
Code of good practice - beef cattle

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Carbon neutral strategy 2050

Introduction

Provacuno has been working since mid-2019 on a strategy to reduce greenhouse gas emissions and increase carbon sequestration. This is achieved through improved management practices and optimized use of pasture and forage resources on its farms. The strategy is called the **2050 Carbon Neutral Strategy**, and its objective is to achieve climate neutrality in the Spanish beef sector by 2050. This will be accomplished by sequestering carbon equivalent to the greenhouse gases generated in the production processes of the sector.

The beef value chain is committed to taking a proactive role in reducing emissions and improving its environmental sustainability. This includes promoting research and technological development, with the goal of applying results to the daily activities of producers. The initial activities of this strategy include the implementation of a Code of Good Practice. Its application will be promoted throughout the livestock sector and later extended to the rest of the value chain. Additionally, a socioeconomic and productive analysis of the sector will be conducted to establish a foundation for applied research projects that support the strategy's objective.

The Code of Good Practice has been drafted in collaboration with Spanish researchers from the Remedia network and experts from the beef sector, all of whom are recognized as authors of the work. **Provacuno** gratefully acknowledges the selfless contribution of the members of the scientific network for the mitigation of greenhouse gases in the agroforestry sector in developing this Code of Good Practice.

Eliseu Isla Argelich
President of PROVACUNO

Greetings from the REMEDIA Network

Since 2012, the REMEDIA Network has served as a collaborative hub for researchers dedicated to mitigating climate change within Spain's agricultural, livestock, and forestry sectors. Our primary objective is to foster research activity through multidisciplinary collaboration. We also prioritize knowledge transfer and the dissemination of scientific information to public administrations, the private sector, and society at large.

Provacuno's request for the REMEDIA Network to collaborate in drafting this Code of Good Practice aligns perfectly with our commitment to knowledge transfer. This project presents an exciting challenge for our network, as it relies on the voluntary contributions of our scientists, who generously dedicate their time and expertise to these efforts. They do so independently, with the network acting as a facilitator for collaboration amongst themselves and with stakeholders like Provacuno.

To assemble a working group, we reached out to all network members, inviting researchers with relevant expertise to participate. This resulted in a team of 17 researchers from 7 research centers who diligently compiled this document, applying rigorous scientific principles while striving for clarity and conciseness to ensure accessibility for producers.

We trust this Code of Good Practice will prove valuable in assisting the sector in reducing emissions. We also hope it serves as a catalyst for further collaborative initiatives.

Salvador Calvet Sanz
Coordinator of the REMEDIA Network

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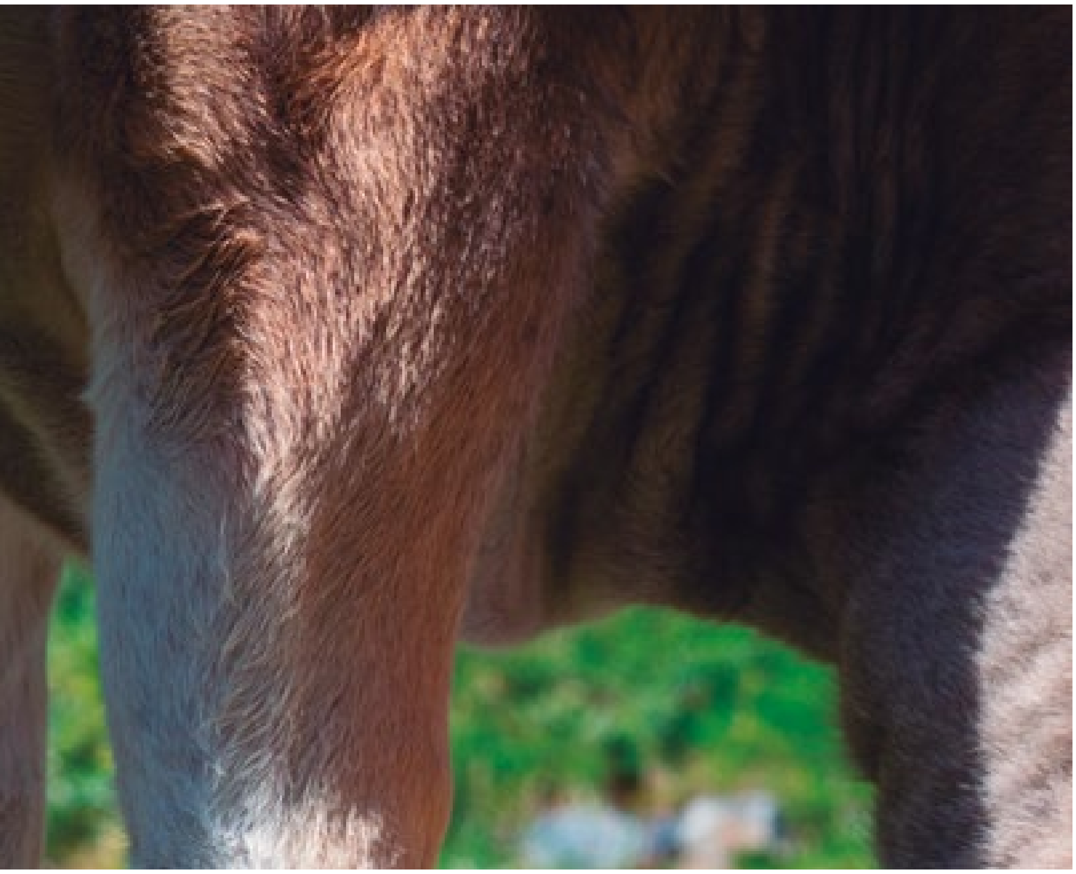
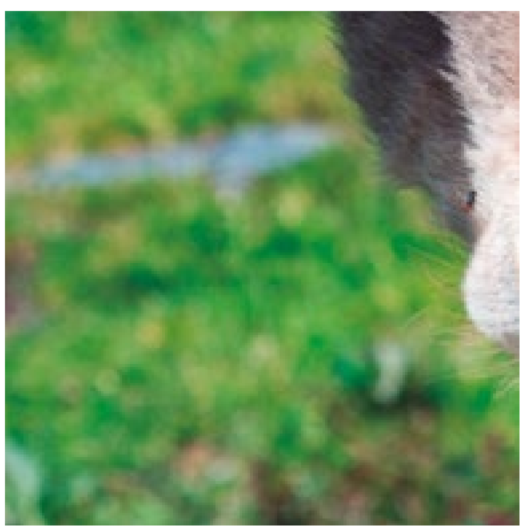
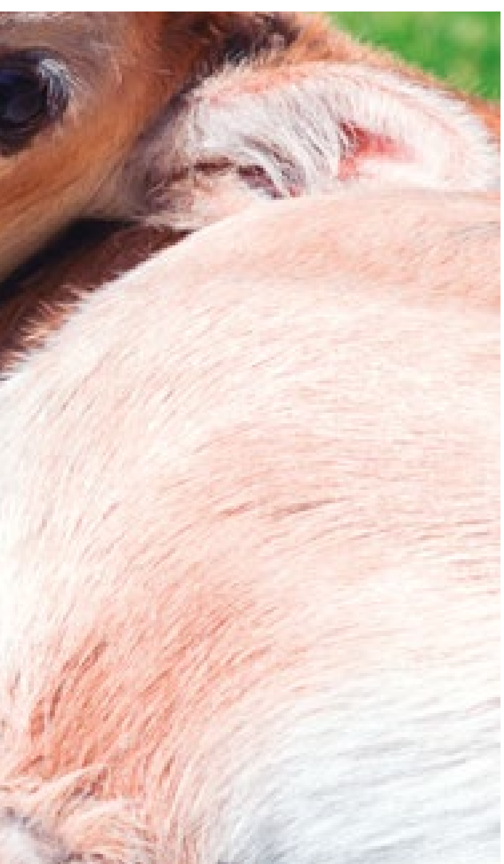


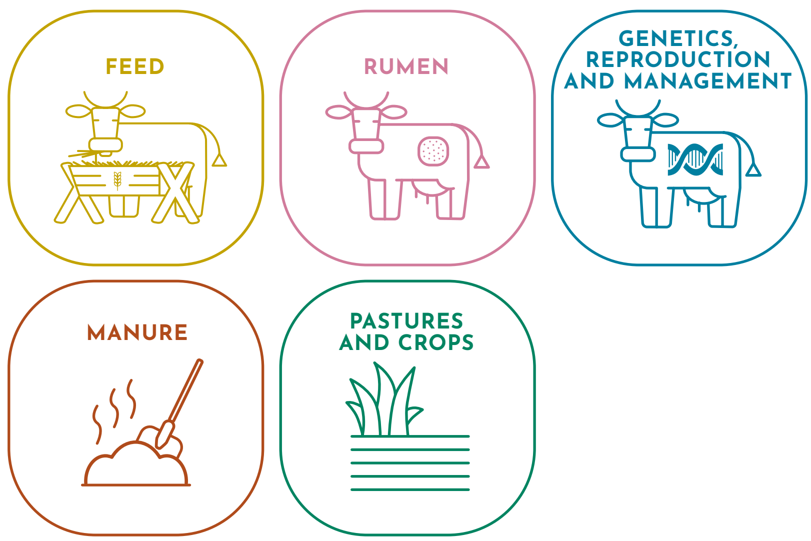



Preliminary Considerations



This document provides a compilation of measures designed to reduce greenhouse gas (GHG) emissions in beef production. These measures focus on livestock farms, both with and without land. However, the potential impact of these measures on other parts of the production chain (e.g., feed production) is also considered. This document is primarily intended for producers and other stakeholders in the production chain (e.g., integrators, feed mills).

It identifies scientifically proven measures applicable to beef production in Spain, organized into five main categories:



Each category outlines available mitigation measures, including a brief description of their rationale, direct and indirect effects on different GHGs, potential synergies or antagonisms with other pollutants, and the technological and economic feasibility of each measure. This information aims to empower producers to identify the 10 most cost-effective measures for their farms.

To facilitate interpretation, semi-quantitative scales have been created to enable quick assessment of a measure's impact on GHG emissions, its cost, and its availability. These scales are detailed on the following page.

GHG Emissions

<10% emission reduction

10-25% emission reduction

>25% emission reduction

Benefits

no benefit and with cost

little economic benefit

with economic benefit

Cross Effects

implies worsening other impacts

no interactions, or they are divergent

entails improvement in other impacts

Availability

laboratory scale

field testing

available now

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GHG EMISSIONS

<10% emission reduction
10-25% emission reduction
>25% emission reduction

CROSS-EFFECTS

implies worsening other impacts
no interactions, or they are divergent
entails improvement in other impacts

.2

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MANURE

BENEFITS
no benefit and with cost
little economic benefit
with economic benefit

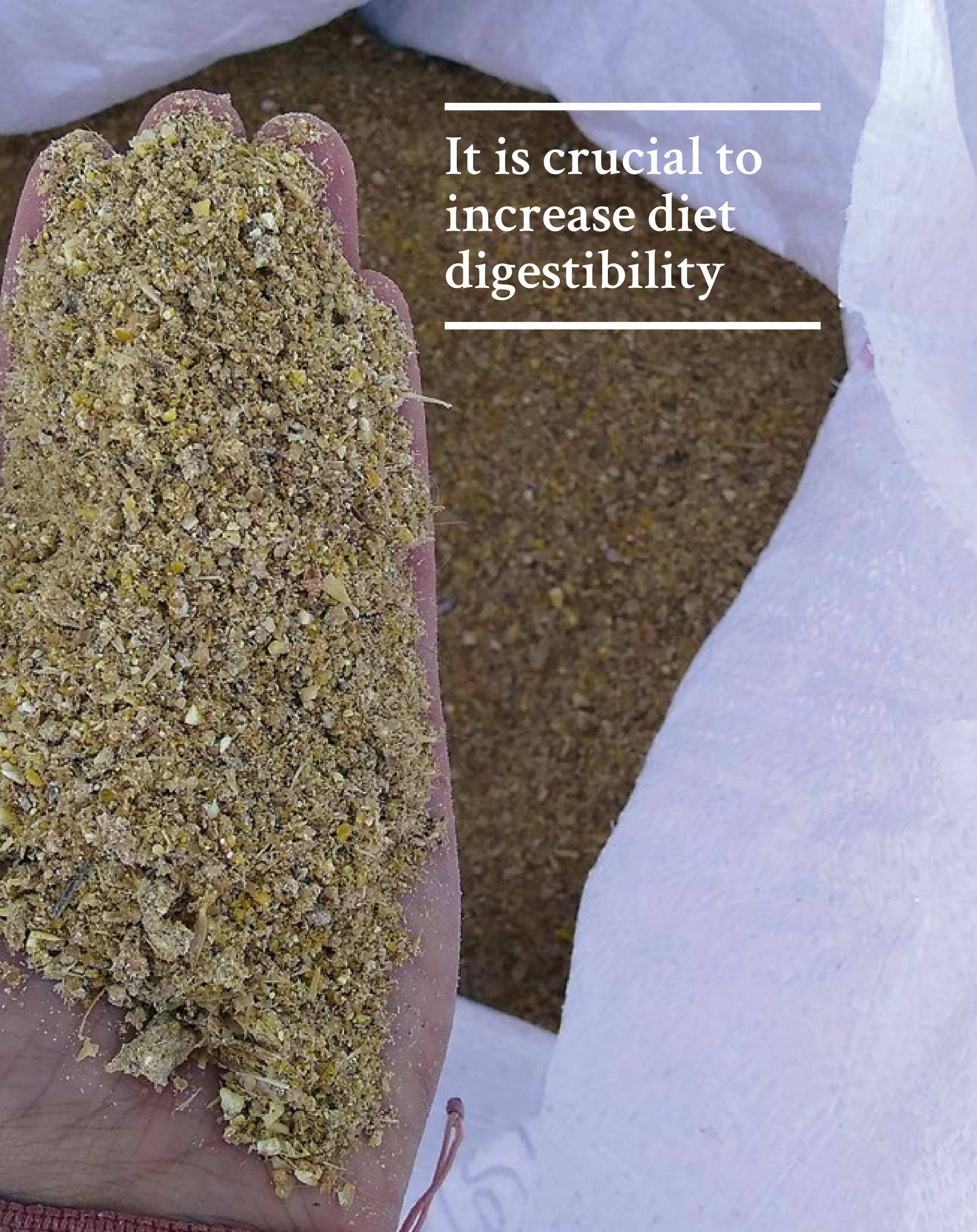
AVAILABILITY
laboratory scale
field testing
available now

1 Feed and Raw Material Management

Measure 1.1
Improve Diet Digestibility Through Increased Concentrate or High-Quality Forage

Brief Description

Diet composition significantly influences enteric greenhouse gas (GHG) emissions, both in absolute terms (g/day) and relative to dry matter intake or product output. Diets with low digestibility (e.g., based on forages or fibrous byproducts) can reduce emissions associated with feed production. However, these diets increase emissions per unit of dry matter consumed and per unit of product. It is therefore crucial to increase diet digestibility through nutritional strategies. The two most common approaches are increasing concentrate levels and utilizing high-quality forages.



It is crucial to increase diet digestibility

Direct Effect on Emissions

Increasing concentrate in the diet reduces emissions by promoting propionate fermentation. Propionate acts as a hydrogen sink, preventing its conversion to methane.

Feeding high-quality forage improves feed digestibility and increases production efficiency, leading to lower emissions per unit of product (although daily emissions may increase). Using forage legumes can reduce emissions by up to 10%. Effective pasture and grazing management, combined with appropriate forage species selection and diet formulation, can reduce emissions per unit of product by up to 30% compared to feeding low-quality forage.

Cross Effects

These strategies may increase feed costs, but also lead to higher production yields. This could allow animals to reach slaughter weight sooner, potentially freeing up space, particularly on fattening farms. Increased concentrate use can raise the carbon footprint due to emissions and other environmental impacts from concentrate production, especially if ingredients like soy, with high life-cycle GHG emissions and other impacts, are used.

