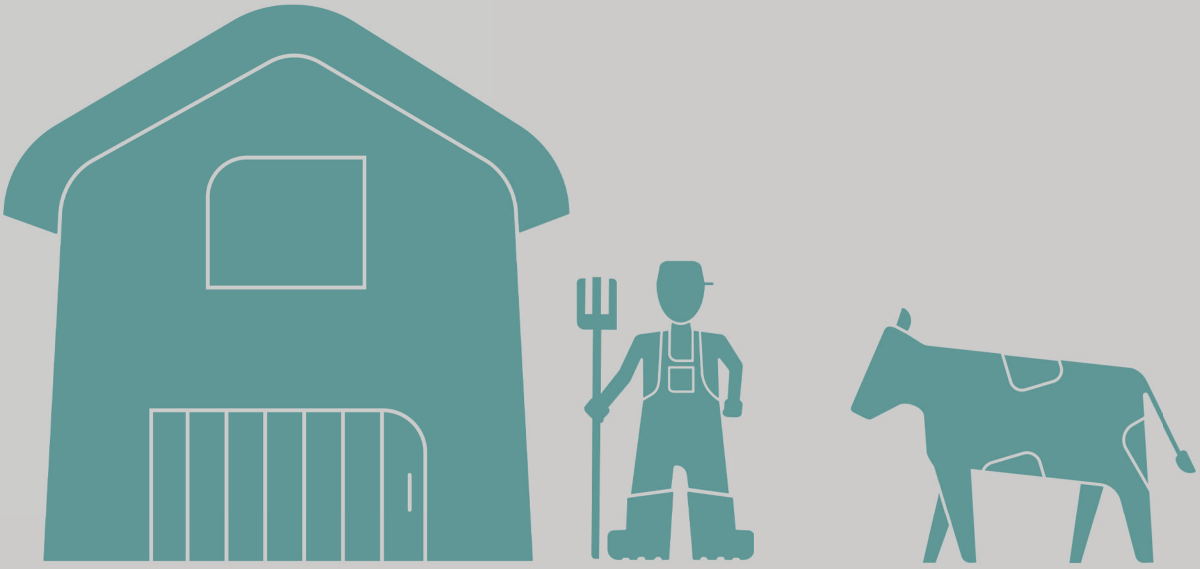
HOW TO REDUCE YOUR FARM'S CARBON FOOTPRINT



FEEDING FATTY ACIDS

Controlling the level of fatty acids within the feed of lactating cows and heifers can produce a significant reduction in your carbon footprint. However, feeding fat to heifers is unlikely to make financial sense. Important consideration should be given to the source of the fat as this can affect both the milk yield and the carbon footprint. The fatty acid content in total fat is usually around 70% in grain and 90% in oilseeds.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

The highest effect on the carbon footprint during milk production comes from methane. This is produced when carbohydrates are digested in the rumen. Fatty acids mixed in ruminant feed decrease methane emissions in multiple ways:

Fats are not digested in the rumen and so do not produce methane

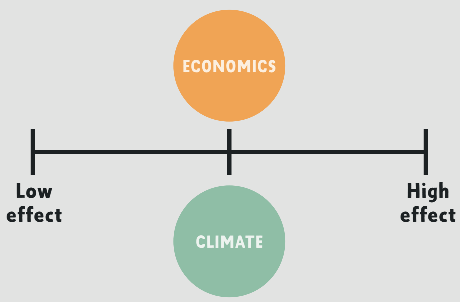
Fat can replace a part of the carbohydrates in the feed as an energy source — therefore, less carbohydrates are digested in the rumen

Fatty acids affect the microorganisms in the rumen by decreasing methane production

HOW BIG IS THE EFFECT?

When adding fat to the ration, the production of methane from the digestion of carbohydrates is reduced by approximately 3,3% per 10 grams/kg DM fat. This is independent of the source of fat (Figure 1).

The overall impact on the carbon footprint will depend on the source of fat being used. For instance, rapeseed products will have a lower carbon footprint compared to palm products. Palm products have a much higher carbon footprint because of the way they are produced, processed and transported.



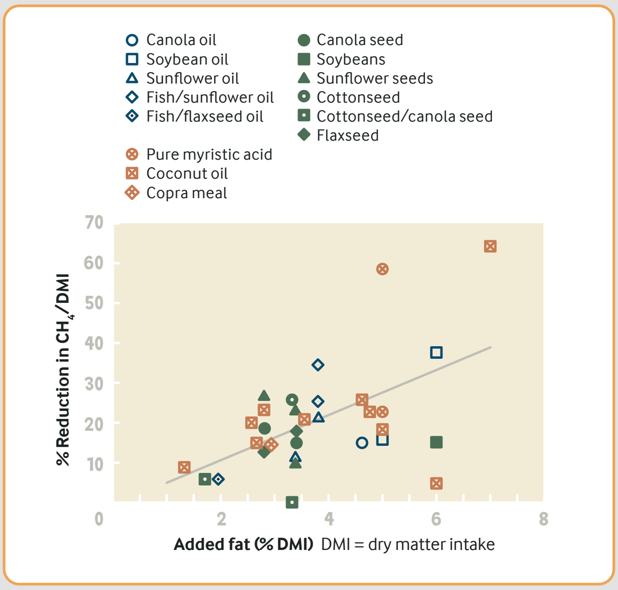


Figure 1: Reduction of methane by adding fat to the diet (Beauchemin et al., 2008)

HOW DO I GET STARTED?

The different sources and prices of fats should be the first consideration. From this you can try to optimise your ration with different fatty acids to see which best meets your requirements. It is recommended that the level of fatty acids does not exceed 45 g/kg DM. If you do not add any fat or feedstuffs with a high content of fatty acids to the ration, the level of fatty acids will usually be around 20 g per kg dry matter.

For a moderate increase to the level of fatty acids by 10–15 g/kg DM, you can use oilseed cakes and similar by-products (with a fat content of around 10%)

To increase fatty acid level by a further 10–15 g/kg DM, you should use whole rapeseed or refined fats

The most climate-friendly way to increase fatty acid levels is by choosing rapeseed. 0.5 kg rapeseed is considered enough to increase fatty acid level by 10 g/kg DM

CASE

In addition to the positive effect on the carbon footprint, feeding fatty acids can also be financially beneficial due to the increase in the energy density of the ration. The financial gain depends on the price and your ability to control fat levels in the ration. Studies in intensive production have shown benefits of £ 0.047 per cow per day.

OPTIMISING PROTEIN SUPPLY

The recommended optimum level of crude protein in TMR feeding is 16%. Often protein is fed at higher levels despite the calculated cow requirements being lower. Although it is believed that it is the higher protein levels that contribute to an increased milk yield, in fact, it is more likely to be the increased energy intake leading to an increased milk yield.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

High-protein concentrates for dairy cattle mostly consist of imported soya and rapeseed products. These products have an increased negative impact on the climate (due to production, processing and transportation) compared to home grown grain and forage. However, the impact is limited when looking at the carbon footprint per energy unit (MJ).

	Soybean meal	Rapeseed meal	Rapeseed cake	Wheat	Clover grass silage	Maize silage
Carbon footprint, g CO_2-equiv. excluding carbon sequestration and LUC (land use change)	76	81	69	61	69	42

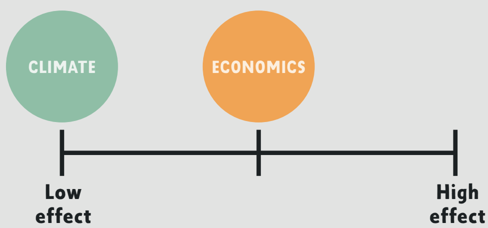
Table 1: Carbon footprint for local produced cereal and roughage and imported soya and rapeseed products given as MJ (NEL20).

HOW BIG IS THE EFFECT?

Feeding more protein than required is inefficient. Reducing the protein fed can have a significant financial benefit as home grown feed or cheaper alternatives could be used.

Including a high energy substitute would result in a higher energy concentration in the diet, lower DM intake and consequently produce less methane through rumen fermentation.

Reducing protein supply will also lower nitrogen excretion. Consequently, ammonia and nitrous oxide excretion from the manure will be reduced. Reducing the protein level from 18%-16% will have a limited impact on the carbon footprint. However bigger gains can be made by optimizing the protein content of diets with a higher starting point (e.g. over 20% crude protein).



