

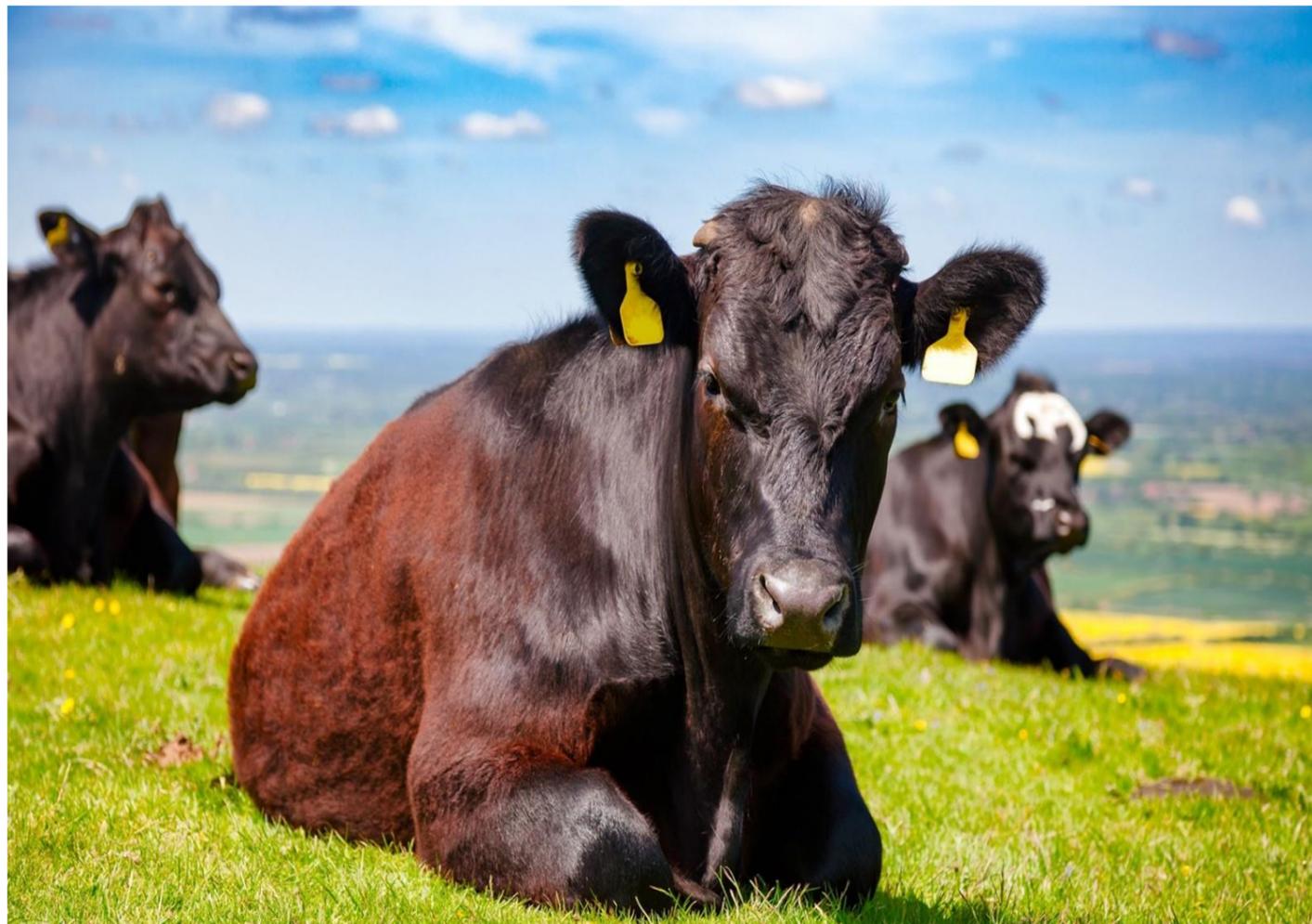


ERBS
European Roundtable
for Beef Sustainability

Mitigating greenhouse gas emissions
in beef and dairy systems

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Introduction

Climate change is the major challenge for humanity in the 21st century and to overcome it, reduction of greenhouse gas (GHG) emissions is essential. Meeting the challenge of climate change needs to be balanced with meeting the increasing demand for high quality food for the growing world population. Therefore, dairy and beef producers are working to develop livestock systems that optimise the use of resources (e.g. land, water, energy) and release few pollutants into the air, water and soil.

The Beef and Dairy industries recognise that GHG emissions produced at farm level are contributing to climate change. The European Roundtable for Beef Sustainability (ERBS) and the Dairy Working Group (DWG) of the Sustainable Agriculture Initiative Platform (SAI Platform) are committed to having a positive impact on driving down GHG emissions in the sector, and many of our members are already actively working to achieve this. SAI Platform is a not-for-profit organisation transforming the global food and drink industry by pioneering solutions to common challenges and promoting sustainable agriculture in a pre-competitive environment. Here we present a summary of two studies carried out by Wageningen University on behalf of SAI Platform DWG and ERBS which reviewed the state-of-knowledge on GHG mitigation and the options that are already being used across the sector:

Mitigation options to reduce GHG emissions at dairy and beef farms

[\[CLICK HERE\]](#)

Literature review of beef production systems in Europe

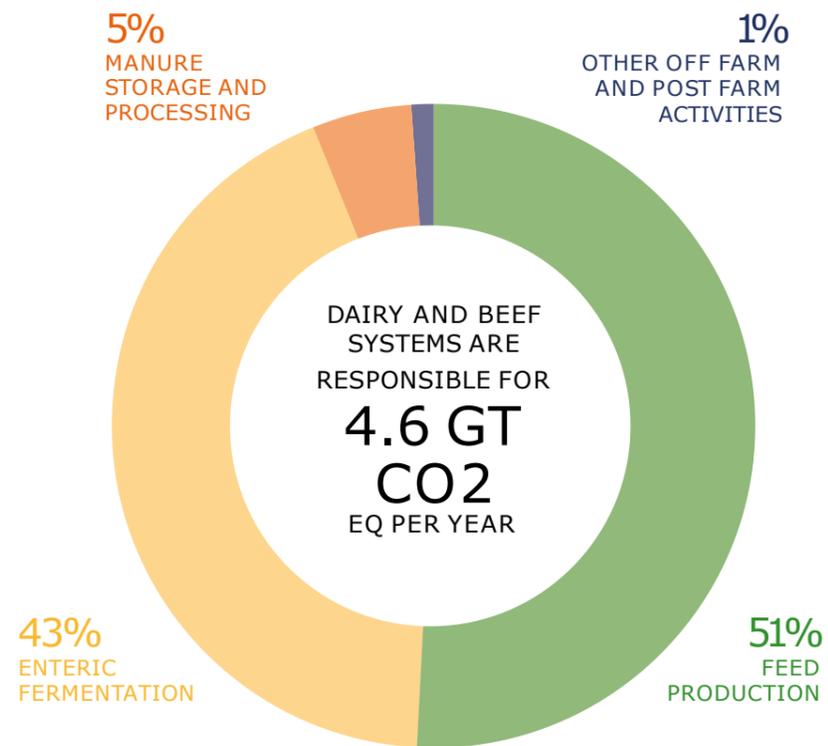
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Whilst the challenge of climate change is significant, this work has shown that there are many mitigation options and strategies available on-farm. Within the beef and dairy supply base, a range of practices that help to reduce GHG emissions are already in use. Increasing overall productivity and efficiency, by optimizing inputs of nutrients and energy, are key strategies to reduce the emissions intensity of beef and dairy systems. We have found that the 5 most frequently used options in current practice are:

- Improving animal productivity by breeding
- Increasing production through improved efficiency
- Improved diet composition
- Improved forage quality
- Improved animal health

The challenge of climate change

Livestock production plays an important role in climate change by emitting GHG either directly (from enteric fermentation and manure management) or indirectly (from use of N fertiliser in feed production and displacement of natural habits for pasture and feed crop production). The Food and Agriculture Organization (FAO) estimates that the livestock sector is responsible for 14.5% of global GHG emissions.



GHG include carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) all of which are released from farm activities. Nitrous oxide (x 265) and methane (x 28) have a greater warming effect than CO₂ when considered over a 100-year time frame. A new methodology for assessment (GWP*) has been proposed and takes account of the fact that methane has a much shorter lifespan in the atmosphere than CO₂ and N₂O. If this metric were applied, then the relative importance of enteric methane as a GHG source from the dairy and beef sectors would reduce. However, many opportunities for GHG mitigation would remain.

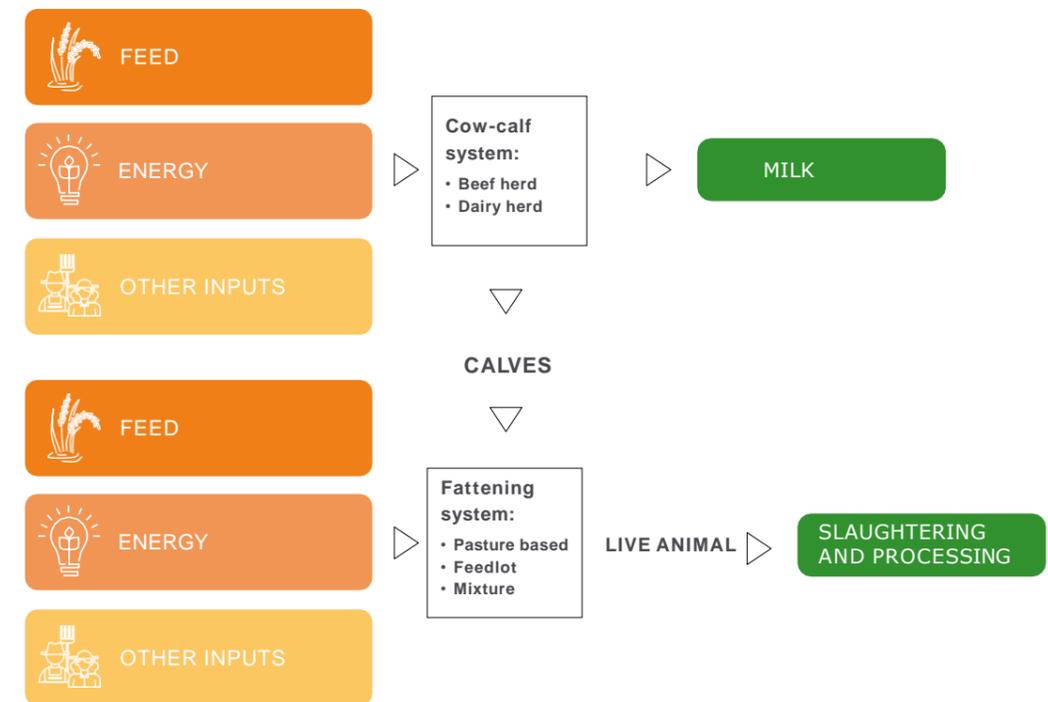
GHG emissions in beef and dairy systems

The main sources of GHG emissions (and hence the most appropriate targets for mitigation) vary in different systems. In low input smallholder systems, methane from enteric fermentation is the largest proportion of the GHG emissions.

In more specialised and highly productive systems, emissions from the production of feed (land preparation, harvesting, use of fertilisers and pesticides, drying, transport, storage, processing, etc.) are more significant.

In housed systems, manure management is a major source of GHG emissions, whilst in pasture-based systems, changes in grassland management, e.g. integration of white clover into grass monocultures, can reduce GHG emissions significantly.

There is a large variety of farm types and management practices in place across the beef and dairy supply base. Systems vary in the intensity of production, origin of calves, diet composition, feed sourcing (on-farm, imported), market requirements, economic, social and cultural factors, as well as the management choices taken on the farm.



The wide range of systems means that GHG emissions vary significantly between farms; for example, one review shows a range from 8.6 to 35.2 kg CO₂eq per kg of beef (meat). Some of these differences are the result of structural factors that are outside the control of the farm. But in a study of 59 beef farms in France, comparison of farms with the highest and lowest GHG emissions showed that there is a potential to reduce 50% of GHG emissions through better management.

Reducing GHG emissions on farm

All beef and dairy systems can reduce their GHG emissions, but because of the diversity of farm types and systems within the sector, choosing the right practices for any farm depends on many factors including technical effectiveness (GHG reduction potential), cost-effectiveness, extent of change and capital investment.

Increasing technological development is expected over the next 5-10 years which will enable:

- more widespread implementation of breeding and selection strategies to reduce methane emissions
- increased use of feed additives or vaccines to alter the pathways of rumen fermentation
- new approaches to manure management for housed systems

Improving productivity without increasing livestock numbers both reduces GHG emissions and increases profitability, depending on the extent of the investment required. This results from increased efficiency in terms of energy, feed inputs, nitrogen fertiliser used. The main drivers for increased efficiency on farm are usually economic benefits through increased resource utilisation efficiency. Reduced GHG emissions per unit of product is often an indirect benefit.

On farms that are already highly productive, the focus should be on increasing efficiency. Key targets should be reducing the use of fossil fuels and manufactured nitrogen fertiliser on farm, as well as adopting as many mitigation options as are suitable and cost-effective for the business.

Farms where productivity is much lower than the regional benchmark for the farm type should focus on approaches that increase productivity per livestock unit. This is very highly likely to reduce GHG emissions per unit livestock product.

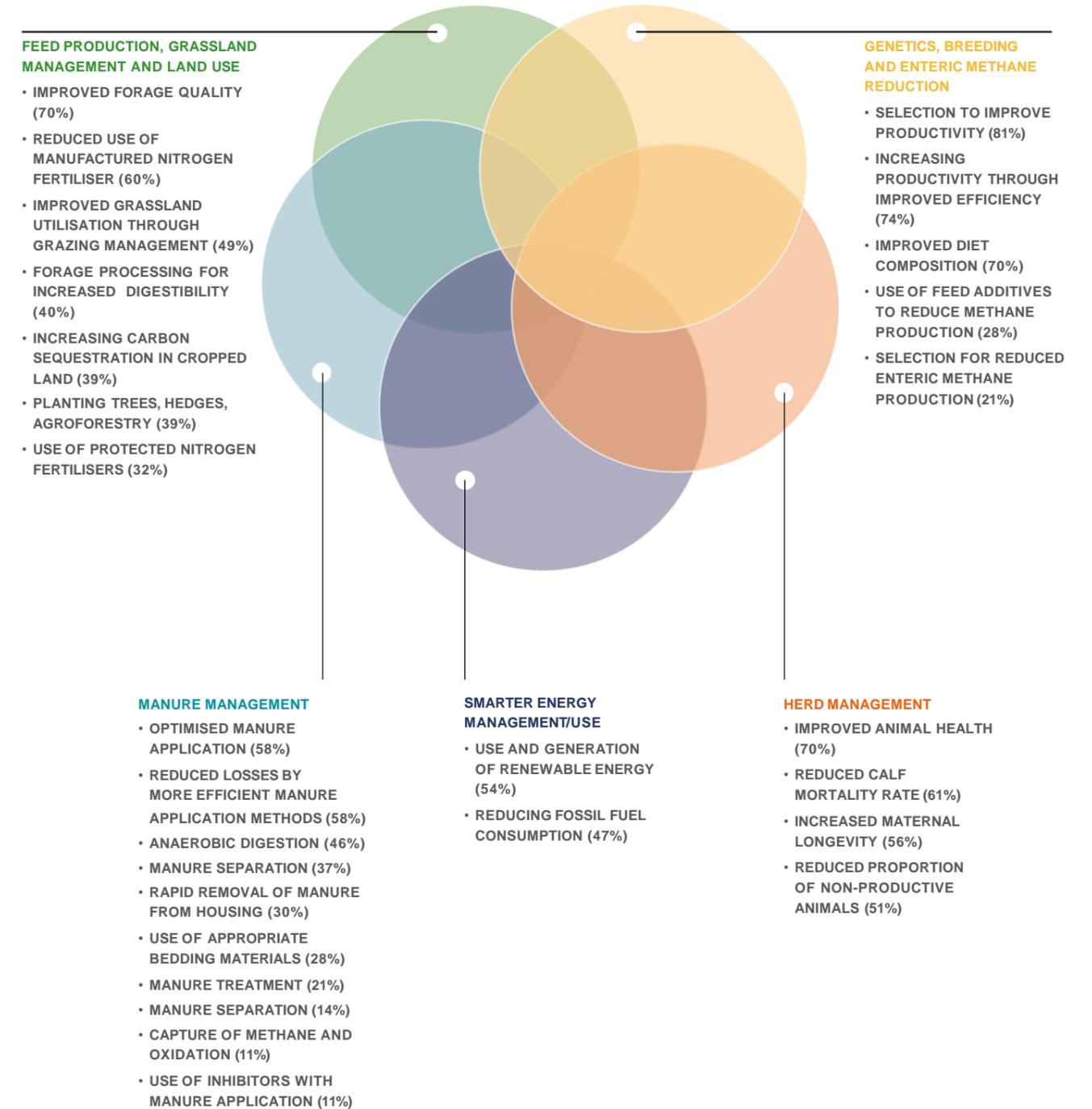
It may also be possible to increase carbon storage (carbon sequestration) on the farm within woody biomass (trees, hedges etc) or within the soil. Grassland soil carbon sequestration could significantly offset emissions. Global estimation of this potential is around about 0.6 GT CO₂-eq per year. However, this potential is difficult to estimate accurately, and we need a better understanding of the costs and practical options at farm scale.

