-animal variations that exists in emission characteristics. Selecting for more efficient and resilient animals may mitigate greenhouse gas production.

Energy consumption/ CO2 emissions

Review energy use and consider energy saving changes to lighting, machinery, dairy equipment (eg, plate coolers, heat recovery units), reduce delivery numbers (increase storage capacity), use of local feeds or by-products.

Consider ‘carbon storage’, for example, conversion of cultivated land to permanent pasture or woodland. Consider production of energy from renewable or home-produced sources.

The effect being at least partly governed by the fat source used. This effect is partially mediated by the depression of protozoal numbers in the rumen, but may also impact on methanogenic bacteria. Rumen protozoa have been shown to harbour approximately 25 per cent of the methanogens in the rumen and lipids appear to represent one of the few practical methods of controlling protozoa in vivo. However, fat inclusion in the diet (particularly at levels above 50 g/kg dry matter) can adversely affect rumen health by significantly inhibiting fibre breakdown.

Another example of a conflict of interest is the use of palm oils in dairy cow diets. Milk price in some purchasing contracts depends on the percentage of butterfat in milk and, considering farm profitability alone, it can be cost effective to boost butterfat by using palm oils (ie, C16 fatty acids). However, the production of palm oil is generally considered to be severely detrimental to the environment.

Modification of the rumen microflora population

Use of ionophore supplements

There are potential methane-reducing effects from feeding ionophores, such as monensin, now licensed in the EU, for the control of ketosis as an individually targeted bolus treatment. It is commonly used worldwide as a feed supplement on a group basis, but growth promoters are generally banned in the EU.

Given the EU-wide ban on the use of subtherapeutic levels of antibiotics and ionophores as growth promoters, there

Table 2: Ways of reducing the environmental impact of dairy farming (Green and others 2011)

| Area                        | Suggested methods for improvement                                                                 |
|-----------------------------|---------------------------------------------------------------------------------------------------|
| Soil                        | Aerate soil if compacted. Conduct soil analysis to precisely evaluate what additivies are required. Higher technology for measuring and differential application of additivies in different locations are at the heart of the ‘precision agriculture’ revolution currently taking place. Improve aerts with minimal soil disturbance to reduce nitrous oxide losses, for example, by oversowing or direct drilling. |
| Water                       | Reduce dietary protein as far as possible – the use of essential oils and more precise rationing to individual amino acid requirements decreases overall crude protein requirement from 17 to 18 per cent (by dry matter) to 15 to 16 per cent, even in high-yielding animals. Adhere to nitrate vulnerable zone (NVZ) regulations if applicable. Excess dietary phosphorus will be excreted in urine and faeces and is a potential cause of eutrophication. Therefore, check dietary content so that mineral specifications are not excessive for phosphorus. |
| Manure/slurry               | Storing solid rather than liquid manure can reduce methane but increase nitrous oxide. Compacting manure and covering slurry stores or manure heaps reduces ammonia and nitrous oxide. Slurry application results in lower nitrous oxide emissions if spread in spring compared to autumn/winter. Understand nutrient content of slurry/manure and match to crop requirements, allowing for ground type and NVZ rules. Direct injection reduces ammonia and nitrous oxide compared to surface spreading. Consider anaerobic digestion to capture and use methane, which can be used as an energy source on farm. |
| Nitrogen                    | Effective nitrogen use: understand soil and crop requirements and match with fertiliser rates and maximise use of organic manures, to reduce nitrous oxide, ammonia and nitrate losses. Feed cattle so as not to provide excess nitrogen in the diet. |
| Health and fertility        | Optimising efficiency of production: fewer cows and less waste milk reduces the environmental impact per litre sold – a major veterinary role. |
| Diet                        | Effective use of feed improves performance and reduces inputs and waste per litre of milk produced. Current areas of research include high dry matter intakes, high-quality forage, high-sugar forage, use of clover, addition of specific oils or other feed addatives to reduce methane emissions. |
| Housing                     | More frequent slurry removal reduces ammonia emissions. Bolder and longer-term strategies could include scavenging greenhouse gases from negatively ventilated, sealed buildings. Collected gases (eg, methane) could be reused on farm. |
| Genetics                    | It may be possible to select for ‘low emission’ animals by making use of the relatively large between-animal variations that exists in emission characteristics. Selecting for more efficient and resilient animals may mitigate greenhouse gas production. |
| Energy consumption/ CO2 emissions | Review energy use and consider energy saving changes to lighting, machinery, dairy equipment (eg, plate coolers, heat recovery units), reduce delivery numbers (increase storage capacity), use of local feeds or by-products. Consider ‘carbon storage’, for example, conversion of cultivated land to permanent pasture or woodland. Consider production of energy from renewable or home-produced sources. |