HOW DO I GET STARTED?

Aim for crude protein levels in your ration of 16–16.5%. It is important to make sure you are always balancing the needs of the cow with the diet composition

It is important that the energy concentration is kept constant when the protein level is decreased. This is to ensure that the cows still receive the same energy supply.

A second consideration is the availability and cost of alternative proteins.

And thirdly, remember to consider the carbon footprint of your feedstuff. Ideally aim to optimise the ration based on the lowest carbon footprint of the available feedstuffs.

CASE

When we compare two rations with 16% and 18% crude protein in a ration calculation programme, we do not see any major differences in the carbon footprint. In the two example rations 1 kg DM soybean meal was replaced by 0,9 kg DM wheat and 0,2 kg DM beet pulp.

These changes in the ration reduced the carbon footprint by 130 g CO_2-equiv./cow/day, - a 0.4%/cow/day decrease - with a milk yield maintained at 35 kg ECM/cow/day.

HERD REPLACEMENT RATE

Herd replacement rate is the share of your dairy cows that are replaced every year. Lowering the rate will reduce the carbon footprint and it has financial benefits.

There can be a number of reasons why some herds have high replacement rates such as heifers been kept back due to lack of markets, retention of higher number of heifers for genetic gains etc.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Replacement rates contribute to the carbon footprint as heifers produce methane from rumen fermentation as well as nitrous oxide and methane from their manure. Emissions from the feed produced for the heifers is also taken into account.

All these emissions are produced before she has had her first calf. Lowering your replacement rate would reduce the number of heifers required, decreasing the demand for young stock feed. Table 1 illustrates how many heifers are needed at a given herd replacement rate and a given calving age.

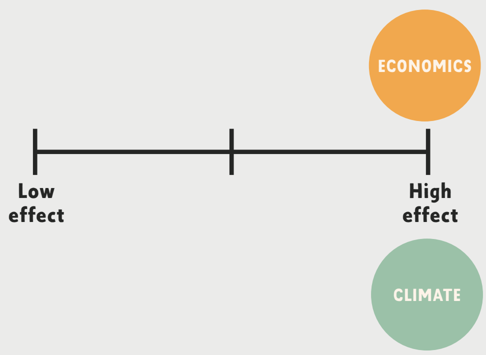
These estimates are based on a herd with 100 cows. If the calving age is 24 months and a herd replacement rate of 40%, you would need 89 heifers.If you reduced the herd replacement rate to 30%, you would need 22 fewer heifers.

	Calving age (months)				
Herd replacement rate	22	24	26	28	30
25%	51	56	60	65	69
30%	61	67	72	78	83
35%	71	78	84	91	97
40%	81	89	96	104	111
45%	92	100	108	117	125

Table 1: The number of heifers necessary to maintain a herd of 100 cows relative to calving age and herd replacement rate (assuming that 10% of the heifers are culled before calving).

HOW BIG IS THE EFFECT?

The effect on the carbon footprint can be quite significant but will vary depending on the age at first calving. You can read more about the effect of age at first calving on a carbon footprint in the lever "Age at first calving". On average, a heifer with an age at first calving of 24 months has a carbon footprint of almost 5,500 kg CO_2 equiv. This is based on average heifer 'costs' of approximately 8kg CO_2e per kg of weight gained. If the replacement rate is reduced from 45% to 40%, 11 fewer heifers would be needed and the total carbon footprint would be reduced by almost 60,000 kg CO2 equiv.



HOW DO I GET STARTED?

Firstly, look at what you can do to increase cow longevity through improving cow health and productivity.

Management tools such as the use of sexed semen and extending lactations would also be of benefit and require strategic planning.

CASE

A herd with 200 cows and a replacement rate of 42% could reduce the replacement rate to 32% by selling surplus heifers. This would result in a financial gain of approximately 12,000 €. This gain comes from the sale of the heifers, reduced costs for feed and increased lifetime yields.

AGE AT FIRST CALVING

Rearing a heifer is a cost to the farm (consuming ... etc.). Without contributing to milk production. This has a negative impact on her total carbon emissions.

Reducing the age at first calving can have a positive effect on her carbon footprint. Rearing healthy and robust heifers who can calve down and enter the lactating herd with minimal problems, will result in higher efficiency animals with the potential for better feed efficiency and milk yield.

As always, heifers must be in the right body condition at breeding and calving. In some cases this will mean that daily live weight gain for heifers may need to increase.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Reducing the age at first calving results in fewer feeding days and lowers total feed-use per heifer reared. Fewer feeding days and feed-use result in decreased methane production from rumen fermentation as well as methane and nitrous oxide from slurry and feed production.

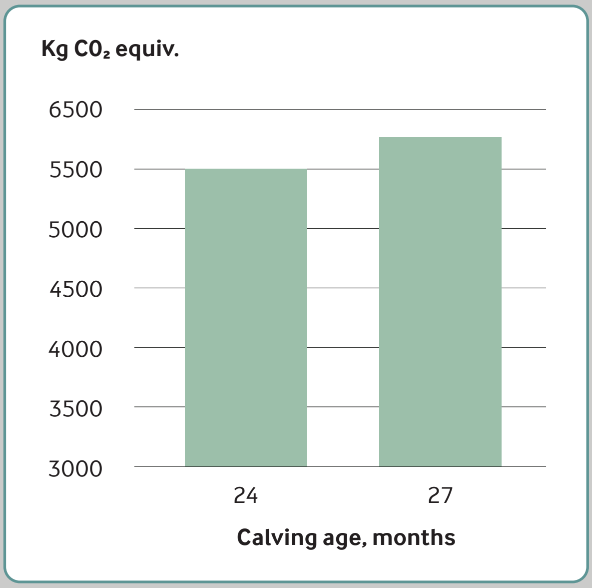


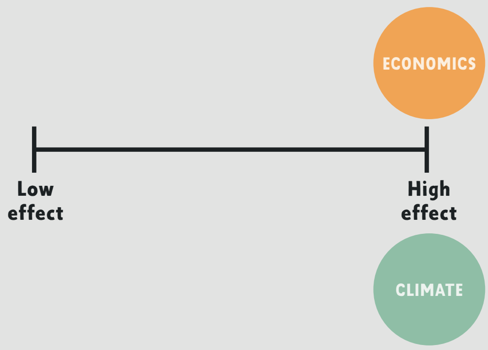
Figure 1: Carbon footprint per reared heifer at calving. Shown with a calving age at 24 and 27 months.

HOW BIG IS THE EFFECT?

The bigger the reduction of age at first calving, the bigger the impact. The impact on the total carbon footprint is approximately 150kg CO_2 equiv. per month per heifer.

For example, when the calving age is reduced from 27 to 24 months, the daily live weight gain needs to be increased by 100g/day to maintain the same calving weight.

Increasing the daily gain requires increased feeding, which would counteract a small part of the benefit. However, the carbon footprint per heifer reared still decreases because the heifers need fewer months to reach calving.



HOW DO I GET STARTED?

To lower the age at first calving, ensure heifers are meeting the required daily live weight gains in order to be at target weight for calving.

CASE

Besides a positive effect on the carbon footprint, a lower age at first calving is also financially beneficial. Calculations show that by reducing the age at first calving from 27 to 24 months, the costs for rearing heifers can be reduced by 120€.

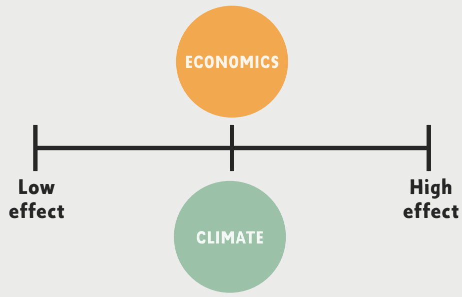
LAMENESS

Besides having serious animal welfare implications, severe lameness can result in culling of continually affected animals, reduced fertility and loss of milk yield. All of this will increase the carbon footprint of a farm. Digital dermatitis, sole ulcers and white line disease are big contributors to a farm's carbon footprint and are also associated with financial loss.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

The three hoof disorders of digital dermatitis, sole ulcers and white line ulcers, affect the cow's climate impact differently. Digital dermatitis is more likely to cause long term fertility issues, resulting in a prolonged calving interval and reducing her efficiency per lactation. Whilst sole ulcers and white line ulcers can impact fertility, these cases tend to result in higher cull rates.

