MISTRA FOOD FUTURES

Evaluating the Impact of the Proposed Dietary Guideline on Red and Processed Meat: Agricultural, Environmental, and Economic Perspectives

Hanna Karlsson Potter, Hanna Astner, Johan Karlsson, Thomas Slijper, Sarah Säll

Mistra Food Futures Report #28
2025

Mistra Food Futures Report #28
Evaluating the Impact of the Proposed Dietary Guideline on Red and Processed Meat: Agricultural, Environmental, and Economic Perspectives
Utvärdering av effekten av de föreslagna kostråden om rött och processat kött: Jordbruks-, miljö- och ekonomiska perspektiv

Authors: Hanna Karlsson Potter, Hanna Astner, Johan Karlsson, Thomas Slijper, Sarah Säll, SLU Swedish University of Agricultural Sciences

The overarching vision of the programme Mistra Food Futures is to create a science-based platform to enable transformation of the Swedish food system into one that is sustainable (in all three dimensions: environmental, economic and social), resilient and delivers healthy diets. By taking a holistic perspective and addressing issues related to agriculture and food production, as well as processing, consumption and retail, Mistra Food Futures aims to play a key role in initiating an evidence based sustainability (including environmental, economic and social dimensions) and resilience transformation of the Swedish food system. This report is a part of Mistra Food Future's work to identify the next generation's food system sustainability indicators, one of the central activities within Mistra Food Futures.

Mistra Food Futures is a transdisciplinary consortium where key scientific perspectives are combined and integrated, and where the scientific process is developed in close collaboration with non-academic partners from all parts of the food system. Core consortium partners are Swedish University of Agricultural Sciences (SLU), Stockholm Resilience Centre at Stockholm University, RISE Research Institutes of Sweden and The Beijer Institute of Ecological Economics.

www.mistrafoodfutures.se

Publication: Mistra Food Futures Report #28
Year of publication: 2025
Publisher: Swedish University of Agricultural Sciences
Cover illustration: Johan Karlsson
ISBN (elektronisk version): 978-91-8046-544-1

Table of Contents

1 Introduction

In June 2023, the Nordic Council of Ministers released the sixth edition of the Nordic Nutrient Recommendations (NNR2023), developed in collaboration with the Nordic and Baltic countries. The NNR2023 is based on a scientific review of nutritional evidence, with expert committees translating this research into practical dietary guidelines (Christensen et al., 2020). The NNR2023 is currently being translated to national food-based dietary guidelines (FBDG) in the Nordic and Baltic countries. The NNR2023 also introduced environmental considerations in FBDG alongside health aspects. Previous versions of the NNR provided FBDG only based on the health dimension. This report is an update to Mistra Food Futures Report #21 (Slijper et al. 2024), which analysed the consequences of implementing the NNR2023 in Sweden based on both environmental and health considerations and compared it to the NNR2023 implementation based only on health considerations in terms of production and environmental outcomes.

During the process of updating the Swedish national dietary guidelines in line with the NNR2023 the Swedish Food Agency has been asked by the Swedish government to further analyze the effects of the new recommendation for red meat consumption. Therefore, this report focuses solely on possible effects of the health-based quantitative recommendation for red meat.

The aim of this report was to analyse the possible impact of changing from the current consumption to 5% and 30% additional compliance with the recommendation on red meat (350 g ready to eat meat per person and week) on agricultural land use, biodiversity (assessed by area of semi-natural pastureland used), animal numbers, climate impact and ammonia emissions. We focus on the Swedish agricultural sector but include estimates on impacts abroad due to changes in import of feed and food products. Climate impact due to potential land use changes in Sweden is analysed and compared with literature values for the import. Further, we discuss possible impacts due to changes in demand on the Swedish food value chain with regards to how dietary changes may influence (i) primary producers (e.g. farmers), (ii) consumers, and (iii) broader implications for food value chains.