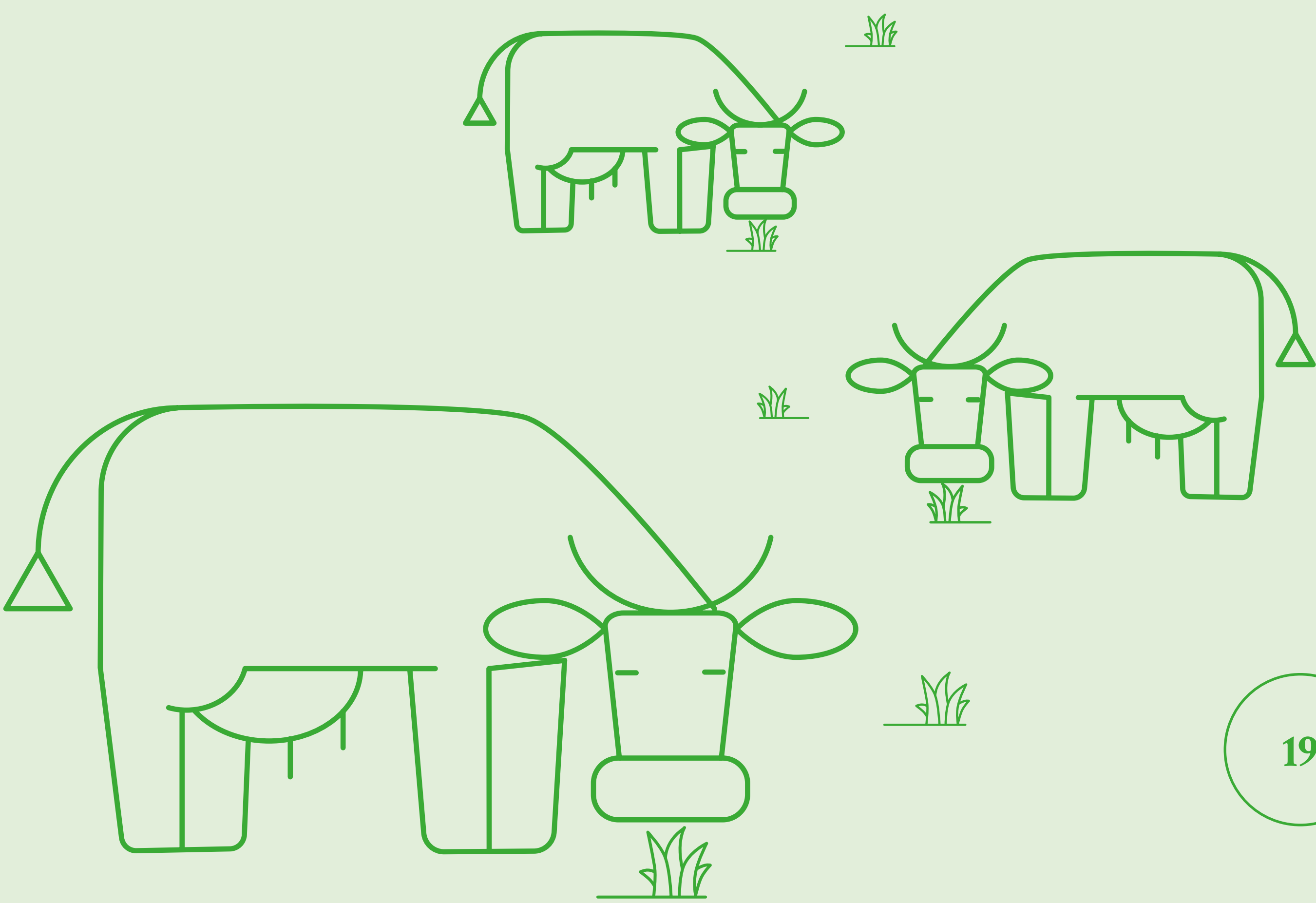
Greater reliance on cereals and oilseeds in feed competes with human food production for agricultural resources.

Benefits

The benefit depends on the type of animal and pasture availability.

Availability

Currently available.



Measure 1.2
Adjust Protein Levels in the Ration

Brief Description

The relatively low price of protein (mainly soy) in recent years has led to its high inclusion in diets to prevent it from being a limiting factor. However, the excess protein is excreted (mainly through urine) as urea. Part of this urea volatilizes as ammonia (NH_3), and subsequently, another part is lost as nitrogen oxides (e.g., N_2O) and nitrate leaching into water. Additionally, ruminant animals need to expend energy to eliminate this excess nitrogen, which could even have negative effects.

Conversely, an excessively low-protein diet can limit rumen microbial protein synthesis and production parameters, making it necessary to adjust the protein (and energy) level in each production stage. This requires a good estimate of nutritional needs and meticulous and frequent feed analysis (e.g., NIRS). In high-producing animals, essential amino acids can also be supplemented in the case of low-quality dietary protein.

All this leads to a reduction in methane emissions per unit of product.

It is necessary to adjust the protein level in each production stage

Direct Effect on Emissions

Reducing the protein level in the diet (if it was in excess) reduces urinary nitrogen emissions and, therefore, N_2O emissions.

Increasing the protein level in the diet (if it was deficient) maximizes productivity, reducing emissions per unit of product.

Cross Effects

Adjusting protein intake reduces the carbon footprint not only by reducing on-farm emissions (e.g., N_2O in grazing), but also by reducing the upstream environmental impact by lowering N inputs (e.g., in concentrates). This is especially true if concentrate ingredients with a high environmental footprint (e.g., soy from deforestation) are reduced. Other pollutants are also reduced, both atmospheric, such as NH_3, and in water and soil.

Benefits

Excess dietary protein, when reduced, yields cost savings without compromising productivity.

Conversely, supplementing low-protein diets elevates costs, yet enhances production parameters.

Technological Level

Tools are available to estimate both the protein content in the diet and its rumen degradation kinetics (NIRS). Essential amino acids are also commercially available.

Measure 1.3
Replace Imported Protein Supplements with Local Protein Sources

Brief Description

Imported protein (primarily soy) has a high carbon footprint, often due to deforestation in the country of origin, heavy use of industrial fertilizers, and the environmental impact of intercontinental transport. Using local or regional protein sources can reduce this carbon footprint. Such sources include legume grains (peas, rapeseed, etc.), alfalfa pellets, and legume forages. Feeding corn or legume silage can reduce emissions compared to ryegrass silage. Rapeseed forage has also been shown to reduce emissions, though its effects on productivity vary. Combining corn and legume silage often increases feed intake and reduces emissions per unit of product.

Using local protein sources can reduce the carbon footprint

Direct Effect on Emissions

Replacing imported soy with local alternatives reduces or eliminates the consumption of imported soy and its associated carbon footprint, which is associated with deforestation and international transport.

Cross Effects

Soy substitutes typically have a lower protein content and biological value than soy, potentially reducing protein utilization efficiency. The price of the ration may also increase.

Benefits

Due to the lower protein quality of soy alternatives, production levels may be negatively affected if the diet is not properly formulated. However, reducing reliance on the foreign soy market can lead to more stable ration prices.

Technological Level

Currently available.

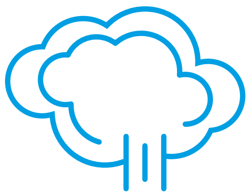
Measure 1.4
Use Agro-Industrial Byproducts, Plant Residues, and Novel Feeds

Brief Description

Agro-industrial byproducts (citrus byproducts, brewer's spent grain (BSG), fruit and vegetable residues, grape pomace, etc.) offer an inexpensive feed source for ruminants, as they cannot be utilized by other livestock species. However, most of these byproducts must be consumed locally or regionally due to their high water content, which makes transport unprofitable. Additionally, these products are often seasonal.

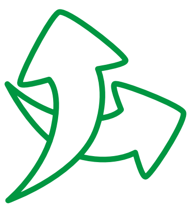
Novel feeds like alkalized feed or straw pellets can be valuable tools in fattening systems.

Agro-industrial byproducts offer significant potential for reducing emissions



Direct Effect on Emissions

These byproducts provide readily fermentable carbohydrates at low cost, reducing CH_4 formation in the rumen and allowing for a decrease in forage in the diet. Many byproducts are rich in active compounds like tannins, saponins, essential oils, or antimicrobial substances that can modulate the rumen microbiota to favor propionate fermentation, further reducing enteric CH_4 production. Similar to byproducts or residues from other industrial processes, their inherent carbon footprint is very low.



Cross Effects

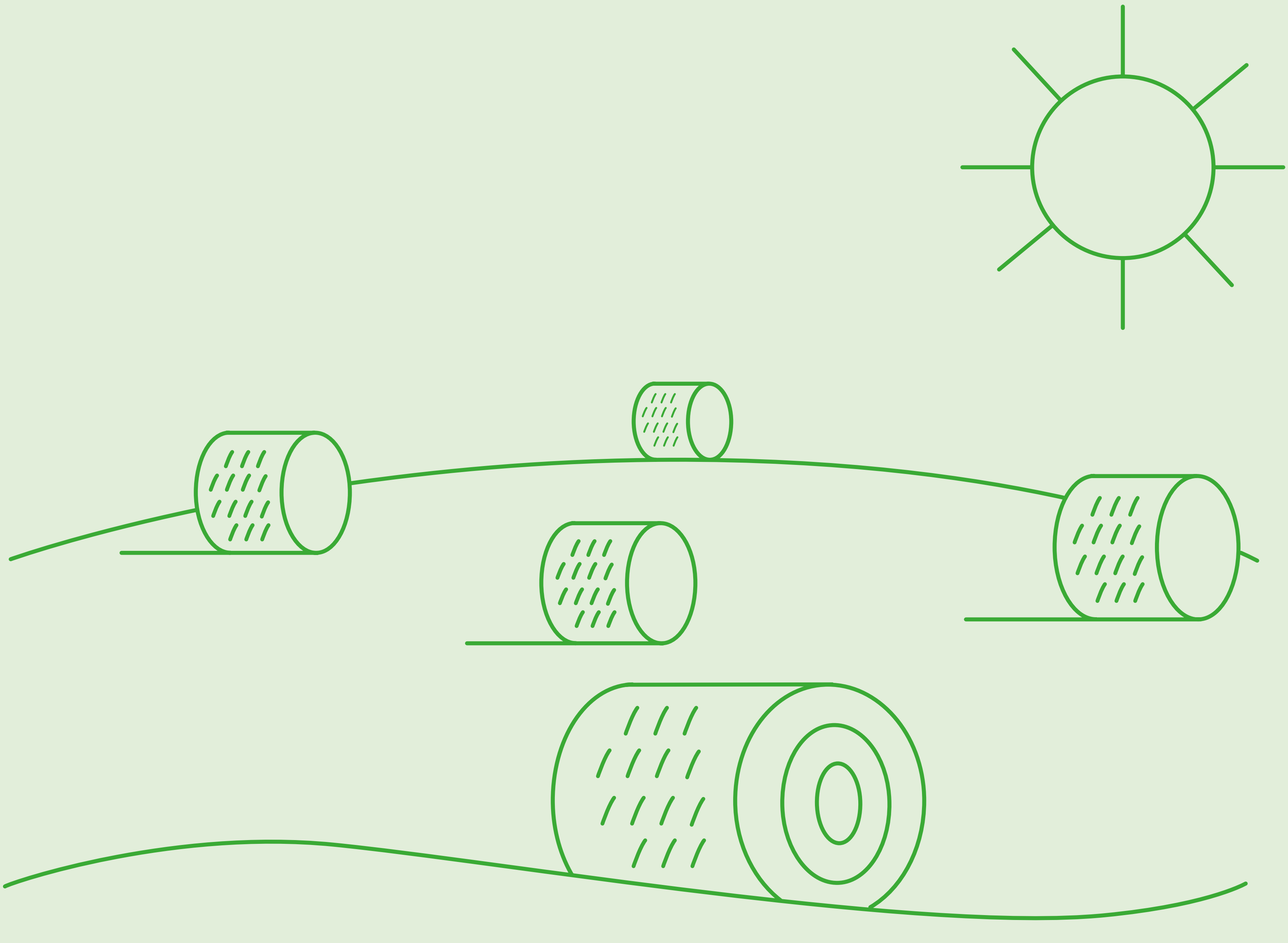
While their direct impact on emissions is minimal, byproducts can replace other feed ingredients with higher carbon footprints, thus reducing upstream emissions. In some cases, using these byproducts or plant residues for animal feed might compete with alternative uses (e.g., bioenergy) that offer greater environmental benefits.

Benefits

Utilizing byproducts offers a mutual benefit when they are locally available at low cost.

Technological Level

While some farmers regularly use byproducts, their adoption is not widespread. Technological investment is needed to increase their energy density, making their transport and distribution over medium to long distances economically feasible.



Measure 1.5
Precision Feeding

Brief Description

Precision feeding consists of providing the appropriate nutrient at the appropriate time to the appropriate animal. This is because the nutritional needs of animals change throughout the production cycle. Understanding daily nutritional needs can therefore represent a strategy to maximize productivity and reduce methane emissions. Making personalized rations for dairy cattle has been observed to increase productivity and reduce methane emissions by 15-20% and nitrogen excretion by 20-30%, resulting in a reduction in emissions from excreta. In addition, constantly monitoring animals using precision livestock tools to assess their physiological, health, productive, and nutritional status, body reserves, and genetic level allows access to "big data", which is an accessible tool for farmers when making decisions and managing the farm. Therefore, precision feeding, which combines pasture management and diet, requires advanced technology to monitor pastures, feed needs, and forage production appropriately.

Continuously adjusting the supply of nutrients to the needs of each animal is a strategy with significant potential to reduce emissions

Direct Effect on Emissions

This measure allows for optimized feeding through the correct management of stocking density, pasture quality, and diet availability, as well as reducing unproductive periods (age at first calving, dry period, etc.) and improved genetic progress if there is thorough control of individual animal data.

Cross Effects

Optimizing resource consumption has benefits by reducing farm inputs, both in terms of greenhouse gas emissions and other pollutants.

Benefits

Precision feeding represents a substantial investment and requires qualified and highly dedicated personnel to collect data. Therefore, the effects are not usually short-term, but rather medium- to long-term.

Technological Level

This technique is very advanced in other livestock species and is beginning to be implemented in beef cattle. The need for precise and exhaustive data collection means that it is still not widespread despite its benefits.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0070

Measure 1.6
Improve Forage and Silage Conservation

Brief Description

Harvesting forage at an early stage of maturity increases its soluble carbohydrate content and reduces the lignification of plant cell walls, increasing its digestibility and decreasing enteric CH_4 production per unit of digestible DM, thus reducing GHG emissions.

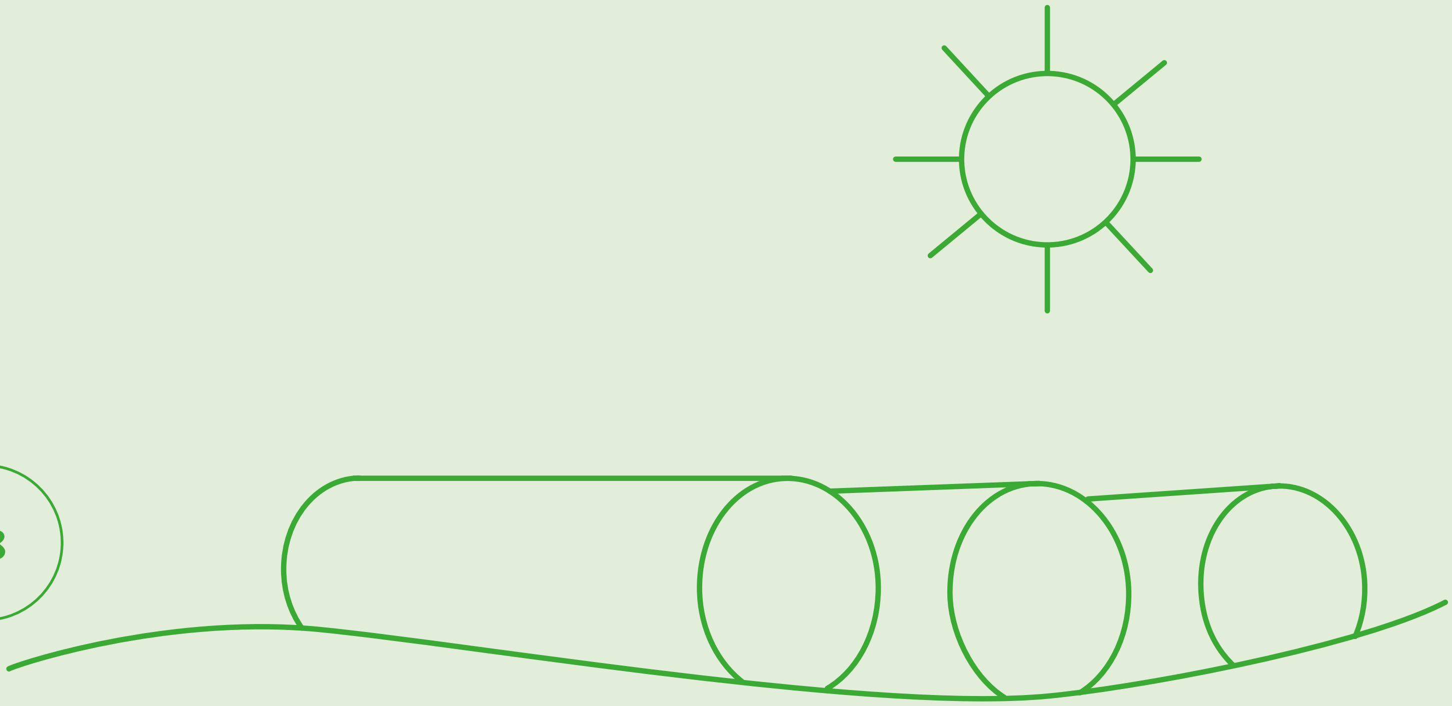
Dry matter loss occurs during haylage or silage production, and varies according to the conservation procedure and storage location. Hay and corn packed and stored indoors may experience losses of less than 6%. When that hay is packed and stored outdoors, dry matter losses can be between 10 and 20%, and occasionally may reach as high as 40%. When the storage procedure is ensiling, dry matter losses range between 5 and 25%.