HOW BIG IS THE EFFECT?



The average impact of lameness on the carbon footprint is an increase of 14kg CO_2 equivalent (CO_2e) per 1000kg produced energy corrected milk (ECM) which corresponds to an increase of 1,5 %. Digital dermatitis contributes with an increase of at least 4kg CO_2e (0,4 %) per case.

While sole ulcer increases the climate impact by 33kg CO_2e (3,6 %) per case and white line ulcer causes an increase of 39kg CO_2e (4,3 %) per case. Digital dermatitis is seen more frequently than the other two.

As shown in Table 1 below, if cases of the three hoof disorders were halved, the emission of CO_2e would be reduced by 36,7kg per cow annually.

Disorder	Kg CO_2e[1]/case/ ton ECM[2]	Cases/cow, yearly[3]	Cases/cow yearly, at a 50 % reduction	Reduced kg CO_2e /cow, yearly
Digital Dermatitis	4	0,5	0,25	10,5
Sole ulcer	33	0,0775	0,04	13,9
White line ulcer	39	0,0625	0,03	12,3

Table 1: Climate impact at three different disorders in the hoof.

1 CO_2e = CO_2 equivalent.
2 10500kg energy corrected milk (ECM) per cow.
3 Estimated. Based on the occurrence when hoof trimming: Digital Dermatitis: 20 %, Sole ulcer: 3,1 % and white line ulcer: 2,5 %. Cases/cow yearly is estimated as 2,5 times occurrence.

HOW DO I GET STARTED?

Preventing lameness and/or treating it in a timely manner, will result in a lower carbon footprint by preventing loss of efficiencies related to milk yields, fertility etc.

Discussions with your vet will enable you to identify prevalent hoof disorders relevant to your herd and by actively following your herd health plan one should see these decrease over time.

This could include actions like mobility scoring to identify causes and prevent future cases but also protocols to follow in order to detect and treat lame cows.

CASE

As well as impacting the carbon footprint, lameness also has a negative financial effect and serious welfare implications depending on the severity of the case. Serious cases of sole ulcers and white line disease often have a larger negative impact compared to digital dermatitis.

DIGESTIBILITY OF FORAGES

An increase in forage digestibility can increase forage intake as well as milk yield whilst at the same time potentially reducing the need for purchased concentrates. High digestibility is, therefore, an important factor for efficient and profitable milk production and it can positively impact on the carbon footprint of milk.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Methane is produced in the rumen when feed is broken down by microorganisms.

The fermentation of fibres (NDF) contributes to higher methane production than a starch feed. This is because NDF is mainly fermented into acetate and butyrate while starch is mainly fermented into propionic acid, a process that is less methanogenic. However, the ration should contain a certain share of NDF in order to maintain healthy rumen function.

Increased organic matter digestibility of roughage is usually caused by decreasing the proportion of NDF and increasing the digestibility of NDF.

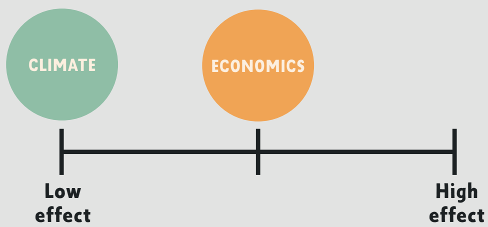
Both play a role in reducing methane production because it pushes the fermentation in the rumen towards more propionic acid and less acetic acid and butyric acid.

HOW BIG IS THE EFFECT?

How big the effect of increasing organic matter digestibility of roughage is, depends on what is changed in the composition of the ration, and how big that change is.

For example, if you:
* *increase* the organic matter digestibility by 2% and
* *decrease* the proportion of fibre by 2-4% and
* *increase* the starch amount correspondingly

you can expect a decrease in methane production of 2-4%.



HOW DO I GET STARTED?

Grass

The digestibility of grass can be increased by harvesting the first cut earlier in the season. This will also increase the digestibility of the later cuts as they are subsequently harvested earlier. In addition, this reduces the proportion of NDF and production is more evenly distributed over the season.

CHECKLIST:

- Consider the right time for harvesting grass silage
- Consider the stubble height when harvesting maize silage
- Choose the right varieties
- Make sure you take representative samples of the feed/silos

Maize silage

The digestibility of maize silage can be increased by choosing varieties with a high digestibility and/or by leaving longer maize stubble during harvest. Maize varieties with a high digestibility or harvested with longer stubble have a lower proportion of NDF and a higher proportion of starch. Maize silage harvested with longer stubble also has a higher NDF digestibility as the lower parts of the stem have the lowest NDF digestibility.

CASE

Case 1: Early harvest
You can increase organic matter digestability by 1-2% over the whole season if you harvest the first cut of grass silage one week earlier than usual, whilst keeping the same number of weeks between cuts. The result will be a 2-4% decrease in the NDF content.

Case 2: Increased frequency of cutting
The digestibility can also be increased by increasing the number of cuts, e.g. from 4 to 5 cuts of grass silage. However, this has negative effects associated with it: an increase in costs and an increase in fossil fuel consumption.

Case 3: Increasing the stubble height
If you increase the stubble height of maize silage e.g. from 30 to 50 cm, the organic matter digestibility of the maize silage will increase by approximately 1% and reduce the NDF content by approximately 1,5%, whilst the starch content increases by the same value. Leaving the maize stubble 20 cm higher will reduce the yield by approximately 5%. This would compensate the climate effect by increasing the carbon footprint for maize silage by approximately 5%.

MASTITIS

Mastitis is caused by infections in the udder. The climate impact depends on how serious the infection is, how long it lasts and where the cow is in her life production cycle.

Besides the climate impact, mastitis also has a significant negative effect on the health of the cow and serious financial implications.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Mastitis increases the carbon footprint per kg of milk due to decreased milk yield, discarded milk and the increased risk of replacements. The cow is likely to utilise more feed in order to maintain her health instead of converting it to milk. This will result in reduced feed-efficiency.

HOW BIG IS THE EFFECT?

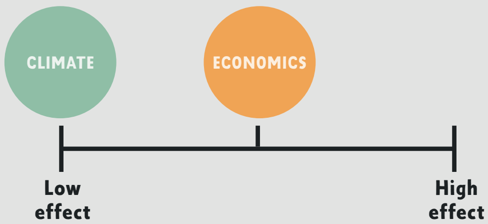
In some cases, cows will show signs of mastitis (clinical) and in others it won't be obvious (sub-clinical). Mastitis can be visible (clinical) or hidden (subclinical).

Clinical mastitis ranges from mild (highlighted by a change in milk appearance) to fatal cases. Subclinical cases are more likely to be recognised through small variations in the cell count. As with everything, the impact on the climate depends on the seriousness of the case.

Reducing the incidence rate of clinical mastitis by 1% can result in a decrease in climate impact of 1,1g CO_2 equivalent per kg milk fat and protein.

Reducing the somatic cell count by 1000 cells/ml milk reduces the climate impact by 0,2g CO_2 equivalent per kg milk fat and protein.

An average Danish cow with 10,500kg ECM, 451kg fat and 376kg protein yearly, where the risk of clinical mastitis is reduced from 30% to 10%, will emit approximately 18kg CO_2 equivalent less. Reducing the somatic cell count from 300,000 to 200,000 will correspondingly decrease the CO_2 emissions by approximately 16,5kg.



HOW DO I GET STARTED?

The focus needs to be on maintaining good udder health to prevent mastitis occurring. Various things affect udder health including milking routines, cubicle and housing hygiene, drying off procedures, general health and welfare, treatment strategies when mastitis is diagnosed etc.

There has to be a constant focus on maintaining good udder health. Numerous conditions have an effect on udder health, such as milking routines, the dimensions of the milking facilities, settings and maintenance, hygiene in cubicles and passageways, the use of teat dip, dry off procedures, general welfare and health, treatment strategies in case of clinical mastitis, treatment strategies in case of a new bacteria type etc.

Keeping the amount of new infections during the lactation to a minimum and avoiding the spread via poor hygiene at milking or in the environment must be prioritised. Reviewing drying off procedures and housing of dry cows is recommended.