The remainder of this report is organised as follows. In section 2, we give a short overview of Mistra Food Futures Report #21 (Slijper et al. 2024), which serves as the starting point for this report. Section 3 then introduces our environmental modelling approach to assess how various levels of reduced red meat consumption influence production and environmental outcomes. Section 4 discusses implications of the modelled dietary changes on the food value chain. Section 5 discusses how impacts on semi-natural pastures. Finally, section 6 provides some concluding remarks.

2 The previous report

This section provides an overview of the previous Mistra Food Futures Report #21 (Slijper et al. 2024) report. Slijper et al. (2024) analysed the implementation of the NNR2023 in Sweden based on both environmental and health considerations and compared it to an implementation of the NNR2023 based only on health considerations. In terms of red meat, considering only health NNR2023 recommends a consumption of maximum 350 g cooked meat per week. The new environmental recommendations in the NNR2023 are qualitative, outlining desired changes such as reducing dairy consumption for environmental reasons or prioritising certain products, like whole grain cereals over rice. Integrating environmental considerations into the NNR2023 promotes a shift towards less animal-based and more plant-based diets, as these generally have a lower environmental impact and results in more environmentally sustainable diets. Slijper et al. (2024) analysed how incorporating environmental considerations in the NNR2023 could impact agricultural production in Sweden and environmental outcomes both domestically and abroad. A large focus was on reduced red meat consumption. Below, we give a brief overview of the research questions, methods, and key findings.

Three research questions were considered:

1. How could including environmental considerations in the NNR2023 potentially influence consumption of different food groups in Sweden?
2. What are the effects of these changes in consumption on Swedish agricultural production?
3. What are the effects of these changes in production and consumption on the environmental outcomes in Sweden and abroad?

Research question 1 – Influence of NNR2023 on food consumption in Sweden
The first research question was answered using scientific literature and analyzing consumer preferences using an economic model called demand system (Deaton & Muelbauer 1980). The scientific literature indicates that changing dietary habits is a complex process shaped by multiple factors. Long-established routines become automatic behaviors, requiring conscious effort to change (SAPEA, 2023). Food availability, accessibility, taste preferences, and limited knowledge of nutrition and meal preparation play significant roles (Lazaric et al., 2020). Given the need to address the health and environmental consequences of food consumption, many advocate for policies that promote healthier and more sustainable eating habits (FAO, 2023; Martini et al., 2021; SAPEA, 2023).
The scientific consensus is that changing dietary habits of consumers requires combinations of policy instruments. Food-based dietary guidelines, such as the NNR, are one of these instruments in that toolbox but are unlikely to change dietary habits of consumers on their own. Note that we will not further address this research question in the current report.

Research question 2 – Influence of changes in consumption on production
The second research question was answered using a biophysical mass flow model of the Swedish food system (CIBUSmod; Karlsson et al., manuscript in preparation). Although this model cannot predict how changes in consumption would influence producer behaviour—which would require more complex general equilibrium models, such as the Common Agricultural Policy Regional Impact Analysis (CAPRI) model—CIBUSmod can address relatively straightforward "what-if" scenarios.

The advantage of using CIBUSmod is that it is tailored to the Swedish food system at a local spatial scale. CIBUSmod quantifies how changes in consumer demand influence agricultural production conditional on the import and export levels. The model optimises outcomes (i.e. production) conditional on an inputted demand (i.e. consumption). A limitation of CIBUSmod is that it cannot predict changes in demand from different policies or price changes and it cannot predict how producers react to changes in demand. It requires assumptions on how the NNR influences consumption and production and takes those changes in consumption as model input.

This led us to develop a range of scenarios to analyse certain changes in consumptions will affect Swedish production. The analysis considered 24 scenarios, including combinations of (i) whether the impact of the NNR would be small (5% uptake) or large (20% uptake), (ii) whether the environmental and health recommendations in the NNR were considered or only health considerations (in terms of red meat this entails a reduction to 350g when only health is considered and an additional 20% reduction was assumed when environmental considerations were included resulting in 280g), and (iii) how changes in consumption affect production (i.e., only in Sweden, based on today's import shares, or only abroad), and (iv) what substituted a reduced red meat consumption (i.e. plant-based proteins or poultry). CIBUSmod considered changes in production in terms of changes in cropland use and animal numbers.

