REPORT | FARMING OF THE FUTURE

Beef & Dairy

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Photo: Fredrik Persson/Svenskt Kött

Pathway towards climate-neutral farming by 2050

Content

Preface

Towards the sustainable beef and dairy production of the future

The world population is expected to reach ten billion within the next 30 years. Global food production therefore must become both more efficient and more productive, while at the same time biodiversity must be protected and negative impact on the climate reduced. The sixth UN Intergovernmental Panel on Climate Change (IPCC) assessment report has determined that measures must be taken quickly to deal with climate change. Above all, the combustion of fossil energy sources and the carbon dioxide emissions this entails must be radically reduced. Also, methane emissions from cattle production must be reduced. Finding more sustainable production methods is going to require substantial investments moving forward. Here, our sector has great opportunities to continue to develop and show the way forward to meet these global challenges.

The starting point for moving towards to a future sustainable food system is good. Swedish beef and dairy production is at the forefront when it comes to animal welfare and environmental sustainability. We have long experience, knowledge and we make extensive use of technology within our sector. In doing so, we have laid the foundation for our world-leading production of highly nutritious food with low environmental impact.

Ruminants contribute to society with essential ecosystem services and support biodiversity. Cattle production will therefore continue to play a key role in the future, where crop farming and livestock farming work hand in hand in a circular system. However, more efforts will be required if the sector is to be able to take the next step and meet the challenges of the future.

Subsequently, companies and organisations throughout the entire value chain have joined forces to create a common, long-term vision for Swedish beef and dairy production in the future. Together we have examined challenges and identified key areas with potential for improvement moving forward. Our results show that there are great opportunities to increase productivity while maintaining a high standard of animal welfare, reducing climate impact in line with the goals set in the Paris Agreement and benefiting biodiversity by 2050. With this report as our starting point, the Swedish beef and dairy sector will be a major driving force in creating the right conditions for a transition to an even more sustainable beef and dairy production in Sweden, while improving farm profitability.

The results of this work will influence the business plans of our respective companies and organisations in the future, as well as forming a platform for sector wide initiatives. The challenges are so great that collaboration, within and outside the sector, is a necessity if we are to realise the potentials we have identified for moving forward. Not least when it comes to financing the necessary investments on beef and dairy farms around Sweden, where parties throughout the entire chain, ranging from politicians to consumers, must value sustainably produced food and energy higher. One of the main challenges is the poor financial sustainability of Swedish beef and dairy production today. A boost is necessary if we are to be able to make future sustainable investments at farm level and make farming more attractive to young people.

We have already done a great deal to reach the position we are in today, and politicians have contributed with positive initiatives within Swedish food production in recent years, such as Sweden Food Arena, an innovation arena within the food sector, and Formas competence forum for more sustainable food. However, more initiatives and measures from more organisations are needed.

An investment in our sector is also an important investment in society at large, for the Swedish economy, jobs and keeping rural areas vibrant.

We want to invite more organisations to join forces with us. This will be crucial if we are to achieve our vision for a sustainable future food system. Our report shows the way towards a more sustainable and competitive beef and dairy production in Sweden up until 2050, where the strength of collaboration will be crucial in enabling this transition.

HKScan Sweden, Arla, Växa, LRF,
Lantmännen, Svenskt Kött, Yara, DeLaval

“One of the main challenges is the poor financial sustainability of Swedish beef and dairy production today. A boost is necessary if we are to be able to make future sustainable investments at farm level and make farming more attractive to young people.”

Photo: Växa

Swedish beef and dairy production is ready to meet the future

Swedish agriculture is amongst the most environmentally sustainable in the world, a position we aim to maintain and develop. This, together with long experience and high productivity at the global forefront, as well as improved profitability, are the necessary conditions for increased Swedish beef and dairy production in the years to come.

We are well-placed geographically

Sweden is well-placed geographically for beef and dairy production, with good access to water and suitable land, to be able to manage climate change. Beef and dairy production is dependent on biodiversity and ecosystem services, but also has a positive impact on these, such as our species rich semi natural pastures.

Plenty of grass and grassland
Ruminants have the ability to convert plant material into high quality proteins and nutritious food that are easy for us humans to digest. In Sweden, large areas are best suited for grassland production. As a consequence, our land is well suited for beef and dairy production. Despite this, agricultural land is becoming overgrown, according to studies by the Swedish University of Agricultural Sciences. Over 90 percent of our meadows and semi-natural pastures have been taken out of production since the start of the 20th century, due to increased mechanisation and structural rationalisation within agriculture, and more recently on account of increased import of milk, meat and protein feed. Nor has it been profitable to maintain production on semi-natural pasture. To conserve biodiversity and an open landscape, a stocking rate of approximately one cattle per hectare is required. There is scope to increase Swedish production of sustainable milk and beef. The unique nature of cattle in the way they graze and how their hooves create conditions for other species to thrive are making them key for maintaining and restoring nature features.

Ecosystem services
Ruminants can contribute to carbon sequestration if their feed primarily consists of forage from perennial ley. Perennial forage species sequester carbon mainly in the roots. Manure from cattle is then returned to farmland and provides energy and nutrition to soil microbes. Similarly, grazing livestock contribute to open landscapes and biodiversity. Natural or seminatural pastures (pasture that has not been ploughed or fertilised for a long time), are Sweden's equivalent to rainforests, when it comes to abundance of species and as home to many species under threat of extinction. To achieve Sweden's environmental goals, species rich pastures need to be retained. Grazing cattle are key to conserving abundance of species in semi-natural pastures. Together with the good conditions for grassland production, there are good opportunities to increase carbon sequestration and further benefit biodiversity.

> "In Sweden, we have large areas which are best suited for forage production, i.e. grass and legumes. This is why our land is well suited for beef and dairy production."

Swedish dairy and beef production in numbers

Dairy
No. of dairy companies: 3,025 (December 2020)
No. of cows for milk production: 304,397 (December 2020)
No. of cows per herd (on average): 98 (June 2020)
Total milk production: 2,772,000 tons, of which, 17 percent organic (December 2020)

Beef
No. of companies with beef cattle: 15,426 (2020)
No. of companies with suckler cows: 10,063 (2020)
No. of cattle total: 1,466,295 (2019)
No. of suckler cows for feeding calves total: 206,950 (2020)
No. of cattle per herd: 94 (2020)
No. of cattle per herd with suckler cows: 21 (2020)
Total production of beef: 1,397,000 tons
Total no. of slaughtered cattle: 425,630, of which 16 percent organic (2018).

Source: Swedish Board of Agriculture, 2020

Good access to water
While water is a renewable resource, it is not unlimited. Globally speaking, water shortage is an enormous challenge and food production uses large volumes of water. In Sweden, water is abundant due to rain- and snowfall, many lakes and watercourses and high groundwater levels. Groundwater in Sweden is sometimes described as a national resource, enough to supply drinking water for millions of people. Access to water is not restricted in a normal year for Swedish livestock farmers, unlike the situation in many countries at more southerly latitudes. However, climate change can lead to local water shortages in the future. In Sweden, farming accounts for 3 percent of total water consumption in total, compared to 70 percent globally. Households account for 23 percent in of water consumption in Sweden (Source: SCB, LRF).

Roughage is cultivated in with natural precipitation as water source. This makes beef produced in Sweden a sustainable alternative with regards to the water aspect, according to the WWF. However, water supply regionally and locally can be a challenge in Sweden too.

Pasture and lay responds well to irrigation, which results in increased yields. Interest for irrigation is rising in line with climate change. On farms, water is used for cattle that drink 20–100 litres of water a day, depending on their age and production. Water is also used for cleaning milking parlours, equipment and waiting areas.

We have built a solid foundation

Based on tradition, experience and long-term structured work, Sweden and Swedish farmers have built a solid foundation. Swedish beef and dairy production are characteriezed by good animal welfare and a unique low use of antibiotics. It is also world leading when it comes to production relative to climate impact –both from livestock and feed production. The level of expertise is high with well-developed processing skills which ensures sustainable development.

Good animal welfare
In Sweden, the beef and dairy sector has been using preventive measures to promote animal health and welfare for many years. Besides ethical aspects of animals welfare, a healthy animal also is more productive, can convert feed efficiently and does not require veterinary care or medication like antibiotics. Animal welfare is protected by Swedish animal protection legislation, which is very far reaching in the world. The legislation is based on animals being able to behave naturally, both indoors and outdoors. Swedish animal protection requirements are stricter in general than the EU requirements, such as in the case of transportation, time spent outdoors, access to roughage, and anaesthesia when de-horning, castrating or slaughtering.

There are several indicators showing the state of health and well-being of animals. In the case of beef cattle, the right amount of body fat, cleanliness and as few signs of lameness or other injuries as possible are important for welfare that can be assessed regularly. In addition to complying with requirements within animal protection legislation, other inspection programmes are employed such as the Arlagården quality assurance programme and Svenskt Sigill. Also, for the tenth year in a row, Sweden is the EU country that uses the least antibiotics to treat livestock. Such low use is important to prevent resistance to antibiotics, an important issue for society. Low use is another indicator of good animal health. Sweden was also the first country in the world to ban antibiotics as growth promoters in 1986. The ambition is to continue to lead the way regarding preventative measures to ensure animals are healthy, and animal welfare standards are high with low use of antibiotics, and effective infectious disease control.

Well-established Swedish production
We have long experience and traditions when it comes to beef and dairy production in Sweden. The sector has built up knowledge and expertise, plus an infrastructure that utilises new technology to a great extent, which has paved the way for the highly productive sector we have today. The know-how and skills available in the sector already mean the prospects are good to further develop the sector in an even more sustainable direction. However, improving profitability in farming enterprises is required to achieve this.

Climate efficient production
Swedish beef and dairy production is amongst the most climate efficient in the world. Via longterm work within the sector, we have been able to reduce our climate footprint to a low level. A glass of Swedish milk has an almost 60 percent lower climate footprint than an average glass of milk in the rest of the world. In the case of Swedish beef, the climate footprint per kg is around 60 percent lower than the global average (expressed as carbon dioxide equivalents GWP-100). The sector continues to drive efforts to make production more efficient and climate friendly, while at the same time further cutting greenhouse gas emissions.

Nutritious food
Dairy products and beef are nutritious and nutrient-dense foods that meet a large proportiont of our daily requirements of many important nutrients with normal consumption. This is especially important for groups such as the elderly and children that can find it difficult to eat large quantities of food. Milk and meat contain iodine, iron, selenium and zinc, plus vitamin B12, and the protein found in milk and beef contains all the amino acids we need.

The role of cattle in a sustainable food system

Cattle have a key role to play in a sustainable food system in Sweden. The strength lies in their ability to live on grass and other crops rich in cellulose, meaning arable land and natural grasslands can be utilised in a resource efficient way throughout the entire country. Similarly, added values such as high biodiversity and ecosystem services, as well as employment opportunities, in rural areas throughout Sweden are created.

A limited resource to feed a growing population

Agricultural land is a limited resource, and at the same time it needs to support a growing global population. It is therefore vital that land is used in the most resource efficient way. The scale of environmental impact, such as emissions of greenhouse gases, soil erosion, nutrient losses and eutrophication, very largely depends on the type of livestock farming. Different countries and different production systems have different impacts and challenges.

Local conditions presents different opportunities

Just over seven percent of the land area in Sweden is farmland, which is a low proportion in an international perspective. In each region in the country the proportion of land suitable for farming varies significantly. In the south of Sweden, almost 45 percent of the area is farmland, while this figure is less than 5 percent in Dalarna and further north.

Cattle eating grass is a resource efficient way of utilising marginal land not suitable for growing arable crops . If animals do not graze on these marginal lands and natural pastures, these areas would quickly become overgrown. Habitats that support many other forms of life, such as various flowers, insects and other animals would also disappear along with the agricultural landscape and other cultural heritage values.

Ruminants use land that cannot be cultivated

Grasslands are important for crop rotation, as this improves the health and organic content of the soil, and in doing so also utilizing carbon dioxide from the atmosphere. These positive effects lead to more fertile soil, improves its water-retaining capacity and reduces losses of nutrients from the fields. At the same time, the animals produce manure that benefits crop cultivation by returning plant nutrients such as phosphorus and nitrogen to the fields. Manure is positive for soil micro life and is important for soil fertility. In other words, integrating crop production and cattle production offers many benefits.


Photo: DeLaval

Cattle can also use by-products from the food industry such as grain and protein crops that do not meet the quality requirements for direct human consumption.

Other added values from Swedish beef and dairy production are employment opportunities in rural areas and jobs throughout the entire value chain.

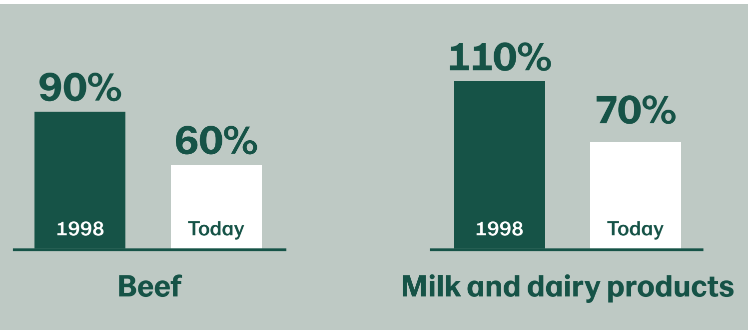
The degree of self-sufficiency would be increased with higher domestic production and indigenous feed production. Today, Sweden only is self-sufficient of grain when it comes to the largest agricultural commodities. When it comes to beef, we are only 60 percent self-sufficient and dairy 70 percent.

Cattle play an important role in the development of a circular bio-based economy where food, feed and energy production are interlinked.

Although cattle create significant added value as such, further measures are required to enable even more sustainable and resource efficient beef and dairy production in the future.