Chronically infected cows should be culled, with milk samples taken regularly from clinical cases to ensure treatment is being effective.

CHECKLIST:

- **Evaluate milking routines and milking facility frequently**
- **Keep the lying areas clean**
- **Analyse which bacteria is causing mastitis in your herd**
- **Review dry off procedures**
- **Cull chronically infected cows**

CASE

Reducing mastitis cases will also have a positive financial impact. The financial loss from mastitis varies a lot and depends on, amongst other aspects, the type of bacteria, how serious the case is, the duration of the case, milk yield level, parity, replacement strategy, reproduction and more.

One case of mastitis costs approximately 200-330 € (Danish calculation). Moreover, mastitis causes pain and discomfort for the cow even in mild cases. Therefore, reducing mastitis cases will also improve animal welfare.

MORTALITY RATE

Typically, a cow that dies has a period of illness prior to death. The period of illness will, despite treatment, have a significantly negative effect on the welfare of the cow.

At the same time, the period of illness will have led to a loss in production shown in reduced milk yield and weight loss as well as costs for treatment, care and housing.

A dead cow means a lost slaughter value and it will need to be replaced by a heifer. All of this will have an impact on the carbon footprint. So there are various reasons for keeping mortality low.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Over and above high feed efficiency and a good milk yield, the climate efficient cow has good longevity, enabling the carbon footprint for her heifer rearing to be distributed over a higher lifetime milk yield.

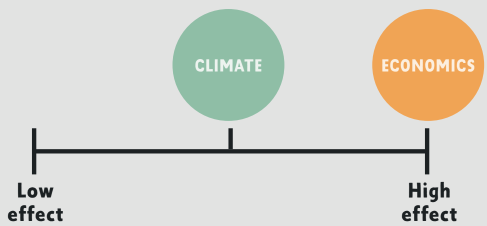
The earlier in her life she dies, the bigger the climate impact due to the need for a replacement. Poor health preceding death will also impact the carbon footprint through reduced productivity.

HOW BIG IS THE EFFECT?

The climate effect varies depending on, amongst other things, how much milk the cow produced before her death as well as how long and serious the illness.

On average the CO_2 emissions can be decreased by approximately 95g CO_2 equivalent/kg milk fat and protein for every %-point the cow mortality rate is reduced.

For an average cow with 10,500kg ECM (451kg fat and 376kg protein), reducing the mortality rate from 5.6% to 3.5% would decrease CO_2 emissions by 145kg per cow.



HOW DO I GET STARTED?

CHECKLIST:

- Know the current cow mortality rate for the last 12 months
- Register the cause of death thoroughly on every dead and euthanised cow (consider an autopsy by a veterinarian if necessary)
- Identify three focus areas (could be done in conjunction with your vet).
- Set up realistic goals for your mortality rate, both short term and long term.
- Follow up on your focus areas as you go and adjust if needed.

If you wish to reduce the mortality rate, the first step is to understand the cause.

When you have an overview of the primary reasons for cow mortality, you can target your preventive actions e.g. for better hoof health, better conditions for dry and fresh cows or avoid poor conditions in the barn that limit sick cows' access to feed, water and rest.

Prevention is always better than cure. Make sure that you and your employees are quick at spotting animals in poor health so they can be segregated immediately and given the appropriate care.

Regularly checking these animals will determine if they are responding to treatment or not and whether or not culling the animal would be in its best interest.

CASE

A lower mortality rate will have a positive financial outcome. The financial loss for one dead or euthanised cow is around £1700, a large proportion of this being on replacement heifer costs and the lost slaughter value of the cow.

If cow mortality is reduced from 5,6 % to 3,5% the annual profit per cow would roughly be increased by £36 .

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WASTE

Resource utilisation and efficiency are essential factors when focusing on the carbon footprint. In almost all processes on a dairy farm, a certain kind of waste will occur, both small scale and large scale. All kinds of waste have an economic cost and a negative effect on the carbon footprint.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Any losses have a negative effect on the carbon footprint.

Examples include spoiled feed (which cannot be fed to an animal and converted to milk/ meat), a dead cow or calf that has used farm resources but cannot repay the herd through milk or meat production.

The examples (adjacent) of on-farm waste are a good starting point from which to consider areas for waste minimisation.

EXAMPLES OF ON-FARM WASTE:

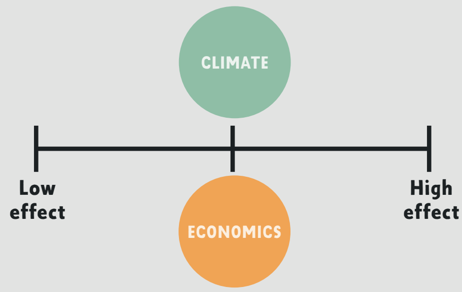
- Feed and milk being discarded
- Resource waste
  - Bought in concentrate and commodities at a high price
  - Poor use of employees' time
- Over-feeding
- Unproductive animals
- Mortality rates
- Poor utilisation of on-farm capital i.e. housing and land
- Unnecessary transport

HOW BIG IS THE EFFECT?

The impact of waste reduction on the climate will vary depending on how big a change has been made.

For example, if you have high calf mortality and managed to reduce it, the effect on the carbon footprint would be significant. There would also be a positive financial impact.

Reducing discarded milk, due to antibiotics, would also have a positive effect on the carbon footprint because it increases milk output which subsequently has a knock on effect on feed efficiency i.e. greater milk producer per kg feed.



HOW DO I GET STARTED?

Consider the list in the section ‘How does this affect the climate impact’, but keep in mind that waste can occur at any point in farming operations.

Consider all the processes on farm and identify waste-reduction opportunities. Then start with the area that will have the greatest impact. It may help to have external advice and ask someone, who does not normally work at the farm, to look at the processes.

Contact a colleague or an advisor and ask them to come up with a few ideas on how to optimise the processes and reduce the waste.

CHECKLIST:

- Set goals for your cow and calf mortality
- Evaluate how much milk and feed is discarded
- Consider if there is any unnecessary power and/or other energy being used in the in the production system (a walk-through with an energy consultant may help).

TIMING FOR ANIMAL MANURE APPLICATION

The timing of animal manure application affects nitrogen utilisation (%). By targeting the application of manure to when the crop is most efficient at absorbing nutrients, it can reduce the need to apply extra (artificial) fertiliser and thereby reduce the emissions of nitrous oxide. Furthermore, the timing of animal manure application has a big effect on the quantity of nitrogen absorbed by the crop and, therefore, can help reduce environmental impacts such as leaching and evaporation.

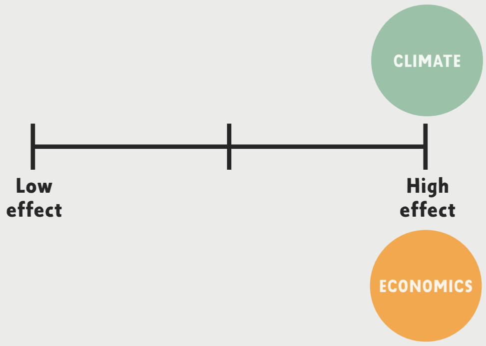
HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Fertiliser application impacts the carbon footprint through the emission of nitrous oxide. Manure is an important source of nitrogen and by increasing its utilisation on farm through increased crop absorption it will have a significant impact on the environment. As well as the climate impact, environmental risks such as run-off and leaching can be reduced as can the costs of purchasing additional artificial fertiliser.

HOW BIG IS THE EFFECT?

The table below shows the impact that the timing of manure application can have on nitrogen utilisation. For example, applying slurry before sowing maize or fodder beet, increases plant utilisation by 15% compared to applying it in late spring.

Generally, crops have a low requirement for nitrogen in autumn. The later manure is applied, the shorter the time plants have to utilise the nitrogen. This is because organic nitrogen needs to be mineralised before it can be utilised. A high utilisation rate of manure in autumn can only be achieved if appropriately small amounts are applied.



Application time, cattle slurry	Early spring/before sowing			Late spring			Autumn
Application technology	Injected*	Acidified, band spreader	Band spreader	Injected*	Acidified, band spreader	Band spreader	Band spreader
Maize and fodder beets	75%***	70%***	50%	60%	55%	35%	-
Grass	60%	60%	-	55%	55%	-	50%**
Spring cereals	70%***	70%***	55%	-	55%	40%	-
Winter cereals	55%	55%	45%	50%	50%	40%	-

***** The effect of slurry injection on sandy soil can be higher than acidified band spreader applicated slurry because of the effect of placement
****** acidified or injected
******* Before sowing

HOW DO I GET STARTED?