Putting any mitigation options into practice requires selection of the most appropriate options for each individual farm's circumstances so that the required adaptations can be made. More details of the options available are given in the following sections. The mitigation options have been categorised into five groups



A survey was created and shared globally through SAI Platform's DWG and ERBSmembers and IDF Partners. The survey collected information on relevant farm level GHG mitigation options that are currently being used through a structured process.

The percentages referenced in this diagram indicate the percentage of survey respondents implementing each mitigation option.



Monitoring GHG emissions

Putting GHG emissions mitigation options into practice for any farming system needs a good baseline understanding of the current site and system. There are many tools available that farms can use to assess their Carbon Footprint used across the sector. Producers should choose a tool that has been verified in their region and production system.

Managing reductions in GHG emissions on farm is an on-going process rather than a single set of actions. Monitoring is essential to measure the effects of implementing the mitigation options, the progress being made towards the outcome of decreasing the farm's carbon footprint and the direction or speed of change. It is very likely that farms will need to allow for adjustments to be made to the current strategy to meet new challenges or address new constraints, whilst keeping the ultimate aim in mind.

To plan a mitigation strategy for any farm, a balanced approach will be needed making use of several of the mitigation options from across the six categories identified. Whilst there are options that are more applicable to different farming systems and farm sizes, many of the mitigation options are universally applicable.

Beware of interactions along the supply chain

When considering mitigation strategies and developing training and support packages for the supply chain, it is important for producer groups and processors to recognize that interventions in the different parts of the sector are often linked and thus, when developing plans across the supply chain, it is recommended that the integrated effects of the intervention on net GHG emissions along the production chain as a whole (positive or negative) together with impacts on other pollutants (ammonia, nitrate and phosphate to water), land-use change, biodiversity and livelihoods are considered.

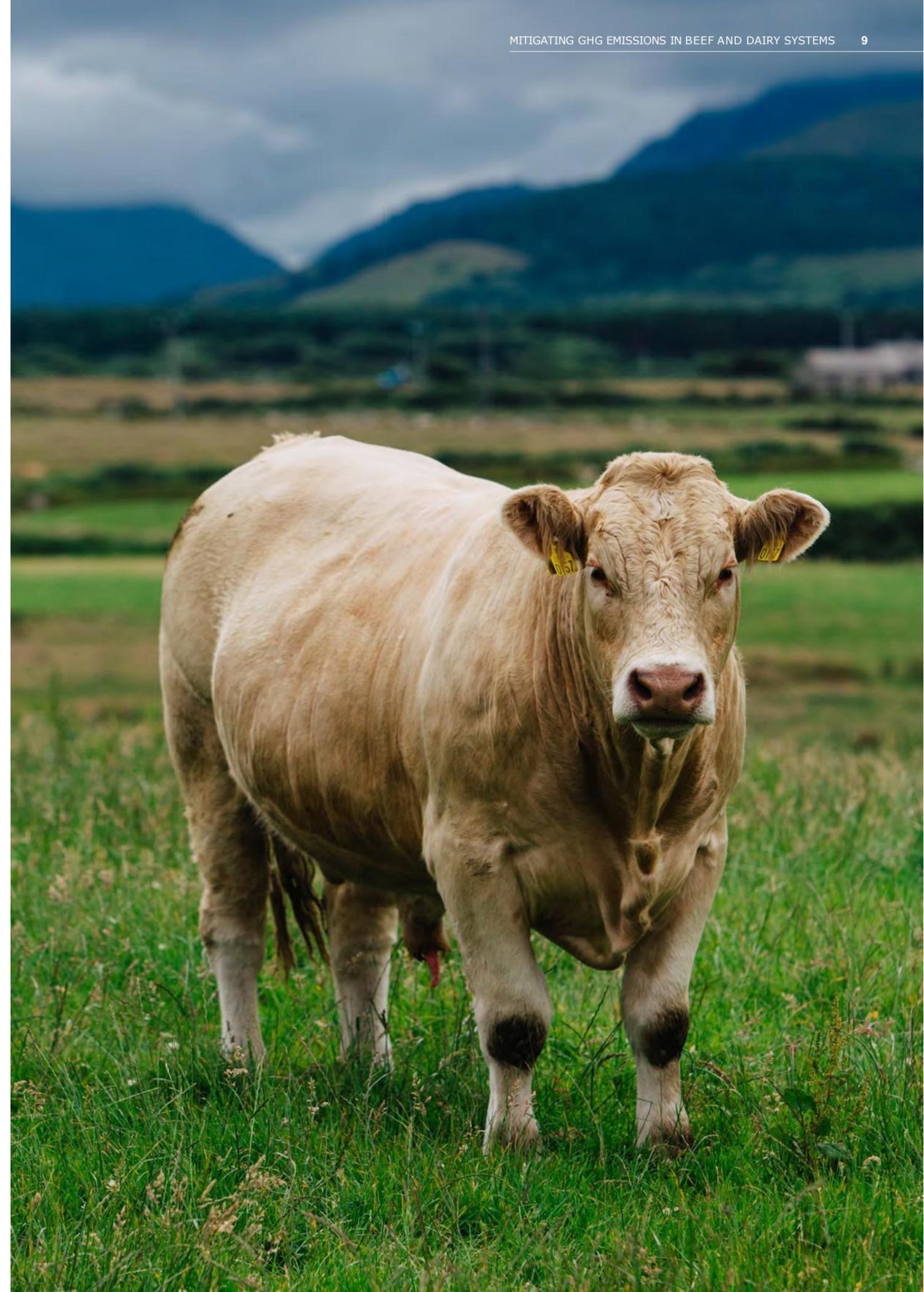
For example:

Changes in feeding systems might reduce GHG emissions at farm level but may require land use change elsewhere, e.g., more cultivation of crops for animal, rather than human, consumption.

Changes in dairy herd structures may reduce the amount of beef available from retired dairy cows and this may mean that more calves are needed from dedicated beef systems.

Changes in bedding with larger requirements for sand may mean competition with the construction sector for materials and higher volumes of sand extraction required.

Levels of GHG emissions vary widely within and across geographic regions and production systems, depending on size and management level. Therefore, it is also important to understand any structural constraints to mitigation actions. For example, fewer options may be available for farmers in high nature value areas. This also implies that a mitigation option that is relevant for one system can be irrelevant for another system. It also means that the effect of one mitigation option can differ between different farming systems. Even within similar farming systems, the effect of a mitigation option may differ a lot depending on the starting point.



Summary table of mitigation options, listed with the most commonly implemented first.

The option number corresponds to the number given in the Report - “Mitigation options to reduce GHG emissions at dairy and beef farms”. Follow the links for more detail about each option.

	Mitigation option	System	Profitability	Required skills	Main stimuli
1	Selection to improve animal productivity (e.g. higher milk yield/number of calves per cow per year)	Universal	Profitable	Medium-high	Knowledge and training, subsidies
2	Increased productivity through improved animal efficiency (e.g. feed conversion rate, calving interval, days to slaughter)	Universal	Profitable	Medium-high	Knowledge and training, technical assistance, subsidies
4	Improved diet composition (e.g. increasing digestibility)	Universal	Profitable	Medium-high	Knowledge and training, subsidies
6	Improved animal health (e.g. vaccination)	Universal	Profitable	Low-medium	Knowledge and training, subsidies, technical assistance
13	Improved forage quality (e.g. earlier harvest, improved varieties)	Universal	Profitable	Medium-high	Knowledge and training, subsidies
7	Reduced calf mortality	Universal	Profitable	Medium	Knowledge and training, subsidies, technical assistance
12	Reduced use of manufactured nitrogen fertiliser (e.g. planting clover, application of manure, composting, soil testing and nutrient planning)	Universal	Profitable	Medium-high	Knowledge and training, subsidies
25	Optimised manure applications (e.g. match crop nutrient demands, soil conditions)	Universal	Profitable	Medium-high	Knowledge and training, subsidies
24	Reduced losses by more efficient manure application methods (e.g. dilution and injection)	Universal	Extra costs	Low-medium	Knowledge and training, subsidies
8	Increased maternal longevity	Universal	Profitable	Medium	Knowledge and training, subsidies
28	Use and generation of renewable energy	Universal	Profitable	Medium-high	Knowledge and training, subsidies and investment
9	Reduced proportion of non-productive animals (e.g. young stock, dry cows)	Universal	Profitable	Low-medium	Knowledge and training, technical assistance
10	Improved grassland utilization through grazing management (e.g. subdividing farms to paddocks, sward analysis, measuring grass growth and planning grazing strategy for grazing season)	Grazing	Profitable	Medium-high	Knowledge and training, subsidies

	Mitigation option	System	Profitability	Required skills	Main stimuli
27	Reducing fossil fuel consumption	Universal	Profitable	Medium	Knowledge and training, subsidies
23	Anaerobic digestion	Size: >500 total herd	Investment required	High	Knowledge and training, subsidies
14	Forage processing for increased digestibility (e.g. chopping, grinding, and steam treatment)	Universal	Profitable	Medium-high	Knowledge and training
11	Increasing carbon sequestration in cropped land (e.g. integrating grassland in cropping areas)	Where low C soils occur	Unclear	Medium-high	Knowledge and training, subsidies
15	Planting trees, hedges, agroforestry	Universal	Extra costs	Low-medium	Knowledge and training, subsidies, suitable land
17	Manure separation	Housing	Investment required	Low-medium	Knowledge and training, investment arrangement
16	Use of protected nitrogen fertiliser (e.g. urea treated with a urease inhibitor)	Universal	Extra costs	Low-medium	Knowledge and training, subsidies
18	Rapid removal of manure from housing	Housing	Extra costs	Medium	Knowledge and training, subsidy and investment
5	Use of feed additives to reduce enteric methane production	Where concentrate / grain-based feeding occurs	Extra costs	Unclear	Innovation and technology, knowledge and training, subsidies
20	Use of appropriate bedding materials (e.g. sand)	Housing	Unclear	Low-medium	Knowledge and training
3	Selection for reduced enteric methane production	Universal	Profitable	Medium-high	Innovation and technology, knowledge and training, subsidies
19	Manure treatment (e.g. application of sulfuric acid, manure aeration, manure cooling)	Housing	Extra costs	Unclear	Knowledge and training
21	Ensuring manure storage tanks are fully emptied (inoculum removal)	Housing	Extra costs	Medium	Knowledge and training
22	Capture of methane and oxidation	Size: >500 total herd	Investment required	Medium-high	Knowledge and training
26	Use of inhibitors with manure application (e.g. DCD, DMP)		Extra costs	Low-medium	Innovation and technology

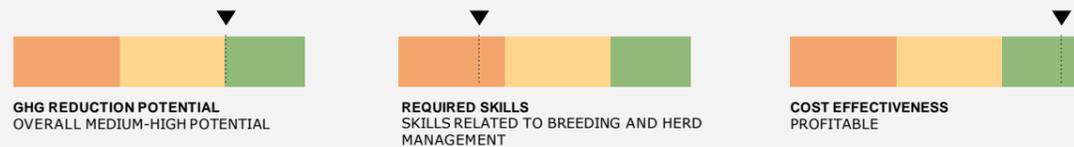
 GENETICS, BREEDING AND ENTERIC METHANE REDUCTION	 FEED PRODUCTION, GRASSLAND MANAGEMENT AND LAND USE	 SMARTER ENERGY MANAGEMENT / USE
 HERD MANAGEMENT	 MANURE MANAGEMENT	

Genetics, breeding and enteric methane reduction



Genetics, breeding and enteric methane reduction

01 Selection to improve animal productivity



Mitigation practices

Improving animal productivity by breeding includes:

- Genetic and genomic selection
- Reproductive technologies
- Artificial insemination
- Oestrous synchronisation
- Sexed semen
- Multiple Ovulation Embryo transfer

Extent of implementation

Selection and breeding to improve animal productivity is the most implemented mitigation option based on the survey results. Increased productivity often also improves other sustainability aspects, because the improvement in productivity occurs with an increase in resource use efficiency.

Background

Increasing animal productivity by improving the genetic potential of livestock, with benefits for reproductive performance, feed conversion efficiency, health and liveweight gain, has been found to be among the most effective approaches to GHG mitigation.

Selection may mean choosing higher genetic merit bulls that are appropriate for the size of cow. This may be achieved using artificial insemination. However, this could include a more radical approach by changing the breed used on the farm to a more productive breed or one more suited to the production system.

Selective breeding can improve the genetic potential for increased production efficiency whilst reducing the environmental footprint. Using reproductive technologies on-farm can increase conception rate and overall reproductive rate, improving productivity and reducing the GHG emissions per product. For example, dairy cows with an average milk production of 40 kg milk per day would have about a 50% lower CO₂-eq per kg milk (standardized for fat and protein) compared to dairy cows with a production of 10 kg milk per day.

Artificial insemination

Artificial insemination with sexed semen can be used to reduce the number of male animals produced where mainly females are required whilst increasing genetic merit for production and reproduction traits.

Required skills

Improving animal productivity through selection and breeding requires a long-term breeding strategy. This often includes the use of artificial insemination with semen from higher genetic merit bulls that are appropriate for the size of cow.

Increasing the herd reproductive rate requires attention to detail with heat detection and pregnancy diagnosis as well as good maternal nutrition to support conception.

The application of good herd management is important where this mitigation option is selected. Achieving genetic potential for any breed requires high-level husbandry skills in health, welfare and nutritional management.

Changing to a more productive breed is likely to mean increased energy and protein requirements overall and can bring health challenges. This needs to be considered carefully in the context of the farming system.

In contrast, changing to a breed more suitable to the constraints of the production system may reduce health challenges and reduce the need for inputs.

Cost-effectiveness

If moving to using a completely new breed, this may require high investment.

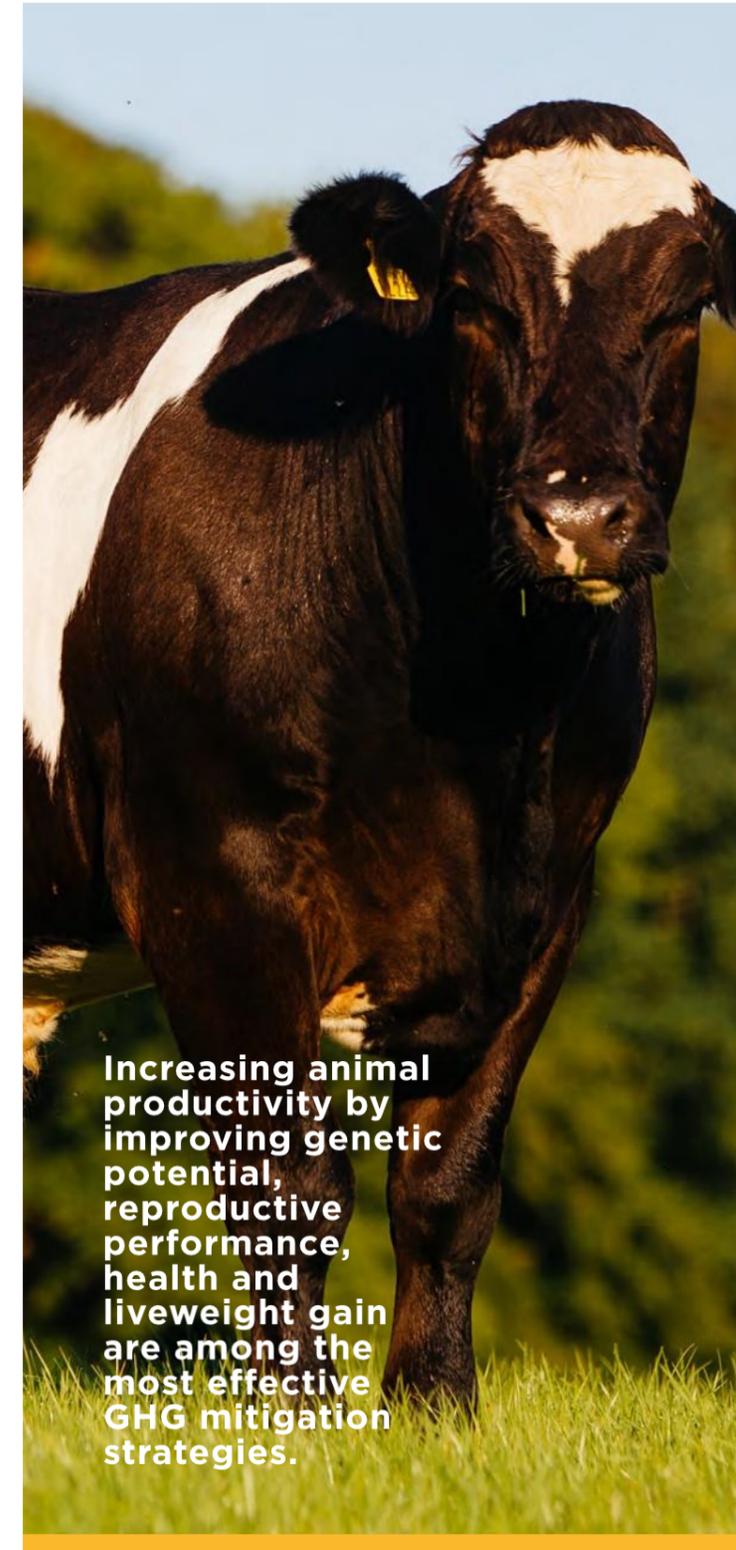
However, if using a more gradual approach to improve the genetic potential within the herd, then the investments required will be limited. Increased production efficiency will reduce costs. Therefore, this mitigation option is considered to be profitable overall.