> "Cattle play an important role in the development of a circular bio-based economy where food, feed and energy production are interlinked."

Sweden's degree of self-sufficiency has fallen sharply since 1998



Source: Swedish Board of Agriculture, SCB


Photo: Øyvind Lund

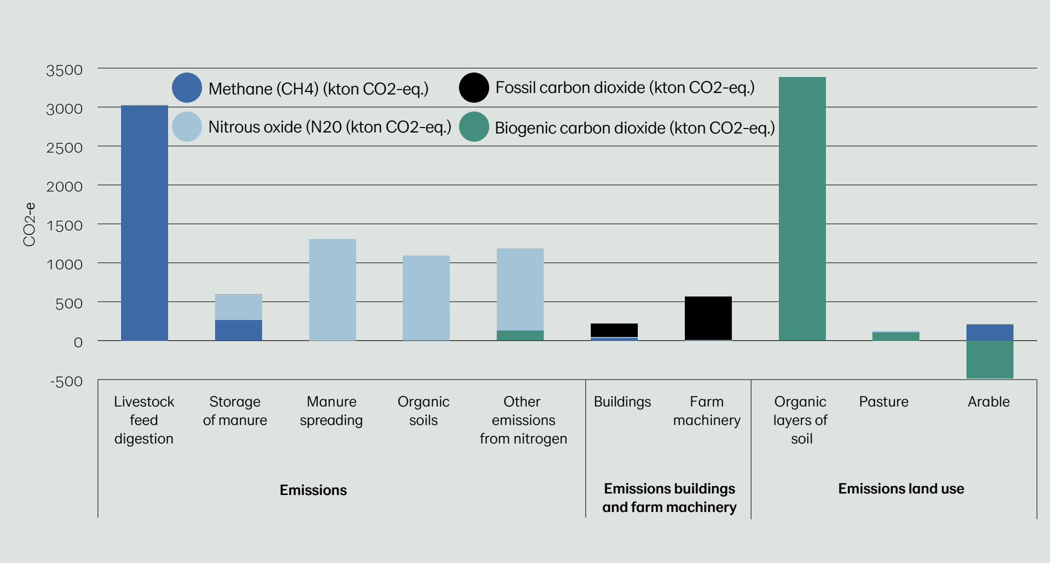
The impact of beef and dairy production on the climate

The world is facing major challenges when it comes to reducing greenhouse gas emissions. Time is limited to stop global warming. We have ten years to reverse the increasing emissions if we are to reach the goals set in the Paris Agreement. It is necessary that we invest in the most effective solutions with support by the most recent science.

Primary production of beef and dairy produces greenhouse gas emissions in the form of carbon dioxide, methane and nitrous oxide. Carbon dioxide emissions occur during the combustion of burning fossil and the cultivation of organic soils. Methane occurs during, among other things, fertiliser processing and via ruminant digestion. Nitrous oxide also arises during the processing and production of fertiliser, production of feed ingredients and from farmland.

Agriculture has a big impact on the climate, but it is still a smaller contributor compared to emissions from the burning of fossils used in transport, industrial processes and to generate electricity to light up communities and to power equipment and technology.

Cattle fill important aspects in the functioning of the food and farming system in Sweden. Hence, a significant reduction in their number can create problems in ensuring food security and sustainable development. Cattle also contribute to preserving biodiversity and several ecosystem services such as carbon sequestration and nutritious and nutrient-rich food. Cattle also use grassland. Keeping grassland and ruminants is a necessity for profitable and sustainable farming in the whole of Sweden.



Source: IVA 2019 Vägval för klimatet

Figure 1: Greenhouse gas emissions from Swedish agriculture, as of 2017.

Climate targets for the future

The different greenhouse gases all have different properties and hence impacts the climate in different ways, see page 13 for more about this. The UN IPCC has divided the emissions scenarios, that are required to achieve the 1.5 degree target in the Paris Agreement, for the respective greenhouse gases. Between now and 2050, carbon dioxide emissions need to be reduced to net zero, methane emissions reduced by about 65 percent and nitrous oxide emissions by around 40 percent. Dividing the greenhouse gases is also our starting point in this report, in accordance with the latest science in the area.

Target levels in the report

In the case of fossil carbon dioxide and nitrous oxide, the report uses the IPCC target graphs, however, with methane, more information is required to obtain a relevant target.

IPCC further states that there is a difference between methane that comes from fossil sources, such as fossil extraction, and biogenic methane that comes from ruminants, for example. The IPCC report claims that the accepted method, GWP100, to weight the combined impact of all climate gases in carbon dioxide equivalents does not provide a completely accurate picture. It overestimates the climate impact from constant methane emissions while underestimating the climate impact from increasing emissions.

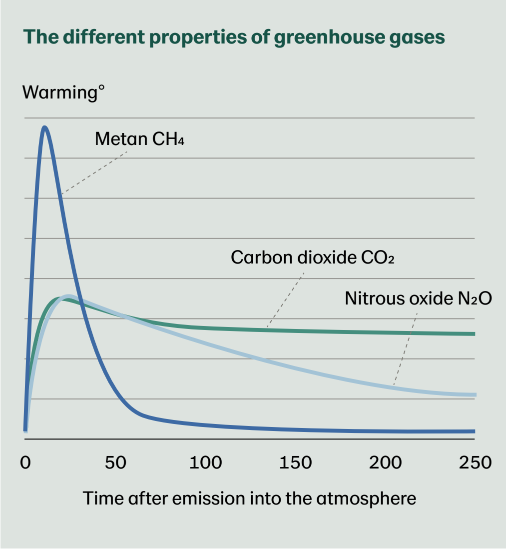
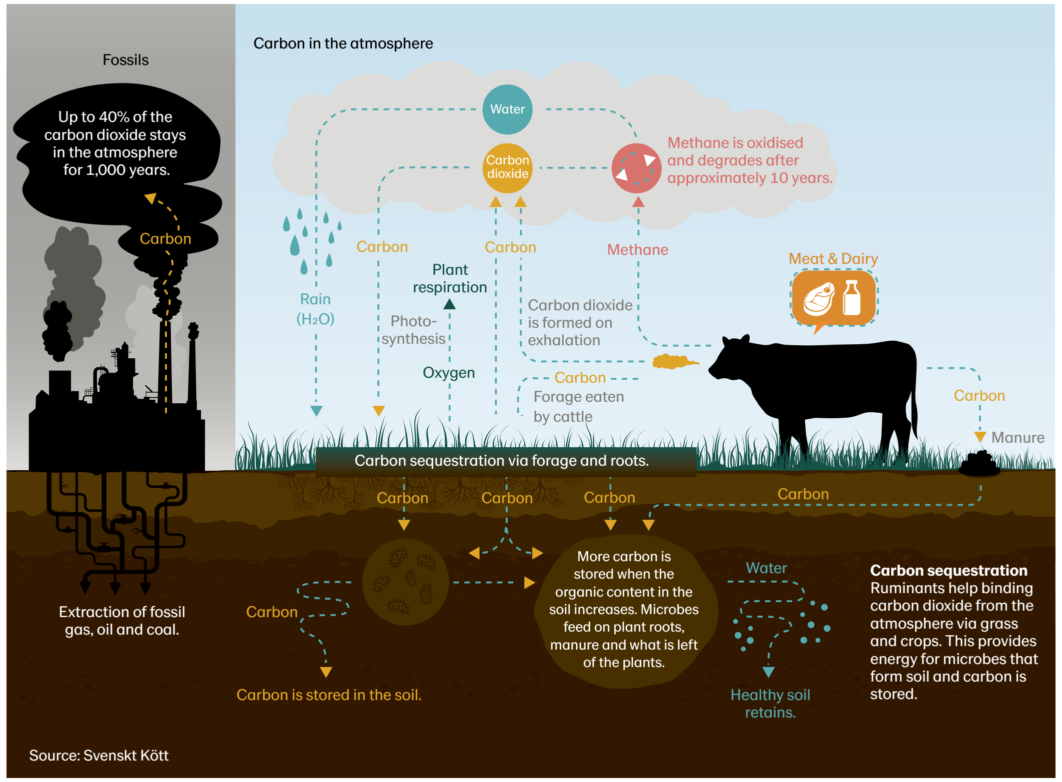


Figure 2: The different properties of greenhouse gases.
The greenhouse gases differ in potency and have different degradation spans. For example, methane is a potent gas and takes around 10–12 years to degrade. Carbon dioxide released into the atmosphere is less potent, but its warming effect endures for longer – up to approximately 1,000 years. (Lynch, J., Garnett, T., Persson, M., Röös, E., and Reisinger, A. 2020).

The different greenhouse gases all have unique properties and are difficult to compare on a common scale.



Source: Svenskt Kött

Figure 3: A large proportion of cattle emissions are part of a natural cycle.

The different properties of greenhouse gases

Methane and carbon dioxide are different
Methane is a potent greenhouse gas compared to carbon dioxide, but degrades in the atmosphere at a far more rapid rate than carbon dioxide. After about ten years, it has oxidised into carbon dioxide and water. If the methane is from a fossil source, the carbon dioxide remains as a net addition and impacts the climate in the same way as direct fossil emissions. In the case of ruminants, the carbon dioxide is biogenic and part of the natural carbon cycle.

These differences result in the fact that every kilogram of fossil carbon dioxide that is emitted has an accumulated stock effect, with a long lasting impact on rising temperatures, as very little carbon disappears from the atmosphere over time.

Methane on the other hand, breaks down quickly which means it continuously disappears from the atmosphere. As such, it is primarily the change in flow of the gas that determines whether methane emissions contribute to a rising global temperature or has a cooling effect.

The flow determines the impact
How the flow of methane impacts the climate can be compared to the water level in a bath tub. If the temperature is illustrated by the water level, it is easy to understand that if you open the tap to let in more water than flows out – the water level will rise. If the water flows out faster than the tub is filled, the water level will fall instead. If the inflow and outflow are equal (the total number of ruminants remains constant), the water level (the temperature) will not change.

To flatten the curve of the warming effect from emissions of fossil carbon dioxide, and to eventually reduce this, emissions must stop. Somewhat simplified, you can say that to achieve climate neutrality, carbon dioxide emissions must go down to zero, or be abated from the atmosphere, while biogenic methane must not increase.

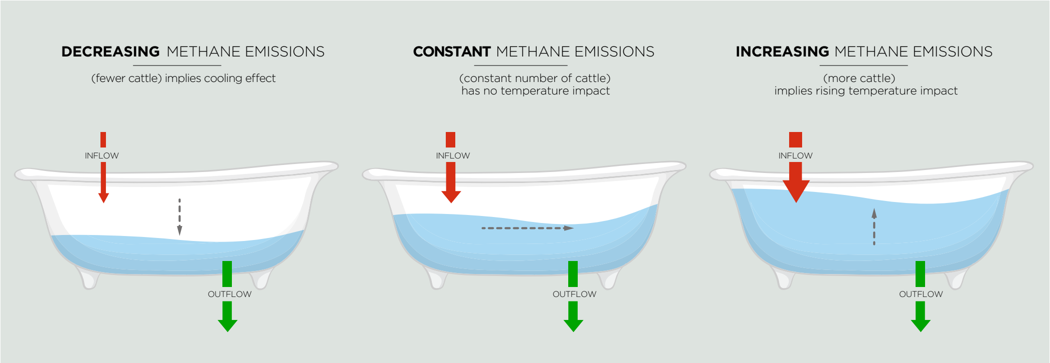


Figure 4: Methane is a flow gas.


Photo: Växa

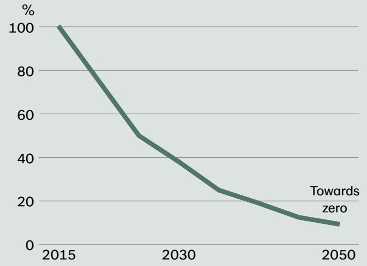
Carbon dioxide

Sources:
Carbon dioxide is emitted during the combustion of fossils within livestock farming. This can be from the production of electricity or fuel for machinery that is used in feed production and emissions from production of mineral fertiliser and agri supplies. In certain countries, large quantities of carbon dioxide are released when clearing and burning forests for pasture and growing feed for livestock. In global terms, forest clearing accounts for around 40 percent of total carbon dioxide emissions from cattle.

The greenhouse effect:
Carbon dioxide has a relatively small warming effect per kg or ton. Even so, it has a big greenhouse effect as it stays in the atmosphere for up to 1,000 years. This results in a cumulative effect which means that the greenhouse effect will continue to increase even if emissions on earth remain the same.

Relevant goals:
As carbon dioxide remains in the atmosphere for a long time, every kg emitted adds to this. According to the IPCC, this means that emissions must be cut to zero as soon as possible and not later than 2050 if the 1.5 degree target in the Paris Agreement is to be reached. The Carbon law, with a rate of halving emissions every ten years, offers a snapshot of how big this challenge is and how quickly it must be done. Beyond 2050, carbon dioxide emissions must be negative, i.e. the carbon dioxide content in the atmosphere needs to go down, which carbon sequestration on farmland can contribute to. This is also the target levels of emission abatement that has been adopted for the assessment in this report.

Target emissions levels of carbon dioxide from beef and dairy production.



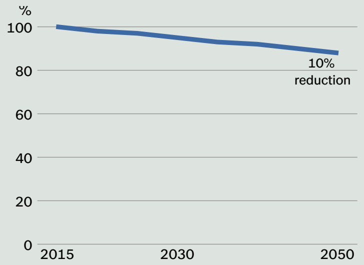
Methane

Sources:
Methane emissions from agriculture arise when handling manure and via feed digestion processes in ruminants who belch methane while digesting. In the case of anthropogenic methane emissions, there are three primary sources: fossil fuels (35 percent), agriculture (40 percent), and waste management (20 percent). Methane accounts for a total of 16 percent of anthropogenic greenhouse gas emissions globally, of which five percent comes from livestock (Global Methane Assessment UNEP, 2021).