Better timing of animal manure application is primarily a planning job.

Manure storage facilities need to be sufficient.

It is also very dependent on weather, ability to access land, soil types etc.

CASE

The carbon footprint can be calculated in a grassland example where 250kg of nitrogen in livestock manure is applied.

Artificial fertiliser could be reduced on grassland by 2.5kg N/ha by increasing nitrogen application from 20% to 40% in spring.

MANURE APPLICATION TECHNOLOGIES

There are various methods which can be used to apply animal manure to land.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

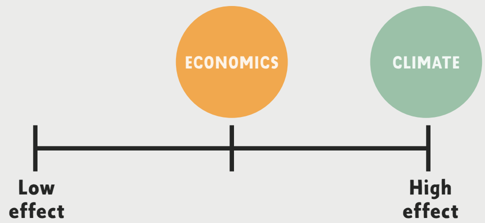
The method chosen has a significant effect on the loss of nutrients from animal manure and, in turn, on nutrient utilisation by the crop. The more effective the application of organic manure, the lower the need for artificial fertiliser which, in turn, reduces nitrous oxide emissions. This lever describes which application methods provide optimum utilisation of nutrients and subsequently lower carbon emissions.

HOW BIG IS THE EFFECT?

The table below demonstrates the variation in nitrogen utilisation based on the application method.

The utilisation is estimated for relevant manure types and frequently used methods. Ammonia emission levels for the different technologies are based on regional and international literature.

The financial benefits of changing application methods would be seen through a reduction in the need for artificial fertiliser but may require investment in new technology.



The utilisation of nitrogen in animal manure compared to the utilisation of the same amount of nitrogen applied as mineral fertilisers. (Land effect = mineral fertilisers equivalent).

Application technology, animal manure	Splash plate	Band spreader	Band spreader + acidified	Injection
Application before sowing maize	50%	60%	70%	70%
Application, grass, spring	40%	50%	60%	60%

Note that the use of certain application technologies might be banned or restricted in your region.

There are different methods for slurry acidification on the market. Please ask the supplier for details including dosage and work safety.

HOW DO I GET STARTED?

Use of a splash plate is the most ineffective method to maxmise nitrogen utilisation, therefore, exploring alternative methods such as acidification of slurry, injection or band spreading would all be preferable.

For cultivated land prior to planting

Injection or application of acidified slurry by band spreader would be the most effective.

For direct application onto grassland or maize

Acidifying slurry, applying it by band spreader or injection would all have more favourable results compared to a splash plate.

CASE

Grassland usually has a nitrogen requirement of approximately 400kg nitrogen/hectare. Applying 144 tonnes of cattle manure per ha would (approximately) equate to 670kg N/ha.

If the slurry is applied by band spreader, the effect of the slurry is equivalent to 335kg artificial fertiliser, meaning that 65kg N/ha of artificial fertiliser is required. However, if the slurry was acidified or injection was used, the same amount of slurry would supply the whole 400kg N because of an improved utilisation rate. By choosing a different method, 65kg of mineral N/ha could be saved.

COVERING THE SLURRY TANK

Covering slurry tanks will decrease ammonia emissions from slurry storage and increase utilisation of animal manure when spread onto the land. Ammonia emissions from slurry storage affect the nitrogen content in the slurry. Covering slurry tanks reduces the need for artificial fertilisers and, therefore, reduce the nitrous oxide emissions from the cultivated surface.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

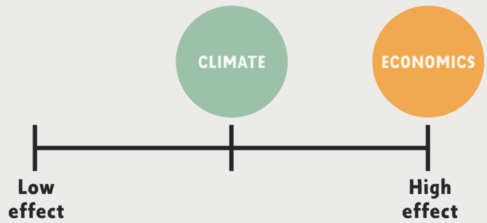
The two main benefits of covering the slurry store are a reduction in ammonia emissions and improved nitrogen utilisation in applied manure, resulting in less demand for artificial fertiliser.

HOW BIG IS THE EFFECT?

The effect of covering animal manure and digestate is shown in the table below. Cattle slurry usually forms a natural crust because of the high dry matter content.

The loss of ammonia can be reduced further by covering the slurry tank with a tent construction or concrete cover (a solid cover). Either type of cover will reduce the nitrogen loss by 50% (from 2% to 1%).

Digestate does not usually form a natural crust. The benefit of covering a slurry tank is, therefore, significantly higher when storing digestate.



Slurry type	Covering method	Emission factor, percent NH_3 loss	
		% of NH_4-N from the stable [b]	% of total N From the stable
Cattle slurry	Natural crust Tent construction or concrete cover	3,4 1,7	2 1
Digestate	Slurry with no cover Covered slurry [a] Tent construction or concrete cover	27,3 5,2 2,6	21 4 2

a. Covered means that the surface of the slurry is covered by crust consisting of chopped straw, barn slurry, Leca stone (hydro clay pebbles), crust cover of plastic, natural crust or other approved covering types.

b. The ammonia loss in percentage of the slurry's NH_4-N content is calculated by the following ratios between NH_4-N and total N in the different slurry types: Cattle: 58% and digestate: 77%

HOW DO I GET STARTED?

Consult the manufacturer of the slurry tank before installing any tent construction or concrete cover

When storing digestate, it is inexpensive and effective to establish a natural crust, e.g. by adding solid manure or straw (thickness: 15cm).

You need to apply 0,2 – 0,4 m^3 of solid manure or deep bedding per m^2 of slurry surface to the tank; or 10 – 20 kg of chopped straw from cereals or from grass seed production per m^2 of slurry surface to the tank.

CASE

Where maize silage is allocated 173 kg N per ha animal manure, containing 4,74 kg N per tonne. Without solid covering, 2% of the slurry nitrogen content will be lost.

With a solid cover, 1% of the slurry nitrogen content is lost. Consequently, 37,2 and 36,8 tonnes slurry/ha is allocated to the maize silage in the two examples. This is a difference of 0,38 tonnes/ha, which corresponds to a reduced need for artificial fertilisers of 1,78kg N per ha.

NUTRIENT CONTENT IN ANIMAL MANURE

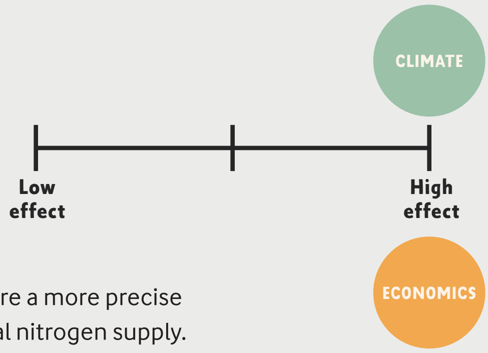
Instead of using standard values for the nutrient content in slurry, a slurry analysis will improve the optimisation of manure as a fertiliser. Knowing the nitrogen content in a slurry tank reduces the excessive use of artificial fertilisers and reduces nitrous oxide emissions from manure applications. Correcting for nitrogen content in the slurry can also have a positive effect on the crop yield and reduce leaching from the cultivated area.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

The highest climate impact from agricultural land comes from the emission of nitrous oxide as a result of the use of both manure and artificial fertilisers. Therefore, reducing the amount of nitrogen applied will have a significant effect on the carbon footprint. Manure is an important source of nitrogen for a dairy farm and analyzing the slurry to know the actual nutrient content could reduce the over-use of nitrogen. Using the actual measured nutrient content of the slurry can reduce the over-use of nitrogen and consequent environmental issues such as run-off and leaching. Optimal fertilisation of the crop ensures that the crop can reach its full yield potential, which also has a significant effect on the climate.

HOW BIG IS THE EFFECT?

The effect of using slurry analysis to correct the amount of N fertiliser depends on the crop and the measured nitrogen content in the slurry. Research has shown that the nutrient content in the slurry tank can vary significantly - up to 25% compared to standard values of the nutrient content of the different slurry types.



Determining the nutrient content before the slurry is applied can secure a more precise dosage and utilisation of nutrients in the slurry, which reduces the total nitrogen supply. The table below shows an example on the effect in maize silage, where the slurry analysis from the slurry tank shows an increased nitrogen level of 20% higher than assumed in the standard values.