Maintaining equipment in good condition is essential for haylage production. Cutting can cause losses of 2%, and baling 6%, but poorly adjusted harvesting can cause losses of up to 12% of the available dry matter. Dry matter loss is frequently associated with moisture content, exposure to precipitation, and bale contact with the ground. Wrapping dry bales that are too wet for conventional hay storage can also reduce losses.


Hay and corn packed and stored indoors may experience losses of less than 6%

Most silage losses seem to occur in the initial loading and fermentation period. Fermentation, which reduces the pH of the silage, occurs during the first week to a month of storage; after this, the silage is relatively stable for up to a year with minimal losses if the silo is well sealed and good storage practices are followed. Therefore, losses are believed to be resistant to variations in storage time. Significant dry matter loss also occurs during removal from storage.

Additives are frequently used to improve silage preservation, especially corn, and can be an important management tool to reduce storage losses, particularly in low-quality silages. However, some additives can contribute significantly to the net greenhouse gas emissions of the stored biomass. The use of urea and ammonia to condition the forage to be ensiled would directly increase GHGs through the volatilization of N_2O from the silos.



Direct Effect on Emissions

Increasing the quality or digestibility of the forage will increase production efficiency, likely resulting in a decrease in the intensity of enteric CH_4 emissions.

On the other hand, the loss of digestible dry matter at harvest or in the silo due to normal fermentation losses will result in reduced animal performance and increased GHG emissions per unit of product emitted.

Cross Effects

Like all measures that lead to increased productive efficiency and use of resources, this measure will directly reduce the production of other pollutants.

Benefits

Improving haymaking and ensiling processes to reduce dry matter loss means improving the nutritional quality of forage at the same cost.

Technological Level

Currently available.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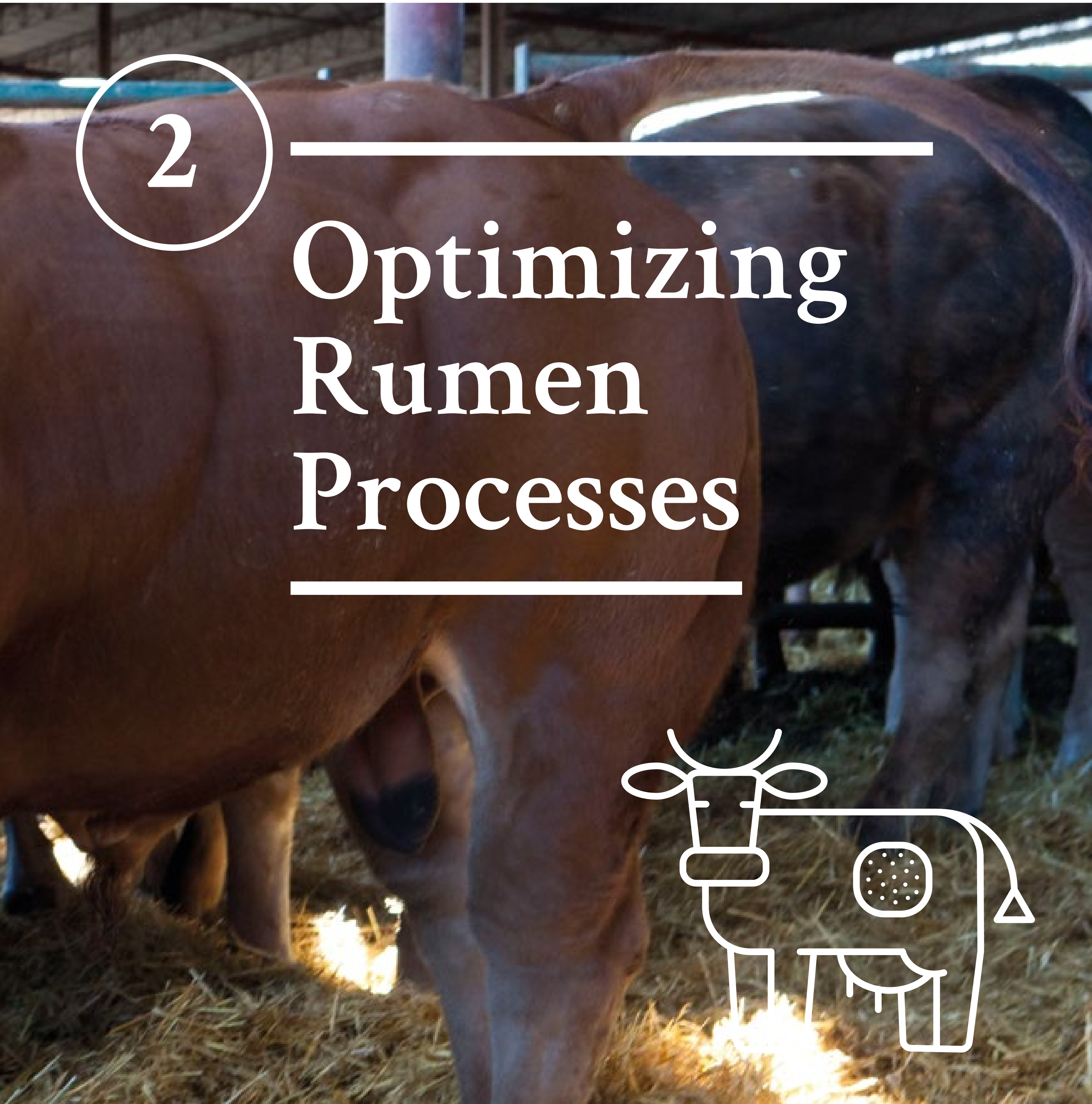


2 Optimizing Rumen Processes

Measure 2.1
Use Additives that Reduce CH_4 Emissions

Brief Description

This measure is based on modulating rumen function in animals by adding additives (e.g., vegetable oils, tannins, organic acids, or phytogenic or synthetic extracts) to feed or drinking water.

Alter rumen function through additives

Direct Effect on Emissions

CH_4 is produced in the rumen by the activity of methanogenic archaea, which use much of the H_2 generated by the anaerobic fermentation of carbohydrates to reduce CO_2 to CH_4. Three stages can be established in this process where additives can exert an action that results in the reduction of CH_4 production: (i) decrease the production of H_2, the main substrate for methanogens; (ii) use alternative H_2 "sinks" by adding compounds that require H_2 to be metabolized; and (iii) use compounds that directly inhibit the action of methanogenic archaea, primarily the activity of the enzyme methyl-coenzyme M reductase (MCR).

Examples of the three categories would be:

i) vegetable oils, saponins, and tannins that reduce protozoa activity and therefore H_2 production;

ii) organic acids such as malate or fumarate, and some polyphenolic compounds that require the consumption of H_2 for their anaerobic degradation;

iii) phytogenic extracts and compounds (such as organosulfur), from microalgae (Asparagopsis taxiformis), or synthetic compounds such as 3-nitrooxypropanol (3-NOP).

Why it reduces emissions:
Given the variability of available additives, there is a wide range in emission reduction, but it is generally high (it can reach up to 30-40% expressed per kg of dry matter ingested).

Cross Effects

The main barrier to using these compounds is that the reduction in CH_4 production rarely results in a greater impact on productivity from more efficient metabolic activity. There are some exceptions, but this undoubtedly limits commercial use to cases where additives are already available on the market. The main negative effects would be reduced intake in the animal at high doses, and decreased fiber digestibility (sometimes associated with the former).

Benefits

In relation to the lack of clear effects on animal productivity, the main obstacle in most cases is the cost of the compounds.

Technological Level

Many products are already on the market, such as plant extracts, but to date, none are officially registered as zootechnical additives to reduce emissions. Some companies that develop these additives have initiated the registration process in the EU.

Measure 2.2
Use Additives to Optimize Rumen Function

Brief Description

This involves using compounds (primarily plant extracts) that have a modulatory effect on the rumen microbiota, such that the anaerobic fermentation profile favors propionate production over acetate production. Probiotics would also be included among the additives that optimize rumen function. Yeast *(Saccharomyces cerevisiae)* is the most widely used probiotic for modulating rumen function in adult animals.

Additives are typically compounds that modulate the rumen microbiota

Direct Effect on Emissions

Propionate, produced during rumen fermentation, provides more metabolic energy to the animal once absorbed and metabolized in the liver. The production of propionate consumes H_2 while the production of acetate generates it, hence the reduction in CH_4 production. This measure is related to some of those presented in the previous section. The degree to which this measure decreases CH_4 will vary depending on whether it is measured in relation to intake or weight gain; generally, the effect is greater in the latter case.

The mode of action for reducing emissions depends on the type of additive:

—Essential oils have antimicrobial and antioxidant effects and improve nutrient absorption. Their effect on emissions is highly variable, and they do not always improve average daily gain (ADG), although they do improve the feed conversion rate.

—Tannins work by preventing protein degradation in the rumen and subsequently promoting its release in the intestine. The effects in vivo are not very consistent with those in vitro. Some trials with various types of tannins have shown a significant reduction in methane emissions. Reducing urinary nitrogen excretion has been observed to be a more consistent effect, preventing the volatilization of ammonium and nitrous oxide. Tannins do not usually improve ADG.

—Saponins have an antiprotozoal effect as their main mode of action. Consequently, they reduce methane emissions by about 6%. In vivo effects are highly variable. One of the primary limitations is their transitory effect, as rumen bacteria develop the ability to inactivate saponins after a treatment period of more than 2–3 weeks. Saponins do not typically improve ADG.

—Yeast works primarily by consuming rumen oxygen, promoting the growth of lactate-consuming bacteria and creating a strict anaerobic environment that promotes the activity of fibrolytic microorganisms and modulates the symbiotic rumen microbiota. Yeast does not typically reduce methane emissions. The advantage of this nutritional strategy is that it promotes fiber degradation and increases rumen pH, preventing rumen acidosis and the resulting decrease in feed conversion rates.

Cross Effects

These additives do not typically reduce methane emissions per se, but in many cases they increase herd productivity and efficiency; therefore, emission intensity (per unit of product) is reduced. This increased efficiency helps to reduce emissions of other pollutants.

Benefits

Many of these additives (e.g., yeast and essential oils) are regularly used in commercial feeds for high-production animals (dairy cows) because they improve productivity and prevent acidosis. Using these additives in calves raised for meat can be profitable. However, using these additives with suckler cows is more complex because of the need to minimize ration costs.

Technological Level

Currently available.

Measure 2.3
Optimizing Rumen Development in Early Life

Brief Description

When a ruminant is born, it lacks a functional rumen, as it feeds on milk that passes directly to the omasum and is digested later. During the first few weeks of life, the rumen develops and is colonized by a complex mix of microorganisms from the animal's food, water, soil, feces, and contact with adult animals. Evidence shows that if this initial colonization phase is modulated to establish a more efficient microbiota, this efficiency will persist into adulthood. This is especially important in dairy systems that produce suckling calves, which are separated from their mothers at birth and have no contact with adult animals until after weaning.

Strategies include phytogenic additives, probiotics or changes in diet.

If the microbiota is modulated in the first few weeks of life, it will persist into adulthood

Direct Effect on Emissions

These nutritional strategies do not typically decrease daily methane emissions (they may even increase them); however, they improve production levels and minimize stress and slow growth during weaning. Therefore, they can indirectly reduce emissions per production unit by improving production efficiency, resulting in reduced emissions over the animal's lifetime.

Cross Effects

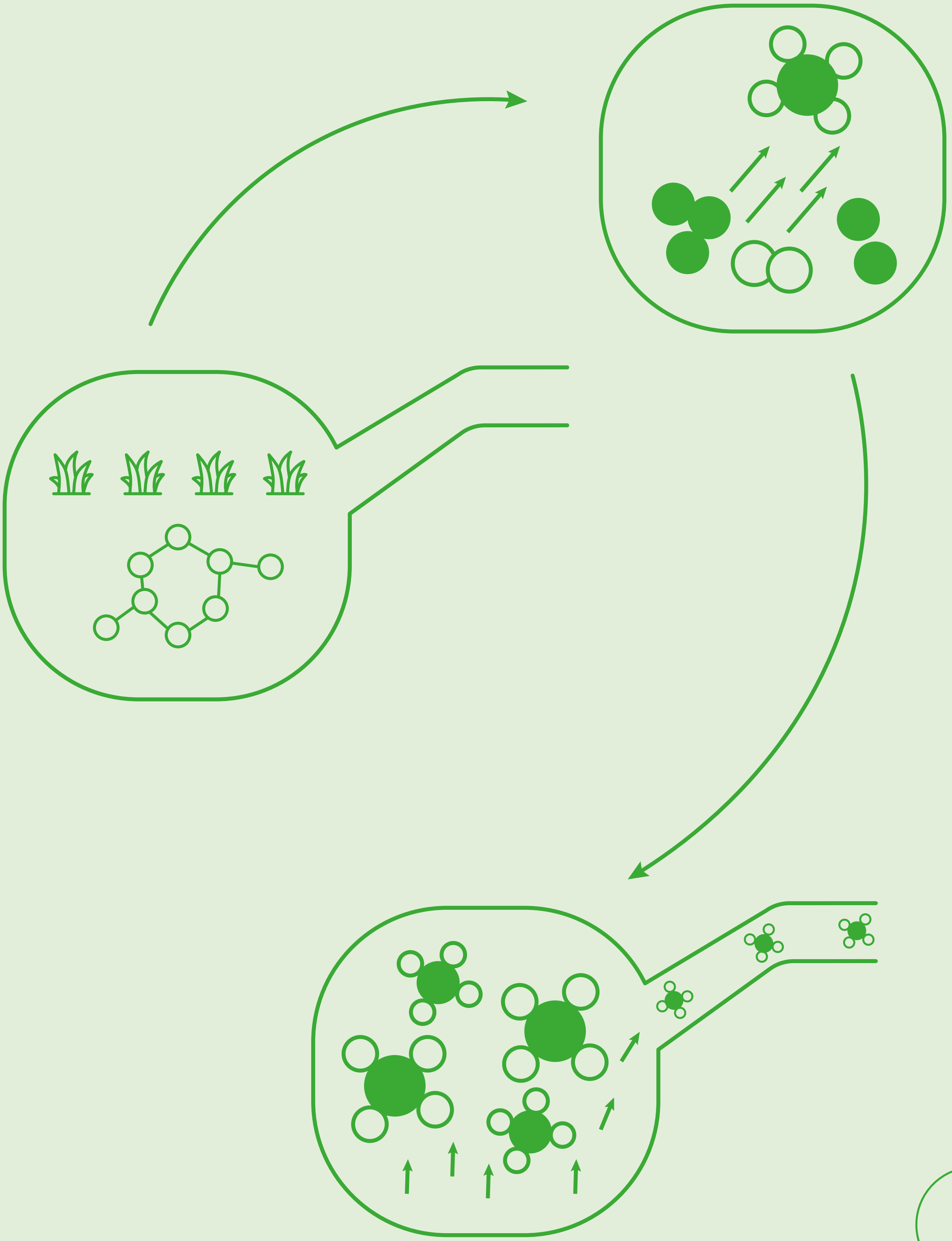
These strategies aim to accelerate the anatomical, microbiological, and functional development of the rumen so the animal can efficiently utilize solid food as soon as possible. This increases the animal's efficiency, increasing productivity and resource consumption per production unit over the long term.