The greenhouse effect:
Methane is a more potent greenhouse gas than carbon dioxide, but unlike the latter, methane degrades within approximately 10 years, which means that over time, methane does not contribute to an increasing greenhouse effect as long as emissions do not increase. If, on the other hand, methane emissions increase, which is happening globally, they have a significant warming effect on the climate right here and now. When methane degrades, carbon dioxide forms and if the methane comes from a fossil source, this will be a net addition of carbon dioxide in the atmosphere. Methane that comes from ruminants is biogenic and part of a natural carbon cycle.

Relevant goals:
The IPCC does not specify a separate goal for biogenic methane from ruminants, but researchers at Oxford University claim that a gradual reduction in emissions of 10 percent over 30 years will not lead to any additional warming and a more rapid reduction would result in a cooling effect (Allen et al, 2018). This is the target for the assessment of opportunities to reduce methane emissions from ruminants. Compared to emissions from fossil fuels the methane emissions from cattle also contributes to environmental benefits that are vital to the farming system, hence it is reasonable to have climate neutrality as a target for methane emissions from ruminants.

Target curve for emissions of methane from beef and dairy production.



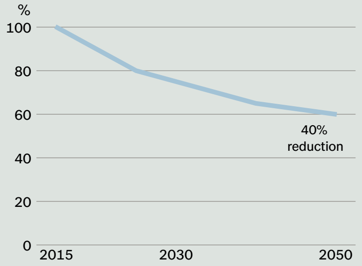
Nitrous oxide

Sources:
Emissions of nitrous oxide that can be traced to milk and beef primary production come from the storage, treatment and use of manure as fertiliser on farmland. Nitrous oxide is formed naturally by microbes in the soil that convert nitrogen compounds in the soil. When more nitrogen is added via fertiliser, the microbes increase production of nitrous oxide. Leaking of nitrous oxide accounts for eight percent of total anthropogenic greenhouse gas emissions.

The greenhouse effect:
Nitrous oxide is one of the most potent greenhouse gases. One kg of nitrous oxide has the same impact on the climate as almost 300 kg of carbon dioxide. There are currently no reliable ways of measuring actual emissions from farming, thus its climate impact.
Nitrous oxide has a relatively long circulation time and on average, remains in the atmosphere for between 110–115 years.

Relevant goals:
Nitrous oxide remains in the atmosphere longer than methane but for less time than carbon dioxide. The IPCC abatement levels for nitrous oxide is set for a reduction of around 40 percent by 2050 to reach the 1.5 degree target. This has also been adopted as the target for the assessment in this report.

Target level for emission reduction of nitrous oxide from beef and dairy production.



Method and definition:

Example farms for calculation of potentials

To be able to calculate sustainable beef and dairy production of the future, a simulation model has been developed to describe the theoretical potentials for the future. Potentials for beef and dairy production at farm level have been calculated using four example farms focused on climate.

These example farms have been defined based on statistics of median Swedish farms and representative farms with values for different basic data (such as number of animals, hectares, yield and lactations). The data has then been adjusted in line with actual production. The typical farms accordingly show an average production system rather than the most common farm per type of production.

Four example farms

These example farms are a way of calculating potential areas for increased productivity and reduced climate impact but have certain limitations. Certain potential areas are difficult to quantify. These example farms are kept intact from 2015–2030–2050 with regard to the number of breeding animals and area as well as crop rotation, as changes to these parameters would be very complex to calculate.

Certain simplifications have also been made, for example with regard to allocation of climate impact

The four example farms can be described as follows:

Small dairy farm – milk production
- Mixed forestry and agricultural area
- 85 hectares including pasture and semi-natural pasture
- 60 cows in production
- 9,900 kg ECM/year average milk yield
- Milking robot

Large dairy farm – milk production
- Lowland
- 256 hectares including pasture
- 240 cows in production
- 10,400 kg ECM/year average milk yield
- Milking parlour or rotary parlour

Suckler cow farm – beef production
- Mixed forestry and agricultural area
- 95 hectares including pasture and semi-natural pasture
- 76 animals in total, including 30 suckler cows
- 28 animals sent for slaughter per year


Photo: Emma Liedberg

Bull farm – beef production
- Lowland
- 56 hectares
- 131 dairy bulls in production indoors
- 105 animals sent for slaughter per year

Method

The method for this report includes studies of literature, surveys, calculations, interviews with researchers, experts, and stakeholders, as well as workshops. The project organisation, which consists of representatives and resources from the participating organisations, has produced its own definition of sustainable production, identified, and analysed potential areas within the focus areas and calculated these for the example farms.

Scope

Farmland as a resource for beef and dairy production is included in this work, but for conclusions about cultivation specifically, we refer to Lantmännen's previous report, Farming of the Future (2019).

This work includes "from farm to gate". This means for example, that the possibility of increasing resource efficiency by a reduction in food waste has not been considered.

Improvement measures within sectors such as transport or slaughtering have not been considered.

Definition of sustainable beef and dairy production of the future

Our starting point is four principles that define sustainable beef and dairy production in the future which serve as long-term goals for development moving forward.

Animal welfare

Livestock should be in good health and have opportunities to behave naturally, in line with Swedish legislation or equivalent level. The production systems that are developed need to be ethically sound and gain broadly acceptable among consumers.

Productivity

Livestock farming must be resource efficient, and food nutrient dense. The degree of self-sufficiency needs to increase as does the possibility of meeting growing global demand. Grassland and pasture should be used in the best way for food production. Nutrients and by-products should be circulated for efficient use and water usage adapted to climate changes and extreme weather conditions.

Planet

Climate impact should be reduced according to the Paris Agreement with the goal of limiting the global temperature rise to less than 2 degrees with a target of max 1.5 degrees. Energy and material use should move from fossil to renewable.

Biodiversity should be assured to maintain ecosystem services. Farmland and pasture must remain fertile, the capacity to deliver a good yield and produce renewable resources. Optimising the potential of farmland and pasture to store carbon, based on local circumstances, is key to contributing to reduce the climate footprint.

The need for plant nutrition, plant protection necessary for high yielding production, are to be met in a sustainable way and such nutrients are to be utilised in full, without systematic loss to surrounding ecosystems.

Profit

Long-term sustainable production includes profitability at farm level, and opportunities for new investments and initiatives that are required to meet the big challenges that food production is facing. Profitability is also crucial for attracting the next generation to invest in a future in farming. At the same time, sustainable production must be cost effective to create affordable products that are competitive on the market, both in Sweden and globally.


Photo: Lantmännen

Results:

Farms of the Future

In the following chapter, we discuss our results and the eleven focus areas and associated potentials which are needed to increase productivity and reduce climate and environmental impact, as well as boosting biodiversity until 2050.


Photo: Växa

Results: Farms of the future

Eleven focus areas for sustainable beef and dairy farming in the future

In the following chapter, eleven focus areas and their potential to increase productivity, profitability and reduce the impact on the climate and environment by 2050 are described. This without compromising biodiversity and animal welfare.

Animal health and lifetime production

Measures that improve the health and lifetime production of cattle in combination with breeding have the potential to reduce climate impact on the dairy farms by up to 25 percent and by up to eight percent on the beef farms by 2050.

Healthy and productive animals have a lower climate footprint per product produced. Swedish production of beef and dairy is efficient with high yield, which results in lower climate impact per kg produced.

The average milk yield per cow in Sweden, is high in a global perspective and continues to rise. Continuous improvements in feeding and management in combination with breeding advances have contributed to a linear increase in average milk yield of about one percent per cow per year over recent decades. On the other hand, it is more difficult to verify a similar trend within beef production, despite the genetic potential. Obviously, there is a physical limit where increased production can affect animal welfare negatively, and increased productivity can no longer deliver any positive climate impact. This increased productivity is being driven by improvements in animal health, breeding, feeding and feed efficiency, better management, routines on farms and automation. Breeding contributes to the positive effects of improved animal health and lifetime production. In the case of dairy and suckler cows, it is important to extend their productive lifespan, while maintaining high productivity. Infections, lameness and udder problems, physical injuries and calf mortality reduce annual production and lifespan. It also results in more input such as feed, buildings and labour in relation to the amount of beef and dairy produced, which is negative for both the climate and profitability.

Potential

For the dairy herds, there is potential for higher lifetime yields via reduced calving age, reduced recruitment percentage and longer lifespan. For recruitment heifers, optimal growth offers an opportunity to lower calving age. A shorter rearing period means fewer biological emissions and lower use of feed and other agri-supplies which reduces climate footprint. Studies of dairy cows show that the current calving age of 27–28 months can be reduced to 24 months. Today dairy cows on average produce milk for 2.5 lactations, which also coincides with the point in time where the average cow starts to generate an economic surplus. Lifespan can be increased via an efficient breeding strategy where you only recruit from the genetically superior dams. If every cow can keep producing for longer, fewer recruitment heifers are needed on farm and the surplus can be sold. Another alternative is to sire heifers or cows of lower genetic merit with beef breeds and increase the output from the replacement rearing. Older cows generally are higher yielding than first calvers, which means that extending lifespan also favourably benefits profitability and productivity in milk production.

Another factor that affects lifetime production is fertility in the herd. For the sake of good profitability and lower climate impact, it is important that cows calve at the right time and that gestation leads to a fit and healthy calf. It is especially important for profitability in suckler cow production. Improved fertility and optimal calving intervals can be supported by technology for measuring and monitoring oestrus, management and genetic improvements.

Växa's vision is to lead the development of sustainable food production and contribute to greater sustainability for animals, people, environment and economy. We are owned by approximately 6,000 members and we are a nationwide consultancy and service company for farming businesses, primarily within beef and dairy production. Växa works with preventative animal healthcare with the aim of promoting good animal welfare and high production. Via official commissions and grants from the Swedish Board of Agriculture, we work hand in hand with our customers to prevent antibiotic resistance and infectious diseases. The Swedish cow recording, with data collection quality assured to international standard by ICAR, is managed by Växa and is globally unique as it includes eleven different sources. Via technical development and member-owned data from cow recording, we provide our customers with key figures for enabling them control of their production via our management tool MinGård®. Right now we are working with breeding for high feed efficiency, feed advice for self-sufficiency of protein rich feed, climate advice and management courses. We also sell technical equipment for monitoring and management of heat and health of beef cattle.


Photo: Fredrik Persson/Svenskt kött

Conception rate, calf survival and calf health are of major importance for sustainable production. Calf mortality is up to 10 percent in Sweden. The most common reasons are partly stillborn calves due to calving difficulties, and health problems in a calf's first year of life. This can be reduced with the right management and rearing during the dry period. Calf health is generally good in Sweden but can be improved with good colostrum routines, optimised rations and focus on calf care.

Preventative measures such as vaccination or infection control programmes can also contribute to improving the health status in the herd. Antibiotic use does not have a particularly big impact on the total climate footprint of a farm, but is, on the other hand, significant for long-term sustainable production. Regular procedures with inspections and monitoring programmes with samples taken for salmonella and paratuberculosis are important. Keeping animals clean is also key to health and welfare of herds. Measures that extend lifetime production such as preventative vaccination programmes and the prevention of other diseases, reduced calf and young animal mortalities, increased growth, efficient breeding work and feeding, reduced calving age and reduced recruitment, can be achieved shortterm, with effect from 2025. Digitalisation, automation and new technology offer support via improved monitoring and decision-making data. Implementation requires good management and a lot of hard work to achieve the right effect.

Challenges

- Optimised management, including increased knowledge and improved routines requires effort but will also benefit profitability of dairy and beef herds.
- Better practical conditions and support to keep beef cattle in the correct body condition score and with optimal growth rate. Better and more effective decision-making support via digital tools and more advice and knowledge transfer will be required moving forward.
- Better profitability in farming is required to enable investments on farms such as digital tools, housing and technological solutions.
- Good access to veterinarians with specialist expertise within beef and dairy production and the area of infection control programs is required.
- Multidisciplinary approaches that include areas such as veterinary medicine, epidemiology, ecology, livestock farming, construction engineering, human medicine, behavioural science and economics are required. Research is based on collaboration between different professions to gain more knowledge on how infections are spread, and sustainable utilisation of our ecosystem.
- Infectious diseases and antimicrobial resistance will be a big challenge for livestock farming and food supply in the world, with many different infections that require coordination between authorities and internationally. Increasing globalisation and global warming will increase these risks.

Lactation
When a cow calves, she starts producing milk. This process of producing milk is called lactation. Lactations are numbered in line with how many calvings a cow has had.
Milk production is greatest at the start of lactation, with over 50 kg of milk per day. This imposes high demands on cows being given good and nutrient rich feed.

Breeding for healthy cattle

Breeding measures in combination with measures that improve the health and lifetime production of cattle, can reduce climate impact on the dairy farms by up to 25 percent and up to eight percent on the beef farms by 2050.

Breeding is improving genetic traits within selected key areas, that result in increased productivity, greater profitability and better animal health. It is possible to breed for traits that contribute to even greater resource efficiency and climate efficient production in the future, with continued high animal welfare.

Potential

Advances from breeding are expected to continue to increase for both dairy and beef breeds. Traits are being improved all the time, and not only for yield and lifespan, but also calving ease and animal health. Factors that boost this development include:

- An effective breeding strategy in dairy herds, where only the cows with the highest genetic merit will be inseminated with dairy sires and the rest with multipurpose or beef sires can increase profitability and reduce climate impact. Alternatively, different dairy breeds can be crossbred to avail of hybrid vigour.
- Genomic testing is an important technique which is based on statistical models and genetic mapping. It provides higher safety and enables shorter generation intervals and a more intensive selection of animals. Today all future AI bulls and many heifer calves are tested genomically, which provides more efficient breeding work at farm level. This area offers further potential, 20 especially within beef herds. Within dairy production, this is particularly effective in combination with artificial insemination of beef breeds and also sexed semen.
- Improved breeding goals that entail the addition of new traits, greater precision and registration of existing traits, such as feed efficiency and looking forward, also methane emissions and heat tolerance.