Linked options

[Back to Summary table](#)

Also consider:

8. Increased maternal longevity
3. Selection for reduced enteric methane production
2. Increased productivity through improved animal efficiency



Increasing animal productivity by improving genetic potential, reproductive performance, health and liveweight gain are among the most effective GHG mitigation strategies.

Genetics, breeding and enteric methane reduction

02 Increased productivity through improved animal efficiency



Mitigation practices

Increasing animal efficiency by:

- Designing feeding systems to meet animal requirements
- Optimizing calving intervals
- Increasing growth rate in beef calves

Extent of implementation

Increasing animal efficiency is one of the most implemented mitigation options and is used by 74% of those surveyed. Increasing efficiency of feed conversion into milk or meat has been found to have many positive side effects (increased land use efficiency, reduced GHG emissions per kg of meat/milk).

Background

Increasing the efficiency of the cattle by improving feed conversion, growth rates and reproductive rate through management reduces GHG emissions as fewer inputs are required for each unit of product.

The application of good herd management is important where this mitigation option is selected. Achieving the productive potential of any herd requires high-level husbandry skills in health, welfare and nutritional management.

Nutritional status

The most common limitation to animal efficiency is inadequate or unbalanced nutrition. It is essential to meet animal nutritional requirements in order to keep animal production efficiency high. Improved diet composition is covered in more detail by Option 4. Effective feeding systems coupled with careful cattle monitoring are essential to ensure that benefits result for the whole herd.

Optimising calving interval

Optimum productivity for cows in most beef and dairy systems requires the production of one calf per cow per year. With a nine-month gestation period, cows must be back in calf within 3 months of calving. Conception can be delayed by lack of energy and ill health. Nutritional status, timing of the initial insemination after parturition, and method and timing of pregnancy diagnosis of females play an important role in maintaining high levels of cattle fertility. There are several approaches to increasing animal fertility that are often low cost and easy to apply:

- Avoidance of inbreeding
- Selecting proven sires and fertility testing bulls on farm
- Reducing stress and improving health in the herd

- Feeding nutritionally balanced rations with sufficient energy
- Heat observation and accurate timing of insemination. Heat synchronisation protocols can help to tighten calving patterns for seasonal calving sustainability aspects, because the improvement in productivity occurs with an increase in resource use efficiency

Required skills

The application of good herd management is key to the success of this mitigation option. To increase animal production efficiency, there is a need to have a good overview of the overall herd productivity, health, and welfare, as well as the impacts on individual animals or groups.

Increasing the herd reproductive rate requires attention to detail with heat detection and pregnancy diagnosis as well as good maternal nutrition to support conception. Technical knowledge of nutritional requirements and practical implementation of an efficient feeding system requires farmers to know the exact nutrient demands of animals and how these change through the production cycle.

Cost-effectiveness

Improving feed and fertility management systems may increase the workload on farm, consultation with nutritionist and/or consultants may be required which will incur additional costs. However, because this strategy leads to higher milk or meat production it will usually be profitable for the farmer (subject to total costs and market prices for products produced).

Linked options

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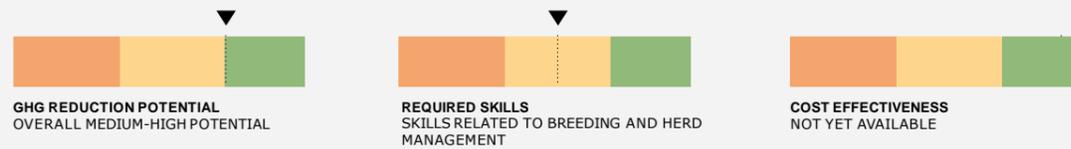
Also consider:

4. Improved diet composition
9. Reduced proportion of non-productive animals



Genetics, breeding and enteric methane reduction

03 Selection for reduced enteric methane production



Mitigation practices

Implementing selection and breeding programmes focusing on low enteric emissions.

Extent of implementation

20% of those surveyed take feed conversion efficiency, liveweight gain potential, health and hardiness traits into account and use of estimated breeding values in sire selection in their breeding and selection strategies.

Background

Improving the genetic potential by selection of animals with low methane emissions per unit of feed consumed could result in a permanent decrease in GHG emissions with no negative impacts on productivity.

Tackling methane emissions can be achieved by selecting and breeding animals with high feed conversion efficiency. This cannot yet be done directly on farm, but research suggests that methane emissions from enteric fermentation can be reduced by around 20% through genetic and genomic selection strategies.

Required skills

The skill requirements for breeding for reduction of enteric methane emissions are like those required in selection to improve animal productivity. There is an additional need to understand genetic and genomic indices and their application.

Cost-effectiveness

Not yet available.

Linked options

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Genetics, breeding and enteric methane reduction

04 Improved diet composition



Mitigation practices

Improving diet composition by:

- Carefully balanced diets specific to animal requirements
- Inclusion of up to 50% maize silage within the ration
- Increased use of home-grown proteins such as forage legumes
- Reduced feed waste
- Inclusion of new feed components with lower enteric fermentation (e.g. seaweed)

Extent of implementation

70% of the producers surveyed are seeking to improve diet composition. The exact impact of this mitigation strategy on any farm depends on the changes made. Where feed quality is low or poorly matched to animal requirements, improving diet composition will result in lower GHG emissions.

Background

Improvement of diet composition through strategic use of nutritionally balanced rations can improve feed conversion efficiency, which can increase animal productivity and reduce GHG emissions per unit of product.

Enteric methane production is highly dependent on the composition of the diet.

Precision livestock feeding

Matching nutrient supply precisely with the requirements of individual animals, throughout their production cycle has been found to increase nutrient use efficiency and productivity, whilst reducing GHG emissions per unit of product and reducing feed waste.

Total mixed rations (TMR)

Evenly mixing all dietary components is a means of providing a consistent supply of nutrients, allowing for more efficient use of maize silage and concentrate feeds. This also prevents selective feeding. TMR can ensure a nutritionally balanced diet containing all required micronutrients, improving nutrient use efficiency and increased productivity.

Feed sources

Selecting feed that has been produced with a lower carbon footprint leads to lower GHG emissions from the livestock system. When determining the carbon footprint there is a need to consider whether some feeds (e.g. soya) have been imported from other countries; in that case, transportation makes a significant contribution to GHG emissions as well as the emissions produced by the crop production methods within the source country. Home-grown feeds often have lower GHG emissions.

Required skills

Good technical knowledge and practical skills for feeding, grassland management and herd management are required. Consultation with nutritionist and/or consultants may be required.

Cost-effectiveness

Although increased concentrate use increases feeding costs, higher revenues may be achieved due to increases in both productivity (milk, meat) and reproductive efficiency to make this strategy profitable. The exact impacts on profitability will depend on the farming system and input costs.

Linked options

[Back to Summary table](#)

Also consider:

- 13 Improved forage quality
- 5 Use of feed additives to reduce methane emissions



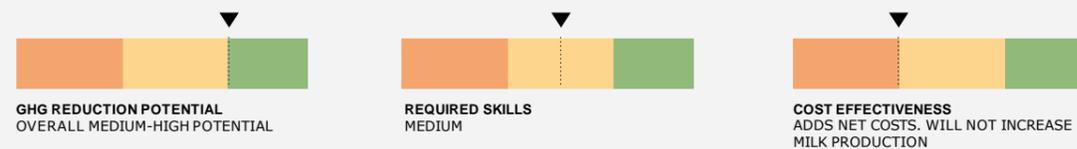
Consider the trade-offs if switching to maize silage -

One long-term strategy for mitigating GHG emissions is replacing grass silage with maize silage in the ration of dairy cows. This change in diet can reduce annual emissions by 12.8 kg CO₂-eq per 1000L milk (standardised for fat and protein).

However, cultivating grassland for maize production results in large C losses from the soil and it has been estimated that it would take 44 years before the annual emission reduction paid off the emissions due to land use change.

Genetics, breeding and enteric methane reduction

05 Use of feed additives to reduce enteric methane production



Mitigation practices

Use of feed additives or vaccines that alter ruminal fermentation to reduce methane such as:

- Ionophoric antibiotics
- Other feed additives
- Vaccines to reduce methane production
- Inhibitors
- Electron receptors

Extent of implementation

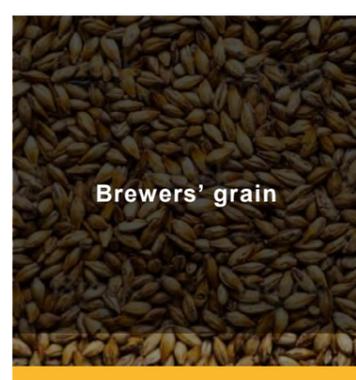
Currently used by less than a third of those surveyed, although more common in dairy systems. Feed additives are easy to implement especially in systems where concentrates are fed. Many of the options for use are still in the early phases of development.

Background

There are various feed additives and supplements which can reduce GHG emissions through enteric fermentation. However, it is not clear whether reducing methane emissions in the rumen will simply shift losses to manure storage or application.

Fatty acids

Widely used as dietary components and effective in decreasing methane production by providing non-cellulose sources of energy. Do not exceed 6% dry matter as this can lead to health issues. High contents of fatty acids can also give poor pelletisation.



Sources of fatty acids

Evenly mixing all dietary components is a means of providing a consistent supply of nutrients, allowing for more efficient use of maize silage and concentrate feeds. This also prevents selective feeding. TMR can ensure a nutritionally balanced diet containing all required micronutrients, improving nutrient use efficiency and increased productivity.

Use of feed additives

Feed additives such as:

- Electron receptors (e.g. fumarate, nitrates, sulphates and nitroethane)
- Inhibitors (e.g. 3-NOP)
- Ionophoric antibiotics

have shown a positive impact in reducing methane emissions, although the health risks associated with using these additives need to be considered.

In North America, the use of ionophoric antibiotic monensin is common in beef production and has been introduced more recently into dairy systems. However, the use of antibiotics as feed additives is prohibited in the EU because of the risk they may lead to anti-microbial resistance.

Vaccines

- Vaccines stimulate antibody production targeting methanogens.
- In vitro experiments have achieved GHG emissions reductions of 30%.
- Long-term impact on cows is uncertain.

Required skills

When using feed additives, it is important to be aware of the acceptable usage levels and to monitor long-term impacts on animal performance.

Use of feed additives would require virtually no change in farm practice nor any extra skills and are applicable to all systems.

Cost-effectiveness

The use of feed additives to alter ruminal fermentation to reduce methane emissions will incur an additional cost. The mitigation option directly aims to reduce enteric fermentation and will not increase milk or meat production.

Linked options

[Back to Summary table](#)

Also consider:

4. Improved diet composition

An aerial photograph of a herd of brown cows grazing in a lush green field. The cows are scattered across the frame, some standing and some lying down. The grass is vibrant green with some patches of brown earth. The overall scene is peaceful and pastoral.

Herd management

Herd management

06 Improved animal health



Mitigation practices

Improving animal health by:

- Vaccination to prevent endemic disease (not available for all diseases)
- Applying health monitoring programmes to prevent diarrhoea and pneumonia
- Effective biosecurity
- Improved housing conditions

Extent of implementation

Steps to maintain a high herd health status are used by 70% of those surveyed. Implementing a herd health management plan may require inputs from specialists such as a veterinarian. It also requires a commitment to on-going monitoring and high levels of livestock husbandry.

Background

Improving animal health is considered an important mitigation option. Although the direct impacts of improved health on GHG emissions are relatively small, the animals' health status affects fertility, and feed conversion and so there are major impacts on the effectiveness of other mitigation options.

Health issues have a negative impact on cow productivity and as a result the GHG emissions per unit of product are increased. If an animal dies before it has completed a full productive lifecycle, some of the GHG emissions produced during the growing period are a net loss.

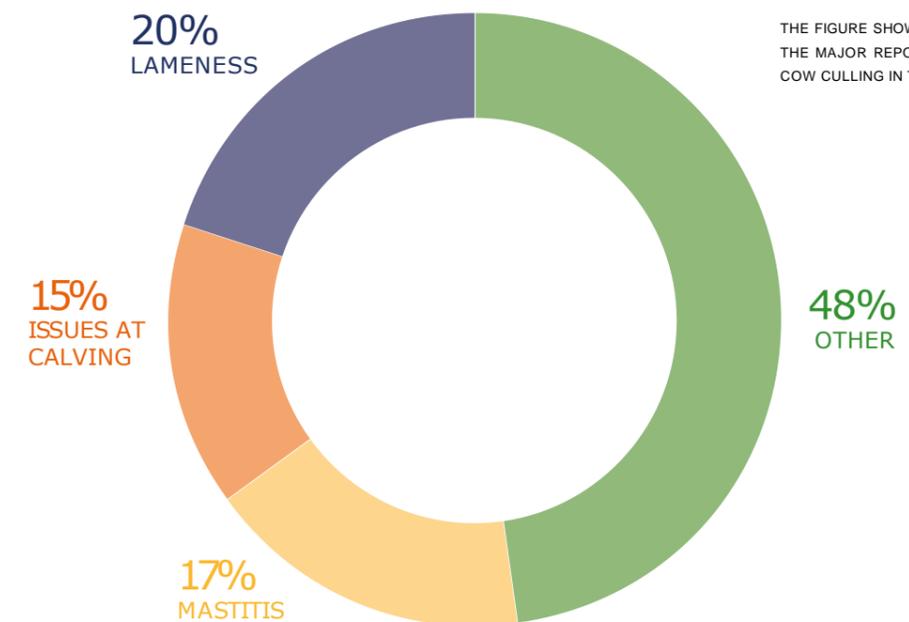
The figure shows United States Department of Agriculture (USDA) data showing the major reported causes of dairy cow culling in the US in 2007.

Around 26% of dairy culls were reported in the first 21 to 60 days after calving.

Health problems like mastitis and lameness are multi-factorial problems and not easily solved.

There are an increasing number of new monitoring tools available to improve herd management by checking the condition of the animal e.g., activity sensors, shed cameras. Early detection of issues can significantly reduce the risk of animal health problems and mortality, and as a consequence can reduce GHG emissions per unit of product.

The main endemic diseases will depend on the livestock system and its location. Each farm therefore needs to develop its own herd health management plan.



THE FIGURE SHOWS USDA DATA SHOWING THE MAJOR REPORTED CAUSES OF DAIRY COW CULLING IN THE US IN 2007.

Required skills

Implementing a vaccination programme does not require specific skills.

The process of improving the animal health situation on a farm does require medium to high level skills (herd management). Regular observation and other monitoring approaches are needed to identify any problems, assess the management options and to develop an improvement plan.

Cost-effectiveness

Health planning and monitoring health issues will have some associated costs and require extra work however, it will be profitable overall as it will prevent loss of production and also decrease animal mortality rate.

Linked options

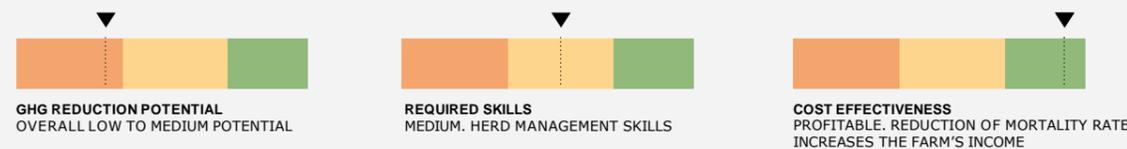
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Also consider:

- 7 Reduced calf mortality
- 8 Increased maternal longevity
- 1 Selection to improve animal productivity

Herd management

07 Reduced calf mortality



Mitigation practices

Reduction of calf mortality rate by:

- Feeding pregnant cows according to their nutritional needs
- Feeding correct mineral balances during the last eight weeks of pregnancy
- Vaccination against scours
- Sound hygiene plan in place
- Feeding colostrum as fast as possible after birth

Extent of implementation

Implementing practices to reduce calf mortality is an option to GHG mitigation that is used by over 60% of those surveyed and is of particular importance in reducing GHG emissions in beef production systems.