Method of fertilising	Slurry quantity, kg N/ha	Deviation from optimum, %
Standard fertilisation[a]	173[c]	
Fertilising based on slurry analysis[b]	208	+20

a. 4,65kg N per ton
b. 5,58kg N per ton
c. Nitrogen requirements for maize silage unirrigated on sandy soil

HOW DO I GET STARTED?

It is easy to get started. Just remember the following:

CHECKLIST:

- You need to take samples from all your slurry tanks.
- Remember that a one litre sample represents 3-4 million litres of slurry, so take the time to investigate how to take a representative slurry sample the correct way.
- The better the slurry is mixed, the more representative the sample.
- You have to take nine sub-samples in three different depths in the slurry tank.
- A local company with advisors specialising in crop production might be able to help with taking a representative sample for laboratory analysis.
- Several laboratories offer slurry nutrient content analysis. Remember to seek advice for correct labelling and transportation if you take your own samples.

CASE

The effect on the climate can be calculated in an example where we wish to supply maize silage with 173kg N per ha from manure. Using table values for slurry N content, the farmer will apply the slurry with an assumed standard value of 4,65kg N per tonne. The farmer will, therefore, apply 37 tonnes of slurry per ha on the field. If a slurry analysis then shows a content of 5,58kg N per tonne of slurry, the farmer has applied 35kg N per ha more than the crop needs.

Determining the nutrient content through a slurry analysis will, therefore, reduce the supply of nitrogen to the field by 35kg N per ha.

NITROGEN FERTILISATION REQUIRED BY MAIZE

The more data available including soil type, nutrient status, knowledge of previous crops and yields, the more accurately the nitrogen requirement for a maize crop can be calculated.

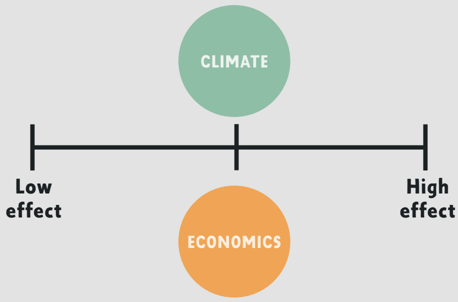
HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

By knowing the optimal N level, a farmer can save money through purchasing less nitrogen and increasing yields and/or reducing nitrogen waste.

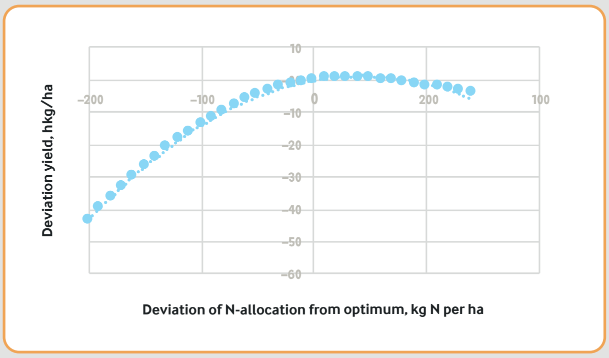
HOW BIG IS THE EFFECT?

The nitrogen requirements for maize can be very variable depending on a range of factors. Calculating the optimum level of nitrogen can also be difficult due to not knowing the variable factors e.g. rain-fall.

Whilst it may not be possible to hit the optimum level every time, it is possible to reduce the deviation by taking into account as much information as possible.



This can have a significant effect on the crop. By reducing the deviation from the optimum from 40 to 20kg N per ha in winter wheat, an increase in yield of 100kg per ha can be achieved. Leaching of nitrogen is also reduced by an estimated 3,5kg N. It is estimated that the effects are approximately the same for maize silage. Improving the deviation from 40 to 20kg N will result in an increase in energy yield of almost 650 MJ NEL/ha.



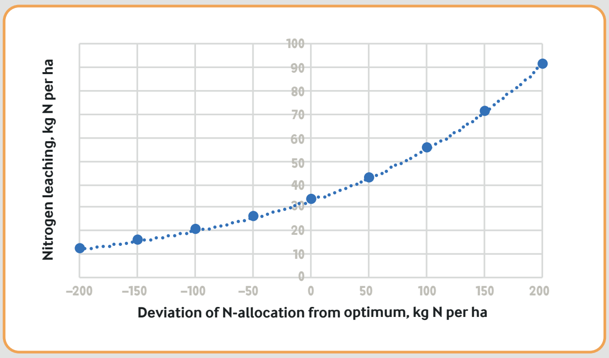


Figure on the left: yield loss as a function of deviation from optimal N-allocation

Figure on the right: Nitrogen leaching as a function of deviation from optimal N-allocation

HOW DO I GET STARTED?

For the farmer to get better in determining the optimal level, a range of parameters can be included in the calculation. These should include:

- Previous crop and track record of crop rotation
- Nitrogen content in animal manure
  (Please see lever: “Nutrient content of animal manure”)
- Utilisation efficiency of animal manure
  (Please see lever: “Timing for animal manure application”)
- Thorough assessment of yield potential in the cultivation year

In addition, you could also include:

- Measurements of N_{min}
- Biomass measurements in the season

CASE

Example: Over a number of years, a farmer has an average statistical deviation of 40kg N. The farmer then improves the accuracy by taking contents and efficiency of the applied animal manure into consideration for an individual maize field.

This then reduces the deviation from the optimum by 20kg N. The yield from the field will be increased by approximately 650 MJ NEL/ha and nitrogen leaching reduced by 3,5kg N.

SLURRY STRATEGY FOR CLOVER GRASS

Applying the optimum amount of nitrogen for the clover content of the grass will have a significant impact on yields. Estimating the clover content of grassland as accurately as possible can be used to adjust the nitrogen applied in order to reach the optimum level. This reduces the need for artificial fertilisers and consequently reduces the nitrous oxide emissions from the land.

The clover content is calculated as a proportion of the dry matter yield and can be estimated visually or by using digital picture analysis with a smart phone or drone.

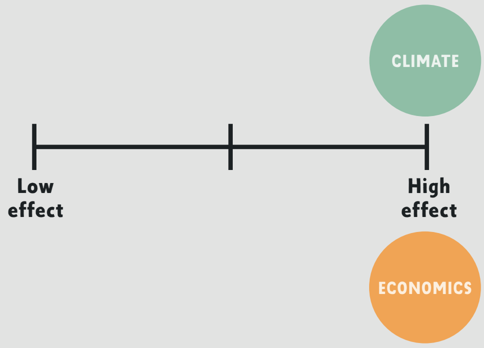
HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

The highest climate impact from the land comes from nitrous oxide emissions as a result of slurry application. Therefore, reducing nitrogen application will have a significant effect on the climate impact.

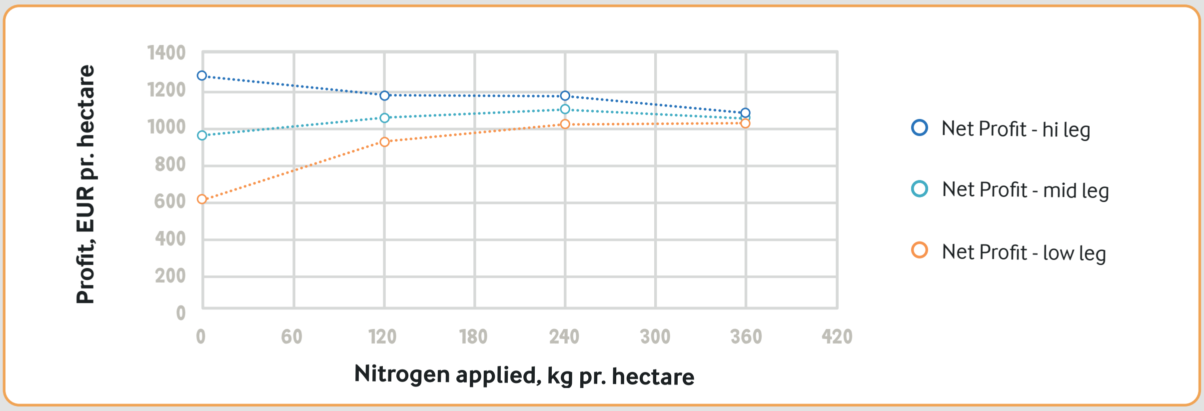
HOW BIG IS THE EFFECT?