Breeding is being done to increase feed efficiency for Nordic dairy livestock, but the results are modest as we do not have enough data on individual feed intake.

An increased use of sensors or other technology that record individual feed intake, will offer significant opportunity to make greater progress with regard to feed efficiency via breeding measures in the future.

Breeding for reduced methane emissions is interesting but relatively unexplored and it is difficult to forecast its potential. This means that cattle with the genetic potential to produce less methane can be identified. Studies show that these properties can have a significant inheritance factor and that there is a correlation with feed efficiency.

Breeding for heat tolerance is another area that is being explored in some parts of the world. This can possibly also be pursued in Sweden as a result of a warmer climate. The main impact will be in both consolidating genetic advances already made via management on farms and developing genomic testing and analysis. Advances within breeding in feed efficiency for example, can be of significance. Progress is expected to continue at the current rate for both dairy and beef breeds unless factors such as a new direction within livestock farming influence such development.

Challenges

- Greater progress within breeding with regard to the climate impact of animals will require access to data and use of such breeding values both by breeding enterprises and producers. Also, an effective breeding strategy and implementation must be pursued at farm level. The strategy should also aim to keep dairy cows in production for longer than the current average of around 2.5 lactations.
- More breed lines suited for different production systems are needed to preserve large genetic variation.
- Continuous genetic improvement is relatively inexpensive, but to maintain constant progress, resources are needed, especially to secure performance under local conditions. Unlike several other countries, Sweden does not provide any government funding for the sector. It is instead up to livestock owners themselves to pay any AI costs or register with control systems.
- Develop breeding with continued focus on production, without compromising natural behaviour traits and acceptance among consumers.
- If further progress is to be made within new areas and traits, international cooperation including data sharing will be required. Better data and artificial intelligence can deliver robust breeding values and quicker results. Studies in rumen microbe productivity and function are one type of data source that could be used to predict key properties in the future.

#SvensktKött

Svenskt Kött is a brand independent organisation and a forum for anyone wishing to learn more about Swedish meat and its added values. Our job is to ensure future development of the sector. Swedish farmers are in the frontier regarding sustaiable meat production, but we can always improve. Cooperation within the sector and with other organisations is the key to success. Our vision is for Swedish meat to be the first choice when you eat meat, both today and in the future.

Photo: Växa

Feeding strategy

Optimised feeding strategy on the farm in combination with improved roughage production and concentrate feed ingredients, climate impact can be reduced by up to one fifth on both the dairy and beef farms by 2050.

A well planned and implemented feed strategy on the farm, based on knowledge, modern technology and access to better feed ingredients, can reduce impact on climate and the environment. Production improvements are also positive for farm profitability. It is possible to find solutions that optimise both the environment, animal health and economy.

Potential

One key area with potential is to ensure animals are given the right feed to be productive and stay healthy. By planning, setting goals for and monitoring the quality of roughage, you increase the chances of providing the right feed for each animal, which increases feed efficiency, i.e. how much feed is required to produce one kg of beef or milk. It also increases the opportunity to produce as much as possible, from the feed on the farm. High feed efficiency is profitable and reduces climate emissions per kg of beef or milk.

By analysing the quality of feed, the nutrient content and digestibility of the feed can be optimised for the different animal groups on the farm and make it easier to plan to allocate feed based on quality and quantity during the housing season. This also improves opportunity to find new feedstuffs, such as by products from food processing like brewer grains etc. Planning and monitoring the quality of feed and rations are a natural part of good management in a farming enterprise.

With the right feed strategy, there is potential to significantly increase feed efficiency and the possibility of saving up to 25 percent of feed while maintaining the same level of production.

Reducing the protein content in the ration can increase nitrogen efficiency and reduce nitrous oxide and ammonia output from the farm with improved profitability.

For example, reducing the crude protein content of dairy cow rations from 18 to 17 percent, will increase nitrogen efficiency from 32 to 34 percent. This can be achieved in the short term. The next step is to reduce protein content even further. Research shows that reducing the crude protein content in dairy cow rations to 15 percent ought to be possible in the long


> "Reducing feed waste and production losses are significant opportunities moving forward."

Photo: Lantmännen

run. In the case of beef production, measures such as increasing the protein content in roughage and optimising the protein content of the feed in line with the growth potential of animals, can have a big effect. Another way is to review the amino acid content in rations and add any amino acids that are missing. Adding amino acids to feed, increases opportunities to use locally grown crude protein content and by-products.

Reducing feed waste and production losses are significant opportunities moving forward. Every kg of waste leads to unnecessary emissions, lower feed efficiency and a risk of reduced profitability. Losses can occur throughout the production chain, from cultivation and harvesting to storage and feeding. Losses and waste can be reduced by using automatic feeding systems, developing more palatable feed, using silage additives and developing feeding equipment for use outdoors. According to estimates, storage losses can be reduced by five to ten percent by using silage additives and the right technology when preserving feed. Feed waste at the feed trough can be reduced by six to eight percent on dairy farms and by over 15 percent on beef farms, by using techniques that keep the feed palatable for longer.

Challenges

- Expert advice and specialist knowledge is needed to help farmers optimise their feed strategies and feed quality. Solutions that provide access to the data required for decision-making will also be needed.
- Better methods and technology to measure feed intake and roughage quality, preferably on farms should be developed.
- Using grass and pasture even more efficiently in rations requires technological developments that enable more efficient harvest and silage processing as well as more plant breeding focussed on yield, nutrient content and climate resilience.
- To be able to reduce the proportion of crude protein in rations, more research on effect on animal health, productivity and lifespan is required. Access to pure amino acids that are adapted for ruminants is limited to date.
- Incentives are required to realise the potentials. New forms of financial compensation for investments in new technology for better management for instance. Another challenge is that many beef farms are managed part-time, which can reduce opportunities to invest the time and money required.

Roughage production

Climate impact can be reduced by up to one fifth on both dairy and beef farms by 2050 through measures for improved roughage production in combination with optimised feed strategies and other feed ingredients.

Grass silage and grazed grass is the core of cattle rations in Sweden. Grassland management and production of other roughages such as maize, whole crop silage etc. not only affects animal productivity and farm profitability but is also of significance for net emissions of greenhouse gases and the impact on biodiversity on the farm.

Grassland ley and semi-natural pasture account for over half of the farmland in Sweden. Agricultural activity is of major significance for rural economies and for Swedish food production, not least when it comes to beef and dairy production. Of the million or so hectares of ley, around 40 percent is utilised for milk production and 25 percent for beef production.

Pasture comprises a significant proportion of roughage intake for Swedish ruminants. Of the 400,000 plus hectares of semi-natural pasture in Sweden, 70 percent is utilised in either milk or beef production. In line with rationalisation and specialisation within agriculture and rising import of dairy products, beef and feedstuffs, large areas of semi-natural pastures have been taken out of production. Also ley areas have shrunk by five percent since 2011 (Swedish Board of Agriculture, 2020).

However, measures have been taken to increase pasture areas again.

The cultivation of forage crops offers many advantages from a sustainability perspective. It provides feed for livestock, but also improves soil health and increases the binding of carbon dioxide in the soil, so-called carbon sequestration. The number of seasons a ley is left before reseeded or followed by other crops, affects carbon sequestration. Where grassland is part of the crop rotation it provides resilience and the best possible production biology to the soil. Grasslands are important for biodiversity, both in the soil and above the soil surface.

Increasing agricultural areas and productivity for grassland accordingly offers sustainability benefits for both farming and society in general, but it can also lead to other challenges. For example, early grass harvests affect species such as larks in certain parts of the country. Incorrect nutrient management of grasslands can lead to increased emissions of greenhouse gases, and increased nutrient run-off that causes eutrophication in lakes and seas.

Potential

The productivity and profitability of grasslands can increase and produce significantly larger yields, via research and analysis of grass quality and optimised management. Yields can also increase and nutrient content improved via precision management, increased irrigation, investment in plant breeding and via improved cultivation systems. Climate change will lead to new conditions with longer growing season and variations in precipitation. Increased production of roughage of high quality will lead to opportunity of increasing the proportion of the ration that is produced on the farm.

By 2050, the proportion of roughage in rations is assumed to be able to rise significantly.

There is significant potential to improve the nutrient quality of roughage, which will reduce the total climate footprint of rations. An investment in biorefining of grass ley could also open the door to developing new feed products with a good amino acid profile for both ruminants and monogastric livestock.

When it comes to environmental and climate impact, there is also potential for improvements connected with production. Emissions of greenhouse gases and nutrient loss from the use of fertiliser can be reduced via new plant nutrition strategies, analysis methods and precision technologies. With precision nutrient management, such as the Yara N-sensor for fertilising, and avoiding using heavy machinery that compacts the soil, yields can be increased and emissions of nitrous oxide reduced. Another potential opportunity is to grow more maize, which is a type of roughage that can provide large yields from one harvest and can replace other less climate efficient feed ingredients.

Challenges

- Investments in new technology and wide implementation of new management systems will be facilitated by advice. Cross disciplinary cooperation between advisors is necessary where grassland management ration formulation and animal performance and health may be more integrated in the future.
- Many of these measures will require investments and further research, such as technology for biorefining forage, research into plant breeding and irrigation systems, plus technologies to be able to connect the different systems and analysis tools that are required for precision farming.

Yara sells plant nutrition to farmers within agriculture, professional gardens, parks and the forestry sector – especially adapted to Swedish growing conditions. We have helped farmers to produce food in the best possible ways for over 115 years. Research, development and innovation are the foundation stones of the company in supplying farmers with the best possible mineral fertiliser products plus knowledge on how best to use them. We are now proud to take cultivation to the next step with new technology that provides fossil free mineral fertiliser and new digital technology in cultivation with a series of tools for optimised fertiliser usage and plant nutrient utilisation – with the least possible impact on surrounding environments.

Feed ingredients and feed additives

Feed ingredients in combination with measures taken within feed strategies and roughage production, can reduce climate impact by up to one fifth on both the dairy and beef farms by 2050. Methane reducing feed additives can reduce climate impact by up to one tenth on the farms.

Feed is a major potential for reducing the climate impact of beef and dairy production. On an average Swedish dairy farm, production of roughage and concentrate accounts for around 35 percent of greenhouse gas emissions. A big part of the emissions comes from ingredients that are used in concentrate and how big an impact this has, depends on how and where these ingredients were grown and produced.

With an increased mix of by-products from grain, such as draff and wheat middlings plus protein crops suited to the Swedish climate, such as rapeseed, faba beans and peas, the climate impact of rations can be reduced. If one protein ingredient is to be replaced by another ingredient with a lower climate load, the protein quality and amino acid composition in the replacement ingredients must be comparable.

This will be possible with the addition of pure amino acids to the ration.

When it comes to protein ingredients currently imported, over half are used in factory produced concentrate. One imported ingredient is soybean meal. Over the last decades the amount used in cattle rations has gradually reduced and accounts for around four percent of the content of conventional concentrates today. Soybean meal has high concentration of crude protein, high ratio rumen undegradable protein and a good amino acid profile. However, growing soy has a big climate impact and other challenges associated with biodiversity, mainly due to deforestation. Today Swedish feed production exclusively uses responsibly produced soy, in accordance with the Swedish Soy Dialogue definition. This means that many sustainability related risks are managed, such as ensuring that there is no risk of deforestation.

The largest protein ingredient in concentrate for cattle today is rapeseed by-products such as rapeseed flour and rapeseed cake. Other protein ingredients include faba beans, draff and peas.

Around half of the rapeseed products used in feed is of Swedish origin and the rest is imported from Europe. Faba beans and peas are grown in Sweden on a limited scale. The climate impact of domestic protein ingredients is relatively small. Soil conditions, damage from wild game animals and cropping related challenges and crop risk are limiting factors. Both faba beans and peas have lower protein content and poorer protein quality than rapeseed flour and soybean meal.

Other important ingredients in beef cattle rations are by-products from the food industry, such as draff and grain by-products.

Feed has historically consisted of ingredients unsuitable for human consumption and this is still the case today. By increasing the use of by-products in feed production, imports of ingredients such as soy and palm oil products can be reduced. Today use is limited by access and nutrient quality. New process technologies and increased food production leading to more by-products with the right nutrient quality may change this. Increased use of protein ingredients and by-products of inferior nutrient content is possible if they are combined with addition of pure amino acids to the ration. Amino acids in concentrate, can also boost nitrogen efficiency in beef and dairy production without reducing animal productivity.

Potential

There is significant scope to reduce climate impact from protein ingredients in concentrate. Replacing imported protein ingredients with domestic alternatives such as rapeseed products, faba beans and peas and adding pure amino acids, can reduce climate impact by five to twenty percent. Reduced crude protein contents in total feed rations is also significant for emissions of greenhouse gases as this increases nitrogen efficiency.

In addition to protein ingredients, varying proportions of grain and corn are also used in concentrate, and the quality of the grain is extremely important. Improved quality can mean that domestic grain can be used to a greater extent. Making this switch can lead to lower climate impact, not the least through programmes such as Lantmännen's Climate & Nature, where the ingredients have up to 30 percent less climate impact.

Vegetable fat from oil palm origin added to rations today, is a by-product of palm oil refining. This is a low proportion of the total diet and does not have a significant impact on the climate and biodiversity per kg milk and beef. Palm oil has a unique composition and there is currently no competitive alternative with similar nutrient content available on the market. Replacing palm oil-fats with other fats, will require new technology and innovation. One first step to reduce climate footprint is to use responsibly produced palm oil ingredients.