Background

Most of the problems which lead to the death of calves can be prevented. Careful attention to maternal nutrition during pregnancy ensures that calves get off to the best start. Health monitoring helps to improve the quality of calf rearing, liveweight gain and overall calf health. Reducing calf mortality requires a multi-factorial set of actions.

Feed pregnant cows according to their nutritional needs

- Over-feeding in the final stages of pregnancy will lead to the cow laying down fat around the birth canal. This increases the risk of calving difficulties and can increase calf mortality rate.
- This is a particular problem with thin cows who may need additional feed.

Feed minerals to dry cows in the last eight weeks of pregnancy.

- The most important minerals are copper, iodine and selenium.
- Mineral deficiency during pregnancy results in weak calves at birth.
- However, it is important to get the balance right. Over-dosing minerals may have negative effects.

Feed new calves with colostrum as soon as possible.

- The rate of absorption of vital antibodies in the colostrum reduces with each hour after birth.
- The amount of colostrum intake is about 10% of the calf's body weight.

Implement hygiene plan.

- Cryptosporidium is the main killer of young calves. Reduce this risk by implementing hygiene measures during calving and the post-calving period.
- When down calving, the cow should be moved to a clean pen with a clean dry straw. Pens should be cleaned and disinfected after each calving.
- The navel of a newborn calf should be dipped in an iodine solution to prevent infection.



Required skills

Herd management skills with a monitoring plan to inform on the condition of calves so appropriate actions can be undertaken at the right time most of the problems which lead to death can be prevented. If high mortality rates are an issue, then additional resource or guidance may be required to overcome the problems.

Cost-effectiveness

Reduction of mortality rate increases the farm's income meaning this mitigation option is profitable. For beef producers, this is important because the calf is the main product.

Linked options

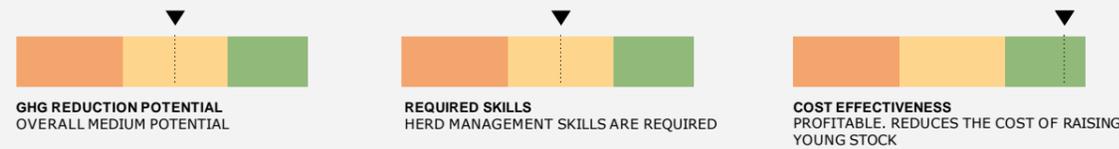
[Back to Summary table](#)

Also consider:

- 8 Increased maternal longevity
- 6. Improved animal health

Herd management

08 Increased maternal longevity



Mitigation practices

Increasing productivity longevity, increasing the number of calves a cow has during its lifetime and reducing the replacement rate.

Extent of implementation

More than half of those surveyed are implementing practices to increase maternal longevity in the herd.

Background

Increasing the productive life span of the cows in the herd means that the GHG emissions produced during the growing period (before first calving) are spread over a larger production volume of milk or number of calves (meat) over the cow's lifetime. By increasing the productive life span of dairy cows (keeping dairy cows for a longer period in herd), fewer replacement calves have to be grown.

The productive life span after first calving ranges from 2 to 6 years on most dairy farms. Research by Vellinga and De Vries in the Netherlands has shown that increasing life span from 2 to 6 years reduces the GHG emissions by 14-19% per kg milk (standardised for fat and protein).

Required skills

Changing the productive life span can be management intensive. Increasing longevity of the herd is achieved by employing good herd health and nutrition.

Cost-effectiveness

This option is profitable in principle. Increasing maternal longevity reduces the number of calves for replacement heifers and the costs are reduced. However, it also slightly reduces beef production from the retired dairy cows, so that more calves would be needed to maintain beef production.

Linked options

[Back to Summary table](#)

Also consider:

6. Improved animal health

Herd management

09 Reduced proportion of non-productive animals



Mitigation practices

Keeping fewer young stock, working with a short dry-off period.

Extent of implementation

About half of those surveyed are implementing practices to reduce the number of non-productive animals (dry cows, calves, heifers, and bulls) in dairy herds.

Background

Herd composition is the result of several management decisions, such as:

- replacement ratio
- rate of reproductive success
- mortality rate (health problems)
- long-term goals regarding herd size

By reducing the number of non-productive animals, the productivity of the herd per livestock unit will increase and GHG emissions per unit of milk produced will reduce. An appropriate herd management plan helps to ensure that the herd remains viable and keeps the GHG emissions as low as possible.

Required skills

Reducing the share of non-productive animals requires good herd management skills and an awareness of the consequences any decisions may have for the long-term overall productivity of the herd.

Cost-effectiveness

Reducing the share of non-productive animals can be profitable although there is a level of risk with maintaining a minimal pool of replacements.

Linked options

[Back to Summary table](#)

Also consider:

6. Improved animal health

8. Increased maternal longevity

Feed production, grassland management and land use



Feed production, grassland management and land use

10 Improved grassland utilisation through grazing management



Mitigation practices

Improving grazing management by:

- Rotational grazing
- Sward analysis and improvement (productive species)
- Measuring grass growth
- Planning grazing strategy for grazing season
- Preventing grazing damage in wet conditions

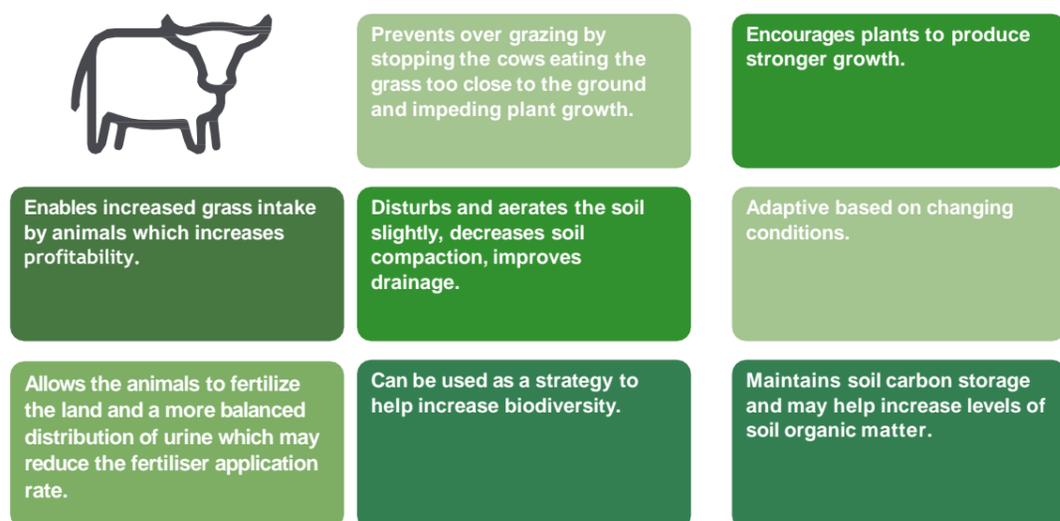
Extent of implementation

About half of those surveyed are using approaches to improve grassland utilisation through grazing management.

Background

Intensive grazing management offers a more efficient use of grassland and leads to higher milk and meat production resulting in a reduction of GHG emissions.

Improving grazing management by moving the animals between paddocks at the right time at the right time has a number of impacts as reflected in the diagram below.



Required skills

Improving grazing management by using rotational grazing requires a high level of competence to develop a clear strategy, including making best use of manure and fertiliser applications, to maximise the production of both grazing and harvested grass (for production of grass silage).

Cost-effectiveness

Applying appropriate grazing management strategies often increases the grassland yields. But even where grass production remains the same, improved grazing management results in higher grass intake by animals which is profitable for the farmer.

Linked options

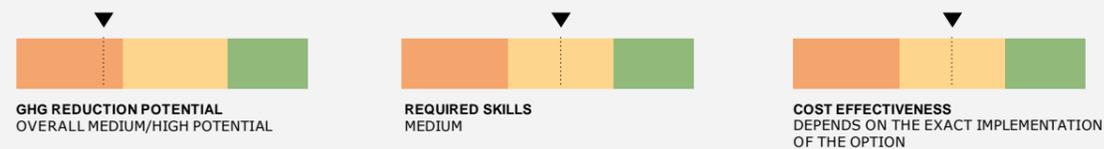
[Back to Summary table](#)

Also consider:

- 13. Improved forage quality
- 12. Reduced use of manufactured nitrogen fertiliser

Feed production, grassland management and land use

11 Increasing carbon sequestration in cropped land



Mitigation practices

Increasing carbon sequestration by:

- Increase area of permanent grassland
- Grassland reseeding/rejuvenation without ploughing
- Grazing management (e.g. sward height/density at grazing, avoiding overgrazing, sowing productive species and improved grass varieties)
- Restoration of organic soils/peatlands
- Preventing land use change (e.g. maintaining forest, preventing change of grasslands to croplands)

Extent of implementation

Over one third of the producers surveyed are putting steps in place to increase carbon sequestration in soils, especially of cropped land.

Background

Carbon sequestration is a strategy to remove CO₂ from the atmosphere by increasing soil carbon storage; this requires increased input of carbon to soil via root exudates and the natural degradation of old plant material together with the stabilisation of carbon-based compounds in the soil.

If soils are degraded with low C contents, then they can be an important carbon sink through sequestration in grassland systems. This can be an important way for a farm to reduce its carbon footprint.

Each soil has a maximum carbon storage capacity and often soils under permanent highly productive grassland are already close to this capacity. These carbon stores need to be protected but it will not be possible to increase them significantly. Permanent grasslands should not be cultivated e.g. for maize production as this will release carbon from the soil.

Grassland type

Permanent grasslands have higher levels of carbon on average than temporary grasslands. When any change is made to increase C inputs to the soil, the sequestration potential will reduce slowly over time until an equilibrium level is achieved. Sequestration is faster with new productive swards on degraded low-carbon soils. The maximum sequestration rate is 3.5 to 4.5 tonnes of CO₂-eq per hectare per year.

Grazing management

Grazing management affects the grassland productivity and the input of C to the soil. Ensuring that the grassland has productive species with locally-suited grass varieties is

important. It is also important to optimise N supply through the integration of legumes within the sward or targeted fertiliser management.

Carbon returns to the soil are affected by sward height/density at grazing. It is most important to avoid overgrazing.

Peatlands

Peatlands are one of the biggest stores of world's soil carbon. They are wetlands with a thick layer of high organic matter soil and in many countries, peatlands have been drained and used for agriculture. In this situation the carbon oxidises and become a net source of GHG emissions. To reverse this it is important to prevent further degradation of peat soils and the primary method of restoration is through the re-wetting of peatland.

Required skills

Increasing carbon sequestration requires good planning and grassland management skills

Cost-effectiveness

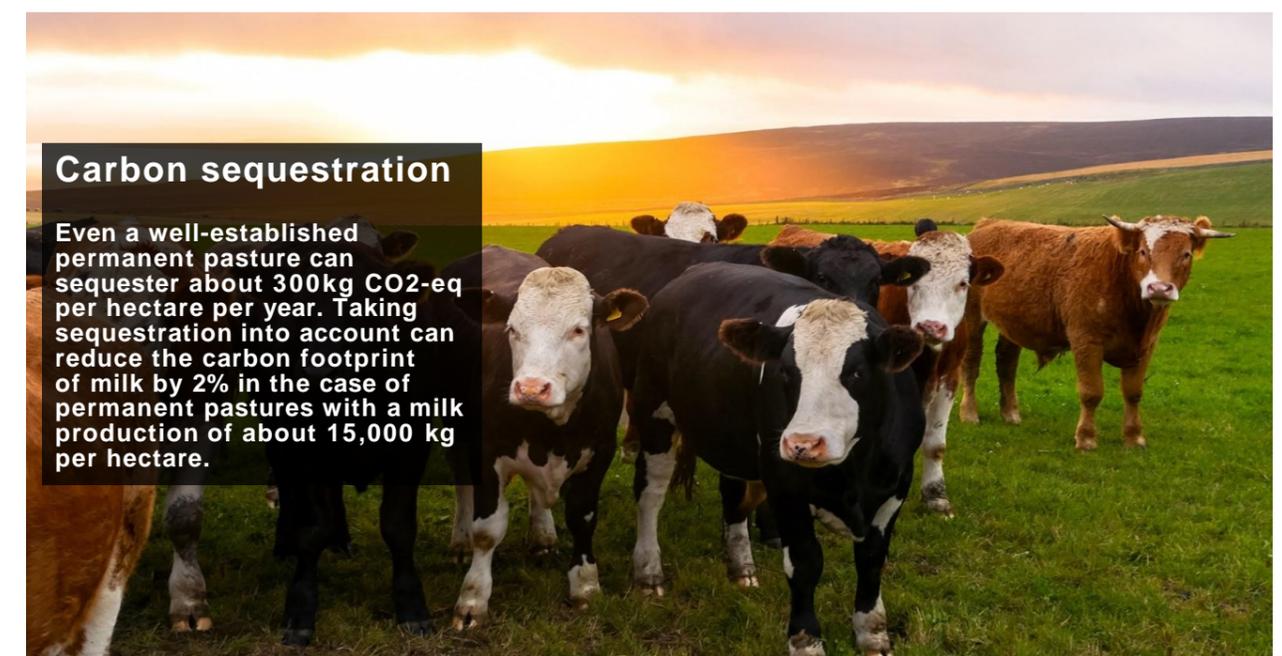
The cost effectiveness of applying this mitigation option is very much dependent upon the strategy applied.

Linked options

[Back to Summary table](#)

Also consider:

15. Planting trees, hedges, agroforestry
10. Improved grassland utilisation through grazing management



Feed production, grassland management and land use

12 Reduced use of manufactured nitrogen fertiliser



Mitigation practices

Reduction of synthetic nitrogen (N) fertiliser application by:

- Planting legumes such as clover
- Application of manure
- Application of composts or other organic materials

Extent of implementation

60% of those surveyed are seeking to reduce their use of manufactured nitrogen fertiliser.

Background

The reduction of manufactured nitrogen fertiliser application is considered to be one of the most important GHG emissions mitigation options and helps to close the nutrient cycle which is a step toward circular agriculture.

The production and transport of synthetic fertilisers have a high carbon footprint and this needs to be considered when determining GHG emissions per kg product (milk, meat). In addition, application of manufactured N fertiliser leads to a greater amount of nitrous oxide entering the atmosphere as a result of nitrification and denitrification processes in the soil. The inclusion of nitrogen-fixing legumes as feed or forage crops for ruminant systems, such as clover in grasslands, makes it possible to reduce the need for additional manufactured N fertilisers, which will reduce the GHG emissions associated with the farming system. It is also possible to substitute N fertilisers with N from organic materials such as manures. These mitigation options help to close nutrient cycles, which is step towards circular agriculture.

Required skills

Availability of N to support plant growth from manufactured fertiliser is both predictable and reliable. The options to replace N fertilisers rely on biological cycling and hence are much less predictable and can be seasonally variable. A more efficient application of manure, in or close to

Optimal use of animal manures
Application of animal manures can be very effective to supply crop nutrients and reduce the requirement for manufactured fertilisers. This is considered in more detail in Option 25

Use of catch crops
By providing growing plant cover between annual cash crops, catch crops can reduce the amount of nitrogen leached from soil. The reduction in nitrogen losses may reduce the requirement for manufactured nitrogen application.

Use of clover in pastures
Including and/or increasing the proportion of clover within grassland swards has been shown to provide up to a 33% reduction in the requirements for manufactured nitrogen fertiliser per kg grass dry matter.

the growing season and with application methods with low N-losses, requires a nutrient management plan approach (including plan-do-check-act cycle). The introduction of legumes as part of the grassland or as feed crops must carefully managed. The management of the clover-grass ratio in the field must also be managed to optimise feed intake.

Cost-effectiveness

Where the farm is aiming to increase efficiency within the current system, then approaches that achieve efficiency gains will be profitable.