Box 3: Resource efficiency and environmental management measures

- Segregate roof water for washing down parlour standings.
- Use plate coolers to cool milk.
- Test nutrient value of manures and produce a nutrient plan matched to slurry analysis.
- Use direct slurry injection to reduce nitrogen losses and anaerobic spoilage.
- Use fuel-efficient tractors.
- Use grass and forage types or strains with better nitrogen usage efficiency.
- Use silage inoculants or preservatives to improve fermentation and aerobic stability to reduce clamp wastage.
- Change slurry management practices to reduce nitrous oxide emissions; for example, avoid application when grass growth is slow.
- Use anaerobic digesters to reduce the emissions from manure and to produce green electricity (Fig 5).
- Recycle bedding, in particular sand. Recycled manure solids are currently the subject of much research and debate in the UK.
- Ensure efficient energy use in the supply chain both pre and post farm.
- Increase the energy efficiency of dairy equipment and farm machinery through effective insulation and heat recovery and GPS precision cropping, or increasing the use of energy from renewable sources.
- Use more homegrown protein feeds to reduce emissions associated with transport.
has been an explosion of interest in other compounds that might modify microbial activity in the gut. With regard to methane production, attention has focused on plant secondary metabolites, probiotics and propionate precursors. While major EU-funded projects on plant materials to decrease methane production are under way, possibly the most promising approach in the short term is the use of propionate precursors, such as malate and fumarate. Some unsaturated oils, such as linseed, and some essential oils, such as extracts from horse radish and garlic, may reduce methane production. However, more research in this area is needed.

**Immunisation**
Immunising ruminants against their own methanogens can successfully reduce the numbers of *Streptococci* and *Lactobacilli* in the rumen, with associated decreases in methane output. This approach is of particular interest in beef and sheep production, where extensive grazing remains the cornerstone of nutrition.

A number of nutrition-based methane mitigation measures have been suggested and identified, but there is a need to know whether these would be effective over broad spatial areas and under future scenarios. Additionally, it is necessary to ascertain whether widespread implementation of these measures would have other consequences, for example, for levels of production and emissions of other pollutants; the nitrogen-based greenhouse gases do not always follow the same trends in mitigation as for methane.

**Improving health and productivity by reducing waste**
UK dairy businesses in the top 25 per cent of performance (measured by cost of production) produce milk with a carbon footprint of over 300 g CO₂ less per litre than farms in the bottom 25 per cent. Improved health and reproductive performance drives this difference; for each day that a calving interval is extended there is an estimated increase of 18 kg CO₂ produced per cow per day. An increase in milk yield per cow (by 30 per cent in the modelled scenario), coupled with a reduction in dairy cow numbers to maintain current levels of production, produced the greatest impact on reductions to methane emissions in the UK (Chadwick and others 2007). A reduction in the milk yield per dairy cow by 30 per cent, coupled with an increase in the number of dairy cows required to maintain national milk production, resulted in an increase in methane emissions by almost 15 per cent.

Beef and sheep production account for around 65 per cent of the total UK agricultural methane emission, but it has generally been assumed that there is less scope for mitigation in these more extensive systems. However, improved health and reproductive performance will represent financial and environmental win-wins for dairy and beef industries alike, and so the mitigation avenues discussed below may apply equally to both sectors.

**Improved health**
A reduction in greenhouse gases and use of non-renewable resources and chemicals, per litre of saleable milk or kg milk produced, can be achieved through a combination of practices, including:

- **Improved feeding systems**
  - Enhancing feed efficiency through improved feeding systems and precision feeding.
  - Optimising feed intake and ration balance to reduce methane production.

- **Genetic selection**
  - Selecting breeds and genotypes with lower methane output and improved health traits.

- **Environmental management**
  - Reducing methane emissions from manure management and storage practices.
  - Enhancing pasture quality and the use of perennial grasses to improve animal health and productivity.