Dairy cooperative Arla is making further investments towards the 2045 net zero target for Sweden. By a climate check programme that is used by Arla farmers in seven countries, Arla aims to reduce the annual CO2e emissions on farms three times faster in the coming years. The programme collects information on CO2e emissions from the dairy sector, which is then stored in what is one of the world's largest externally verified climate databases to contribute to more sustainable farming in Europe. Already today, Arla farm's CO2e emissions per litre of milk are less than half the average figure in the dairy sector. With the new climate check programme, Arla's 9.900 farmer owners can reduce their climate emissions even further.

Development of new additives within feed production has made rapid advances in recent years. This includes products that have positive impact on productivity, cull-age, health and greenhouse gas emissions, especially methane.

There are a number of different feed additives that are being developed and tested, and which are showing good potential to reduce methane emissions from ruminants. However, further studies are required to ensure that animal health and product quality are not affected while the effect of reduced methane emissions is long-lasting.

Implementation of methane reducing feed additives is probably possible as early as 2030.

The speed of implementation will be dependent on cost, production and feed system.

Challenges

- If it is to become possible to increase the proportion of locally produced feed ingredients and by-products, conditions for growing and processing these must become more efficient. It will impose new demands on both growing, access to land and improved knowledge about crop rotation and plant breeding. For an increased domestic production of feed crops, losses caused by wild game must be reduced.
- Transition to new and more sustainable feed ingredients and by-products will require research and development focussed on new ingredients, process technologies and methods, plus feed evaluation, nutrition and production response.
- Replacement of ingredients and new additives that cut emissions will entail new costs, and payment models that deliver profitability must be developed where the consumer also is willing to pay for the value added to the products.
- The development of methane reducing additives will require investments in research and verification that the effects will be both long-lasting and have no negative impact on animals or products. Large scale production will also require large investments.

"Increasing the use of by-products in feed production can reduce imports of ingredients."


Photo: Växa

Photo: Yara

Fossil free farming

Measures promoting fossil free farming can reduce climate impact by up to ten percent on the farms by 2050.

The primary causes of carbon dioxide emissions of fossil origin within beef and dairy production are fuel for machinery on farms, fertilisers that are produced using natural gas, agricultural plastic for conserving and storing feed. Fossil diesel is the most common fuel in tractors and other farming machinery.

There are several fossil free alternatives on the market, of which HVO (hydrogenated vegetable oil) is the most common, as it can be used in ordinary diesel engines without any modifications. Biogas is another renewable fuel but is not as widespread today.

A cheaper fuel option which is forecasted to make advances is RME (bioethanol). The step away from fossil diesel is somewhat larger, as machinery manufacturers do not automatically offer any guarantees for its use today. Trials have shown that RME works well in new tractors following minor modifications. In the long run, there is also possibility of developing other renewable fuels and electrifying farm machinery.

Mineral fertilisers are a concentrated product, composed to deliver the right nutrition to crops and increase yields. Climate impact from the manufacture of plant nutrients consists of two parts, nitrous oxide from the production process and the use of fossil natural gas as energy source. Emissions of nitrous oxide from production process can be avoided by using Best Available Techniques (BAT), which is already being implemented in the EU. Fossil natural gas is used as a source of both energy and nitrogen when ammonia, which is the base for mineral fertiliser, is produced, and this has a large climate footprint.

Ammonia can also be produced with the aid of hydrogen from electrolysis, which can be done without using fossil fuels. Despite this method being energy intensive and expensive at present, it is considered to be possible to scale up the process in the short to medium term.

Organic nutrient sources primarily are residues from harvest or manure from livestock. The nutrient supply from manure covers considerable share of the nutrient demand on beef and dairy farms in Sweden but is strongly correlated to the level of production intensity. Plant nutrition from wastewater and sludge may also come into consideration in the future if the right conditions exist.

Milk production requires a substantial amount of energy and electricity for milking, ventilation, feed management, scraping manure, chilling milk, heating of water and buildings. In the case of beef production energy demand is generally lower.

As technological developments increasingly move towards more automation and robotisation of manual work, there is a need for more electricity while new technology and a focus on energy efficiency offer opportunities to reduce consumption – something that is important from both a climate and profitability perspective.

There are also good opportunities for farmers to procure or produce their own renewable power, such as wind, solar and biogas.

Potential

Replacing non-renewable Agri supplies with renewables results in an immediate climate effect. Replacing fossil fuels and a shift to fossil free mineral fertilizer makes the biggest potential, but consumption of energy and plastics on farms is also of importance. Cropping methods with reduced tilling also reduces fuel consumption.

Challenges

- Techniques that are required are already largely in place, but fossil free agrisupplies such as fuels and mineral fertilisers entail production costs that are far too high and that mean many Swedish farming enterprises do not have the financial means to contemplate them, as the corresponding cost increase cannot be passed on to the market today.
- A lot of farm machinery is not approved by manufacturers to run on renewable fuels. At present, warranties and insurance do not cover the use of alternative fuels.
- Liquid biofuels need to be supplemented with other solutions, such as biogas operation or electrification.
- Compensation to farmers or a change in financial conditions in switching to new fuel systems, investments in electrification on farms, and the approval of fuel standards for HVO with sustainable ingredients are required moving forward.

Lantmännen

Lantmännen is an agricultural cooperative and Northern Europe's leader in agriculture, machinery, bioenergy and food products. Lantmännen is owned by 19,000 Swedish farmers. Farming of the Future is our vision and strategy for sustainable and profitable Swedish farming with the aim of being climate neutral by 2050. Within Farming of the Future, we have set out what is required within eleven critical areas for crop farming and identified potentials and challenges moving forward. We are actively striving to achieve this goal – to increase yields and reduce climate impact – for example by major investments in knowledge and research, the development of climate smart feed, precision farming and plant breeding for high yielding, drought resistant crops.

Carbon sequestration

Measures for increased carbon sequestration on Swedish farmland have potential to reduce climate impact by up to 10 percent on the farms.

Carbon sequestration is positive for soil health and soil fertility. If Swedish farmland is to retain the carbon already sequestered in soil and continue to be able to sequester even more of carbon by the net addition of organic material and via plant root systems grassland management and cattle enterprises are key.

In addition to carbon sequestration, the circulation of biogenic carbon also has a positive effect as carbon is absorbed in growing crops – especially if fossil energy can be replaced by biobased energy from farmland.

Swedish farmland sequesters around 2.4 million tons of carbon dioxide per year, according to estimates from SLU. Pastures sequester around 0.3 million tons of carbon dioxide per year. To be a functioning carbon sink, atmospheric carbon must be absorbed and remain in the soil.

The potential of carbon sequestration varies widely depending on the conditions for storage and management and is best measured over a longer time period, preferably up to 10–25 years. This makes it a challenge to quantifying carbon sequestration so that it becomes useful in climate calculations and for carbon credits.

Potential

Swedish farmland generally contains carbon sequestration, and this could increase via active measures by 2030.

Scope for this varies from region to region. In lowland areas with a high proportion of annual crops, there is greater potential to increase carbon sequestration with the aid of more perennial leys in crop rotation, while grass ley already is dominant in mixed forestry and mountainous areas, where the potential for further increase is smaller.

The main driving force behind increased sequestration is large root systems that remain intact for long and gradually turn into carbon sinks over time. If agricultural systems do not change much, the potential is primarily in increasing biomass yields via more intensive farming, leaving grassland for longer, crops with larger root systems, and crop rotation that maximises yields. Increased farming intensity, perennial crops such as grassland, catch and intermediate crops are driving carbon sequestration.

Temperature increases in association with climate changes will also drive increased in yields. This may lead to at least one additional silage cut in intensive systems, in almost all of Sweden, by 2030. This will however also depend on future precipitation patterns.

Estimates of semi-natural pastures show that carbon sequestration can amount to around 30 kg of carbon per hectare per year on extensive pasture, while grass leys can sequester 200 kg of carbon per hectare per year. By developing grassland management systems for increased yields and growth rates, using high yielding varieties and new crops, sequestration can be further increased.

Photo: Yara

Other practical farming measures that contribute to increased yields and carbon sequestration, include fixed routes in fields, irrigation of grassland, well-functioning drainage and manure management.

Agroforestry is a collective term for farming systems that combine trees with crops or pasture. There is potential to increase carbon sequestration but farming methods will require significant adaptations when introducing agroforestry.

Via factors such as intensification, the impact of climate changes on growing conditions, plus choice of crops, the potential for carbon sequestration can amount to around 645 kg of carbon per hectare per year from 2030 and onwards. That is three times the current sequestration level if you compare it with sequestration for annual crops (Bolinder et al., 2017).

Staying green throughout the year also has a positive impact on biodiversity, and nutrient loss is reduced and soil health is improved with increased carbon in the soil.

Challenges

- At the moment, there is no generally accepted system for how future potential for carbon sequestration in farmland should be calculated and techniques for measuring are relatively expensive. Cost effective alternatives can speed up the development of a trading system here.
- There is no payment model that works for already sequestered carbon today, even though several projects have been started to tackle the issue. Measures for carbon sequestration requires compensation to farmers for loss of income due to lost production. Alternatively, production must increase on remaining land to compensate for the loss. One challenge can be to keep the carbon in the soil. A change of land use can have the opposite effect. The compensation issue could be resolved by political means for example, that create a market for carbon sequestration or if carbon sequestration is included as a price control parameter in trading systems.
- Finding the best possible farming systems that match demand for feed and with good carbon sequestration capacity, at the same time as climate changes are imposing high demands on new crops and varieties, will be a challenge moving forward.
- Research is needed to obtain a better understanding of the quantifiable effects of different kinds of crop rotation and farming systems. How carbon sequestration capacity will be affected by probable climate scenarios in the future should also be further illuminated.

Photo: Johan Olsson

Photo: DeLaval

Digitalisation, automation and new technology

Digitalisation, automation, and technology can reduce climate impact by supporting management and make farms more efficient.

Automation and robot technology can lead to efficiency gains. When feeding, waste is reduced and feeding becomes more precise at the feed trough. Automatic milking systems offer efficient and gentle milking and udder draining, which means the process is quicker – but does not affect the quantity, composition or quality of the milk. More cows can be milked per day and each cow gets more time at the feed trough and for ruminating. Automation frees up labour and enables greater precision, which leads to fewer losses.

Precision farming for liming, fertilising and manure spreading is being further developed. Technologies such as N-sensors are used in agriculture and there is potential for further implementation, both for tillage and grassland production. This can increase nutrient efficiency and production.

Technology on farms, such as robots and automation, makes daily management of animals, stalls and milking easier. It can also improve managing and monitoring animal health and welfare. If deviations can be identified at an early stage, the correct measures can be taken before an animal becomes too ill and to improve welfare and production.

Sensor systems for precision livestock farming are becoming increasingly common on dairy farms, such as activity monitors and sensors that detect oestrus, lameness and rumination time. Virtual fences are being developed and tested, primarily on semi-natural pastures. This reduces the workload for farmers, creates flexibility and supports strategies for grassland management. Exchanging services and products can also make a difference, where growing protein crops or grass for milk production can be done in exchange for manure, for example. Cooperation on biogas facilities, machinery and technology are other examples where there is a big potential to achieve efficiencies.

Potential

The effects of increasing automation, robot technology and sensors for data processing and analysis are difficult to quantify as a potential. They will deliver definitive effects that support optimal management on farms, for example when it comes to supervision and increased precision in pasture management.

Studies from several countries show that traditional feeding practises in dairy herds results in around ten to twelve percent losses and optimal feeding around two to four percent losses (DeLaval customer survey). In other words, the potential for reduction appears to be relatively large.

The development of sensors and algorithms that enable early detection of deviations is positive for animal health and has the potential to result in more lactations and more milk per cow, reduced calving age and fewer cattle reared for recruitment.

This development also means better technology for more efficient automated milking and automatic body condition scoring. The role of a farmer requires expertise in managing advanced technology and in time, translating data into decisions, which brings with it, a need for more interaction and support from advisors. All such agriculture related data is a big asset.

With AI, data can become valuable, provide opportunities for forecasts and act as a decision-making platform for both farmers and the processing industry.

Developments towards both cooperation and specialisation can deliver effects for productivity. A specialised breeder can improve the rate of growth with a lower calving age and smaller recruitment percentage, which will result in lower climate impact.

Precision farming is at a very early stage and is estimated to be able to deliver a three percent increase in crop yield in a short period of time, with an increased effect when digital platforms and technologies in agricultural machinery are available at affordable prices. A next step is to use sensor technology for precision fertilising of grassland to increase yields. Good planning and storage of feed reduces feed and financial losses, something that also is likely to be an important measure to reduce greenhouse gas emissions. Good storage also contributes to forage being of high quality which contributes to lower feed usage with less need for other feed products.

Challenges

- There is an extensive need for increased know-how and a greater interest in the use of technology within the sector.
- There is a need to continue to develop services or technologies that convert data into information to support decision-making around production and animal health in general. Enhancing farmer management can unlock big potential benefits.
- Feed technology that measures feed intake and contributes to greater precision and improved digestion, will make it easier to provide the right ration at all times.
- Data from different sensors is an important area and the question of who owns the data must be resolved.

DeLaval

DeLaval offers milking equipment and solutions to dairy farmers all round the world that help them produce more food and at the same time reduce their environmental footprint while improving food production, profitability and the well-being of the people and animals involved. Automation and digitalisation are two areas that are becoming increasingly important where new technology and data offer many opportunities to run more sustainable dairy farms. With the support of technology and sensors from DeLaval, milk producers can measure different parameters that provide insights into both animal well-being and milk quality, which lay the foundation for good animal health, high milk production, optimised feeding, good reproduction and cow longevity.