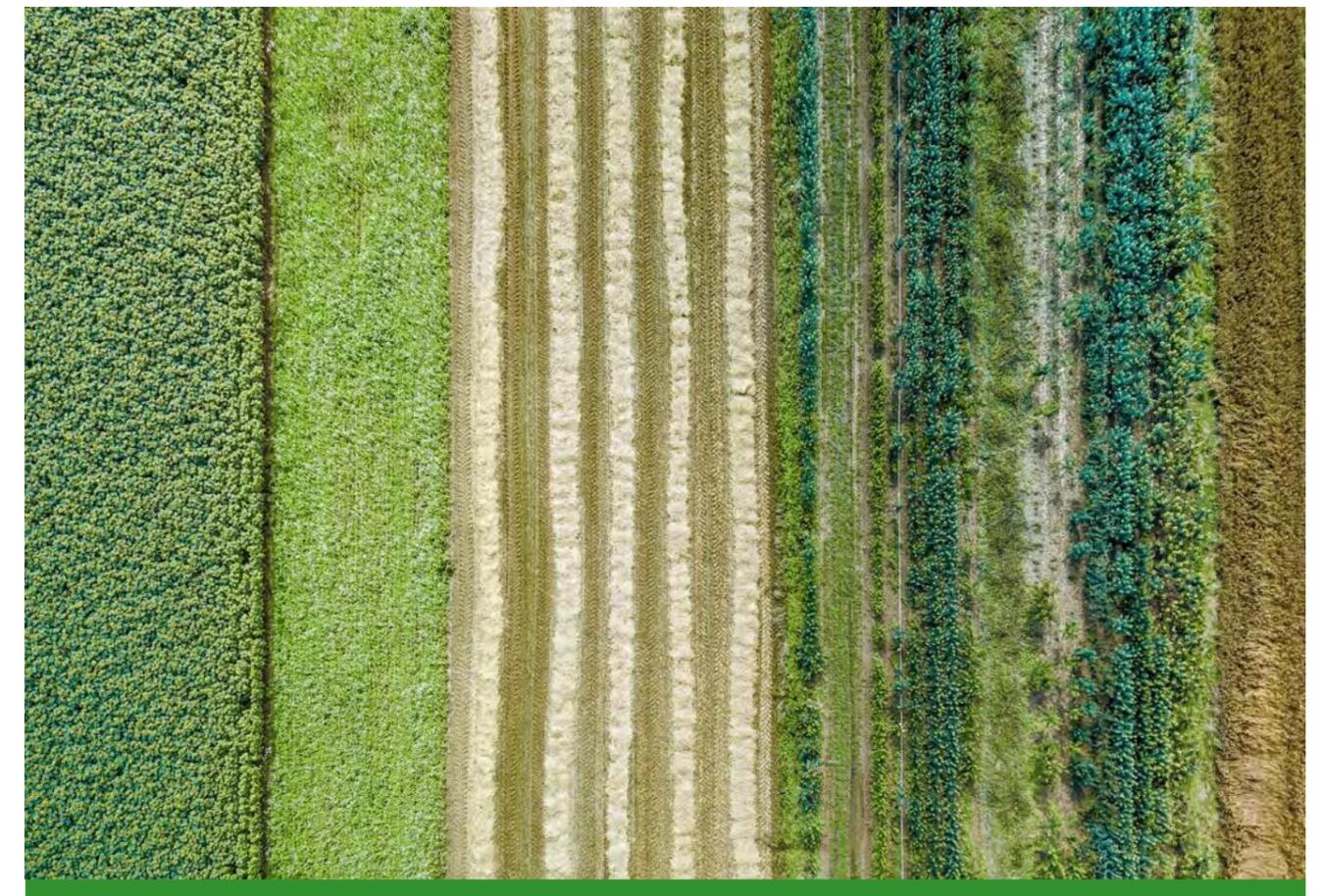
Using clover should lead to a saving in fertiliser costs, but mixed grass-clover systems tend to have lower dry matter production depending on the current level of nitrogen application. So overall, profitability will be in the range of break-even - extra net costs.

Linked options

[Back to Summary table](#)

Also consider:

16. Use of protected nitrogen fertiliser
24. Reduced losses by more efficient manure application methods
25. Optimised manure applications



Feed production, grassland management and land use

13 Improved forage quality



Mitigation practices

Forage quality may be improved by:

- Early harvesting (higher digestibility)
- Forages with higher nutrient content
- Using improved varieties of forage with higher nutrient use efficiency

Extent of implementation

70% of producers surveyed are seeking to improve forage quality to increase productivity and reduce GHG emissions.

Background

Improving forage quality increases feed use efficiency and productivity. Therefore, a focus on ensuring that forage is of the highest quality has a positive impact on the reduction of methane emissions.

Optimising yields of forage and providing more and higher quality feed reduces GHG emissions per kg of forage dry matter produced, through increased animal growth rates and reproductive efficiency. The quality of forage is usually assessed in terms of nutrient content and digestibility. Low quality feeds with low digestibility negatively affect nutrient uptake and lead to low animal productivity.

Improving forage quality in grasslands

- Ensure grassland swards contain productive species, by reseeding if needed
- Increasing soil pH (to >pH 6) where needed through the addition of lime
- Use accurate fertiliser application (N, P, K, Mg) to match crop need

However, it is important to assess the potential for negative impacts of fertiliser application on ecosystems (e.g., nitrate leaching, growth of invasive species and loss of habitats).

Improving conserved forage quality

Generally, practices that increase conserved forage quality (fast wilting and ensiling, good clamp/bale consolidation, good quality ensiling wraps and covers) improve conversion of forage to product (milk, meat) and also lead to less wastage.

Balance approaches that increase digestibility with the impacts on production

- Harvesting grass and maize silage at earlier growth stages increases digestibility. Early harvested silages are degraded faster in the rumen with lower enteric fermentation, leading to lower methane emissions.
- However early harvest will reduce forage yield and an increased number of harvests will increase fossil fuel use within the farming system.

- Forage variety can be selected to increase digestibility and nutrient content.

For example, brown mid-rib varieties of maize and sorghum have reduced lignification and consequently a much higher digestibility.

This advantage is offset for maize as current brown mid-rib varieties are less productive and harder to grow in cooler climates compared to conventional varieties.

Select appropriate high quality forage species

- Forages such as maize silage and coarse millet and sorghum straw have higher feed quality than wheat and barley straw. Typical feed quality for the range of forages available in a region can be checked by reference to national databases.
- The inclusion of legumes, such as white clover within grassland swards and forage crops such as lucerne, red clover and sainfoin can reduce fertiliser use and increase protein supply, reducing the need for imported protein feeds.

Required skills

Managing forage supply (amount and quality) requires a good understanding of the animals' nutritional requirements and the agronomic opportunities and constraints on the farm. There is a need to be aware of the options for improvement, and how they might fit within the system.

Cost-effectiveness

The cost effectiveness of applying this mitigation option is very much dependent upon the strategy applied.

Linked options

[Back to Summary table](#)

Also consider:

4. Improved diet composition
14. Forage processing for increased digestibility



Feed production, grassland management and land use

14 Forage processing for increased digestibility



Mitigation practices

Improving forage digestibility by:

- Chopping
- Grinding of straw
- Steam treatment

Extent of implementation

Improving forage digestibility by forage processing has been implemented by 40% of those surveyed.

Background

Where feed processing is used to increase digestibility (chopping, grinding), it can reduce methane production by around 15% per animal. However, the energy requirements for processing also need to be taken into account. In dairy systems, the GHG mitigation potential has been reported to be less than 2% per kg milk (standardised for fat and protein)

Required skills

The required skills for improving forage digestibility by forage processing are mostly related to the use of the machinery used. Moreover, in some cases, such as steam treatment, training and experience are required to ensure the highest forage quality is obtained.

Cost-effectiveness

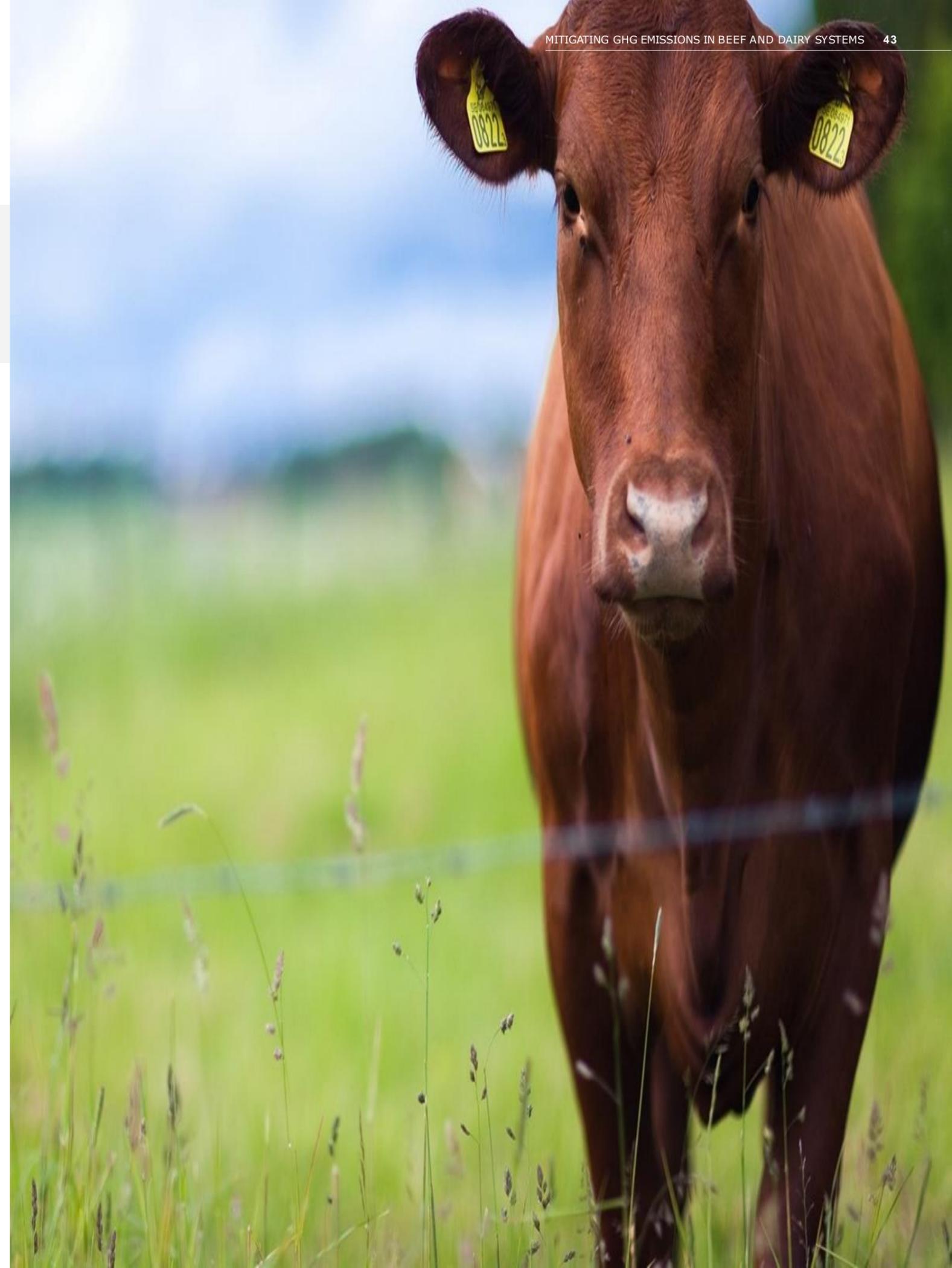
Break-even. Forage processing results in higher consumption of forage which may reduce the requirement of, and therefore offset the cost of, feed supplements. The cost-effectiveness of this mitigation option is dependent upon what investment is required in the purchasing of equipment. Steam flaking is the widely applied method in the US, although the high operation costs limit the mitigation potential in small-scale farms.

Linked options

[Back to Summary table](#)

Also consider:

- 13. Improved forage quality



Feed production, grassland management and land use

15 Planting trees, hedges, agroforestry



Mitigation practices

- Planting trees, hedges
- Agroforestry systems integrated with pastures

Extent of implementation

Agroforestry as a mitigation option to reduce GHG was selected by 40% of dairy and beef producers responding to the survey.

Background

Carbon sequestration into woody biomass (trees, hedges etc) can make a significant contribution to increasing carbon sequestration at farm scale. Agroforestry is a land management approach that combines trees and shrubs within crop and livestock farming systems. This practice can deliver a multitude of benefits both for the farm and for nature. The UK Committee on Climate Change estimates that agroforestry systems could result in carbon emission savings of 5.9 Mt CO₂eq per year by 2050. This is similar and additional to the sequestration potential estimated for increased carbon storage in soils.

Afforestation (the planting of new trees in an area where there were no trees before) is one of the main strategies implemented to increase carbon removal from the air at landscape-scale. Although carbon sequestration by trees can be high, especially in degraded soils, it can be variable and should be considered alongside other land use options, such as perennial cropping and grassland.

Benefits of increased integration of trees and other woody biomass on farm

- Trees consume more methane (CH₄) than other crops and plants, thus reducing net losses to the atmosphere
- Woody biomass can provide a source of animal feed or renewable fuel
- Nitrogen use efficiency is often improved in the agricultural systems (crops/ pasture) leading to increased biomass production per unit land
- Planting trees and the presence of forests can help to moderate temperature changes leading to lower ammonia (NH₃) volatilisation and reducing other gaseous losses (N₂O)
- New forests, especially as buffer strips along water courses, can reduce nitrate losses which will lead to a better nitrogen recycling and management
- Trees and woody perennials can help stabilise eroded and degraded land as roots in deeper soil layers than crops and herbaceous vegetation

Required skills

The level of competency required is very much dependent upon the approach being taken. The planting of individual trees does not require extra skills, although some training may be beneficial to optimise site selection and maximise efficiency. Agroforestry is a more complex approach and will require more planning and additional skills to manage cattle within the agroforestry system.

Cost-effectiveness

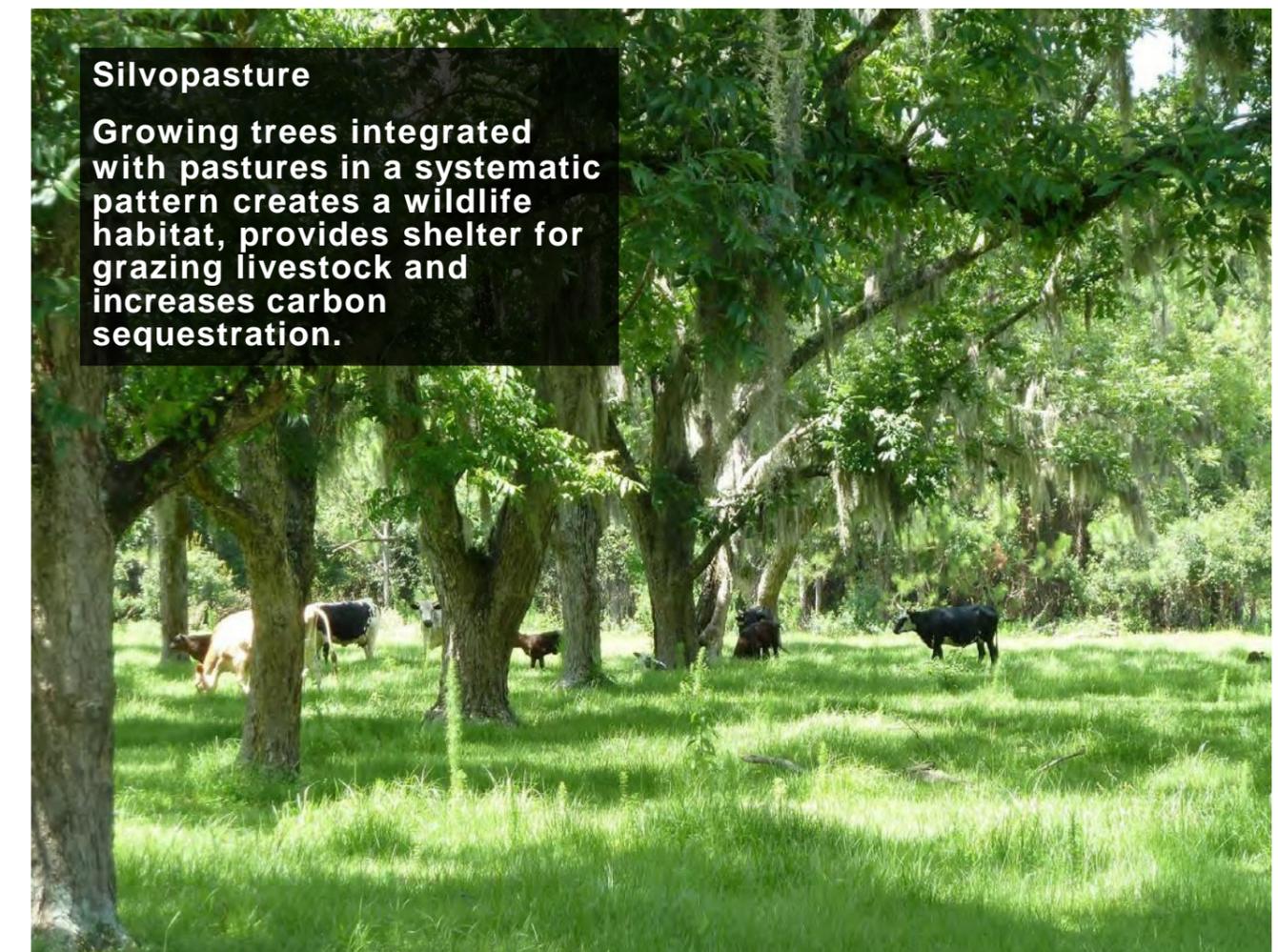
There are a wide range of implementation scales. Therefore, assessing whether this mitigation option is costly or profitable for farmers needs to be carried out for the specific farm.