The figure below shows the net financial gain by fertilising clover grass with different contents of clover.

In fields with a high clover content (>40%) the net profit decreases correspondingly as the nitrogen application increases. The Economic optimum for fields with moderate (20-40%) and low (<20%) clover content is 200 and 300kg N per hectare, respectively.



Net profit with increasing nitrogen supplementation with different legume proportions in grass clover leys



HOW DO I GET STARTED?

Visual evaluation of the clover content can be supported by the use of photographs, which can then be used to group your fields into low, normal and high clover content.

CASE

The climate effect can be calculated in an example based on a farm where 33% of the fields have a low, normal and high clover content respectively, and all the fields are fertilised with 280 – 290kg N per hectare.

By correcting the nitrogen application based on the clover content, the average nitrogen need will decrease to around 160kg N per hectare, corresponding to a reduction of 120 – 130kg N per hectare.

This will increase the farmer's net income by an average of approximately €60 per hectare.

MANAGEMENT OF HIGH-YIELDING PERMANENT GRASSLANDS

Permanent grass represents a substantial area and can, potentially, have a high yield with optimum management. The conditions for this include over-seeding regularly with high-yielding varieties and fertilising relative to the nutritional needs, including sufficient fertilisation with phosphorus and potassium. Nitrogen requirements will be determined by the yield potential.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

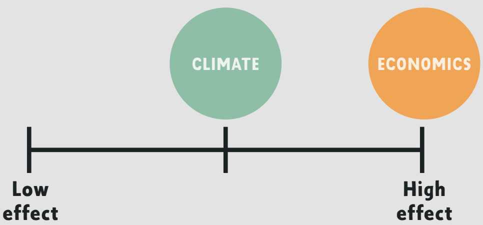
Permanent grassland typically has a low content of legumes such as clover. Consequently, the nitrogen requirement and the yield response to N application is relatively high.

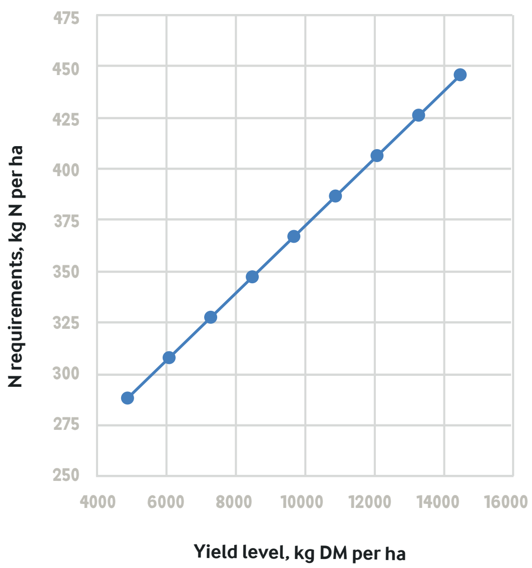
That is why estimating the potential yield and calculating the nitrogen requirement accordingly is essential.

HOW BIG IS THE EFFECT?

The graph shows the nitrogen requirement for varying yields. The nitrogen requirement changes by approximately 17kg N per hectare per 1000kg DM per hectare.

An accurate estimate of the expected yield and consequent nitrogen requirement can be improved by systematic recordings of the historic yields.





HOW DO I GET STARTED?

Ensure that soil pH and the need for other nutrients does not limit plant growth.

Tools that measure harvested yields e.g. a weighbridge, chopper with massflow meter or a forage wagon with a weight cell will ensure more precise information.

Alternatively, monitor what is coming from each field and weigh only a few representative loads to give an overall estimate.

Dry matter content in the grass can be measured with simple analysis devices on the farm or by laboratory analysis of a sample.

CASE

An estimate of the yield and consequent nutrient requirement with, for example 2000kg DM per hectare, will reduce the need for nitrogen application by approximately 35kg N per hectare, reducing artificial fertiliser use.

COVER CROPS

The purpose of cover crops is primarily to absorb nitrogen in Autumn when the risk of nitrogen leaching from the root-area is typically high. The cover crop is not harvested so the plant material stays on the field. To achieve the desired effect, it is necessary to sow the cover crop early and establish it properly.

The effect also depends on the species chosen as it is necessary to use species that can grow quickly in Autumn at relatively low temperatures. Examples of cover crops are:

1. Cruciferous species (primarily radishes and mustard), phacelia or grain can be sown before or after the harvest of the main crop.
2. Grass lays in spring barley or maize.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Cover crops reduce the nitrogen leaching from the root area in Autumn compared to not having plant growth. The effect will depend on the starting point and what is already in the field in Autumn.

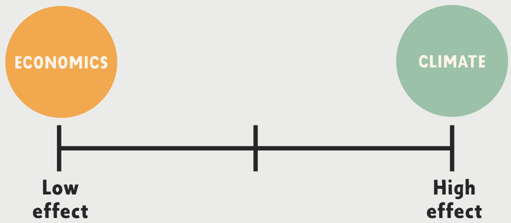
For example, a lot of weeds and volunteer crop can reduce the leaching compared to bare soil and can catch nitrogen like a cover crop. Besides nitrogen, leaching of sulfur and potassium will also be reduced. In addition to reduced nutrient leaching, cover crops will contribute to an improved soil structure and soil fertility.

HOW BIG IS THE EFFECT?

The table below demonstrates the estimated amount of nitrogen leached based on soil type and nitrogen.

Where soils are sandy and/or there are larger quantities of animal manure spread, the benefit of cover crops is much higher. Whilst there is a cost to sowing cover crops (seed and labour), they are often associated with higher yields.

Cover crops also reduce greenhouse gases by replacing nitrogen from artificial fertiliser due to the long-term effect of cover crop plant residues.



The reduction effect of cover crops on leaching (reduction shown in kg N/ha).

	Below 0,8 LU*/hectare		Over 0,8 LU/hectare	
	Clay	Sand	Clay	Sand
Kg N/hectare	16	34	28	46
Average	25		37	

*LU = livestock units

HOW DO I GET STARTED?

Cover crops need to be sown early on, preferably before mid-August.
Sowing options into stubble include:

- Direct drilling
- Power harrow and combination drill
- Broadcast seed and harrow

If you were sowing fodder radish then the recommended sowing quantity is 10-15kg seeds per hectare.

Another possibility is to lay perennial ryegrass in Spring-sown barley, where the recommended sowing quantity is 5-10kg seeds per hectare.

CASE

On sandy soil, where the potential for leaching is higher, growing radish instead of leaving the soil bare would be highly beneficial. Sown early, the cover crop can become well established and absorb 60kg nitrogen per hectare. Leaching could be reduced by 60kg nitrogen per hectare.

This would save 20 – 25kg nitrogen for the following Spring-sown crop and potentially increase the barley crop yield by 100-200kg per hectare.

The economic benefit is small but not negative. On clay soil, the effect on yield will typically be positive but the economic outcome is often negative because the costs for seeds and machine work exceed the gain from cover crops.

ANAEROBIC TREATMENT OF ANIMAL MANURE

Anaerobic treatment of slurry and farmyard manure (FYM) in a biogas plant will produce renewable energy and digestate to be used for fertiliser. This can reduce the need for artificial fertilisers.

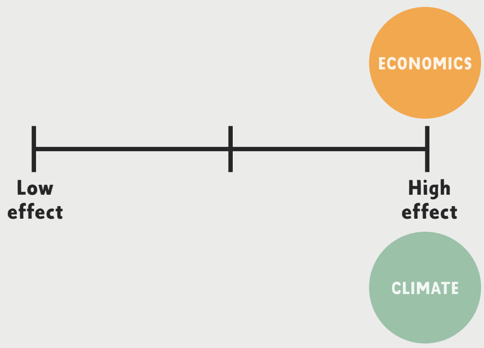
HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

Slurry and FYM contain organic material which is converted into methane in cattle housing and slurry/muck stores. Biogas treatment reduces GHG emissions from both manure storage and on-field application. Methane emissions to the atmosphere are reduced when treating slurry and deep FYM in a biogas plant because the methane is converted to a fuel. In the biogas plant the FYM is converted into a liquid digestate which is easier to handle and has greater nutritional benefits.