Three key findings were:

- There is room to decrease Swedish red meat consumption without affecting Swedish production. This occurred in the scenarios considering that a reduced red meat consumption will only affect imported red meat. However, a scenario where only imported red meat is reduced seems unlikely to happen.
- If a reduction in red meat consumption were to impact Swedish red meat production, replacing red meat with poultry or plant-based protein sources would lower the demand for Swedish cropland. Compared to the NNR2023 recommendations based solely on health considerations, cropland demand decreased further when environmental factors were also considered. The reduced demand for red meat led to a reduction in cropland demand by 0.3-0.7 percentage points under a scenario of low impact from the recommendations and by 1.3-2.3 percentage points under a scenario of high impact. There is also potential to expand cropland for grain legumes and rapeseed, increasing Swedish production of these crops.
- For food groups other than red meat or poultry, we explored the potential changes resulting from incorporating environmental considerations into the NNR2023, compared to its health-based rationale. The NNR2023, with environmental factors included, recommended increasing the consumption of easily stored fruits and vegetables while reducing rice consumption in favour of other cereals. If these recommendations were followed, it could create opportunities to expand Swedish production of these storable fruits, vegetables, and cereals.

Research question 3 – Environmental impacts of changes in consumption and production

The third research question was answered using CIBUSmod. The same set of 24 scenarios was analysed, with changes in consumption and production taken from the analysis corresponding to research question 2. The environmental impacts of changes in consumption and production were considered for the following environmental outcomes: (i) greenhouse gas emissions, (ii) ammonia emissions, and (iii) the area of grazed semi-natural pastures (as biodiversity indicator).

A key limitation of CIBUSmod is that it does not account for environmental impacts occurring outside Sweden due to changes in feed or food imports. To address this, a second modelling approach that builds on static life cycle assessment (LCA) data on carbon footprints (Moberg et al., 2020) was used.

This approach examines how shifts in red meat consumption influence climate impacts, also beyond the Swedish agricultural system. It considers the entire (international) supply chain from cradle to Swedish retail, capturing the climate effects of both imported and domestically produced food.

Four key findings were:

- In the scenarios including environmental considerations in the NNR2023, we observed greater reductions in greenhouse gas emissions compared to health-based recommendations alone, with decreases of 0.4-0.8 and 1.6-3.1 percentage points under small and large impacts of the NNR on consumption, respectively.
- Ammonia emissions were further reduced when environmental considerations were included, with differences of 0.5-1.1 percentage points under a small impact of the NNR and 2.0-3.8 percentage points under a large impact.
- Grazing of semi-natural pastures is not directly correlated to meat production, as other factors, including the level of payments to farmers to preserve these, are highly influential. It is therefore not possible to assess how a general reduction in meat production would impact grazed areas using the CIBUSmod. Under current rates of grazing and shares of this from semi-natural pastures, reduced animal numbers in the scenarios resulted in a corresponding reduction in grazed area. However, it was also shown that current areas could be maintained with the modelled reductions in animal numbers if grazing in semi-natural pastures is prioritised.
- The climate footprint of the Swedish diet decreased more when environmental considerations were included, with neglectable reductions of 0.3-0.4 percentage points under a small impact of the NNR and 1.3-1.5 percentage points under a large impact.

3 Modelling effects on production and environment

3.1 Methods and model description

We used a biophysical mass-flow model of the Swedish food system, CIBUSmod (Karlsson et al., 2025), to quantitatively assess the potential effects of twelve main scenarios on how changes in red meat recommendations may influence red meat consumption and production in Sweden. The main indicators in the assessment were agricultural land use (including the area of semi-natural grasslands), livestock numbers, climate impact, and ammonia emissions.