Linked options

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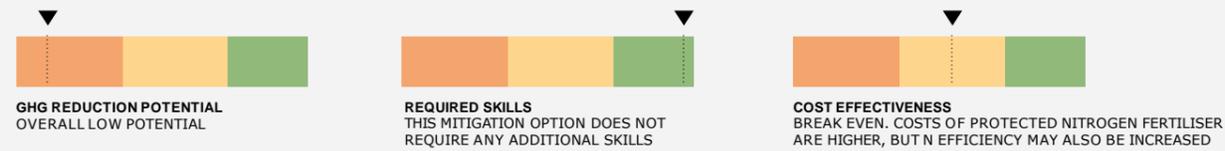
Also consider:

11. Increasing carbon sequestration in cropped land



Feed production, grassland management and land use

16 Use of protected nitrogen fertiliser



Mitigation practices

Application of protected or enhanced efficiency nitrogen fertiliser.

Extent of implementation

32% of producers surveyed are using protected nitrogen fertiliser to increase N use efficiency and reduce GHG emissions. The risk of milk contamination with inhibitors is still not clear and needs further assessment.

Background

Urease inhibitors, nitrification inhibitors and slow-release (polymer-coated) fertilisers stop or slow biological processes in the soil and reduce N losses associated with manufactured N fertiliser application. Inhibitors can be applied with the fertiliser or applied as a fertiliser coating. By slowing the release of nitrogen into soluble forms, inhibitors and slow-release products reduce losses to the environment as ammonia volatilisation and through GHG emissions. As a result, nitrogen use efficiency increases, reducing the amount of synthetic fertiliser that needs to be applied.

Urease inhibitors have been shown to reduce ammonia volatilisation (NH₃) by nearly 70% and also reduce nitrous oxide (N₂O) significantly.

Required skills

This mitigation option does not require any additional skills.

Cost-effectiveness

The costs of protected nitrogen fertiliser are higher, but N efficiency is also higher, so the costs are offset.

Linked options

[Back to Summary table](#)

Also consider:

12 Reduced use of manufactured nitrogen fertiliser

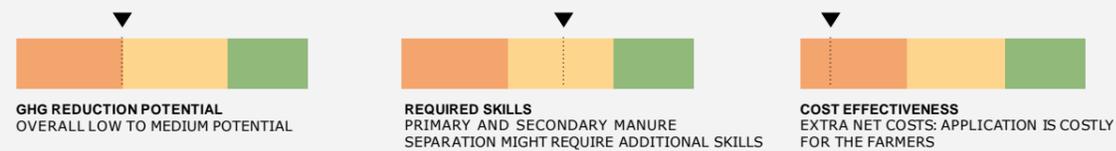


Manure management



Manure management

17 Manure separation



Mitigation practices

Primary and/or secondary separation of manure before storage.

Extent of implementation

A range of manure separation systems are in development and being tested for impact on methane emissions. 37% of producers surveyed are using manure separation as part of their GHG mitigation strategy. After primary and/or secondary separation of manure it is essential to use machines for application of liquid and solid manure on farmland.

Background

Primary separation followed by storing and handling faeces and urine separately can reduce GHG emissions by 75%.

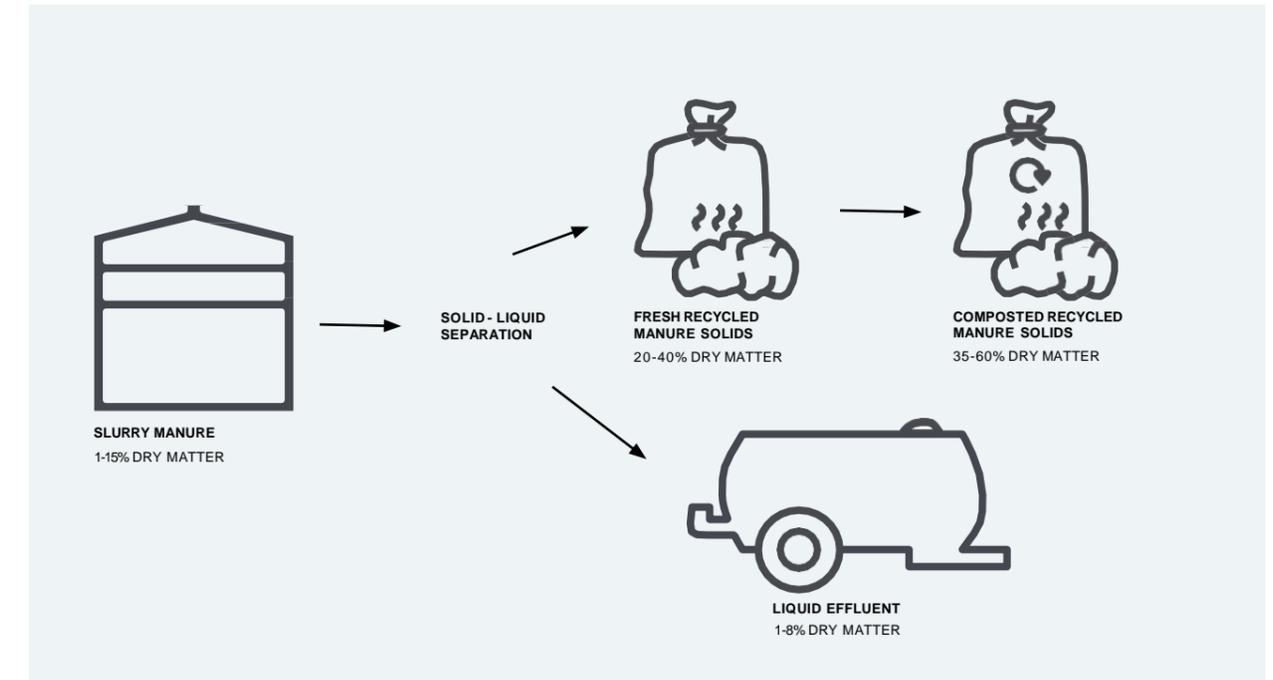
Low emission floor systems integrate primary separation of urine and faeces in the barn, with separate storage for both components. The separate manure products can be better processed or used more specifically meaning more biogas can be extracted from the fresh manure and there is less methane emitted from livestock housing.

Applying solid and liquid manures separately following separation can reduce ammonia volatilisation very significantly and reduce GHG emissions by 30% compared to spreading of unprocessed manure.

A number of different techniques are used for secondary separation, such as:

- Sedimentation
- Mechanical separation (centrifuge systems, belt press, etc.)
- Evaporation
- Coagulation and flocculation (chemicals are added to aggregate suspended solids (coagulation) to form settleable particles and to convert particles into large, rapidly settling flocs (flocculation))
- Filtering

Primary and/or secondary separation of manure before storage



Required skills

Overall, primary and secondary separation of manures might require additional skills regarding the design and management of housing, use of manure separation facilities or application machinery.

Cost-effectiveness

Application of primary and/or secondary separation of manure is costly, and this mitigation option may require additional investments in barns, manure storage or application machinery. Where the solid part of the separated manure is used for further processing (e.g., anaerobic digestion) there may be some added value.

Linked options

[Back to Summary table](#)

Also consider:

22. Capture of methane and oxidation
23. Anaerobic digestion

Manure management

18 Rapid removal of manure from housing



Mitigation practices

Reducing manure storage time in the barn by adopting systems that quickly remove manures to closed storage to prevent methane emissions.

Extent of implementation

This mitigation option is in development and is being tested for impact on methane emissions. 30% of those surveyed said that they were implementing this option. There is some concern whether any captured methane might be released during manure application.

Background

Methane emissions from housing can be significant due to continuous inputs of fresh excreta. Where storage is well designed, moving manures quickly into storage can significantly reduce methane emissions. New designs for cattle house flooring seek to reduce ammonia volatilisation. Studies have shown that flushing every two hours with 50 litres of water per cow per day directly after scraping, can reduce ammonia by around 34% compared with scraping alone. These systems can also significantly reduce methane emissions from the barn.

In many systems, manure is stored for extended periods and applied to crops in the spring to reduce the need for synthetic fertiliser applications (see Option 25). CH₄ emissions during storage can be managed if the waste is stored with a gas-tight seal and methane is removed and used as a fuel (Option 22).

Required skills

Reduction of manure storage time does not require additional skills.

Cost-effectiveness

Investment is required to adapt barn systems to be able to remove manure quickly and/or to make the manure storage facilities gas tight to prevent loss of methane to the atmosphere.

Linked options

[Back to Summary table](#)

Also consider:

- 22. Capture of methane and oxidation
- 25. Optimised manure applications



Manure management

19 Manure treatment



Mitigation practices

Treating manures by:

- Lowering manure pH by acidification
- Reduction of storage temperature
- Manure aeration

Extent of implementation

This mitigation option is being implemented by 20% of those surveyed.

Background

Manure storage is an important source of emissions of methane and, following application and oxidation of ammonia, nitrous oxide. To reduce these emissions, several options to treat manure in stores have been developed.

Lowering manure pH by acidification:

Lowering the pH to 5.5 reduces microbiological activity in the manure, which reduces methane production from the store. Breakdown of the organic materials after application is more likely to happen under aerobic conditions and then CO₂ is released rather than methane. Slowing decomposition in the store also helps hold nitrogen. Acidification also reduces ammonia volatilisation by moving the chemical equilibrium from ammonia (NH₃) to ammonium (NH₄⁺). This also has the additional benefit of increasing the amount of nitrogen available in the liquid phase, increasing the value of the manure as a source of nitrogen fertiliser. Care must be taken when using sulphuric acid as the amount of sulphur applied may exceed crop requirements.

Reduction of storage temperature:

At higher temperatures, bacterial activity increases resulting in more methane production. By reducing the storage temperature, methanogenic activity decreases. However, the energy consumption must be considered if applying this strategy.

Manure aeration:

Dairy farms that have a slatted floor above a deep manure pit can have high emissions of methane and ammonia, as the stored manure cannot be easily sealed. Between 40% and 60% of total emissions from these slatted floor systems come from the housing and the storage pit beneath. Aeration of manures through mixing prevents crust formation in the slurry pit and has been tested as a mitigation approach for ammonia emissions with little impact. However, there was a 40% reduction in methane emissions. It is likely that aeration allowed some decomposition to occur aerobically and also some of the methane emitted was oxidised in the store.

Required skills

Applying manure treatment needs a medium level of skills. Manure aeration, acidification and reduction of manure storage temperature may require additional skills and training, especially if new facilities are required.

Cost-effectiveness

Extra net costs. All manure treatment approaches will have additional costs for the farm. For manure acidification, manure aeration and reduction of storage temperature, additional facilities and buildings may be required which will require additional investment.

Linked options

[Back to Summary table](#)

Also consider:

- 25. Optimised manure applications
- 17. Manure separation



Manure management

20 Use of appropriate bedding materials



Mitigation practices

Application of bedding materials such as:

- Sand
- Straw
- Dried manure solids
- Wood chips
- Saw dust

Extent of implementation

28% of those surveyed are seeking to choose appropriate bedding materials to reduce emissions at the same time as achieving good animal welfare.

Background

Slatted-floor facilities require no bedding, but other systems typically have some bedding for animal comfort and welfare. The bedding used will depend on availability and cost, as well as the type of housing and manure handling facilities. The choice of bedding materials will affect ammonia and GHG emissions.

Compost-bedded pack barns can provide excellent animal health and welfare with reduced ammonia and carbon dioxide emissions when wood by-products are used. However, pre-composted material may increase emissions when used as bedding material.

Ammonia emissions were reduced by 31% where cows were housed in straw-bedded free stall barns, but methane emissions were increased by 34% and nitrous oxide emissions were 14 times higher when compared to a housing system on a slatted floor where slurry is collected.

When choosing a bedding material, it is important to make sure it will keep your animals dry and clean. The bedding needs to be:

- Highly absorbent of water and urine
- Able to maintain a healthy environment
- Non-abrasive
- Non-slippery
- Low in bacteria
- Comfortable

There are two main types of bedding materials:

Material	Advantages	Considerations
Organic Straw, sawdust, wood shavings, paper-based products, and recycled manure solids	Good source of food for bacteria, especially when urine, faeces and milk leakage are added	Requires careful management to provide optimal lying conditions and maintain animal health and welfare
Inorganic Sand, calcium carbonate (chalk)	Sand and calcium carbonate provide soft dry lying surface Better at preventing mastitis and reducing lower leg issues Sand below straw can aid drainage	Separation of sand, straw and manure may require additional facilities and equipment

Required skills

There is a need to know how frequently the bedding materials need to be replaced and for some bedding materials, such as sand, additional machinery (for separating manure and sand) would be needed which might require additional skills.

Cost-effectiveness

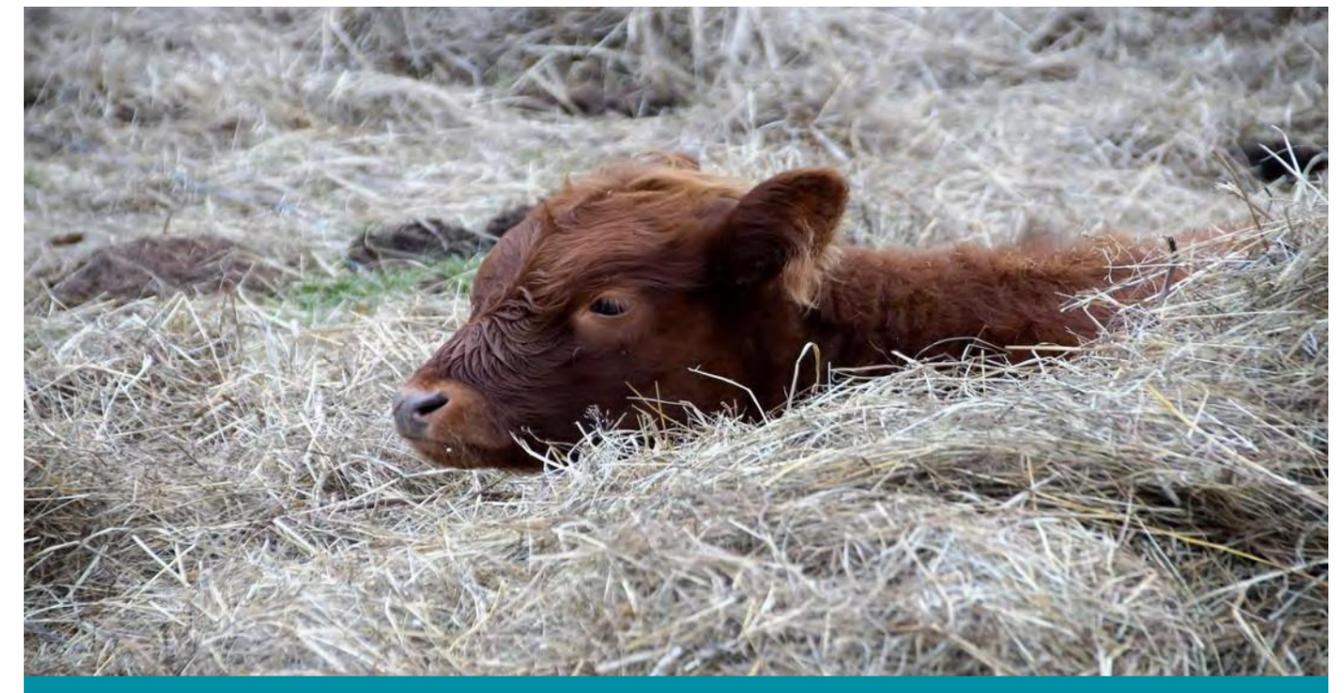
Any extra costs should be compensated by the positive impact on animal health and productivity.

Linked options

[Back to Summary table](#)

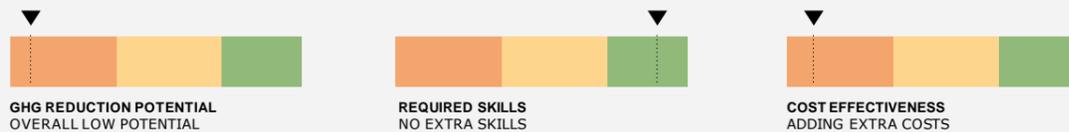
Also consider:

- 25. Optimised manure applications
- 23. Anaerobic digestion



Manure management

21 Ensuring manure storage tanks are fully emptied



Mitigation practices

Complete removal of liquid manure from the stores when emptied (e.g., by flushing).

Extent of implementation

The impacts of flushing to achieve complete removal of liquid manure from storage tanks is currently being studied to quantify the impact on methane emissions. This approach is being used by 14% of those surveyed. This mitigation method is more relevant for housed systems and will incur extra costs and may be impractical for larger manure storage tanks.

Background

When liquid manure is removed from storage for land application, the sludge that remains at the bottom of the tank may serve as a source of microbial inoculum when fresh manure is added which can increase methane emissions.

In a research study, the impact of inoculum removal was evaluated with overwintered liquid manure storage tanks. Overall, there was a significant reduction in GHG emissions where inoculum was removed by flushing. More work is needed to evaluate the impacts at farm scale, taking increased water use into account.

Required skills

No extra skills are required.