Benefits

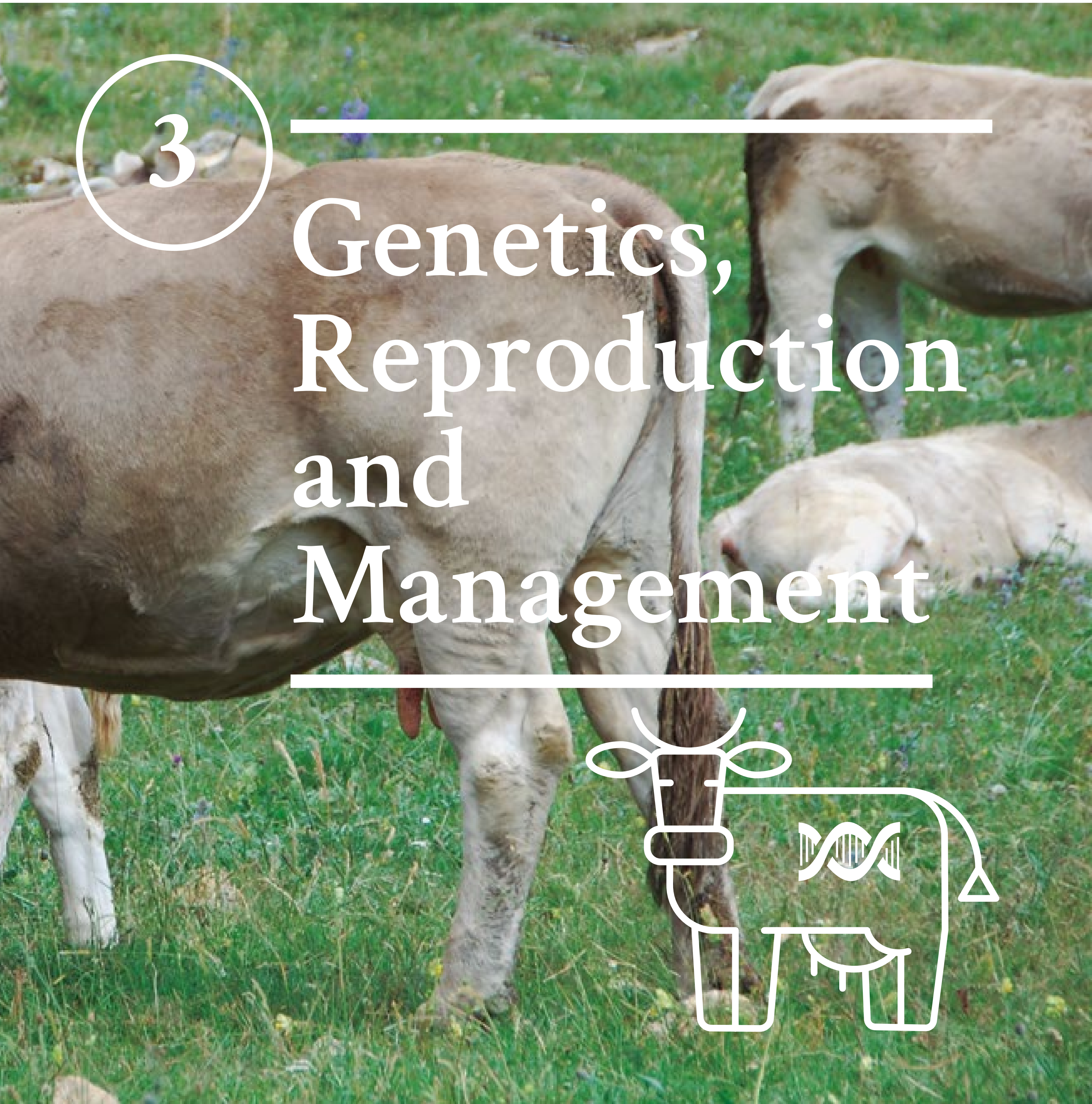
Early nutritional interventions are especially recommended for calves separated from their mothers after birth and raised with artificial lactation. The resulting economic benefit offsets the operating costs.

Technological Level

Available now, although with huge potential for development.



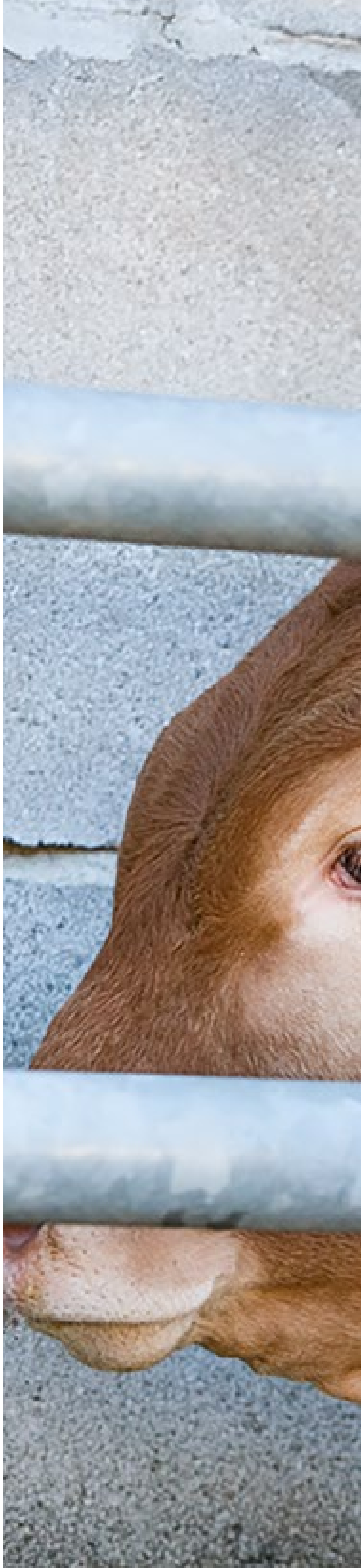
3 Genetics, Reproduction and Management



Measure 3.1
Data Collection / Precision Livestock Farming

Brief Description

Obtaining production data is essential for making evidence-based decisions. Precision livestock farming uses information and communication technologies to improve farm and animal control, with the goal of enhancing overall farm performance. It encompasses a wide range of technologies for monitoring, management, feeding, behavior control, etc.



Obtaining information is essential for decision-making

Direct Effect on Emissions

The effect of this measure is entirely indirect. That is, it does not in itself limit the processes that produce emissions; rather, it helps optimize farm management, increasing efficiency and preventing emissions caused by inefficiencies (e.g., early detection of unproductive animals).

The magnitude of its impact is limited: it optimizes production but does not eliminate necessary emissions. Even so, the potential for reducing CH_4 at the farm level can exceed 20%.

Cross Effects

This measure can increase the efficacy of other measures, such as feed control (quantity and type), livestock optimization, grazing management, etc., thus reducing emissions of other gases like NH_3, and soil and water pollution.

Benefits

Most of these measures involve installing automatic data collection systems, although systematically collecting and analyzing data with traditional methods is also very important.

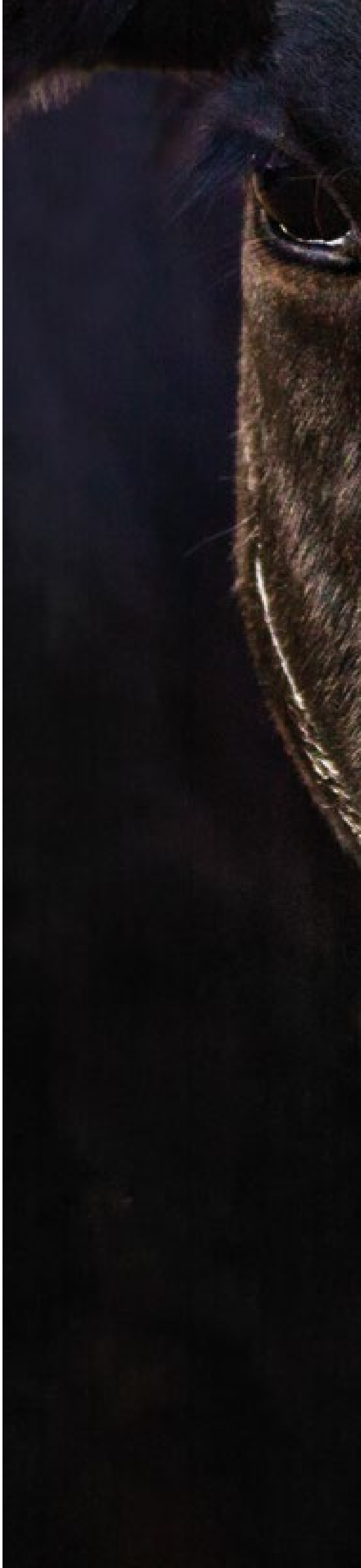
Technological Level

This technique is more developed for dairy cattle, although there are also applications for grazing. Technologically, it is an available measure, although its implementation is limited by other issues: rural connectivity, ownership of generated information, the training and education level of the farmer, etc.

Measure 3.2
Selection of Breeding Stock

Brief Description

Selecting breeding stock involves using bulls and cows with superior genetic values for traits of interest as the parents of the next generation. Breeding stock catalogs offer a wide variety of males that can be used for artificial insemination. Furthermore, encouraging and participating in breeding programs is important for determining the genetic value of the cows in the herd.



Using animals with high genetic value helps to improve productivity

Direct Effect on Emissions

Selecting animals with higher efficiency rates leads to lower feed intake per kilogram of product and faster growth, requiring less production time and reducing emissions.

Another related trait is the calving interval. Selecting more fertile animals with optimal calving intervals reduces unproductive periods, minimizing overall emissions.

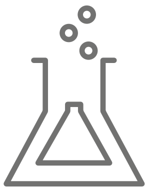
Genetic selection has a medium-to-high effect on emissions in the long term.

Cross Effects

As a measure for increasing herd efficiency, there is also high potential for reducing other pollutants, including non-GHG gases and emissions to soil and water.

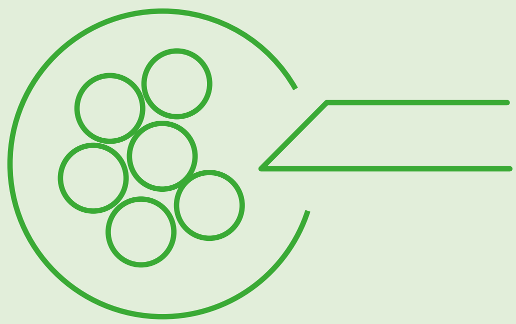
Benefits

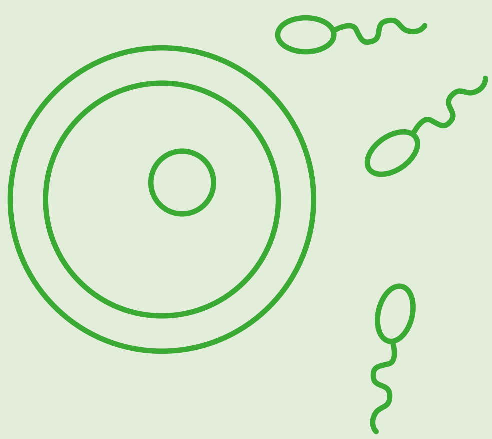
Selecting breeding stock for lower emissions can also improve herd profitability, and is one of the most cost-effective strategies for improving profitability and production efficiency. Additionally, each year's improvements accumulate in subsequent generations. However, this requires investment to implement artificial insemination and time to plan and choose pairings between cows and the most suitable males to avoid potential negative effects on offspring.



Technological Level

Genetic evaluations for some emissions-related traits are already available. Breeding programs must include the evaluation of traits related to direct methane emissions.





Measure 3.3
Improve Animal Welfare

Brief Description

In some cases, improving animal welfare can increase productivity. For example, decreasing social stress, improving health, and improving offspring survival can improve animal welfare while also improving productivity and reducing emission intensity.

Improving animal welfare can increase productivity

Direct Effect on Emissions

Generally, increasing animal welfare typically leads to increased production efficiency, achieving more production units with the same amount of feed or less. This is mainly due to a reduced stress response, which in turn reduces the ability to mobilize resources for production. At the same time, stress increases susceptibility to disease, which strongly increases GHG emission intensity.

Cross Effects

Strategies for reducing GHG emissions that are based on improving animal welfare have the clear double benefit of improving two important aspects of social concern: the ethics of animal production and its environmental impact. These strategies usually improve production efficiency, so they tend to positively affect the economic sustainability of livestock farms. Increasing herd efficiency also reduces emissions of other gases and pollutants per production unit.

In other cases, improving animal welfare can have the opposite effect—that is, it can increase GHG emissions. One example relates to the ability of animals to express their natural behavior, such as grazing. Under certain circumstances, if grazing is not managed properly, it can increase GHG emissions (especially nitrous oxide).

Benefits

These measures have a double, or even triple benefit, if they improve welfare, reduce emissions, and increase profitability.

Technological Level

Currently available.

Measure 3.4
Housing Strategies

Brief Description

Housing intensification, based on confinement in enclosed spaces and increased density (number of animals per unit area), can contribute to decreasing the relative emissions of GHGs. Intensification seeks to maximize the profitability of the system by optimizing resources. This improves system efficiency, resulting in less waste per production unit and, therefore, lower GHG emission intensity.

Intensification seeks to maximize profitability by optimizing resources

Direct Effect on Emissions

Increased density and restricted access to pasture are common features of intensive systems. On the one hand, increased density is associated with increased productivity. On the other hand, restricted pasture access (confinement) decreases the proportion of energy used for maintenance. Additionally, confinement allows for capturing excreta, which in general terms decreases N_2O emissions.

Reducing GHG emissions in intensive systems can also be achieved through additional factors such as improving diet digestibility, since this type of housing involves a diet unrelated to grazing (high-fiber forage), and is typically based on concentrated feeds.

Cross Effects

For efficient GHG mitigation, high density must coincide with an increase in the food supply, as increased density alone is expected to reduce production and increase GHG emission intensity per animal. Additionally, if density in grazing systems reaches a threshold (which varies with the pasture ecosystem), it can exceed the capacity of pastures to act as a carbon sink and cause the opposite effect.

Additionally, emission reductions are primarily obtained in relative calculations of emissions based on the production unit; if calculations are based on area, increased density results in a relative increase in emissions.

Benefits

Increased density can compromise animal welfare because of increased competition for resources, resulting in greater aggression and more social stress, which can compromise productivity. It requires using more facilities, with the associated costs.

Technological Level

Currently available.

Measure 3.5
Increase Longevity

Brief Description

Increasing the lifespan of breeding females (while remaining within tolerable production and health parameters) helps to reduce the number of replacement animals needed. Replacement stock consume resources and emit greenhouse gases during their unproductive period, increasing herd emissions.

Replacement stock consume resources and emit greenhouse gases

Direct Effect on Emissions

Total herd emissions are reduced by having fewer unproductive animals, which consume fewer resources and generate less CH_4 and manure. Depending on the current longevity on the farm, the margin for improvement and emission reduction is variable, but falls within a medium range.

Cross Effects

This replacement measure would not affect other sources of GHG emissions, but would improve animal welfare. Any reduction in resource consumption and manure production would mitigate pollution from other gases, water, and soil.

Benefits

If the optimum is reached, this measure should improve the farm's economic productivity by reducing resource consumption.

Technological Level

Currently available.

Measure 3.6
Improve Fertility

Brief Description

Increasing the fertility of breeding females helps reduce the number of suckler cows needed in the herd to maintain a given level of production. Unproductive animals that do not give birth in a timely manner consume resources and emit greenhouse gases during their unproductive periods, increasing herd emissions.