- **Biological and management practices**
  - Implementing conservation agriculture practices to improve soil health and methane emissions.
  - Promoting organic farming systems to reduce methane emissions and improve animal health.

- **Nutrition**
  - Feeding high-quality forages and balanced diets to maintain animal health and reduce methane production.
  - Using feed additives and probiotics to improve health and reduce methane emissions.

- **Sanitation and disease control**
  - Implementing good hygiene practices to reduce disease incidence and methane production.
  - Recognising and treating health issues to improve animal welfare and reduce methane output.

These approaches not only reduce methane emissions but also enhance animal health and productivity, leading to financial benefits for farmers and improved environmental outcomes.
Table 3: Practical climate change mitigation opportunities for the cattle veterinary surgeon

| Mitigation opportunity | Method of veterinary input |
|------------------------|---------------------------|
| Measure environmental impacts | Record and report data on health, production and reproductive events to facilitate evidence-based mitigation strategies and costings |
| Resource efficiency | Provide input to sustainable building design, track construction in catchment sensitive water areas and support applications for renewable energy systems |
| Nutrition | Engage with nutritionists and the farm team to balance the conflicts between health and welfare, production and greenhouse gas production |
| Health | Lead the farm team in measuring, managing and monitoring herd health through proactive advisory services |
| Reproduction | Lead the farm team in sustainable reproductive management (including regular fertility visits) and integrated herd health strategies (including addressing the root causes of infertility such as infectious disease and nutrition). Monitor bull and artificial insemination performance, including semen quality and synchronisation techniques where appropriate |
| Genetics | Engage with an opportunity for veterinary advisory input to shape the future of cattle farming through genomics |
| Welfare | Prioritise high welfare to promote the added value of high welfare dairy production to the consumer |

National cattle health schemes
Improving productivity nationally through control of key endemic diseases is an approach being embraced across dairy and beef sectors. Although national schemes to improve mastitis and lameness control are targeted at the dairy sector, initiatives to control bovine viral diarrhoea virus are seeing success in Scotland, Ireland and widely across Europe, led by the Scandinavian countries. Bovine TB remains a significant cause of wastage in the UK and, although a range of control strategies are being implemented, there appears little cause for optimism regarding eradication in the short to medium term.

Improved reproductive performance
Suboestrous and poor oestrus detection leads to reduced submission rates to service and inefficient dairy or beef herd performance—delays in calving to conception, prolonged lactations, lower reproductive efficiency and 100-day in-calf rates and higher 200-day not in-calf rates. Garnsworthy (2004) used a modelling approach to predict the effects of fertility on emissions by constructing a model that linked changes in fertility to herd structure, number of replacements, milk yield, nutrient requirements and gas emissions. Fertility had a major effect on the number of heifer replacements required to maintain herd size for a given number of cows. Herd replacements produced up to 27 per cent methane and 15 per cent ammonia of the herd’s total at typical commercial fertility levels. Improving submission rate from 50 per cent to 70 per cent could reduce emissions of methane by up to 24 per cent and ammonia by about 14 per cent (Garnsworthy 2004). Improved submission rate could represent one approach to achieving improved environmental sustainability for a fixed level of dairy or beef production.

Role of genetics and reproductive technologies
A range of different breeding strategies, such as traditional genetic selection methods to improve production efficiency, or biotechnology tools, such as semen sexing, could be used to mitigate the global warming impact of farm livestock. In the future, it may be possible to selectively breed animals with low methane production [there are variations between the emissions of individuals]. Embryo collection and transfer, ovum pick-up and in vitro production all offer techniques for accelerated selection of sustainable production traits.

Bell and others (2010) investigated the effect of long-term breeding for kg of milk fat plus protein production and the influence of parity, genetic line and diet on predicted methane emissions of Holstein Friesian dairy cows using 17 years of experimental data from the Langhill herd in Scotland. This herd comprised genetic lines selected for increased kg of milk fat plus protein (‘Select’ cows) or selected to remain close to the UK average (‘Control’ cows). ‘Select’ cows had a higher weekly DMI and milk yield but a lower predicted methane output per kg of milk by approximately 12 per cent when compared to ‘Control’ cows. In terms of diet, low-forage cows had a higher daily DMI and milk yield but a lower predicted methane output per kg of milk than the high-forage cows.