Biodiversity

Ruminants and grassland are crucial for biodiversity in Sweden. Ruminants maintain species rich semi-natural pastures that are under constant threat of overgrowth. Cattle also utilise grass ley, which is Sweden's largest crop and important for many ecosystem services like carbon sequestration, soil health and structure.

Biodiversity and functioning ecosystems are necessary for agriculture. Fertile soil with microorganisms and pollinating insects is vital ecosystem services that agriculture sustains and is dependent on. For thousands of years, ruminants have been a fundamental part of food production in Sweden. Grazing livestock have shaped landscapes with nature types of with aesthetical, cultural and biodiversity values. Swedish meadows and pastures are among the most species rich environments in the world today (Anthology ed. Tunón, Sandell, 2021). By continued utilisation of semi-natural pastures and grass ley as part of the modern agricultural system, we can increase the opportunity to produce food in a sustainable way. This also enhances our capacity as a society to adapt to climate change from via species diversity, as different species manage different climate factors in different ways. What's more, ley and pasture are positive for the soil structure and the water-retention capacity of the soil, and ley is a failsafe crop that sequesters carbon in the soil.

On pastures, grazing and cattle hoof marks are important in keeping away more competitive grass, herbs and scrub that can otherwise take over. Pastures facilitate many species to co-exist in a small area. Semi-natural pastures are also often home to several different tree species, including old trees, which are very important for birds, insects, mosses, lichen and fungi. Grazed forest margins are particularly species rich habitats with flowering bushes and deciduous trees.

According to the Swedish species information centre report of 2020, overgrowth in agricultural landscapes is the biggest cause of loss of biodiversity in Sweden and has negative impact on over 1,400 species, classified as endangered. Several different landscape types are affected by overgrowth, but species rich semi-natural pastures are especially hard hit and the area has reduced by over 95 percent since the mid-19th century (assessment CBM SLU, 2021). Today, around 400,000 hectares of semi-natural pasture remain (Sweden's environment goals, 2020). The development is generally due to a lack of ruminants from structural rationalisation and lack of profitability maintaining production on these areas. The authorities have concluded that more ruminants are needed in all of Sweden and that large areas of pasture must be restored and taken into production if Sweden is to meet its environmental objective of a varied agricultural landscape. The area of for semi-natural pasture may need to increase fourfold, to achieve the environmental objective a rich diversity of plant and animal life.

Meadowland is grasslands that has not been ploughed, fertilised or sown for many years. Mowing and harvesting hay has led to a species rich flora with many flowering plants.


Photo: Pär-Johan Lööf

Potential

Viewed from a historical perspective, the number of grazing livestock, and how pasture is utilized, have varied over time and in different areas. Such variation has been of major importance for the ecology of these areas and is still significant for the structure of management today and for the future. The benefits from good grassland management should increase and pasture as a profitable resource for production further developed.

Profitability and livestock availability differ between regions and grassland types. In some parts of the country, there is a sufficient number of grazing livestock, cattle horses and sheep, to maintain semi-natural pastures, while there is a shortage in other parts (Spörndly & Glimskär, 2018). The unique conditions of each farm is also key. With greater knowledge of grassland types, biodiversity, and feed requirements animal feed needs and different properties, it will be easier to choose suitable stocking rate and group of cattle for each paddock.

There is a need to increase the number of flowering plants in the agricultural landscape to compensate for the radical decrease of meadowland. Restoration and management of habitats and heritage sites are also generally positive for biodiversity.

Different concepts that are beneficial to biodiversity in the agricultural landscape have been introduced within beef production and arable farming, like flowering field margins, field lark plots, riparian zones and buffer strips. Other measures include developing crop rotation, catch crops and managing species rich habitats such as wetlands and non-arable outcrop areas. More untilled arable areas is positive for soil biodiversity and there is scope for broader implementation of these practises.

The climate benefits of grassland production are well documented. Ley is also very important for soil micro life, soil structure and nutrient management. Grass ley as part of a crop rotation is also positive for soil fertility. There is potential for increased grassland productivity and area, especially in the southern lowlands of Sweden. Grassland is a fundamental for beef and dairy production in Sweden and has a major indirect significance for biodiversity. Boosting the profitability of sustainably produced roughage is therefore an important part of securing biodiversity. Grassland also increases opportunities for farms and to produce their own feed, which also can increase the national feed self-sufficiency and resilience. This, in turn will reduce the negative impact on biodiversity from imported feed ingredients.

Other potential areas to protect and increase biodiversity is precision nutrient and crop protection management as well as the transition from chemical to biological crop protection as well as increased mechanical techniques for weed control. Nutrient management has an effect on flora and biodiversity and fertiliser should end up in the right place where it delivers benefits, and not outside the agricultural areas. Precision farming and technology are already important tools today and can be further developed.

Challenges:

- Financial incentives and improved profitability are necessary to enable grazing of cattle that currently do not have access to pasture. Less complicated rules and long-term compensation for restoring and managing semi-natural pasture and meadows are required. Profitability of grassland on lowlands and tillage-based crop rotations also needs to be strengthened.
- Climate change increases the risk of loss of biodiversity, while at the same time, climate measures must be taken to prevent biodiversity being disadvantaged. Afforestation and invasive species climate changes should not be done on species rich land whose values are dependent on custom and tradition.
- Biological crop protection products must be further developed.
- Continued support for technology and management is required with regards to pasture management, such as the development of enclosures and fencing, and innovation for virtual fencing can be important in the future. Opportunities for extending the grazing season and outwintering must also be explored further.
- Knowledge transfer to promote biodiversity must be increased, such as initiatives similar to the Focus on Nutrients programme.


Photo: Fredrik Persson/Svenskt kött

Manure management and biogas

With optimised management of manure and conversion to biogas, climate impact can be reduced by up to nine percent on the farms by 2050.

Methane and nitrous oxide are released from manure. Technologies that reduce emissions will enable climate impact to be reduced, and the manure can be used more efficiently. One way is using manure as a substrate in biogas production before it is and returned as nutrients in the fields. The biological degradation process anaerobic digestion converts organic biomass into biogas, primarily in the form of methane. The gas for is used for heat production and can also be upgraded to vehicle gas or renewable electricity. The digestate can be spread in the field or further processed for nutrient extraction and new products. Manure can also be processed to recycle nutrients via separation and fractioning. This reduces the physical volume of manure and facilitates transport to other regions with lower animal density, for energy production or to be upgraded to specific nutrients that are more accessible to crops. Optimised manure spreading and nutrient utilisation can balance the need for mineral fertiliser on the total farm area.

Emissions of ammonia and greenhouse gases from manure can be reduced by covering storage tanks, using plastic sheeting or a permanent roof. In addition, the pH value can be reduced by so-called acidification. The method leads to higher nitrogen utilisation in manure which drives bigger yields, reducing the risk of nutrient loss to air and water with acidification and eutrophication as a result.

There has been an increase in the volume and number of biogas production facilities on farms and cooperative facilities since 2015. Two years ago, anaerobic digestion of manure accounted for about ten percent of Swedish biogas production as a result of support from the Swedish Board of Agriculture. and other bodies. Livestock farming is dense in certain areas of the country where there can be a need to distribute manure to arable farms. The warmer climate means that the manure temperature is rising, which in turn, increases methane emission. The techniques for manure management and biogas production are well in line with what is required and are supported by Sweden's environmental objective to return more phosphorus and nitrogen to food production by 2030.

Potential

Biogas production

Biogas production can reduce climate emissions of methane and nitrous oxide in particular when organic fractions are converted into carbon dioxide as they are used. The combined climate benefits will vary depending on factors such as type of manure, storage of digestate, the way the gas is produced and which source of energy it is assumed to replace.

Photo: HKScan

> “Most larger farms ought to be able to have biogas production on site by 2030, while for smaller farms it is reasonable to belong to joint biogas plants by 2050.”

The reduction in emissions is between 50 and 95 percent. The biggest reduction and climate benefit will be in upgrading biogas to vehicle fuel, as this can demonstrably reduce emissions by 90 percent.

A biogas facility can contribute to the reset when it replaces fossil energy sources such as natural gas. Aerobic digestion for biogas production is an all-year round process and accordingly reduces the need to store manure.

Under certain conditions, however, anaerobically digested manure may have a higher methane gas emission than undigested and leakage-free storage is then required. Other benefits include reduced smell. Studies performed in Sweden and Denmark suggest that biorefining ley in combination with biogas can be profitable together with cattle farming.

Most larger farms ought to be able to have biogas production on site by 2030, while for smaller farms, it is reasonable to belong to joint biogas plants by 2050.

Nutrition utilisation from manure

Processing and nutrient utilisation can reduce nutrition losses to the air and water from both storage, handling and spreading. The extracted nutrients can be spread and increase opportunities for precision farming. Separation of water reduces transport needs and the effect of soil compression that can also be reduced via trailer hose systems and satellite wells.

By covering tanks or pits with plastic cloth or a permanent roof on slurry or solid manure storage, emissions of methane and ammonia can be significantly reduced. In a study, methane emissions fell from 1.3 to 0.17 percent of the original carbon content in the summer months when covered.

Techniques for processing and upgrading nutrients from manure are unlikely to occur at farm level, instead commercial facilities are more likely and should be able to be implemented by 2030. Coverage can be implemented in a relatively short time and a Swedish target indicate that this can be introduced by 2030.

Acidification

Acidification can reduce emissions of ammonia and methane from manure storage and requires certain equipment. It can be introduced gradually towards 2030 and 2050.

HKSCAN

With over 100 years of experience HKScan produces high quality and responsibly produced pork, beef, chicken and lamb products, as well as charcuterie, vegetarian products and ready meals. HKScan's Farm Initiative is the next and longest climate initiative to date. Together with the Swedish farms, our suppliers, we are going to make one of the world's most climate friendly meat and charcuterie production even more sustainable. The aim is to illuminate and create climate and environment positive effects based on the conditions of each farm, with the goal of reducing the climate impact of Swedish meat and increase the environmental benefits. Until 2030 we aim to: reduce the climate impact of meat by 20 percent, increase acreage benefiting biodiversity by 5 percent and reduce eutrophication by 20 percent and by 2040, the entire value chain from field to fork should reach net zero.

Photo: DeLaval

Challenges

- Increased biogas production can reduce positive effects on soil health and carbon sequestration, by reduced spread of organic material in fields if only using substrate from the farm. There is, however, a possibility of continuing to spread digestate and other residual materials to compensate, and to complement with biochar which also can act as a carbon sink.
- Acidification of slurry with sulphuric acid will in most cases increase the need for liming, which leads to additional costs.
- Many biogas facilities are dependent on investment grants. The biogas market inquiry is completed and if the proposals are approved implemented from 2022 onwards, such long-term conditions and targets are likely to drive development forward.
- For farms with large manure volumes, it is easier to achieve both financial targets and a stable process without losses, while smaller farms will have to invest in joint local facility hubs to share investment and operating costs.
- The need for innovation is relatively low, and development should focus on achieving stable and nutrient efficient operation.
- Innovation needs and cost challenges exist concerning the upgrading of tractors to run on biogas or upgrade them to electric power.

Nutrient losses to air and water

Via measures for improved nutrient management losses of nitrogen and phosphorus including ammonia from manure can be reduced.

The consequences of nitrogen and phosphorus losses to water includes risk of raised levels of nitrate in the groundwater, which may impose health risks via our drinking water. Nutrient losses from agriculture causes eutrophication in lakes, streams and sea environments, and ammonia leakage to the air leads to acidification of the soil and changes to the flora and fauna in forests, when it turns into becomes nitrogen via precipitation. Systematic effort to reduce losses has been going on in Sweden since the 1980s. Despite this, the issue of nutrient losses is not resolved and more measures are required to meet Swedish environmental objectives and Sweden's international commitments. Phosphorus losses from agriculture in Sweden still needs to be reduced in the order of 30 percent and nitrogen losses somewhat less.

When it comes to ammonia from manure, Sweden has a commitment in the EU National Emissions Directive to reduce losses 17 percent from 2005 until 2030.

Potential

The most recent assessment of the potential to tackle eutrophication caused by agriculture has been made by the five regional water authorities that are responsible for the implementation of the EU Water Directive in Sweden. An initial proposal for a package of measures to move towards the goal of "good ecological status" has been made. This includes buffer strips in annual crops, liming to improve soil structure, two-level dikes, wetlands, lime-based ditch filters, catch crops and spring tilling. However, these measures are not expected to be enough to fully reach the target and therefore work is now being done to quantify additional measures, such as intermediate crops, reduced soil preparation, and precision farming which will lead to further necessary reductions.

Phosphorus loss can be reduced by 30 percent in a single field with liming and nitrogen losses can be cut by the same amount with catch crops, for instance. More wetlands are needed in Swedish agriculture, however not on every farm. Wetlands as an environmental measure have a good effect on biodiversity and ecosystem services such as catching nutrients, flow attenuation and as an irrigation source, if correctly designed.

In the case of ammonia losses, measures such as maintaining a natural crust oon slurry pits, manure spreading with trailing hoses, covering slurry containers and direct deep fertilising and slurry injection into the soil are good. Overfeeding of protein occurs on some farms. A well-balanced feed ration with the optimal level and quality of feed protein is important to avoid contributing to increased ammonia loss.

Challenges

There are challenges to further reduce the nutrient loss from agriculture, despite the work that has been done over the last 40 years.

- Some of them are often not profitable to rectify. One obstacle is that many measures cost more for farmers to implement than the value of the nitrogen and phosphorus saved, and the generally low profitability within the sector is a limiting factor.
- Sometimes there is a lack of knowledge by authorities, advisors and farmers. It is important that the right measure is carried out at the right place.
- It takes time to become acquainted with new knowledge either via education or environmental advice on the farm.
- The EU rural programme includes many different financial forms of environment compensation. In addition, there are national initiatives. Many of these are not applied for because they are not known, the terms are impractical or the compensation is too low.