Increasing the fertility of breeding females helps reduce the number of suckler cows

Direct Effect on Emissions

Reducing unproductive animals within a herd lowers overall emissions by decreasing resource consumption, methane (CH_4) output, and manure production. Depending on the current fertility on the farm, the margin for improvement and emission reduction is variable, but falls within a medium range.

Cross Effects

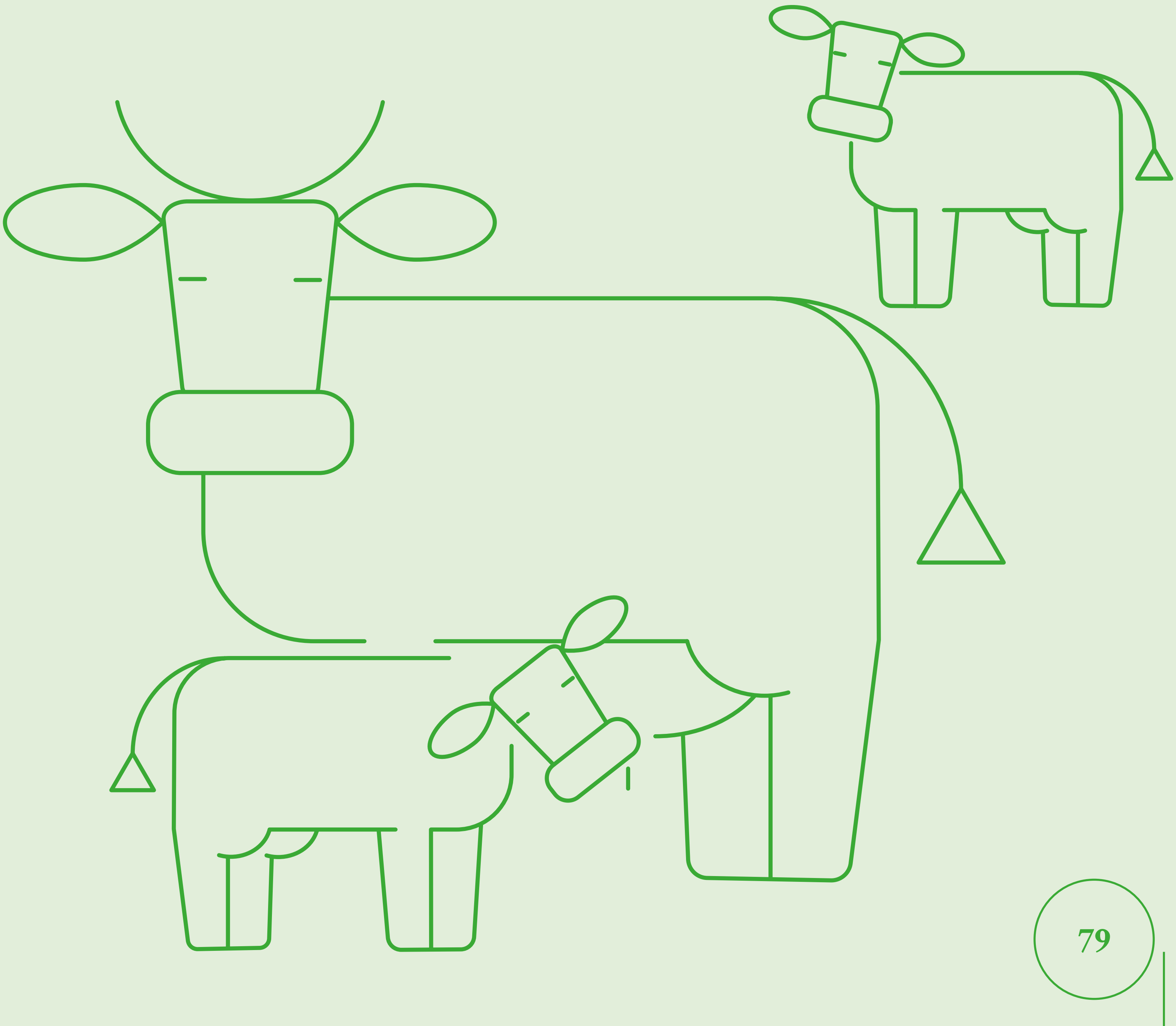
Enhanced herd efficiency, achieved by minimizing unproductive periods and animals, diminishes resource use and manure output per production unit, potentially mitigating other pollution sources.

Benefits

Boosting fertility offers a cost-effective strategy with substantial benefits, enhancing both farm profitability and reducing greenhouse gas emissions.

Technological Level

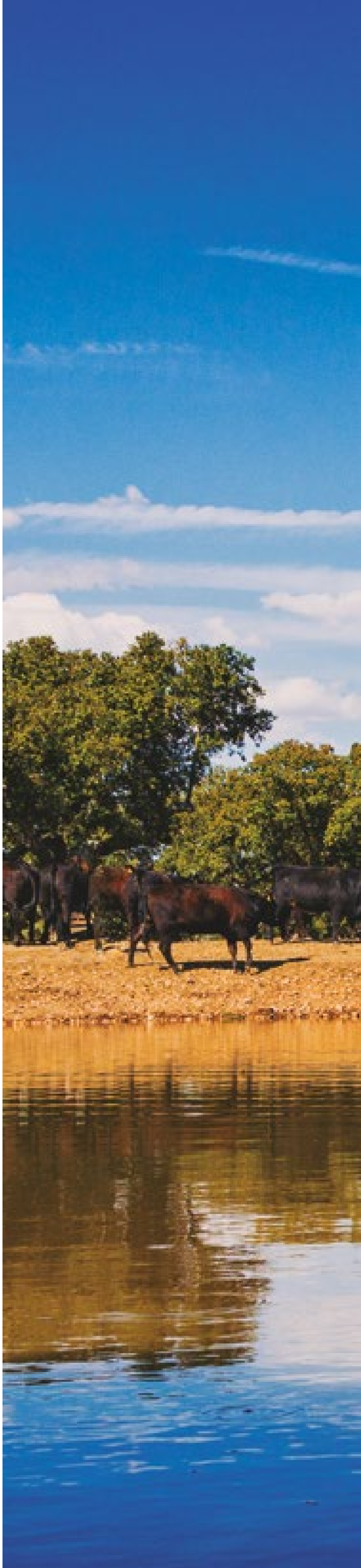
Currently available.



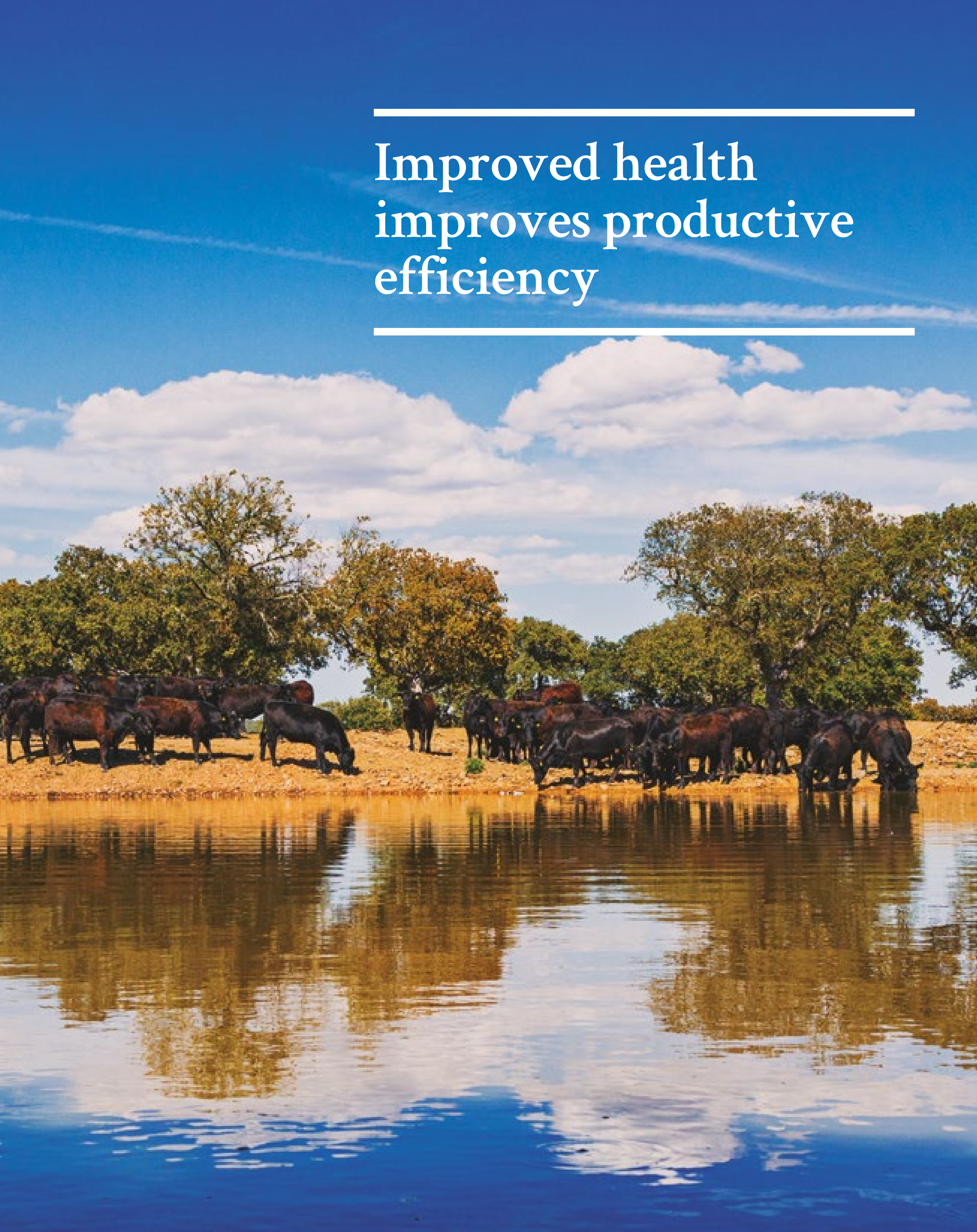
Measure 3.7
Improve Health

Brief Description

Health problems such as diseases and injuries increase the number of animals needed to produce the same amount of product. Improved health increases herd productivity, allowing more food to be produced with fewer animals. A healthy herd maximizes its productive capacity by optimizing resources and reducing waste.



Improved health improves productive efficiency



Direct Effect on Emissions

Poor livestock health and physical condition lead to lower feed intake, reduced ability to digest feed, and higher energy requirements for maintenance. This can lead to an increase in the involuntary culling rate, which increases emission intensity.

Additionally, better health can reduce the replacement rate due to injuries and diseases, likely extending the average productive life of the herd. Increased longevity as a means of improving productivity and reducing GHG emissions is addressed in another section of this document.

Improved animal health also improves production, increasing resource use efficiency and enabling the full use of all animal by-products, which also improves efficiency.

Cross Effects

As with other measures, improving overall herd efficiency reduces emissions of other gases and pollutants on the farm. Improved health also increases animal welfare.

Benefits

Improved health has a positive impact on animal productivity, increasing the productivity of the farm.

Technological Level

Currently available.

4 Manure Management

Measure 4.1
Liquid Manure:
Covering Slurry Tanks

Brief Description

Slurry tanks from housing systems without bedding are significant sources of CH_4. Covering these tanks prevents uncontrolled emissions of this gas. This technique works best when the cover is completely impermeable, and the tank is equipped with a gas recovery system or a pilot light that burns the gases produced, preventing damage to the cover. If the cover is not impermeable (e.g., naturally forming crusts or the addition of organic covers such as straw), the effect is less certain.

Covering slurry tanks reduces uncontrolled CH_4 emissions

Direct Effect on Emissions

If the cover is impermeable, CH_4 can be captured, which can then be burned to form CO_2 (a gas with 24 times less greenhouse effect potential than CH_4). The biogas can also be used for energy generation. If the cover is semi-permeable, N_2O emissions may increase.

Cross Effects

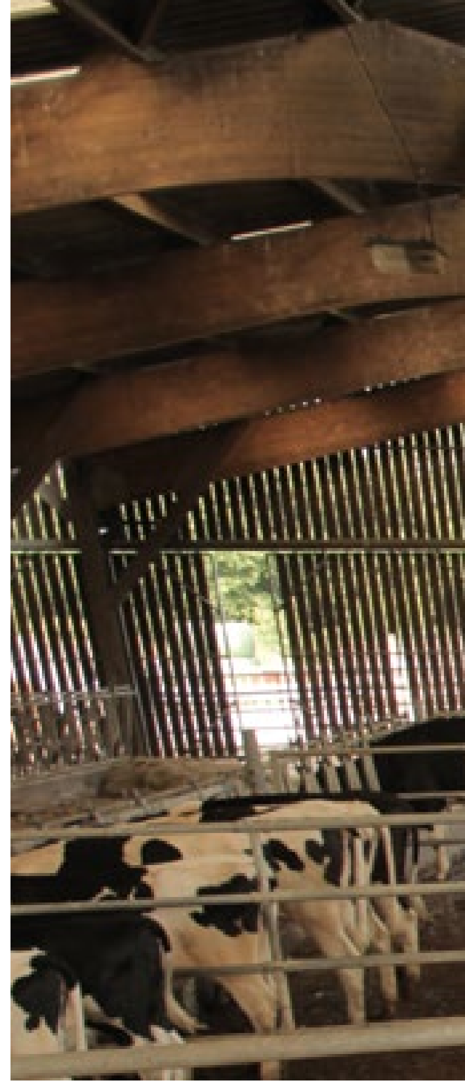
Reducing nutrient loss from the slurry increases its capacity as a fertilizer, potentially reducing the use of synthetic fertilizers. However, increasing the nitrogen content of the slurry may increase N_2O emissions during field application if preventative measures are not taken. NH_3 emissions and odors are reduced.

Benefits

This is a high-cost measure, especially for large tanks.
It should not be prioritized.

Technological Level

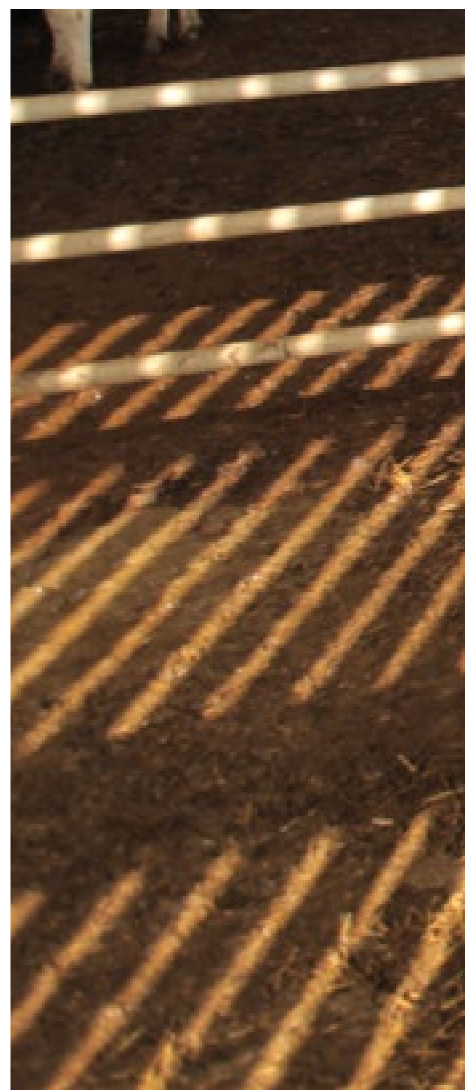
Currently available.



Measure 4.2
Solid Manure:
Bedding Removal Frequency

Brief Description

Deep bedding (storage for long periods) can cause higher N_2O and CH_4 emissions, as more degradable material accumulates and becomes compacted (lack of oxygen). Removing the bedding frequently (e.g., at least once a month) would prevent these gases from being emitted indoors.



Removing the bedding frequently would prevent N_2O and CH_4 emissions

Direct Effect on Emissions

CH_4 emissions decrease because it is more difficult for the necessary anaerobic conditions to develop, and frequent removal limits emission time. Solid manure emissions are inherently low, so this measure yields only modest reductions in farm emissions. Similarly, N_2O emissions are reduced due to substrate scarcity and hindered denitrification. The reduction potential remains uncertain due to the high variability of N_2O emissions.