Genomics and big data: breeding for resilience and production efficiency
Many of the mitigation opportunities discussed above include a genetic component. Genomic selection has developed rapidly to the point where it is now being deployed commercially. Although this is mostly in the Holstein dairy breed, initiatives are underway to develop genomic selection in other breeds, for both milk and...
meat-producing cows. The challenge is now to target the most appropriate traits.

If production efficiency is measured over the lifespan of the animal it is evident that the ability to carry on producing becomes a positive attribute. Being able to select animals with ‘resilience’ for a particular farm system could increase efficiency and reduce environmental impact. Evaluating such resilience relies on the ability to phenotype the key components on a sufficiently large scale to create the necessary reference populations for genomic evaluation. In this way, evidence-based breeding and culling decisions could be made using ‘big data’; the large volumes of field data that potentially facilitate more efficient ‘precision farming’.

### A role for the veterinary surgeon

Improving health and fertility leads to a reduction in greenhouse gas emissions because fewer cows at a given level of production will be required to produce the same quantity of milk or beef. Therefore, an active herd health management programme should fundamentally reduce the climate change impact of food production. This offers clear, practical opportunities for the cattle veterinary surgeon working in practice, as summarised in Table 3.

The veterinary surgeon in practice has a key role at the hub of the farm team to deliver an appropriate balance (Fig 8).

Undoubtedly, future challenges will create complex conflicts. These include the globalisation of food markets, national and global population growth, consumer demands for better welfare and the ‘one health’ agenda with regard to antimicrobial resistance-related challenges between human medicine and veterinary medicine. The veterinary surgeon has a role to play in achieving an appropriate balance in cattle farming. What may happen in the future in terms of cattle and the environment is far from clear and is certain to be politically driven. Some areas where change should occur are proposed in Box 4.

The environmental impacts of cattle farming are now well recognised. While it is important that agriculture deflects unnecessary scaremongering, it is also important that measures are taken to develop and introduce improvements that will lead to sustained reductions in climate change impacts in the long term. The veterinary profession has the opportunity to be central to this process. Cattle farming is associated with climate change, but these impacts can be measured, as outlined in this article. The veterinary surgeon can also play a critical role in this area and can be involved in the potentially important redefining of cattle veterinary practice, by considering the need to balance food production with health and welfare, antimicrobial resistance, one health and the environment.

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### Summary

The environmental impacts of cattle farming are now well recognised. While it is important that agriculture deflects unnecessary scaremongering, it is also important that measures are taken to develop and introduce improvements that will lead to sustained reductions in climate change impacts in the long term. The veterinary profession has the opportunity to be central to this process. Cattle farming is associated with climate change, but these impacts can be measured, as outlined in this article. The veterinary surgeon can also play a critical role in this area and can be involved in the potentially important redefining of cattle veterinary practice, by considering the need to balance food production with health and welfare, antimicrobial resistance, one health and the environment.
Quiz: Climate change and cattle farming

1. The UK Climate Change Act 2008 outlines one of the most ambitious national climate change programmes, with targets for reduced greenhouse gas emissions, compared to the levels recorded in 1990, of:
   a. 4 per cent by 2020 and 8 per cent by 2050
   b. 14 per cent by 2020 and 28 per cent by 2050
   c. 58 per cent by 2020 and 64 per cent by 2050
   d. 25 per cent by 2020 and 75 per cent by 2050
   e. 34 per cent by 2020 and 80 per cent by 2050

2. Of the five major sectors that make up total greenhouse gas emissions (energy, industry, waste, land use, land use change and forestry [LULUCF], and agriculture), what percentage were livestock activities postulated to contribute by the FAO in 2006?
   a. 58 per cent
   b. 18 per cent
   c. 34 per cent
   d. 72 per cent
   e. 8 per cent

3. Which one of the following options does not represent an area of opportunity to mitigate the impact of cattle farming on climate change based on nutrition and modification of enteric fermentation:
   a. Feeding a high forage diet of low digestibility
   b. Strategic use of dietary oil supplements
   c. Feeding more starch and less fibre
   d. Use of ionophore supplements
   e. Immunising ruminants against their own methanogens

4. Which of the following do not represent areas of opportunity to mitigate the impact of cattle farming on climate change through health and reproduction management:
   a. Increased submission rate to service
   b. Control of bovine viral diarrhoea virus
   c. Control of liver fluke
   d. Calving replacements into the adult cattle herd at three years old rather than two years old
   e. Control of mastitis

Answers: e, b, a, d