Research has been carried out for a long time into measures to prevent nutrient losses. This has resulted in measures like catch crops, buffer strips and precision fertilising. It is important that such research continues, so that more environment measures can be implemented. Greater precision with lower losses all the way from handling, storage to spreading of manure would mean a higher proportion can be utilized.

LANTBRUKARNAS
RIKSFÖRBUND

The Federation of Swedish Farmers, LRF, is an interest and business organisation for the green industry with approximately 140 000 individual members. Together they represent about 70 000 enterprises, which makes LRF the largest organisation for small enterprises in Sweden. In 2020, LRF set sustainability objectives within the social, financial and environmental areas to ensure that Swedish agriculture continues to be a world leader in sustainable production and that Swedish agriculture and forestry receive the support needed from politicians and consumers. When it comes to the environment, focus is on increasing climate benefits, promoting biodiversity and the more efficient use of resources. On the financial side, the focus is on increasing profitability and competitiveness as well as increasing farming and forestry production in Sweden. The social goal is to make rural areas more attractive.

Photo: Lantmännen

The example farms’ potential to reduce climate impact and increase productivity

Calculations of the climate impact from production on the example farms show that emissions from 2015 to 2050, can be reduced in line with the Paris Agreement, which means roughly halving greenhouse gas emissions every ten years. The reduction applies to both climate gases combined and separately for all three; carbon dioxide, methane and nitrous oxide. The results are relatively similar for all four example farms, but larger farms can drive changes by as early as 2030, primarily due to economies of scale, and therefore achieve results quicker. Productivity will increase on the farms with more resource efficient production of both beef and dairy, while other sustainability aspects are safeguarded.

Photo: Arla

The climate impact can be reduced in line with the Paris Agreement targets

Carbon dioxide emissions from the example farms decrease in line with the Paris Agreement reduction rate (Carbon law) until 2050. If the effects of carbon sequestration are added, climate impact will be further reduced.

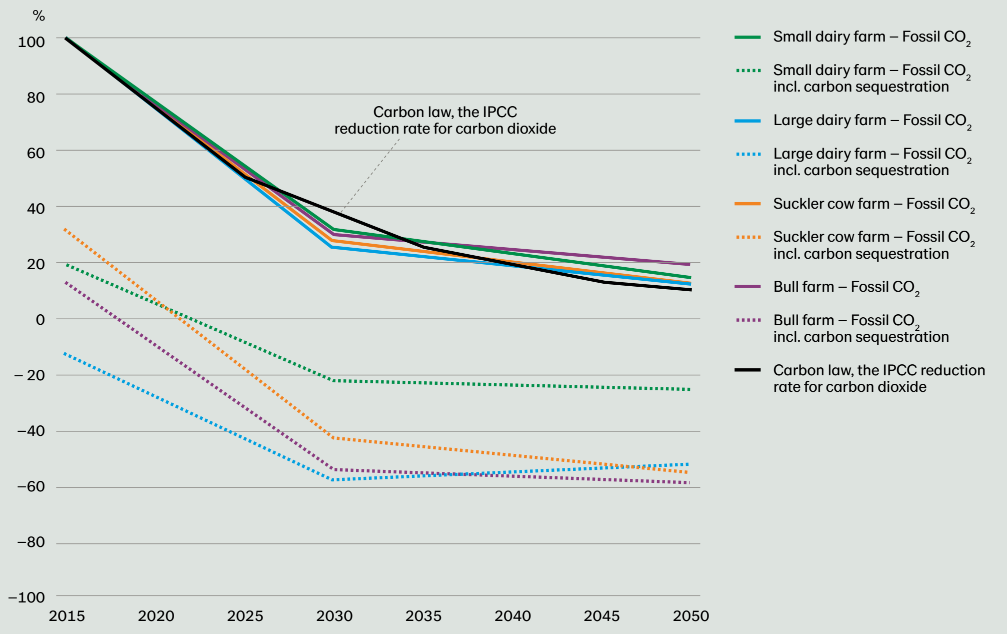
Reduced carbon dioxide emissions depend on

- Phasing out fossil fuels, energy, and other fossil farm inputs. Fossil energy in the production of chemical fertilizer and transport is phased out. The transition has high intensity over the next 20 years. Even after the transition, there will still be small carbon dioxide emissions left from the production of electricity and renewable fuels.
- Replacing ingredients in feed, particularly imported ingredients with a large climate footprint, but also using ingredients with better climate performance after advances in domestic production. This will also reduce nitrous oxide emissions. Changed rations with an increased proportion of forage will also contribute to reduced carbon dioxide emissions. By 2050, the land use change factor, where carbon dioxide emissions from growing imported ingredients, can disappear if such ingredients are phased out of feed.
- Increased efficiency leads to increased productivity, but also higher resource efficiency, resulting in lower climate impact per unit produced. The driving force is improved feed efficiency via breeding advances and improved management. Also plant breeding is an important factor.
- Energy produced on farms in the form of both biogas and green electricity can also drive the transition.

Carbon sequestration will be maintained and increases slightly:

- Soil carbon content can be maintained and additional carbon can be sequestered with favourable management as higher proportion of perennial grass ley, pasture, plus intermediate and catch crops.
- The increased yields and new methods mean carbon sequestration increases. Carbon sequestration appears to be lower for the small dairy farm than for the other farms. In actual fact, it is higher both per hectare and kilo milk, however emissions of fossil CO2 per kg/ECM are higher, and therefore the curve is higher than for the other farms.
- Climate emissions that are difficult to address can be balanced against carbon sequestration on farms and contribute to climate neutrality.

Target and reduction potential for carbon dioxide per example farm*



* Relative per kg product

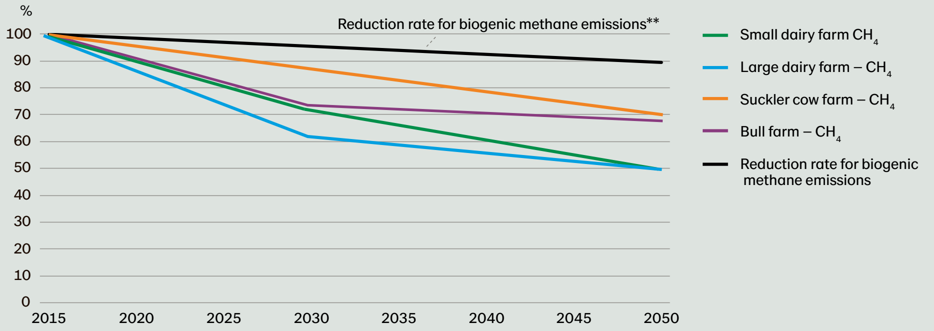
Summary of results

Methane emissions from the example farms are decreasing in line with the target level for biogenic emissions and by 2050 both types of dairy farms will reach the general IPCC target levels for methane. Even if the effects of methane reducing feed additives were removed, the example farms would still reach the target level for biogenic emissions.

Reduced methane emissions depend on

- General efficiency improvements and productivity increases that deliver increased resource efficiency, i.e. more beef and milk per cattle, via increased lifetime production.
- Management of manure – that has retained its nutrient value – via different available and developed techniques as well as biogas production that also results in reduced emissions of nitrous oxide and ammonia.
- Additives in feed that inhibit methane release. It is assumed that a limited number of animals will receive additives by 2030. By 2050, additives will be given to animals when this is financially beneficial for example by being able to allocate costs to products and where distribution in the feed works. There is additional potential for methane reducing feed additives, but more research and innovation will be required.

Target and reduction potential for methane per example farm*



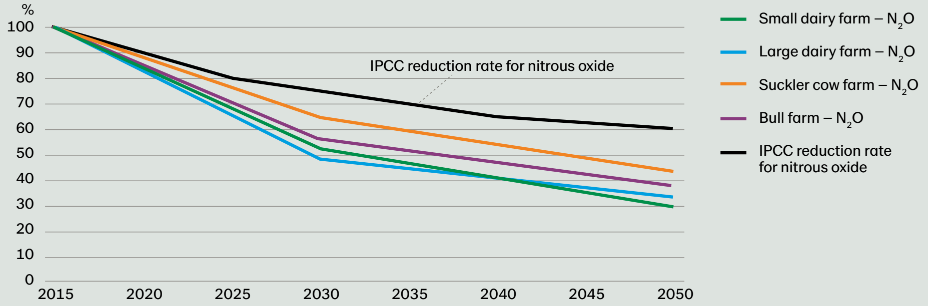
* Relative per kg product
** Allen et al 2018

Nitrous oxide emissions from the example farms have been decreasing in line with the IPCC reduction rate already from the base year 2015. The small dairy farm shows greater potential to reduce emissions than the larger dairy farm, however the larger farm already had lower emissions per kg ECM in 2015.

Reduced emissions of nitrous oxide depend on

- Precision farming that both reduces emissions from land and manure and increases productivity.
- Implementation of best available techniques within mineral fertiliser production, such as reduction of nitrous gas emissions.
- Management and storage of fertiliser and production of biogas. To reach the larger yields more crop nutrition will be needed, however this is included in the calculations. In the case of nitrous oxide, there is still room for increased knowledge and innovation, better measuring methods and site-specific activities. By 2050, emissions from feed production will in principle, consist solely of nitrous oxide released from soil.

Target and reduction potential for nitrous oxide per example farm*



* Relative per kg product

Table 1: Potential for reduced climate impact by 2050*

Potential (GWP 100/kg)	Small dairy farm	Large dairy farm	Suckler cow farm	Bull farm
Animal health, lifetime production and breeding	25%	25%	5%	8%
Fossil free farming	5%	8%	12%	8%
Feed production, strategies and ingredients	18%	12%	9%	16%
Methane reducing measures	6%	7%	10%	7%
Manure management and biogas	9%	9%	9%	7%
Total	**63%**	**60%**	**45%**	**46%**
Carbon sequestration	8%	10%	11%	11%

* The calculations should be viewed as indicative levels rather than exact forecasts. They indicate theoretical opportunities to develop production.

Productivity will increase on the example farms by 2050

Swedish beef and dairy production has come a long way in terms of productivity. One key factor for the future is to keep building on the good animal health and low use of antibiotics that we have managed to achieve via preventative work for healthier animals. Animals in good health are more productive, which is also crucial for profitability on farms.

There is still potential to increase productivity within Swedish beef and dairy production, even though good results have already been achieved over time. All farms are unique in their own way and it can be difficult to compare individual farms. The difference between farms with the highest productivity and those with the lowest, still shows that there is potential for all of them to continue developing. There are a variety of different parameters that influence productivity such as breeding, development of feed, digitalisation and new technology. But above all, it is about good management and the know-how available on the farms if such potential is to be realised, where good animal health is a crucial factor.

Crop cultivation is also a key part of the productivity increase in beef and dairy production, where increased crop yields will contribute to lowering the climate impact per kilo of beef or milk. This increase is driven by the possibility of producing higher yields of good quality and more efficient use of resources in fields via precision farming and fertilising, plant breeding and water management such as irrigation and drainage.

Climate changes with longer growing seasons and new or improved crops for feed and better management of pasture will contribute to these increased yields that will lead to a large surplus of forage and grain. Also reduced waste and losses in the entire production chain will have effect on productivity.

The dairy farms show that productivity, measured per kg ECM per year, can increase by up to 40 percent from the 2015 level to 2050. The beef farms can increase their productivity, measured per kg carcass weight per year, by around seven percent for the Suckler cow farm and around ten percent for the Bull farm, mainly via improved rations for increased growth. However, there is a lack of access to robust data for cattle growth for beef production, which means there is an innovation gap and an important area for improvement in the future.

More resource efficient production with high yields can boost profitability for the farmer, which in turn will be vital in enabling the next step to be taken in development and to make important investments to meet future requirements.

Table 2: Productivity increase by 2050

	Small dairy farm	Large dairy farm	Suckler cow farm	Bull farm
Productivity (kg ECM, kg carcass weight)	42%	42%	7%	11%

The farms create different benefits

In addition to reduced climate emissions and increased productivity, farms contribute with different benefits based on production system. Adapting to local circumstances, often site-specific, will determine how production can be pursued in the most sustainable way in terms of both environmental, financial and social aspects.

Local site-specific circumstances dictate the size of an enterprise, its product orientation and productivity. It will still be suitable for farms in mixed forestry and arable areas to have specialised suckler cow herds and smaller dairy production, or a combination of these systems where utilizing semi permanent ley and semi-natural pastures in a more profitable way is key. To increase the number of grazing cattle, that can make use of such land, rearing steers is a possibility, with benefits for biodiversity and utilisation of forage. However, the conditions for profitability of such systems must be improved. In lowland areas, specialised bull rearing and dairy production is good, as by-products from arable framing can be utilized by cattle and the manure returned into the arable system. Also, biodiversity is site bound and the right conditions are required there on site. The importance of perennial ley for biodiversity and carbon sequestration in crop rotation in areas dominated by annual crops is well documented. It is important to protect and improve the species rich semi-natural pastures that remain in Sweden today. Financial and practical conditions that support cattle production based on utilizing these, is crucial for conserving biodiversity. Carbon sequestration can offer further potential than quantified on the example farms, but this would then require more radical change in crop management systems.

System perspective on production

The example farms are illustrations of current Swedish cattle production. In the future, production systems will probably be driven by research, innovation, politics and market forces.

Cattle production and arable farming are interlinked systems and synergies between them can be further strengthened.

By developing and integrating both systems, productivity and production conditions can be further developed and deliver higher profitability. Farms of the future will achieve an even more efficient integrated production. For example, there can be greater cooperation between farms within forage production and manure utilization. This will lead to arable farms having better crop rotation with forage and manure, and their by-products utilized for animal feed.