Cross Effects

This measure can also effectively reduce NH_3 emissions and increase the fertilizer value of slurry. The problem of these emissions is transferred to manure piles, where emissions that would normally occur on farms with less frequent bedding removal may continue. To avoid this, frequent removal should be accompanied by proper management of stored manure (composting).

Benefits

There is no added installation cost, but there is an operating cost: more work and energy are required for frequent removal.

Technological Level

Currently available.

Measure 4.3
Solid Manure: Storage

Brief Description

How solid manure is stored after it leaves the farm has little effect on gas emissions. However, storage on a concrete surface or compacted, impermeable soil is recommended to prevent potential environmental pollution. In both cases, runoff should be collected in a gutter and stored in a designated tank. The manure pile should be covered, and the manure itself can be covered with straw or flexible plastic to prevent direct contact with the air.

Manure should be stored on an impermeable surface

Direct Effect on Emissions

Reduced gas emissions result from preventing direct contact between manure and the air, which is where CH_4 is released. This emission decreases substantially below 10°C and increases above 25°C. Assessments have been made of the impact of manure management, estimating the percentage reductions in emissions that are achieved. When manure is kept on impermeable ground with a drainage system, emission reductions range from 0% to 3%. If the manure is covered with straw or with UV-stabilized plastic, emission reductions range from 2% to 5%.

Cross Effects

Protecting manure piles with a cover to prevent direct sunlight, placing them inside a shed, or covering the manure surface reduces NH_4 emissions. Storing manure on compact or impermeable surfaces and collecting leachate reduces the risk of aquifer contamination.

Benefits

Concreting the manure pile floor, constructing a gutter and a tank, and adding a cover have an investment cost that is only partially offset by the increased fertilizer value of the manure.

Technological Level

Currently available.

Measure 4.4
Liquid Manure: Solid-Liquid Separation

Brief Description

Farms with systems for collecting liquid manure can install systems to separate the solid and liquid fractions, allowing for different management of the two. This includes a wide range of technologies that allow for separating the solid components of the slurry (feces and bedding) from the liquid phase (water and dissolved elements) to a greater degree. The degree of separation depends on the technology used (more expensive technology leads to better separation). For this to be effective, it must be done as soon as possible, preferably on freshly excreted slurry or slurry that has been stored for a short time.

Ideally, separation should be done as soon as possible, on freshly excreted manure

Direct Effect on Emissions

While separation treatment itself does not directly alter emissions, it enables targeted processing of the separated phases for overall gas emission reduction. Composting the solid phase, with nitrous oxide (N_2O) emission risk, and reducing organic matter in the liquid phase to minimize methane (CH_4) from anaerobic fermentation in storage, are possible. Results vary based on the separator employed, but this system can significantly lower CH_4 emissions.

Cross Effects

Elevated mineral nitrogen concentration in the liquid phase may amplify ammonia (NH_3) emissions, potentially increasing secondary nitrous oxide (N_2O) emissions. Mitigation strategies, such as rapid application and soil incorporation of the liquid phase, should be implemented to minimize NH_3 release.

Benefits

Two-phase manure management, tailored to distinct characteristics, enhances agronomic efficiency. The compostable solid phase elevates fertilizer product value. However, due to the high equipment costs, this approach is best suited for medium to large-scale farms.

Technological Level

Currently available. A wide variety of separators are available.

Measure 4.5
Maintain a Crust in Slurry Tanks

Brief Description

Slurry pit surface crusts, of varying thickness, have demonstrated efficacy in reducing ammonia (NH_3) emissions and odors by limiting atmospheric contact and air circulation. Optimal crust morphology and formation, influenced by factors such as bedding materials (sawdust, straw, etc.), nutrition, pit filling methods (upper or lower), filling frequency, and weather, remain largely uncharacterized. While the precise mechanisms are unclear, crust formation is believed to be modulated by these key variables.

The crust prevents contact between the slurry and the atmosphere

Direct Effect on Emissions

CH_4 emissions can be reduced by the creation of aerobic zones in the top few centimeters of the surface, where methanotrophic bacteria convert CH_4 to CO_2. Conversely, the measure can increase N_2O emissions due to the creation of these aerobic and anaerobic zones, which result in nitrification and denitrification.

Cross Effects

Slurry storage with sufficient crust formation can diminish ammonia (NH_3) emissions by up to 60%, enhancing the slurry's fertilizing capacity through reduced nitrogen loss. This translates to decreased reliance on synthetic fertilizers and necessitates optimized field slurry management to minimize both NH_3 and nitrous oxide (N_2O) losses.

Benefits

There is no added installation cost.

Technological Level

Currently available.

Measure 4.6 Composting

Brief Description

Composting is an aerobic treatment applied to manure piles, the final product of which is a stabilized organic fertilizer called compost. The solid fractions from solid-liquid separation of slurry can also be composted. The main benefits of composting for livestock farms are (i) reducing the volume of organic material to be managed (storage and application), (ii) obtaining a product with homogeneous physicochemical characteristics, (iii) increasing nutrient concentrations, (iv) effectively reducing pathogens, and (v) reducing odor.

Composting increases the fertilizer value of manure

Direct Effect on Emissions

Compared to standard solid storage, this system halves CH_4 emissions (which are a minor source of emissions on farms with these characteristics). N_2O emissions are not significantly affected compared to the same reference system. Because the final product (compost) is a stabilized fertilizer in terms of nitrogen (high concentration of slow-release organic N), N_2O emissions after field application are significantly reduced, potentially offsetting emissions from the composting process.

Cross Effects

Composting is primarily associated with increased NH_3 emissions due to the mineralization of organic N during the composting process. NH_3 emissions can account for up to 45% of the initial nitrogen content in the manure. N_2O emissions due to nitrification and denitrification have also been reported, but their magnitude during composting is significantly lower than NH_3 emissions. Nitrogen emissions can be significantly reduced by covering the pile to limit internal air transfer, avoiding excessive turning, controlling the aeration system, applying structuring agents to improve the C/N ratio, or compacting the manure pile.

As previously mentioned, the stabilized nitrogen content of compost, characterized by a high concentration of slow-release organic nitrogen, substantially mitigates ammonia (NH_3) emissions.

Benefits

There are different composting systems, and their costs can vary considerably. The simplest and cheapest systems are open-air composting systems with mechanical turning or forced aeration. Closed systems with or without mechanical turning, or reactor-based systems (horizontal, vertical, or tunnel), provide better control of composting conditions, but at a higher cost. Livestock farms interested in composting manure or the solid fraction of slurry should analyze the cost-benefit ratio for each case. One strategy for reducing costs is to create a composting network in which different farms participate. Because of its physical properties, stability, and organic form of nitrogen, compost is an organic fertilizer with added economic value compared to untreated manure.

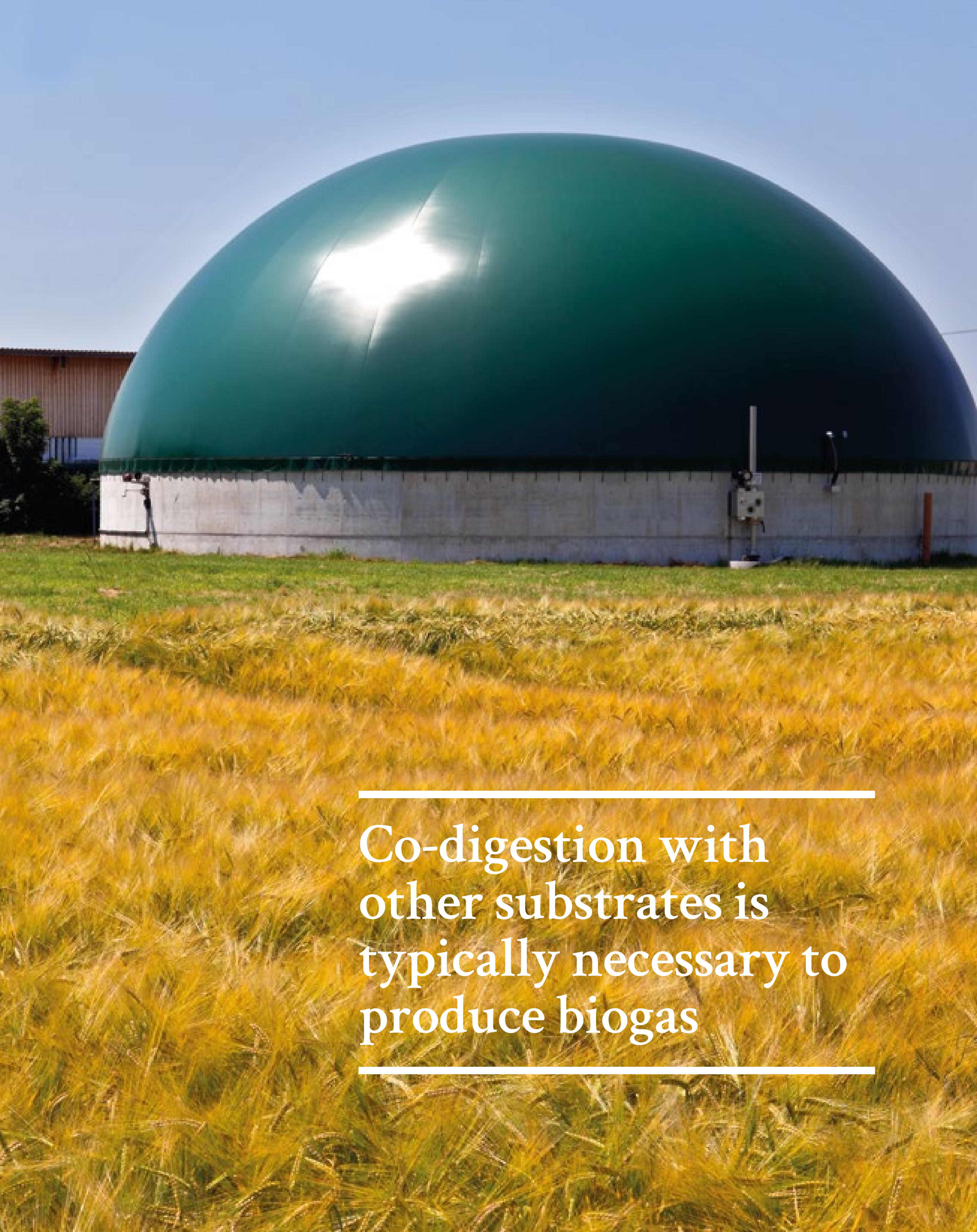
Technological Level

Currently available.

Measure 4.7
Anaerobic Digestion

Brief Description

Anaerobic digestion, a controlled manure treatment, maximizes methane production for energy generation through combustion, often in cogeneration systems producing heat and electricity. Co-digestion with complementary, locally sourced substrates is generally required to optimize biogas output.



Co-digestion with other substrates is typically necessary to produce biogas

Direct Effect on Emissions

Anaerobic digestion mitigates methane emissions from liquid manure by channeling them into controlled production. This process offers a clean, renewable energy source, yielding biogenic CO_2, unlike fossil fuel combustion. Prompt anaerobic digestion of slurry is crucial to prevent uncontrolled methane release, potentially achieving substantial emission reductions. However, this method is ineffective for reducing methane emissions from solid manure.

Cross Effects

The anaerobic digestion process does not reduce the nitrogen load of the manure and does not necessarily reduce ammonia emissions. Managing anaerobic digestion requires additional oversight from qualified personnel, both for the digestion process itself and for managing the substrates and the effluent or digestate.

Benefits

Economic feasibility hinges on energy value, which fluctuates by country. Currently, in Spain, this technique's viability is limited, making it practical only for larger farms or collectives capable of managing the substantial investment and ongoing maintenance, encompassing both equipment and skilled personnel.

Technological Level

This is a mature technology that is available on the market.

Measure 4.8
Use of Inhibitor Additives

Brief Description

The microbiological processes that produce N_2O can be modified through the use of chemical additives. There are two types of inhibitor additives:

Nitrification inhibitors: These inhibit the oxidation of NH_4+ to NO_3-. Animals that receive these inhibitors in their feed excrete them without the inhibitors affecting their urine, allowing the inhibitors to function on the excreta.

Urease inhibitors: These prevent the conversion of urea to ammonium, enhancing the potential to reduce NH_3 losses from volatilization. These inhibitors have been applied to both soil and stored manure.

The microbiological processes that produce N_2O can be modified through the use of chemical additives

Direct Effect on Emissions

Using nitrification inhibitors reduces urine-associated N_2O emissions by more than 60%, and can increase pasture production when used with grazing animals. Urease inhibitors reduce NH_3 volatilization by preventing NH_3 from forming; this also reduces N_2O emissions, as NH_3 is a precursor to N_2O.

Cross Effects

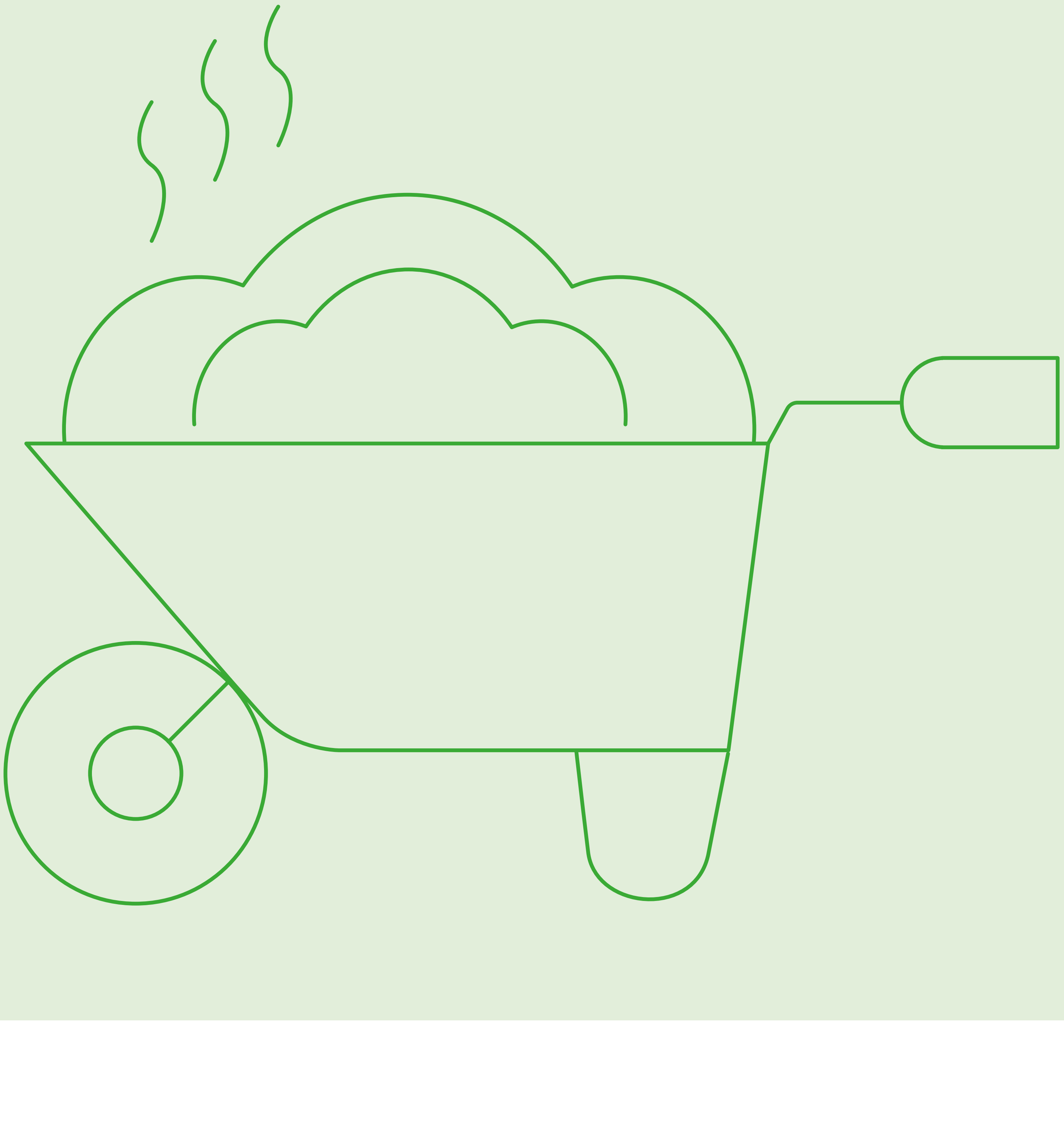
Nitrification inhibitors directly reduce NH_3 emissions but can increase available ammonium in the soil, increasing volatilization of this gas in the long term.