Cost-effectiveness

Adds extra costs. Frequent removal with water will increase water use on the farm.

Linked options

[Back to Summary table](#)

Also consider:

25. Optimised manure applications

Manure management

22 Capture of methane and oxidation



Mitigation practices

Capture of methane in the manure stores and oxidation of the methane by flaring or filtration.

Extent of implementation

This option is suited to only a small number of producers. Larger producers are likely to use anaerobic digestion systems. 11% of those surveyed are using this mitigation option.

Background

Where manure stores are covered, then a gas-tight lid can be added to the store. This allows for the capture of methane and oxidation to CO₂ which has lower global warming potential compared with methane.

About 60% of the gas produced during manure storage is methane which has a potency as a greenhouse gas 34 times higher than CO₂. If the methane is captured, then it can be oxidised to CO₂ by combusting it in a flare. The captured methane may also be used to produce heat or in a generator for the co-generation of heat and electricity.

Required skills

No additional skill is required.

Cost-effectiveness

Managing manure to reduce emissions can be economically viable for larger enterprises or cooperative facilities that use the captured methane to generate heat and electricity. For small operators, the offset value alone is unlikely to warrant the large capital cost of infrastructure.

Linked options

[Back to Summary table](#)

Also consider:

23 Anaerobic digestion

Manure management

23 Anaerobic digestion



Mitigation practices

Generating methane by anaerobic digestion of manures and organic materials and using it as energy source.

Extent of implementation

This mitigation option is most suited to large dairy or housed beef systems. 46% of those surveyed are using anaerobic digestion as part of their manure management strategy. The processed manures are available for application to land.

Background

Anaerobic digestion (AD) is a process through which bacteria break down organic matter in the absence of oxygen. This takes place in a sealed reactor, designed and constructed specifically to meet the site and feedstock conditions. The complex microbial community breaks down (digests) the waste. The anaerobic biological processes produce biogas, largely methane, and solid and liquid end-products (digestate). AD is not a zero-carbon technology, but it has the potential to recycle nutrients, add value to waste products and provide a step towards circular agriculture. Biogas can be used like natural gas to provide heat, generate electricity, and power cooling systems, etc. or purified by removing impurities, such as CO₂, water, H₂S, etc. to generate renewable natural gas (RNG) which can be sold and injected into the natural gas distribution system or compressed and used as vehicle fuel.

Using anaerobic digestate

The solid and liquid digestates are often separated and handled independently. All the nitrogen, phosphorous and potassium present in the feedstock remain in the digestate. However, the nutrients are more available than in raw slurry or manure, and they need to be stored, handled carefully and applied with low emission techniques e.g., band application or injection to reduce the risk of ammonia volatilisation and losses to water (see Option 24).

The separated fiber (solid) can be used for animal bedding or composted as a soil conditioner. The liquid digestate is a nutrient-rich fertiliser. Whole digestate may also be spread as fertiliser (see Option 25).



Required skills

Managing an AD plant requires specialist skills.

Cost-effectiveness

Set-up of anaerobic digestion requires a high investment. Overall, high investment and operating costs may limit the feasibility of using anaerobic digestion in the absence of any financial support. Profitability depends on the price of electricity and subsidies.

Linked options

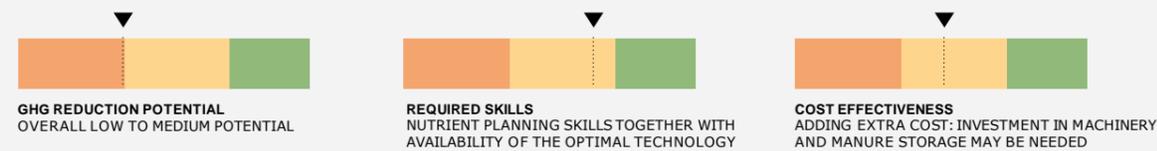
[Back to Summary table](#)

Also consider:

25. Optimised manure applications

Manure management

24 Reduced losses by more efficient manure application methods



Mitigation practices

Use appropriate manure application methods to reduce losses by:

- Manure dilution
- Manure injection

Extent of implementation

More than half of those surveyed are implementing manure application methods to reduce losses; in some countries this is required to reduce ammonia volatilisation.

Background

A range of factors including manure composition, storage conditions or pre-treatment, application method and soil conditions define the potential for GHG emissions from manures.

Surface spreading was the most common practice for manure application but there is increasing awareness that this can lead to the loss of N by ammonia volatilisation, phosphorus through runoff and this can also cause odour issues. Placing manure below the soil surface reduces these environmental impacts.

Injection of liquid manures is very effective in reducing ammonia volatilisation and odour issues. However, injection of liquid manure into the soil adds soluble carbon and can create anaerobic conditions which may increase CH₄ and N₂O emissions compared with surface application. Diluting liquid manures, or pre-treatment through manure separation or anaerobic digestion reduce the risk of anaerobic conditions in soil after manure injection. This can reduce methane emissions and will further reduce ammonia losses. Since no tillage operation is needed for manure injection, farmers are able to apply manure to the growing crops such as grass, alfalfa, etc.

Control of N₂O emissions is much harder as the emissions relate closely to the amount of available N added. Since N₂O production is affected by N availability, soil temperature, pH and soil aeration, timing of manure application (e.g., to match crop nutrient demands, avoiding application before rain) and maintaining soil pH above 6.5 can help reduce N₂O emissions from soil. Manure injection tends to increase crop N availability from applied manures. However, in the first few weeks after application, manure injection often increases N₂O emission compared with surface applied manure.



Required skills

Using different manure application methods on land requires the skill of knowing the dilution and injection methods and how to apply it with the machinery required for these techniques. Overall, it is more about availability of the optimal technology than about required skills.

Cost-effectiveness

Investment in machinery, possibly also in storage of water (for dilution). Dilution requires extra capacity for manure application on the land and will also lead to extra costs. If this requires additional investments this will not be profitable.

Linked options

[Back to Summary table](#)

Also consider:

25 Optimised manure applications

26 Use of inhibitors with manure application

Manure management

25 Optimised manure applications



Mitigation practices

Optimise manure application rates and timing by:

- Matching the amount of applied manure to the crop nutrient demands
- Avoiding application during cold seasons (autumn and winter)
- Avoiding application on wet soils

Extent of implementation

58% of those surveyed are already seeking to target manure applications appropriately to optimise nutrient use and reduce the need for purchased fertiliser.

Background

Manure contains nitrogen, phosphorus, potassium and other nutrients. Careful recycling of manure to land allows this nutrient value to be used for the benefit of crops, which can result in large savings in the use of manufactured fertilisers and their associated GHG emissions. Bulky solid manures and composts may also add organic matter to the soil which may improve soil structure, aeration, soil moisture-holding capacity, and water infiltration.

To maximise benefits, animal manures need to be applied:

- At the right time
- At the right rate
- With an appropriate method of application (see Option 24)

Organic materials can present a considerable environmental risk if not managed carefully. To be used successfully as a fertiliser, it is important to assess the nutrient content of the manure and ensure the correct application rate is used to meet the demands of the crop. Excess nutrients can be a source of pollution if they get into watercourses, lakes and groundwater through run-off or leaching through the soil.

The timing of application is also important. For example, in temperate regions where crop growth in winter periods is very low, manure application in winter will lead to higher losses of nitrogen to the environment and contamination of ground and surface waters. Even when overall application rates are correct and the manure is evenly applied, if the ground is too wet, leaching can take the nutrients through the soil and beyond the crop and into the watercourse causing water pollution. This is particularly important where land drains are present, and also on shallow sandy soils over groundwater.

Ammonium and nitrate in manures are immediately available to crops. Organic material needs to decompose to allow mineralisation of nutrients to inorganic forms that plants can use. Manure type affects the rate of mineralisation, often due to differing carbon:nitrogen ratios.

Nitrous oxide production is affected by N availability, soil temperature, pH and soil aeration, and timing of manure application (e.g., to match crop nutrient demands, avoiding application before rain). Maintaining soil pH above 6.5 can help reduce N₂O emissions from soil.

Spring is the best time of year to spread manures with a high concentration of available nutrients as this is when crops are actively growing and most likely to be able to make use of the nutrients applied to maximise yields, reduce fertiliser costs, and minimize nutrient losses to the environment.

Required skills

Using different manure application methods on land requires the skill of knowing the dilution and injection methods and how to apply it with the machinery required for these techniques. Overall, it is more about availability of the optimal technology than about required skills.

Cost-effectiveness

Investment in machinery, possibly also in storage of water (for dilution). Dilution requires extra capacity for manure application on the land and will also lead to extra costs. If this requires additional investments this will not be profitable.

Linked options

[Back to Summary table](#)

Also consider:

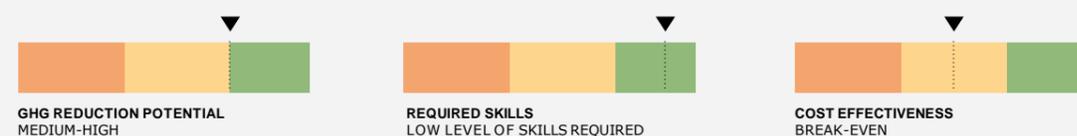
25 Optimised manure applications

26 Use of inhibitors with manure application



Manure management

26 Use of inhibitors with manure application



Mitigation practices

Application of urease and/or nitrification inhibitors with manure

- Dicyandiamide (DCD)
- Dimethylpyrazole phosphate (DMP)

Extent of implementation

A small number of producers surveyed are using inhibitors with manure application (11% of those surveyed). More producers are using protected fertilisers and the knowledge developed with fertiliser application is likely to be applied to use of inhibitors with manure applications in the future.

Background

Urease inhibitors and nitrification inhibitors stop or slow biological processes in the soil and reduce N losses associated with the biological transformations of urea and ammonia in soil. Inhibitors can be mixed with the manure before application or sprayed onto the soil. By slowing the release of nitrogen, inhibitors can reduce losses to the environment as ammonia volatilisation and through GHG emissions. As a result, nitrogen use efficiency increases, reducing the amount of synthetic fertiliser that needs to be applied.

Required skills

Low skills. The only skill required is the knowledge of determining the appropriate dosage of using manure inhibitors.

Cost-effectiveness

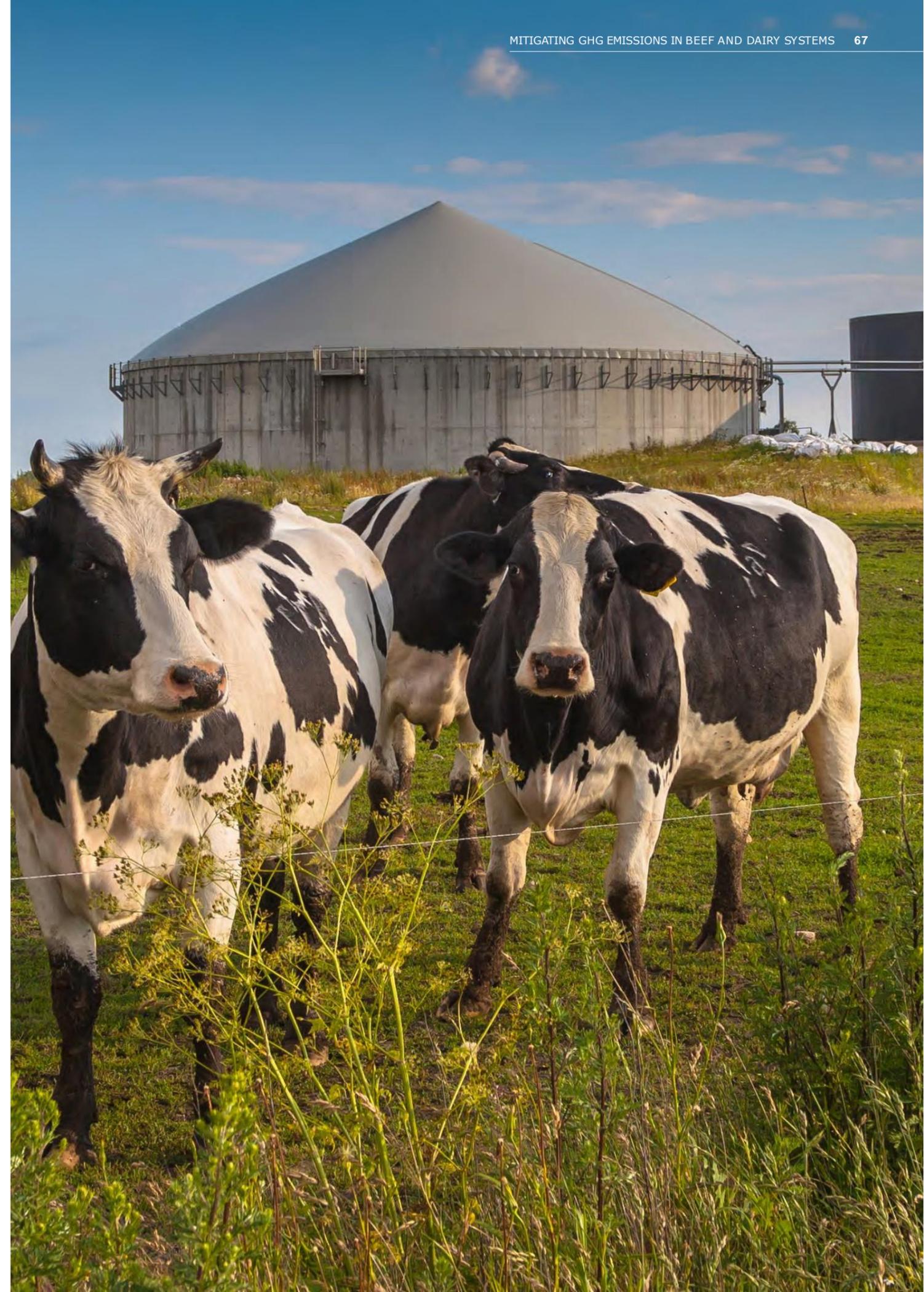
Break-even.

Linked options

[Back to Summary table](#)

Also consider:

25 Optimised manure applications

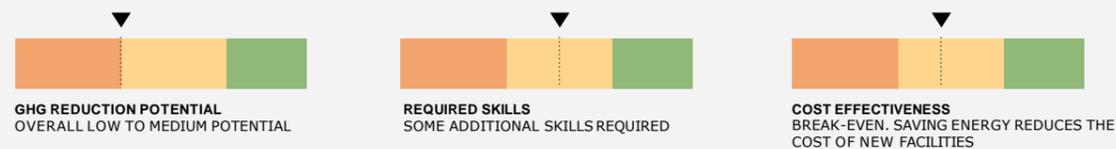


Smarter energy management/use



Smarter energy management/use

27 Reducing fossil fuel consumption



Mitigation practices

Reducing fossil fuel consumption by:

- Adopting energy efficiency measures and using new technologies that will directly reduce the energy use (e.g., LED for lighting, high efficiency electric motors in livestock equipment, high efficiency equipment for milking parlors and cooling milk)
- Smart control of energy processes and optimal energy management for maximising the use of energy
- Thermal and/or electricity storage where appropriate

Extent of implementation

Almost half of those surveyed are seeking to reduce fossil fuel consumption.

Background

Milk production is the most energy consuming subsector of livestock production. To identify areas in need of improvement and to implement changes to reduce fossil fuel consumption, conducting an on-farm energy audit is essential. In this process it is important to be aware of what incentives and rebate programmes are available to assist in investing in the latest, most-efficient technologies, to reduce the use of fossil fuels and reduce GHG emission.

To reduce energy consumption, a range of different options should be considered:

- Fit innovative ground heat pumps, for maintaining a controlled environment in livestock buildings (i.e., heating, cooling and dehumidification)
- Adopt energy efficiency measures that will directly reduce energy use (e.g., LED lighting and high efficiency electric motors)
- Maximise energy savings by using smart control processes and optimal energy management
- Implement thermal and/or electricity storage where appropriate

Required skills

Medium skills.

Using different manure application methods on land requires the skill of knowing the dilution and injection methods and how to apply it with the machinery required for these techniques. Overall, it is more about availability of the optimal technology than about required skills

Cost-effectiveness

Break-even. Some new facilities may have some additional costs for farmer however, because saving energy reduces the cost, break-even is possible.

Linked options

[Back to Summary table](#)

Also consider:

28 Use and generation of renewable energy



Smarter energy management/use

28 Use and generation of renewable energy



Mitigation practices

Use and generation of renewable energy by:

- Photovoltaic systems generate electricity for lighting, equipment, heat pumps etc.
- Producing biofuels (e.g., biogas)
- Using electricity and other energy sources produced from renewable sources

Extent of implementation

More than half of the producers surveyed are using or generating renewable energy on-farm.