The twelve scenarios represent a range of potential outcomes resulting from the recommendations of reduced red meat consumption. They were constructed based on different combinations of three key dimensions:

1. Level of compliance with the recommendation to limit red meat intake to 350 grams per week—either 5% or 30% of the population.
2. Assumed substitute for red meat consumption—either chicken (C) or a plant-based product (P).
3. Assumed origin of red meat consumed in Sweden—either based on current (2023) market shares (CMS), 100% Swedish red meat for the group that complies with the recommendations (SE), or 100% Swedish red meat for all consumers (SE-all).

The scenarios were defined by the Swedish Food Agency based on the assignment from the Swedish government, informed by results from the previous report (Slijper et al., 2024) and in discussions with the authors for this report. For the level of compliance (5% and 30%) this refers to additional compliance, it has been estimated that currently around 30% of the Swedish population already comply with the guidelines on red meat (i.e. lower red meat consumption than 350g per week) (Swedish Food Agency, 2025a).

For the scenarios that result in reduced production of red meat in Sweden (i.e. the CMS scenarios where current market shares are maintained) an additional scenario was also introduced to represent a situation where the area of semi-natural grasslands are maintained through agricultural policies (+AP). As CIBUSmod is a strictly biophysical model that does not incorporate any economic decision-making logics, we can assess the technical feasibility of achieving this but cannot indicate e.g. the level of support payments that would be required.

CIBUSmod incorporates a dataset representing the Swedish agri-food system in 2016-2020. Where possible, input data have been averaged over these years, and key output variables have been validated against available statistics for this period (Karlsson et al., 2025). However, given the significant changes in red meat consumption and Swedish market shares for different meat types since 2016, we also developed a second baseline representing 2023, the most recent year with available data. In this 2023 baseline, consumption levels of red and poultry meat, as well as their net import shares, were adjusted to reflect statistics for 2023, while all other input parameters—such as crop yields and animal productivity—remained unchanged from the 2016–2020 baseline. Both baselines are presented in the results, but the effects of the scenarios are primarily assessed against the 2023 baseline.

In CIBUSmod, meat consumption is defined as raw meat after accounting for losses in processing, retail, and households. Baseline consumption data (2016–2020 and 2023) were calculated using statistics on total consumption ("totalkonsumtion") in terms of carcass weight (Swedish Board of

Agriculture, 2025a). Carcass weight was converted to retail weight using standard conversion factors (pig meat = 0.78, cattle meat = 0.70, sheep and poultry meat = 0.88) from the Swedish Board of Agriculture (2025a). Finally, loss factors from Gustavsson et al. (2011) were applied to estimate the amount of raw red meat consumed. This method differs slightly from the one used by the Swedish Board of Agriculture (2025a) to calculate "raw meat ready for cooking," meaning the figures are not directly comparable, but both equate to the same total consumption in terms of carcass weight.

To calculate the raw red meat consumption in the scenarios, a percentage reduction in red meat consumption was calculated based on cooked red meat consumption “on the fork” (i.e., after accounting for all losses) in 2023 according to national statistics (Swedish Board of Agriculture, 2025b), the recommended maximum intake of 350 g cooked red meat per week, and the assumed compliance levels in each scenario. These percentage reductions were applied uniformly across all red meat types, based on 2023 consumption levels (see Table 1)

Table 1. The different scenarios on level of additional compliance with red meat recommendations, assumed origin of red meat consumed and assumed substitute and their effects on cooked red meat consumption “on the fork” (i.e., after accounting for all losses) and the corresponding raw meat consumption (used as input in CIBUSmod) as well as the effects on net import shares (i.e. (imports-exports) / consumption). Abbreviations for the origin scenarios are: CMS = current market shares, SE = current market shares for non-compliant individuals and 100% Swedish origin for individuals complying with red meat recommendations, SE-all = 100% Swedish origin of red meat for all consumers. Abbreviations for the substitute scenarios are: C = Chicken, P = plant-based.