Benefits

In principle, the only cost increase is the purchase of the additive.

Technological Level

Currently available.



Measure 4.9
Solid Manure Application

Brief Description

Manure must be applied to the soil using appropriate machinery. If a manure spreader or rotary trailer is not available, the manure should be spread with a cultivator or harrow. Regardless of the application technique used, the manure must be buried or mixed with the soil at the time of application or within four hours. Burying it after 12 hours results in significant nitrogen loss due to volatilization as N_2O.

Other precautions for manure application include the following:

- Do not apply to wet soil or when rain is likely, as this facilitates N_2O release. The same applies to flooded, snowy, or icy areas.
- Analyze the characteristics of the land where it is to be applied, especially slopes or proximity to waterways, springs or wells, to prevent runoff or washout.
- Apply manure when required by crops, at the appropriate dose, as recommended elsewhere in this guide.

Manure must be buried or mixed with the soil as soon as possible

Direct Effect on Emissions

The recommendations in this section reduce greenhouse gas emissions by reducing N_2O emissions, as described.

Cross Effects

Applying manure correctly prevents contamination of waterways by runoff that may occur on slopes or near waterways.

Benefits

Implementing these good practices does not increase application costs; on the contrary, more nitrogen is retained in the soil, improving the fertilizer capacity of the manure.

Technological Level

Currently available.

5 Pasture and Crop Management

Measure 5.1
Increase Grazing Time

Brief Description

Extending animals' outdoor time results in increased pasture manure deposition, facilitating nutrient return to the soil via manure and urine. Furthermore, grazing reduces the need for supplemental cereals and soybeans, thereby lowering emissions associated with their production and transportation.

Grazing reduces the need for supplementation with concentrates

Direct Effect on Emissions

As long as the stocking density is appropriate for the pasture, increasing grazing time allows for even manure distribution across the pasture, reducing CH_4 and N_2O emissions compared to storing and treating manure and/or slurry and applying it during field fertilization. It is important to control grazing intensity, as high animal load can lead to higher N_2O emissions. This is because when the soil is compacted by trampling, the feces are more exposed to environmental conditions. This effect is even more unfavorable in humid soil and warm temperatures, which favor anaerobic microbial growth and, therefore, CH_4 and N_2O emissions.

While forage-based diets typically correlate with elevated rumen methane emissions, the potential mitigating effects of high-quality forage consumption, driven by animal selectivity, and the presence of tannins in various shrub species warrant careful consideration.

Cross Effects

Ammonia (NH_3) emissions are low during grazing because the soil quickly absorbs total ammoniacal nitrogen (TAN) in urine deposited directly onto the pasture. This also hinders contact between the urease in the feces and the urea in the urine, slowing ammonia emissions.

The proportion of NH_3 emissions from housing and manure or slurry application decreases as grazing time increases.

Grazing systems also have advantages in terms of sustainability and efficiency, such as using marginal land that does not compete with agriculture, improving animal welfare, promoting nutrient cycling in the soil, and acting as a greater carbon sink than cut and mowed meadows. Using stubble and fallow land would reduce fossil fuel use (for cleaning farms) and inorganic fertilizer use (from grazing). This would also promote the image of livestock farming that is more connected to the land and the "naturalness" of livestock systems.

Benefits

Implementing appropriate grazing plans requires continuous analysis and management of available resources, which requires labor. In terms of manure management, this saves energy by eliminating emissions associated with handling, treating and transporting manure stored on the farm.

Technological Level

Currently available.

Measure 5.2
Create a Fertilizer Plan

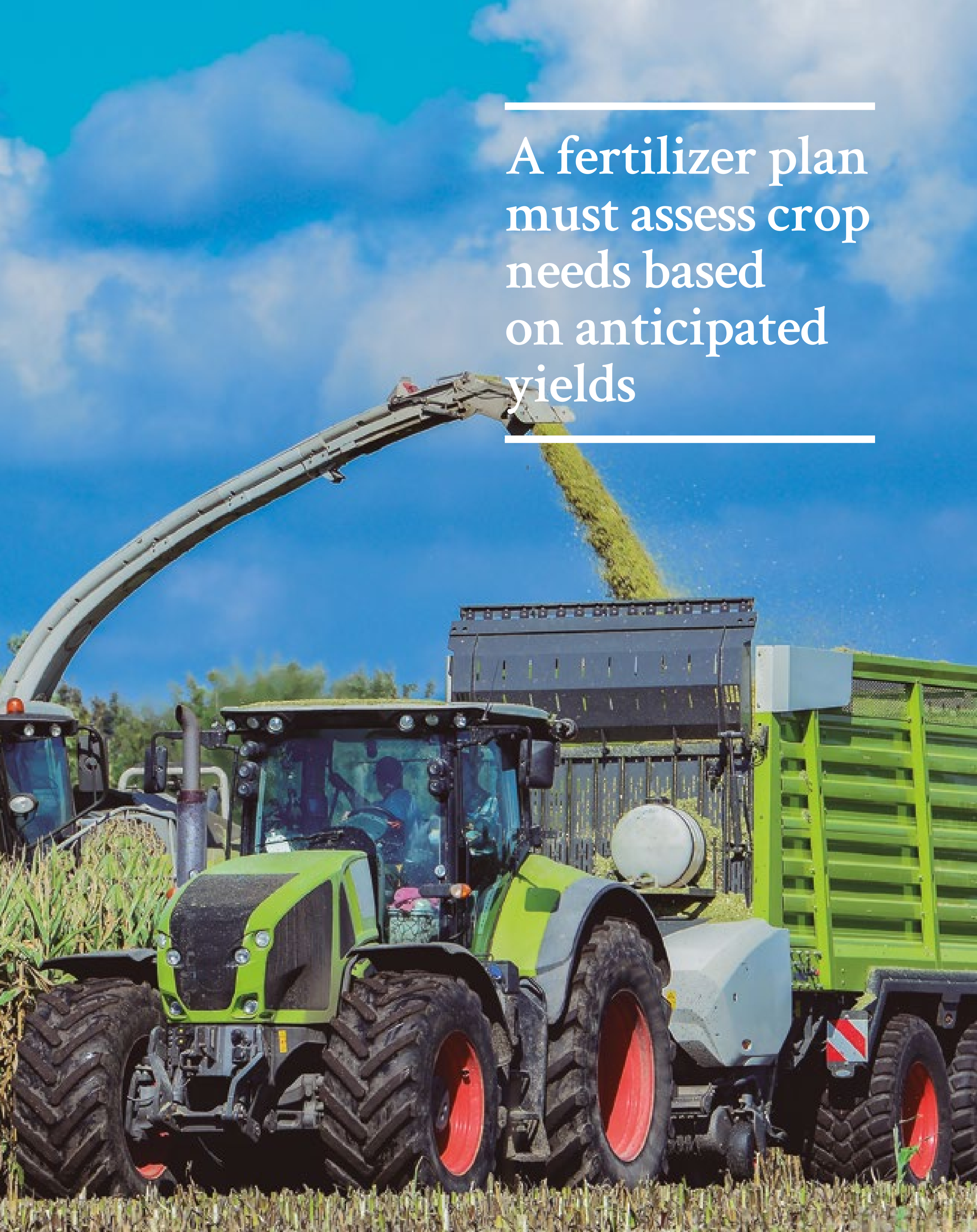
Brief Description

Nitrogen fertilization of forage or grain crops has productive effects on both the nutritional value of fresh grass and animal nutrition. However, applying more fertilizer than crops need leads to excess nitrogen, reducing nitrogen use efficiency and increasing nitrogen loss to the air and water.

In terms of gaseous pollutants, nitrogen fertilizer applications are associated with nitrous oxide (N_2O) and NH_3 emissions.

Effective fertilization requires a plan that assesses existing soil nutrients and crop nutrient needs, based on anticipated yields, to determine appropriate application rates and types.

A fertilizer plan must assess crop needs based on anticipated yields



Direct Effect on Emissions

N_2O emissions are reduced when fertilizer applications are in line with crop needs. Overapplication leads to nutrient loss in the form of emissions, while underfertilization reduces productivity. The fertilizer plan should account for grazing contributions, and prioritize the use of organic fertilizer produced on the farm over mineral nitrogen fertilizer.

Cross Effects

NH_3 emissions and nitrate leaching losses are also reduced when fertilizer doses are adjusted to crop needs.

Benefits

This technique involves costs for soil testing and fertilizer recommendations from advisors. The economic benefit comes from adjusting fertilization and its associated costs to the actual needs of the crops.

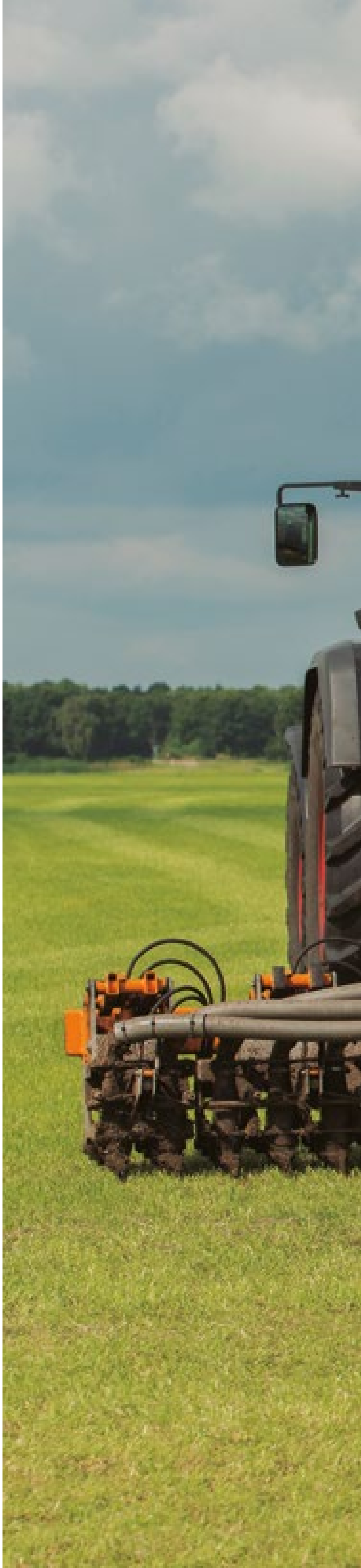
Technological Level

Currently available.

Measure 5.3
Trailing Hoses

Brief Description

This method entails the targeted application of slurry via pipes directly onto the soil surface, minimizing ammonia emissions. This technique, a permitted alternative to broadcast spreading, aims to reduce the atmospheric exposure of the slurry.



The goal is to reduce the contact surface between the slurry and the atmosphere

Direct Effect on Emissions

While this technique does not directly alter greenhouse gas emissions, it indirectly lowers nitrous oxide (N_2O) emissions. Its precision allows for reduced application rates, minimizing direct N_2O release. Additionally, by lowering ammonia emissions, it further decreases indirect N_2O formation. Consequently, the overall potential for greenhouse gas emission reduction is modest.

Cross Effects

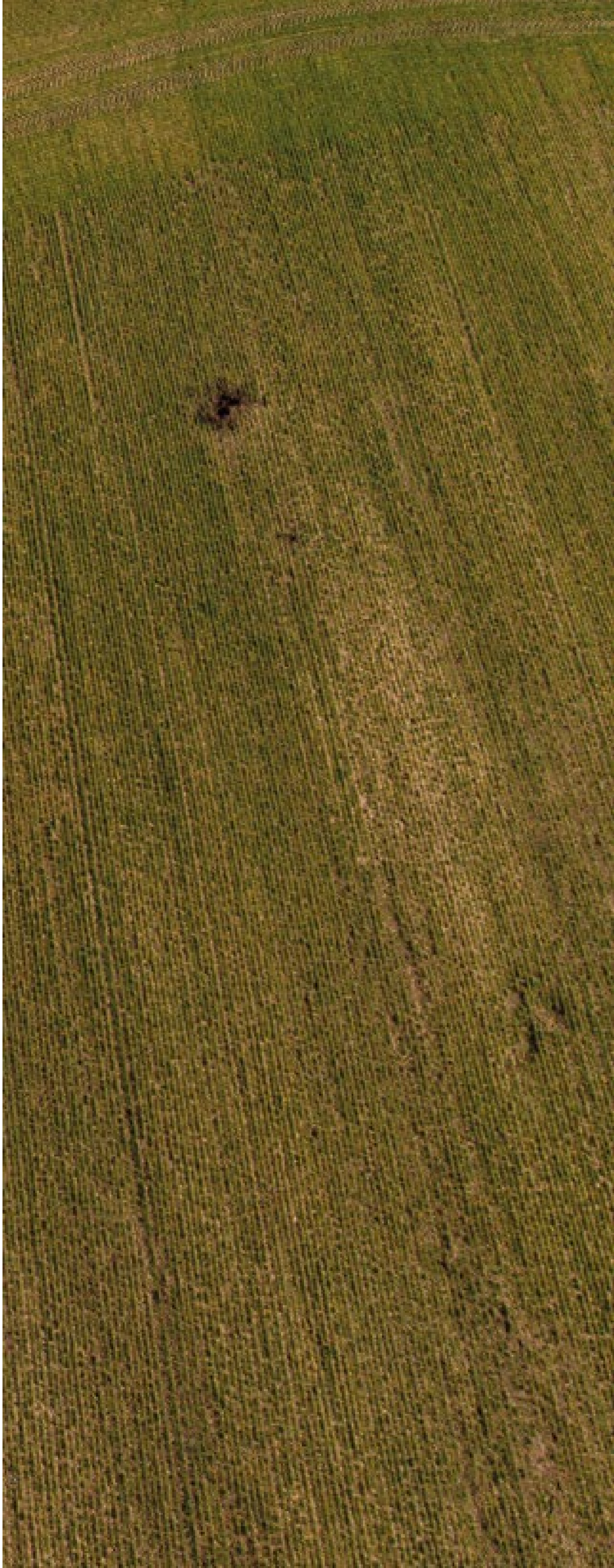
This technique offers significant positive cross-benefits, notably reduced ammonia emissions (its primary goal), diminished odors, and improved fertilizer dose precision. However, its application is limited to specific crops, primarily herbaceous, and particular growth phases. While unsuitable for woody crops, it proves effective for herbaceous cover crops due to its minimal soil disturbance.

Benefits

With the restriction of broadcast slurry application, application using trailing hoses is likely the best available alternative. This allows for better use of slurry fertilization capacity, reducing fertilizer consumption. Small farms likely cannot afford to own this technology, so shared or rented use is recommended.

Technological Level

Available on the market.

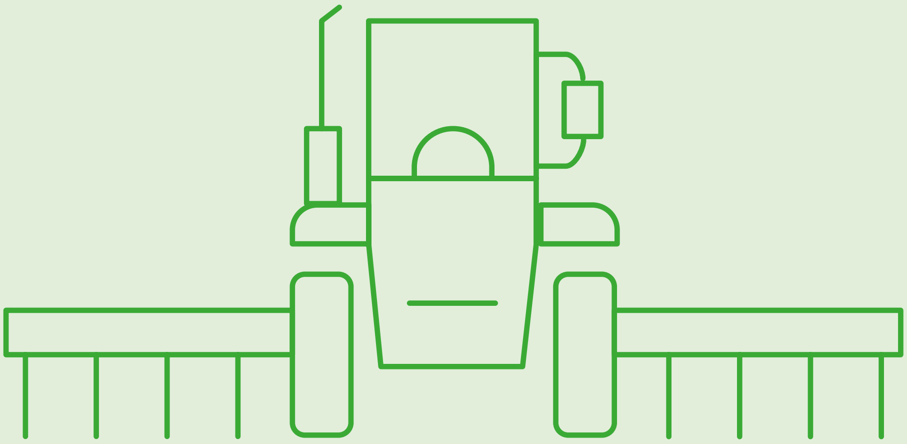


Measure 5.4
Injection

Brief Description

This method delivers liquid manure directly into soil furrows, created by a plow to varying depths, via attached hoses. Designed primarily to curb ammonia emissions, it is a permitted alternative to broadcast spreading. However, its implementation is challenging in clay-rich soils.