Background

To increase the generation of renewable energy in the livestock sector different activities can be conducted:

- Use solar photovoltaic (or solar PV) panels, that convert sunlight directly into electricity, to cover electricity consumption (lighting, equipment, heat pump etc.)
- Use wind turbines to generate electricity
- Use biofuels (especially biogas derived from combined digestion of animal waste and crop residues optimising C/N ratio - see Option 23)
- Production of oils and starches for biodiesel and bioethanol is often controversial, as they require extra land for production

In addition to looking for opportunities to generate renewable energy, it is important for all farming systems to explore the use of renewable energy efficient solutions (including smart farming technologies/systems) capable of:

- Establishing optimal conditions in agricultural buildings
- Investigate the use of heat pumps to provide low C cooling options for milk
- Change the energy consumption mix in buildings in order to reduce the farm's dependency on fossil fuel and electricity providers
- Reduce direct energy use in crop (feed) production
- Produce feed using
 - (a) biofuels for self-propelled machinery (tractors, sprayers, fertiliser spreaders either granular or liquid, mowers and harvesters)
 - (b) pulled machinery electrification
 - (c) smart farming techniques and technologies

Required skills

Low-Medium. PV systems are not complicated to operate once professionally installed. Thermal and/or electricity storage where appropriate may need extra skills.

Cost-effectiveness

Break-even - net costs. Depends on the ongoing development in the cost of non-renewable sources, and available subsidies.

Linked options

[Back to Summary table](#)

Also consider:

- 23 Anaerobic digestion
- 22 Capture of methane and oxidation
- 27 Reducing fossil fuel consumption



Glossary

Afforestation - Afforestation is a process where new forests are planted across land without trees. As a forest grows, it naturally removes CO₂ from the atmosphere and stores it in its trees.

Age at first reproduction - The time spent between birth and first calving (farrowing). If an animal dies before it has completed a full productive lifecycle, some of the GHG emissions produced during the growing period are a net loss.

Anaerobic - Respiration in the absence of oxygen. The conditions are conducive to the conversion of organic carbon by microorganisms for the production of CH₄, CO₂ and other gases as by-products.

Atmosphere - The gaseous envelope surrounding the earth. It consists almost entirely of nitrogen (78.1%) and oxygen (20.9%), with several trace gases, such as argon (0.93%), helium and greenhouse gases (GHGs) methane (CH₄) and nitrous oxide (N₂O), and carbon dioxide (CO₂)

Biodiversity - Biological diversity means the variability among living organisms from all sources and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystem

Biofuel - A fuel, usually in liquid form, that is produced over a short time span from biomass, rather than by the very slow natural processes involved in the formation of fossil fuels, such as oil.

By-product - Material produced during the processing (including slaughtering) of a livestock or crop product that is not the primary objective of the production activity (e.g., oil cakes, brans, offal or skins).

Carbon cycle - The flow of carbon through the environment. Carbon enters the atmosphere as carbon dioxide from respiration and combustion. Carbon dioxide is absorbed by plants to make glucose during photosynthesis.

Carbon dioxide (CO₂) - A naturally occurring gas, but also a by-product of burning fossil fuels (such as oil, gas and coal), of burning biomass, of land-use changes and of industrial processes (e.g., cement production). It is the principal greenhouse gas (GHG) and is the reference gas against which other GHGs are measured and therefore has a global warming potential (GWP) of 1.

Catch crop - A short duration cover crop. A fast-growing crop that is grown between successive plantings of a main crop and used to uptake and hold on to nutrients during periods of high leaching risk, such as winters with high rainfall.

CO₂-equivalent emissions - Where several gases are being emitted, GHG emissions are often expressed in an aggregated unit called CO₂-equivalent emissions, or CO₂-eq. CO₂-eq emissions are determined by multiplying the emission of each gas by its Global Warming Potential (GWP), which is a multiplier that accounts for the different warming effects and lifetimes of non-CO₂ greenhouse gases over a given time horizon compared to CO₂ (usually 100 years, GWP100).

GWP values are: 1 kg CO₂ = 1 kg CO₂-eq; 1 kg CH₄ = 28kg CO₂-eq; 1 kg N₂O = 265 kg CO₂-eq.

Co-benefit - The positive effect(s) that a policy or measure aimed at one objective might have on other objectives. For example, the primary goal of a change in farm practice may be to increase profitability per hectare, but it may also lower GHG emissions per unit of product.

Cost-effectiveness - A process used to examine both the costs and outcomes of one or more interventions. It enables the comparison of one intervention to another intervention (or the status quo) by estimating how much it costs to make any economic gain from undertaking the option. In the context of climate change, the cost-effectiveness of measures to reduce GHG emissions can depend strongly on the assumed cost associated with GHG emissions, and hence the economic benefits from reducing such emissions.

Cover crop - A cover crop is a non-cash crop grown primarily for the purpose of 'protecting or improving' between periods of regular crop production. They manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity, and wildlife in an agroecosystem.

Crop residue - Plant materials left in an agricultural field after harvesting (e.g., straw or stover). They play a crucial role in sequestering carbon, which is vital for reducing global CO₂ emissions

Deforestation - Conversion of forest to non-forest. In terms of climate change, cutting down trees both adds CO₂ to the air and removes the ability to absorb existing carbon dioxide.

Dairy herd - A group of animals kept for milk production. Animals in a dairy herd include: milked animals, replacement stock and surplus calves that are fattened for meat production.

Direct emissions - Emissions that physically arise from activities within well-defined boundaries (such as a farm) or, a region, an economic sector, a company, or a process.

Ecosystem - An ecosystem is a functional unit consisting of living organisms, their non-living environment, and the interactions within and between them.

Emissions intensity - Total emissions of GHGs resulting from an activity, per unit of product generated by this activity (such as kg CO₂-eq per liter of milk, or per kg of meat). Where a single activity generates multiple products, emissions intensities have to be calculated by allocating emissions from this activity to different products (e.g., milk and meat produced by dairy herds).

Enteric fermentation - Enteric fermentation is a natural part of the digestive process for many ruminant animals where anaerobic microbes (methanogens) decompose and ferment food present in the digestive tract producing compounds that are then absorbed by the host animal.

Extensive farm systems - An agricultural production system that uses lower levels of inputs of labor, fertilisers, and capital, relative to the land area being farmed.

Feed balancing - The action of selecting and mixing feed materials (e.g., forages, concentrates, minerals, vitamins, etc.) to produce an animal diet that matches the animals' nutrient requirements as per their physiological stage and production potential.

Feed digestibility - The relative amount of ingested feed that is absorbed by an animal and therefore the availability of feed energy or nutrients for growth, reproduction, etc. In practice, it represents the difference between the amount of feed ingested and amount of feces produced. It can be calculated in terms of dry weight, organic matter or any proximate constituent.

Feed processing - Processes that alter the physical (and sometimes chemical) nature of feed commodities to optimise utilisation by animals (e.g. through drying, grinding, cooking and pelleting).

Fossil fuels - Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas.

Greenhouse gases (GHG) - Greenhouse gases (GHG) are gaseous constituents of the atmosphere (both natural and resulting from human activities) that absorb and emit thermal infrared radiation. A build-up of the concentration of those gases due to human activities causes global average temperature to increase and the climate to change; this is also referred to as the enhanced greenhouse effect. Agriculture is primarily responsible for the direct on-farm emission of two greenhouse gases, methane (CH₄) and nitrous oxide (N₂O), with additional direct on-farm and off-farm emissions or removals of carbon dioxide (CO₂) from changes in soil carbon, energy use, and indirect CO₂ emissions from the production of fertiliser and deforestation.

Greenhouse gas (GHG) Emissions - Release to air and discharges to water and land that result in GHGs entering the atmosphere. The main emissions of GHGs from agriculture are carbon dioxide (CO₂), nitrous oxide (N₂O) and methane (CH₄). GHG emissions are usually reported in terms of CO₂-eq which expresses the impact of the different gases in terms of the amount of CO₂ that would create the same amount of warming.

Global warming - The estimated increase in global mean surface temperature (GMST) averaged over a 30-year period and usually expressed relative to pre-industrial levels. The current warming trend is assumed to continue.

Global warming potential (GWP) - Global warming potential is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of carbon dioxide. GWP is 1 for CO₂. For N₂O GWP is 265 and for CH₄ it is 28.

GWP* - An alternative approach to report emissions as 'warming-equivalents' that result in similar warming impacts without requiring a like-for-like weighting per emission. As such, this approach considers the fact that methane has a much shorter lifespan in the atmosphere than CO₂ and N₂O. The GWP for methane is 28 when considered over a 100-year time frame, but this masks the fact that whilst CH₄ has a strong warming influence when first emitted, the impact then diminishes rapidly over a few decades.

Grazing farm systems - The herd acquire most of their feed from grazing either rangelands or improved pastures. Some grazing systems can involve periods of housing depending on climatic conditions.

Housed farm systems - Animals spend most (or all) of their time in a housed situation, and have feed brought to them. The feed may be produced off-farm (particularly in intensive systems) or on-farm.

Indirect emissions - Emissions that are a consequence of the activities within well-defined boundaries of, for instance, a region, an economic sector, a company or process, but which occur outside these specified boundaries. For example, emissions arising from deforestation to provide land for livestock activities are generally considered indirect emissions, since they do not directly contribute to the operation of the livestock system. By contrast, 'off-farm' emissions usually refer to emissions that occur from production inputs produced outside the boundary of a farm (such as fertiliser or brought-in feed).

Inhibitor - An agent that slows or interferes with a chemical action reducing or suppressing the activity of another substance (such as an enzyme). In agriculture, urease and nitrification inhibitors are used to reduce the breakdown of animal excreta into nitrate and N₂O, while methane inhibitors are intended to reduce the activity of methane-generating microbes in the rumen of animals.

Glossary

Intensive farm systems - Intensive farming is characterised generally by a high use of inputs such as capital, labor, or higher levels of use of pesticides and/or fertilisers inputs relative to land area. In animal husbandry, intensive farming involves either large number of animals raised on limited land, usually confined animal feeding operations, or managed intensive rotational grazing.

Methane (CH₄) - One of the main greenhouse gases (GHGs) and is the major component of natural gas and associated with all hydrocarbon fuels. Significant emissions occur during ruminant digestion and in paddy rice systems. As a GHG, CH₄ has 28 times the warming potential of CO₂ (when considered over a 100-year time frame) but has a shorter lifetime in the atmosphere than CO₂ and N₂O of around 12 years.

Mitigation (of climate change) - A human intervention to reduce emissions or enhance the sinks of greenhouse gases.

Mitigation potential - A method to assess the scale of GHG reductions that could be made, relative to emission baselines. The mitigation potential describes the amount of emissions reductions that could be - but are not yet - realised over time.

Monogastric - A monogastric organism has a simple single-chambered stomach, compared with ruminant organisms like cows, sheep or goats, which have a four-chambered complex stomach. Herbivores with monogastric digestion can digest cellulose in their diets by way of symbiotic gut bacteria. However, their ability to extract energy from cellulose digestion is less efficient than in ruminants.

Net zero emissions - Net zero emissions are achieved when emissions of greenhouse gases to the atmosphere are balanced by removals over a specified period.

Nitrous oxide (N₂O) - One of the main greenhouse gases (GHGs). The main source of N₂O is from microbial processes within the nitrogen cycle. In agriculture, emissions of N₂O are increased by the use of N fertiliser, animal manure management, but important contributions also come from sewage treatment, fossil fuel combustion, and chemical industrial processes. As a GHG, N₂O has 265 times the warming potential of CO₂ (when considered over a 100-year time frame) and stays in the atmosphere for an average 116 years.

Off-farm emissions - Direct emissions generated outside the boundaries of a farm, but used to support production within that farm (e.g., emissions arising from supplementary feed produced off-site).

On-farm emissions - Direct emissions generated within the boundaries of a farm.

Precision livestock feeding - Matching nutrient supply precisely with the requirements of individual animals, throughout their production cycle to increase nutrient use efficiency and productivity, whilst reducing GHG emissions per unit of product and reducing feed waste.

Productivity - Amount of output obtained per unit of production factor. The productivity of an individual cow is the sum of the value of the milk she produces, the value of her offspring, and her individual market value when she leaves the herd.

Ruminant - Mammals that acquire nutrients from plant-based food by fermenting it in a specialised stomach (the rumen) prior to digestion, principally through bacterial actions. The process typically requires the fermented ingesta (known as cud) to be regurgitated and chewed again. The process of rechewing the cud, which further breaks down plant matter and stimulates digestion, is called rumination.

Replacement rate - The percentage of adult animals in the herd replaced by younger adult animals each year.

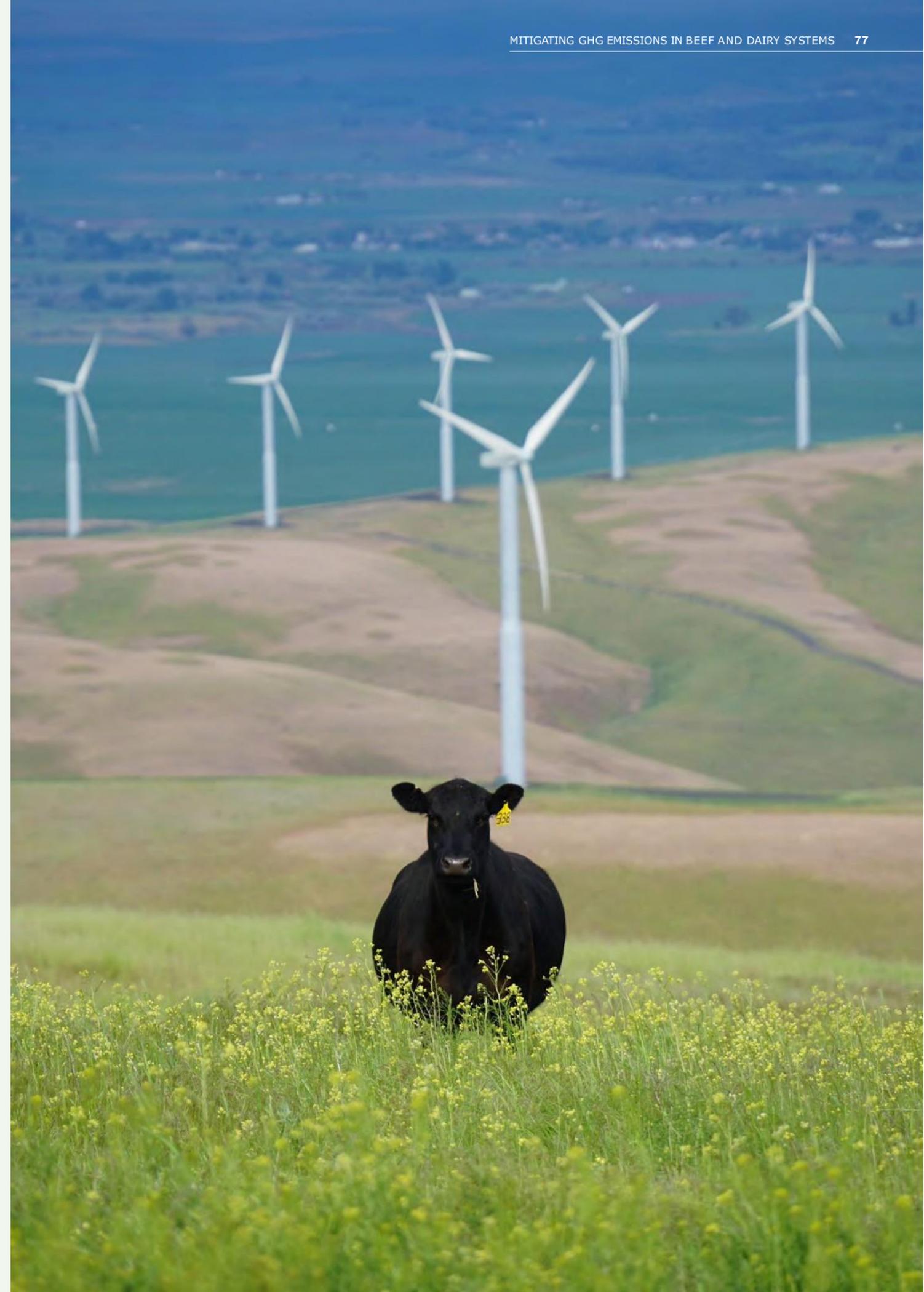
Silvopasture - Growing trees integrated with pastures in a systematic pattern creating a wildlife habitat, providing shelter for grazing livestock and increasing carbon sequestration.

Sustainability - A dynamic process that enables the persistence of natural and human systems in an equitable manner. Usually considered as a balance between economic, social and environmental outcomes.

Sustainable development (SD) - Development that meets the needs of the present without compromising the ability of future generations to meet their own needs, and balances social, economic and environmental concerns.

Total mixed rations (TMR) - Evenly mixing all dietary components to provide a consistent supply of nutrients, allowing for more efficient use of feeds. This also prevents selective feeding and can ensure a nutritionally balanced diet containing all required micronutrients, improving nutrient use efficiency and increased productivity.

Trade-off - The negative effects that a policy or measure aimed at one objective might have on other objectives. For example, the primary goal of a change in farm practice may be to increase profitability per unit area, but it may result in increased leaching of nitrate into waterways.





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