HOW BIG IS THE EFFECT?

The effect of anaerobic treatment of slurry and FYM in a biogas plant is shown in the table below as utilisation percentages of nitrogen for the different products.

The use of animal manure is only improved by 1% through biogas treatment when taking long-term effects into consideration, whilst the effect for FYM is 35%.



Maize and beets	1st year effect [%N]	Long-term effects over 10 years [%N]	Total effect [%N]
Animal manure (injected)	75	10	**85**
FYM from cattle	35	16	**51**
Digestate (injected)	80	6[1]	**86**

[1] The long-term effect of digestate from slurry is estimated as the same as the long-term effect of pig manure, which has a comparable 1st year effect.

Furthermore, biogas treatment reduces the climate impact as methane emissions from cattle housing and storage are avoided. The CO_2 reduction potential is shown in the table below.

	CO_2 emission [kg CO_2 equiv./ton slurry]		
	Untreated slurry	Digestate	**Reduction**
Dairy cows	19	11	**8**

HOW DO I GET STARTED?

To be able to sell slurry and FYM to a biogas plant you need to investigate if there is a biogas plant nearby and if the biogas plant has any additional capacity.

Not all biogas plants have the technical facilities to handle FYM. Some biogas plants will not want to take slurry from farms that use sand bedding in cubicles unless a sand washer is installed.

Typically, biogas plants do not want to use acidified slurry.

CASE

The climate effect is calculated in the example below on a 300 cow herd. Number of animals, slurry quantity and the benefits for the climate through reducing methane emissions by degassing is shown in the table below:

	Number	Tonnes slurry/year	CO_2 reduction [ton CO_2 equiv./year]
Cows	300	9.510	**76**
Calves	40	-	**-**
Heifers	130	0.664	**5.3**
Total			**81.3**

GENETIC YIELD POTENTIAL OF NEW GRASS VARIETIES

Plant breeding and the varieties now available mean yields, disease and pest resistance and crop digestibility are constantly improving. This effect is particularly pronounced for rotational grass because the crop is usually there for 2-5 years.

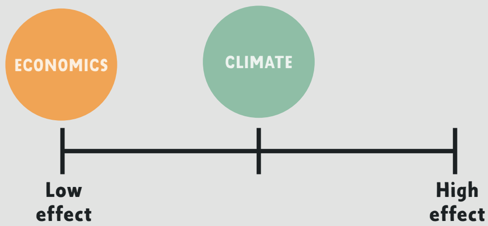
HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

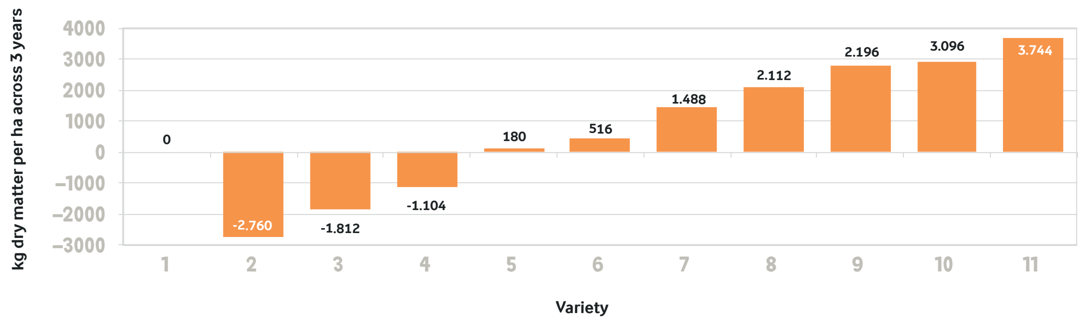
Genetic improvements increase yields whilst utilising the same inputs. Variety selection when establishing grass has a high effect on the yield and, therefore, the climate impact.

HOW BIG IS THE EFFECT?

The figure below shows the difference in the total yield over three years for 11 varieties of perennial ryegrass relative to the current measured mixture of cultivated varieties of perennial ryegrass.

By choosing between the best three varieties, an improved yield of 3000 - 3500 kg DM/ha could be achieved. Choosing between varieties should not solely be based on the yield potential but also on the digestibility of the cell walls (NDF) as well.





HOW DO I GET STARTED?

Data from trials with varieties for grassland plants can be found for, amongst others England, Germany and Denmark.

You could choose the varieties with the highest yield potential and a high feed value

CASE

Using the best varieties gives on average a 10% higher yield with the same nitrogen quantity. Therefore, the carbon footprint is reduced because the same amount of fertiliser used results in a greater yield (i.e. increased kg feed DM).

REDUCING DIESEL CONSUMPTION

You can lower the climate impact of your farm by reducing diesel consumption. It is important to remember that the diesel used by a contractor on farm will be included in your carbon footprint. One of the best ways to reduce diesel consumption is by regulating tire pressure according to the task and tyre mounting.

For conducting field work, the tyre pressure should be as low as the tyre mounting allows. For transportation on the road, a higher tyre pressure should be used. In addition, a key focus should be on reducing the tillage depth to the optimum level.

HOW DOES THIS AFFECT THE CARBON FOOTPRINT?

There is a strong correlation between climate impact and financial cost to the farmer when reducing diesel consumption. Lower diesel use results in cost savings and a reduction in your carbon footprint.

TYRE PRESSURE: By using modern very high flexion tyres (VF-tyres), the tyre pressure can be lowered to 0,8 – 1,5 bar when ploughing, harrowing and driving in the fields with heavy equipment such as forage wagons and slurry spreaders. This gives the tyres an increase in support surface and the rolling resistance is also reduced. The result is a reduction in diesel consumption. When travelling on the roads, the opposite applies and the tyres should have a tyre pressure of 3,0 – 3,5 bar to reduce the rolling resistance on the harder surfaces. Ideally, your vehicles should be equipped with a system for regulating tyre pressure.

MINIMISING MACHINING DEPTH: Diesel consumption increases exponentially in relation to machining depth. This is why, for example, it is ill-advised to deep-harrow without a good agronomic reason.

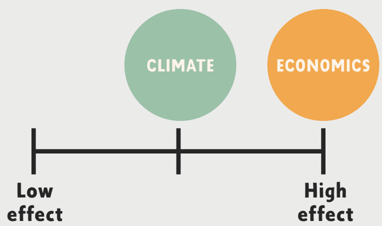
HOW BIG IS THE EFFECT?

In 2017, research was carried out on the impact of harrowing depth and tyre pressure on diesel consumption and capacity. The conclusion from the research was that increasing harrowing depth increased diesel consumption and, at the same time, the capacity decreased because of wheel slip. Increased tyre pressure (from 0,8 to 1,9 bar) in 20cm plots resulted in an 8% increase in diesel consumption and a 5% decrease in capacity due to increased wheel slip.

Lowering the tyre pressure from 0,8 to 0,6 bar (less than recommended) led to a reduction in the wheel slip of 2%. Moving road transport from tractors to trucks should be considered where possible.

Road transport with trucks use approximately 80% less diesel per tonne per km than road transport using tractors.

Harrowing depth **Tyre pressure**	**10cm** **0,8 bar**	**20cm** **0,8 bar**	**20cm** **1,9 bar**	**30cm** **0,8 bar**
Diesel consumption [litre per hectare]	8,6	11,7	12,6	17,9
Capacity [hectare per hour]	8,1	6,0	5,7	4,7



HOW DO I GET STARTED?

Buy good VF-tyres when buying tractors and other mobile machinery.

Talk to your machine consultant or tyre supplier and get them to make a list showing the full range of recommended tyre pressures for each of the different machines used by the tractor. When changing regularly between driving on the road and in the field e.g. when applying slurry, a tyre pressure regulating system should be considered.

The estimated cost for equipping a tractor and slurry spreader with a system for tyre pressure regulation is between £12,000 to £23,000

CASE

The climate effect when reducing tyre pressure from 1,9 bar to 0,8 bar can be calculated per 100 hectares. In a system without ploughing, where the fields are harrowed three times and sown once a year, and the capacity when harrowing and sowing is the same, then the area will be run over four times.

The estimated savings would be approximately 360 litres of diesel. In addition, a reduction of the harrowing depth from 20 to 10cm would lead to a further saving of 840 litres of diesel.

CARBON NET ZERO 2050

Arla