Injection is challenging to use in clay-rich soils



Direct Effect on Emissions

This technique reduces indirect N_2O emissions by significantly reducing ammonia emissions. However, direct N_2O emissions can increase when incorporating slurry superficially compared to injecting it deeper into the soil.

This technique offers limited greenhouse gas emission reduction. Furthermore, emission levels are highly susceptible to environmental fluctuations, particularly soil moisture.

Cross Effects

The greatest added value of this technique is the possibility of localized manure application at adjustable doses, combined with a significant reduction in ammonia emissions.

Benefits

Compared to trailing hoses, this technique reduces emissions to a greater degree, but incurs higher energy costs and increased machinery wear due to furrow creation. It also enhances slurry fertilization efficiency, reducing reliance on commercial fertilizers.

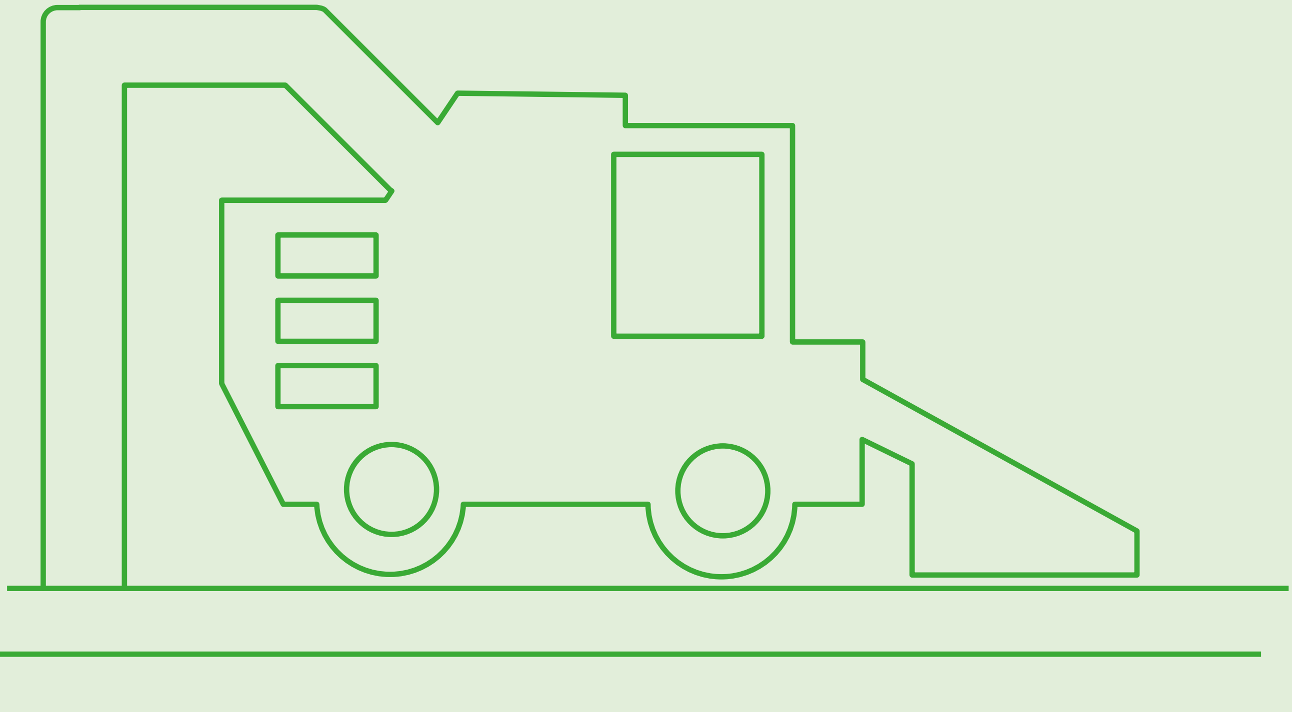
Technological Level

Available on the market.

Measure 5.5
Improve Soil pH

Brief Description

Liming can improve the quality of acidic soil by adjusting the pH to the levels required by farm crops, offering greater nutrient availability, better soil structure, and higher infiltration rates.



Direct Effect on Emissions

The final step in the soil denitrification pathway, the reduction of N_2O to N_2, depends largely on soil pH. This pathway is progressively inhibited when the soil pH falls below 7. Thus, liming acidic soils to a pH near 7 makes N_2O reduction more efficient, decreasing direct N_2O emissions from the soil.

This measure has been shown to reduce N_2O emissions in acidic soils by 49–66%.

Cross Effects

The benefits of liming acidic soils include greater nutrient availability, better soil structure, and higher infiltration rates, resulting in greater productivity and lower risk of water contamination.

Benefits

This measure has very low execution costs and significant benefits.

Technological Level

Currently available.

Measure 5.6
Establish Legume-Based Grasslands

Brief Description

Cultivating legume-rich grasslands enhances pasture quality and diminishes fertilizer requirements. Legumes naturally fix nitrogen, enriching soil fertility and promoting pasture growth. Opting for increased legume coverage over nitrogen fertilization is particularly advantageous during droughts.

Legumes enhance pasture quality

Direct Effect on Emissions

Animals grazing on legume-rich pastures produce fewer CH_4 emissions than those grazing on grass-rich pastures. This reduction in emissions can be attributed to the presence of condensed tannins, a lower proportion of fiber, greater dry matter intake, and faster passage through the rumen.

The presence of legumes reduces N_2O emissions in grazing systems because atmospheric nitrogen is fixed in the rhizomes of legumes, preventing it from reacting to form N_2O. In optimized grass-legume mixtures, grasses obtain nitrogen from the legume roots, reducing reliance on external fertilization.

The presence of legumes in pastures contributes to carbon fixation, which is influenced by nitrogen availability.

This practice can reduce CH_4 emissions by up to 20%.

Cross Effects

Reducing the need for external fertilizers reduces the farm's energy demands, contributing to lower upstream emissions and a smaller carbon footprint.

Additionally, some legume species contain secondary compounds that can improve animal health.

Certain legume varieties necessitate periodic reseeding, potentially offsetting greenhouse gas reduction benefits due to tillage-induced soil carbon release. Furthermore, limited persistence and extended establishment phases can present significant agronomic challenges.

Benefits

In addition to the environmental benefits, this practice can reduce livestock feed costs by supplementing a portion of the feed supply. However, this reduction may be offset in the first year by planting costs.

Technological Level

Currently available.

Measure 5.7
Replace Inorganic Fertilizers with Organic Fertilizers

Brief Description

This approach substitutes synthetic fertilizers with organic amendments, green manures, or nitrogen-fixing crop rotations, optimizing nutrient cycling and eliminating synthetic fertilizer production costs. These practices align with the principles of a circular economy. Successful implementation requires a tailored fertilization plan with precise application rates, aligned with pasture needs and timing, and application systems that minimize nutrient loss.

This measure optimizes nutrient cycles

Direct Effect on Emissions

This measure reduces direct N_2O emissions, especially in humid climates. In general, an estimated 1.6% of nitrogen applied using synthetic fertilizers in humid climates is emitted as N_2O, compared to 0.6% for other nitrogen inputs (2019 IPCC Guidelines). In dry areas, an estimated 0.5% of nitrogen is emitted as N_2O, whether from synthetic fertilizers or manure and slurry.

Cross Effects

This measure is considered highly beneficial because it reduces emissions and saves energy by avoiding the production of synthetic fertilizer (upstream emissions). It also avoids emissions from transporting manure and slurry if they are applied to other land.

Benefits

This measure reduces costs by replacing synthetic fertilizers with organic fertilizer sources, promoting a circular economy with both environmental and economic benefits.

Technological Level

Currently available.

Measure 5.8
Use Low-Emission Inorganic Fertilizers

Brief Description

N_2O emissions from soils can be reduced by improving the crop's ability to take up nitrogen and compete with other processes that lead to nitrogen loss in the soil-plant system. This can be done by using slow-release fertilizers, using ammoniacal fertilizers instead of nitrate-based fertilizers, using nitrification inhibitors, and combining urea fertilizers with urease inhibitors.

Direct Effect on Emissions

Ammoniacal or urea-based fertilizers reduce N_2O emissions compared to nitrate-based fertilizers. To avoid ammonia emissions, urea fertilizers should be combined with urease inhibitors. Nitrification inhibitors can reduce direct N_2O emissions by up to 50%, but they are less efficient in wetter areas.

Cross Effects

Urea application may result in substantial ammonia emissions as a notable side effect.

Benefits

These fertilizers are typically more expensive, with the exception of urea (although the cost of urease inhibitors must be considered for urea).

Technological Level

Currently available.

Measure 5.9
Implementing Rotational Grazing Strategies

Brief Description

Rotational grazing strategies are used to optimize pasture resource use on farms. These strategies involve dividing the farm into paddocks and creating a grazing schedule that defines when and where a group of animals will graze throughout the year. The animals cannot move to the next paddock until they have adequately grazed the current one. If they have too much space, they become selective in their eating and do not properly utilize the available grasses.

This technique allows grazed paddocks to rest and, if the stocking density is properly adjusted, improves both the quantity and quality of pasture production. It also facilitates significant soil carbon sequestration, considerably improving soil quality.


Rotational grazing allows for significant soil carbon sequestration

Direct Effect on Emissions

Good grazing distribution increases soil carbon content by increasing organic matter and reducing erosion.

Rotational grazing has been shown to contribute to significant soil carbon. An annual growth rate of 0.4% in soil carbon stocks in the top 30-40 cm of soil would significantly reduce atmospheric CO_2 concentrations. Pastures with proper management therefore have significant potential in the fight against climate change. However, carbon sequestration may be limited over time when soil management stabilizes. It is also reversible; if land use is modified again, emissions may increase.

Cross Effects

Increased pasture production reduces the need for supplementary feeding, reducing associated emissions, although increased consumption of these less digestible foods could increase biogenic emissions. This measure has other environmental benefits, such as improving ecosystem services (better soil, land, and landscape management; reduced use of fossil fuels and inorganic fertilizers; reduced fire risk; and improved biodiversity), and can enhance the image of livestock farming among the public and consumers. In the medium to long term, this can improve the landscape and cultural value of these ecosystems and the value of the products obtained.

Benefits

This measure is easily implemented, with primary economic costs stemming from land division via fixed (posts and mesh) or electric fencing, grazing area reduction for animal access, water point installation, and associated labor and technical support.

However, once paddocks are established, farm labor is streamlined, requiring only animal rotation between areas and reducing time spent on feed collection, distribution, bedding, and manure removal. This also decreases reliance on external feed supplements, enhancing farm self-sufficiency and lowering feed expenses.

Technological Level

Currently available.

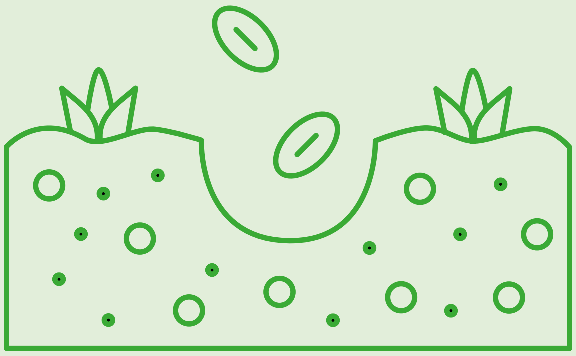
Measure 5.10
Use No-Till or Minimum-Till Techniques

Brief Description

No-till or minimum-till techniques involve direct seeding, leaving more than 30% of the soil surface covered. This preserves year-round soil vegetation and prevents erosion.

An alternative reseeding approach, minimizing soil disruption, involves surface seeding followed by livestock trampling for seed incorporation.

This measure preserves year-round soil vegetation cover



Direct Effect on Emissions

Soil management has a direct influence on CO_2 emissions because it can stimulate CO_2 production and accumulation in the porous soil structure through organic matter mineralization.

Specifically, the mechanical action of tilling breaks down soil aggregates, releasing trapped CO_2 into the atmosphere. Maintaining the soil structure reduces CO_2 loss to the atmosphere and increases soil organic matter, which increases the soil's productive capacity.

Cross Effects

This reduces emissions associated with machinery use and reduces fertilizer use, optimizing productivity and reducing the risk of other pollutants.

Benefits

Replacing traditional tillage with direct seeding does not necessarily involve a significant cost difference.

Technological Level

Currently available.

Measure 5.11
Conserve and Improve Grazing Areas

Brief Description

Conserving and improving grazing areas is a long-term improvement strategy that benefits both livestock and pasture. This measure includes the following:

- A comprehensive grazing improvement plan, maintaining a percentage of legumes.
- Controlling pasture height, targeting approximately 9–16 cm when livestock enter the paddock and removing them when the pasture height drops to 5 cm. This avoids overgrazing and allows for pasture regeneration.
- Improving ecosystem resilience to drought by using techniques that improve soil water holding capacity, such as keyline design, which considers contour lines.
- Increasing plant diversity to ensure productivity under different climatic conditions and/or at different times of the year (different phenologies).
- Producing crops (cereals, legumes, etc.) on grasslands (pasture cropping) or other areas suitable for mechanization.

This is a long-term strategy that benefits both livestock and pasture

Direct Effect on Emissions

When grazing occurs under balanced pasture-livestock conditions with high stocking densities, carbon inputs to the soil result in carbon sequestration. The amount of carbon sequestered depends on the soil type and the type of vegetation, but the measure does offset some of the farm's greenhouse gas emissions.

Grazed areas require reduced agricultural machinery operation and diminished synthetic fertilizer application due to manure's organic nitrogen content. Consequently, optimal grazing management effectively reduces both carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions.

Cross Effects

This practice minimizes fodder conservation needs through direct animal grazing, eliminating energy consumption for harvesting and storage, as well as nutrient losses during storage. This enhances production system efficiency, reducing greenhouse gas emissions and other pollutants per unit produced.

Furthermore, improved pasture availability and quality, a provisioning ecosystem service, are expected to positively impact other ecosystem services, particularly biodiversity enhancement and wildfire risk reduction.

Benefits

In addition to increasing productivity and efficiency, in the short term this measure reduces machinery and energy costs, as well as fodder conservation costs. This measure requires more training for producers, who must understand pasture dynamics, as well as greater dedication or more labor to move the herd between paddocks.

This type of management improves the image of livestock farming among the public and consumers. In the medium to long term, all of this could lead to greater generational turnover, which is a key factor in conserving grazing practices.

Technological Level

Currently available.

Measure 5.12
Conserve and Improve Dehesa and Agroforestry Landscapes

Brief Description

Dehesa, as an agroecosystem, requires a comprehensive approach that balances all its elements and enhances the strengths that lead to emission reduction.

Recommendations include maintaining a balanced stocking density (between 0.15 and 0.3 LU/ha, depending on the plot type), promoting seasonal use of pastures to encourage herbaceous vegetation growth, and diversifying species (sheep, goats, cattle and pigs) to optimize pasture use.

Tree stands must be conserved. Prevent livestock from damaging them, and prune them appropriately, at least every five years for holm oaks and cork oaks.

Clearing scrubland, which is necessary to maintain herbaceous vegetation, should preferably be done using livestock (the most appropriate species or breed depends on the initial state of the pasture) rather than physical or mechanical means (machinery). Avoid massive clearing, and maintain a mosaic landscape.

Forage crops should be rotated on a flexible, diversified 4- to 7-year cycle that improves soil fertility using legumes.

Direct Effect on Emissions

Conserving dehesa or other agroforestry landscapes increases the CO_2 fixation capacity of the tree stands, which must be maintained. Similarly, to ensure the greatest carbon sequestration capacity of dehesa soil, the grazing area must be managed appropriately, as recommended for any grazing area.

Cross Effects

This measure reduces emissions from purchased feed by using forage crops for livestock feed.

Benefits

Growing forage crops for livestock reduces the cost of purchasing feed.

Technological Level

Currently available.

Thank you to all of the companies and people who helped to illustrate and improve this project. It would not have been possible without your help.

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