Beef and dairy production will continue to take care of and use waste and by-products from the food system and the production of biofuels. These flows will increase if plant-based food production rises. Such increased production will be more sustainable if it is integrated with livestock that can utilise forage and semi-natural pastures.

In the same way that arable and livestock farming are interlinked, so is beef and dairy production. A system where the main part of beef production is integrated with milk production will have lower climate emissions. Developments since the 1990s have moved towards specialisation. The next step can be to take the strengths of today's production and move towards greater integration.

> “It is important to protect and improve the species rich semi-natural pastures that remain in Sweden today.”

Photo: Linda Engström/LRF

The size of the farm is a factor for economies of scale. The farms of the future may grow with an orientation towards diversification, rather than specialisation. Specialisation can still occur and develop, such as specialized forage production or heifer rearing, as the need for resources and know-how paves the way for such services. Specialisation via direct sales to consumers and farms sharing machinery, equipment and biogas facilities can also increase. In the future, farms will have good support in daily management via digital surveillance. This supports good animal health and pasture management, that can be utilised for longer periods than today due to climate changes.

If infrastructure is in place, there are business opportunities within biorefining of ley that can become feed for ruminants, monogastric animals such as poultry and pigs, as well as green proteins suitable for human consumption. By products from biorefinery becomes cattle feed or substrate for bioenergy production. Feed rations are changing with more ley, domestic protein crops and by-products. However, measures to reduce wild game crop damage is required if domestic production of feed crops is to be increased. Increased access to maize via changed growing conditions can replace concentrate in the ration to a greater extent, but maize has limitations in terms of cultivation. In general, quality and digestibility can be improved via modified varieties.

On farms of the future, nutrient losses, which leads to eutrophication from both arable and livestock farming, have reduced. Better precision with lower losses all the way from handling, storage and spreading of manure means a higher proportion of the nutrients can be returned to the system. Phosphorus loss can be reduced by liming and catch crops, for example. Water management, drainage and irrigation, is a necessity for crop and livestock husbandry, which in addition has big potential for increased yields.

Table 3: Contribution of the different farms to ecosystem services and biodiversity

	Example farm 1 Small dairy farm	Example farm 2 Large dairy farm	Example farm 3 Suckler cow farm	Example farm 4 Bull farm
Production of food	◕	●	◑	◕
Utilisation of farmland	●	◔	●	◔
Processing of residues	◑	◑	◔	●
Biodiversity	◑	◔	●	◔
Soil health/fertility (forage in crop rotation)	◑	●	◑	●
Carbon sequestration/storage	●	●	●	◕
Organic crop nutrition for arable farming	●	●	◑	●
Open landscapes and experiences	●	◑	●	◔

◔ Low
◑ Significant
◕ High
● Very high

Diversity of farms creates sustainable systems for the future

The table presents a summary that shows:

- The smaller dairy farm, example farm 1, utilises the growing conditions of mixed forest and arable area through a high proportion of forage, significant for maintaining an open agricultural landscape.
- The larger dairy farm, example farm 2, has high productivity and makes a positive contribution to lowland landscapes by providing scope for forage in crop rotation. However, there are alternatives to grassland, which is why the use of farmland as a resource is not dependent on dairy production.
- The suckler cow farm, example farm 3, is of major importance for biodiversity, as production is pasture based. However, this reduces the contribution of manure for crop production. As with example farm 1, The growing conditions of the mixed forest and arable areas are used and are significant for maintaining open agricultural landscapes. Productivity is lower due to more extensive production.
- The bull farm, example farm 4, contributes to food production via higher productivity. The rations include a high proportion of by-products and as the production is indoors, the manure can be used efficiently. As for example farm 2, the farm contributes providing scope for forage in crop rotation. On the other hand, a barn-based system does not contribute to biodiversity via grazing.
- One potential to increase biodiversity is to invest in more extensive rearing with steers on semi-natural pastures.


Photo: Eva Karlsson/LRF

Conclusions and Next step

Our results show the way forward for Swedish beef and dairy production, where cattle will play a key role in sustainable food systems of the future. There are great opportunities to increase food production and profitability, while still maintaining animal welfare, reduce emissions in line with the Paris Agreement, and achieve climate neutral farming by 2050, without compromising biodiversity. Much of the knowledge and technology required for the transition is already available today, but further initiatives are needed throughout the value chain to realise the full potential.

Many measures can already be implemented in crop and cattle production by implementing best practice. The realisation of the identified potentials is dependent on knowledge and good management, which generally has a positive effect on resource utilisation and cost efficiency. It encompasses already known knowledge, such as preventative measures for animal health, reduced calving age and recruitment rate, but also breeding for optimised growth and feed management with less losses. Farmland is a valuable resource. With circularity and closed loop thinking on farms and throughout the entire value chain – where initiatives are optimised, and manure and waste are fully utilised– efficiency improvements can reduce the environmental and climate impact even before 2030.

However, to achieve the full potential, investments will be required by both by the sector and other parties within society. Not the least, a greater financial sustainability and room for further investment in sustainability is required at farm level.

Together we can make the transition possible
With this report as the starting point, the sector now commits to drive development together and create conditions for farmers to utilise new technology, increase productivity without compromising animal welfare, make more sustainable agri-input materials and other measures available at farm level, for an even more sustainable beef and dairy production. With the right conditions in place, we can enable the transition and increase profitability within beef and dairy farming.

The strength of collaboration, which this report illustrates, bringing together organisations from all parts of the value chain, is a crucial driving force for a more sustainable development.

Sustainable food must be valued
Swedish cattle production systems are some one of the most sustainable in the world today and provide us with good and nutritious food, where meat, milk and dairy products are important sources of protein and other essential nutrients. More and more people are starting to appreciate the added values produced by farms and farmers. However, sustainably produced Swedish beef and dairy must be valued even higher throughout the entire value chain. The costs for the required investments on the farms - where the biggest potential to make a difference lies- must be shared throughout the entire value chain. A smaller product price increase, that goes directly to the primary producer, can create the necessary scope for sustainable development of the sector. Also, food waste, an enormous waste of resources, must be dramatically reduced.

Research required for the future
This work has identified several challenges and innovation gaps until 2050. Critical investments for the future, in all parts of the value chain, include:

- New ways of valuing methane in lifecycle analyses for food are needed to better describe the role of methane in the climate footprint of food products. IPCC states that GWP100, the current model used, does not given an entirely fair picture and in the long run, which may lead to misguided policy developments and incorrect measures.
- Further research is needed for calculating nitrous oxide emissions, to verify carbon sequestration in the soil, to quantify and set a value on biodiversity, and to further investigate the possibility of reducing methane emissions, for example with feed additives.
- In the case of plant breeding, the continued use of genomic selection is needed, as well as further investments in forage and more research on climate adaptation.
- For animal breeding, further development of methods needs to be continued, along with global collaboration and access to data. Also, the use of genomic selection and new breeding values such as feed and methane efficiency, as well as ability to adapt to climate change, such as heat stress in animals, is needed.
- Collecting, analysing and being able to make decisions based on data from different sensors in beef and dairy production is a prioritised area for research, where storage and ownership of data issues and information must be managed. Digitalisation and new technology will have a positive impact on animal health and can support the development of knowledge around feed efficiency. Technological advances within precision farming also need to be developed.
- The possibility of replacing ingredients in feed with locally produced alternatives and by-products is good but requires further research and development.

Long-term political initiatives
Beef and dairy production is important for the food supply in the entire country and contributes to achieving the goals in the Swedish food strategy for increased food production and the Swedish environmental objectives. Politics must support the sector in the climate transition with the necessary long-term investments required. This will ensure that vital functions for society work well and continues to deliver crucial value in the future. The report clearly shows that profitability in the food chain is key, something that must be strengthened to increase attractiveness and to be able to make the necessary sustainability investments needed, especially on farm. To realise the potentials for the sector identified in this report, the following will be required of politics, in cooperation with the beef and dairy sector and other parties in the value chain:

- Sharply increased and long-term public investment in research, innovation and advisory services that leads to an increased sustainable production, productivity and profitability in the beef and dairy value chain, including forage and pasture production.
- Internationally competitive taxes on energy and other agri supplies that support the transition to fossil free energy and inputs. be ensured.
- Rules, regulations and implementation of these must be improved systematically by ensuring a long-term perspective and service mindedness when public authorities interact with farmers and the sector.
- Financing new and sustainable investments on farms, especially for new young farmers needs to be secured.
- In public procurements, the proportion of food products that have been produced in line with Swedish environment and animal protection legislation needs to increase.
- National financing and implementation of the EU common agricultural policy in Sweden needs to increase and be adapted, so that it favours an increased production and profitability within agriculture.

Swedish beef and dairy production can increase in a sustainable way
We have the opportunity to increase productivity with reduced climate impact while benefiting biodiversity. Within the framework of the global methane budget, it is important that a higher proportion of cattle are found where conditions are the best and where production can occur in a sustainable way. Swedish production can therefore contribute with a larger share of global production of beef and dairy products, strengthen sustainable development and create growth opportunities for the sector.

The findings in the report reveal the big potential there is in Sweden, with the unique conditions we have from both an environmental perspective but also in terms of technology and knowledge. We have highly productive systems and can continue to develop the sector even further in an even more sustainable direction, where good management and investments at farm level will be key moving forward. This report, which marks the route, should therefore be seen as a growth strategy for the whole sector, and a business opportunity for Swedish agriculture. Sweden is also going to play an increasingly important role in the global food supply in the future, where demand for our sustainable food will increase and in time, Sweden ought to become a net exporter of beef and dairy products. Creating the right platform for this growth is a priority and something the sector will pursue together, as well as within each respective company and organisation, mapped out in their future strategies and business plans.

Photo: Arla

A word from the external reference group

A holistic approach to the beef and dairy production of the future

It is important that businesses show leadership in major social issues, such as the food supply of the future, and this project addresses broad sector issues and specifies and formulates many of the measures, investments and technology advances that are required for future. The report focuses on the role of cattle in Swedish agriculture and contributes to developing the perspective of ruminant methane emissions, in particular. The report covers several key issues in addition to the climate and not only highlights them from a farm level perspective, but partly also from a system perspective. The results of this work point to challenges, opportunities, the need for knowledge and that there are several conflicting targets, which emphasises the complexity in the issue of sustainable food systems of the future. Farmers have a key role to play in the transition, but no party or organisation can drive the changes that are necessary alone. Changes must happen at all levels, from farm level to market, consumer and to society. One very important conclusion is that the role of farmers and the value created on the farms needs to be further strengthened.

The external reference group was asked to participate in the work, and we were happy to be at disposal. The external reference group has had an advisory role in the work and has presented viewpoints primarily linked to the scientific area and policy issues. The work of the reference group has not included assessments of the comprehensive results analyses for each respective example farm.

In our opinion, the report contributes with interesting results and conclusions showing concrete measures and possible paths forward to achieve a more sustainable production system. However, the reference group would like to note that in future analyses, animal welfare ought to be given yet more prominence, and that the example farms concept could be further developed. Through this report, the sector shows that they want to take leadership and be an even stronger part of the solution. One of the most important things Sweden can do, especially in the climate reset globally, is to show the way forward. We support the initiative to further develop Swedish agriculture with its beef and dairy production in a sustainable direction, contributing to a more sustainable global production, adhering to international climate agreements, reducing climate impact and creating the conditions for economically viable and profitable Swedish beef and dairy farms.

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Thank you!

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References

Allen M, Lynch J, Cain M et al, 2018, Climate metrics for ruminant livestock. Oxford Martin School. Published by the Oxford Martin Programme on Climate Pollutants

Allen M, Shine K, Fuglestvedt J, et al, 2018, A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. npj Climate Atmospheric Science 1(16). volume 1, Article number: 16 2018

Bolinder T, Börjesson G, Kätterer T, 2017, Odlingssystemens effekter på kolinlagringen i jordbruksmark, SLU

Centrum för biologisk mångfald SLU, 2021.

Jordbruksverket, 2008, Ängs- och betesmarker – en genomgång av tillgänglig statistik. Rapport 2008:30, Jönköping

Jordbruksverket, 2020, Antal nötkreatur i december 2020

Jordbruksverket, 2020, Jordbruksmarkens användning 2020

IPCC, 2014, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

IPCC, 2021, Sixth Assessment Report on Climate Change: The Physical Science Basis

IVA, 2019, Så klarar det svenska jordbruket klimatmålen, Vägval för klimatet, delrapport 5 i samarbete med KSLA

Lynch J, Cain M, Pierrehumbert R, Allen M, 2020, Demonstrating GWP*: A means of reporting warming equivalent emissions that captures the contrasting impacts of short and long-lived climate pollutants, Environmental Research Letters, 15(4)

Lynch J, Garnett T, Persson M, Röös E, Reisinger A, 2020, Methane and the sustainability of ruminant livestock. Foodsource: building blocks, Food Climate Research Network, University of Oxford

Lynch J, Cain M, Frame D, Pierrehumbert R, 2021, Agriculture's Contribution to Climate Change and Role in Mitigation Is Distinct From Predominantly Fossil CO2-Emitting Sectors. Frontiers in Sustainable Food

Kander A, 2007. Blir det bara värre? Svensk klimatpåverkan under 200 år, KSLA

Spörndly E, Glimskär A, 2018, Betesdjur och betestryck i naturbetesmarker. SLU, Inst. för husdjurens utfodring och vård, Rapport 297, Uppsala

Antologi av Tunón och Sandell, et al, 2021, Biologisk mångfald, naturnyttor och ekosystemtjänster. Svenska perspektiv på livsviktiga framtidsfrågor, Vetenskapliga rådet för biologisk mångfald och ekosystemtjänster

United Nations Environment Programme (UNEP) & Climate and Clean Air Coalition, 2021, Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi: United Nations Environment Programme

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