Scenario			Red meat consumption, g/week			Net imports, %	
Compliance	Origin	Substitute	“On the fork”	Raw meat			
Baseline (BL), 2016-2020			**565**	**Total**	**706**	**Total**	**34**
				Pork	402	Pork	25
				Beef	278	Beef	45
				Lamb	26	Lamb	69
Baseline (BL), 2023			**511**	**Total**	**636**	**Total**	**29**
				Pork	354	Pork	17
				Beef	259	Beef	42
				Lamb	23	Lamb	69
5%	CMS	C or P	**503** (-1.6%) = 511 × 95% + 350 × 5%	**Total**	**626**	Same as 2023	
	SE	C or P		Pork	348	**Total**	**28**
				Beef	255	Pork	17
				Lamb	22	Beef	40
				Subst.	**+12**	Lamb	67
	SE-all	C or P				0% for all red meat	
30%	CMS	C or P	**463** (-9.5%) = 511 × 70% + 350 × 30%	**Total**	**576**	Same as 2023	
	SE	C or P		Pork	321	**Total**	**22**
				Beef	234	Pork	13
				Lamb	21	Beef	32
				Subst.	**+72**	Lamb	54
	SE-all	C or P				0% for all red meat	

It was assumed that the reduction in red meat was substituted by chicken or a plant-based protein rich product (based on pea, broad bean and rapeseed oil). Chicken was chosen as earlier studies indicate that consumers tend to substitute red meat with other meat, including chicken (Slijper et al., 2024). The plant-based protein product was chosen as there is a recommendation in the NNR2023 to increase the consumption of legumes. Choice of substitution product is discussed under Section 3.3.2. Amount of substitute (chicken and plant-based) was calculated based on weight. For the plant-based product it was assumed that 1.5 kg plant-based protein rich product constituting of cooked broad beans (0.7 kg), cooked pea (0.7 kg) and rapeseed oil (0.1 kg) replaced 1 kg red meat. The protein content of the plant-based product is then similar to 1 kg red meat (Table 2). However, 1.5 kg plant-based products contain more carbohydrates and fibre than meat, and lower content of fat. Nutrient content is taken from The Swedish Food Composition Database (Swedish Food Agency, 2025b). For chicken, it was assumed that 1 kg of chicken meat replaced 1 kg of red meat.

Table 2. Nutritional content of meat and the plant-based substitute

	Energy kcal/kg	Protein g/kg	Carbohydrates g/kg	Fat g/kg	Fibre g/kg
Meat					
1 kg pork	2020	168	0	150	0
1 kg beef	2110	194	0	150	0
1 kg lamb	2470	174	0	197	0
1 kg chicken	1150	215	0	31	0
Plant-based substitutes					
1 kg with 0.9 kg dry grain legumes and 0.1 kg rapeseed oil	3841	203	428	109	117
1 kg with 0.9 kg cooked grain legumes and 0.1 kg rapeseed oil	2362	101	214	105	59
1.5 kg with 1.4 kg cooked grain legumes and 0.1 kg rapeseed oil*	3184	158	333	107	91

*Used in the modelling

In CIBUSmod, meat imports are defined as the net import share of consumption, calculated as imports minus exports divided by total consumption. This means that exports are not explicitly modelled, but are indirectly accounted for through the net import shares. For baseline data (2016–2020 and 2023), market balances in terms of carcass weight (Swedish Board of Agriculture, 2025b) were used to determine net import shares. In the scenarios where individuals complying with red meat recommendations exclusively consumed Swedish meat (SE), net import shares were calculated under the assumption that non-compliant individuals continued consuming meat according to 2023 market shares. A weighted average was then derived based on the total red meat consumption of both groups (see Table 2).

For chicken and plant-based substitute products, net import shares were maintained at the same levels as in the 2023 baseline. These were 29%, 5%, 0.4% and 52% for chicken, peas, broad beans and rapeseed, respectively.

3.1.1 Justification of indicators used

Semi-natural grasslands have formed through a long history of mowing and grazing and are today among the most species rich habitats in Sweden (Eriksson & Cousins, 2014). Currently, most Swedish grassland habitats under the Habitats Directive (92/43/EEC) does not meet the criteria for 'good conservation status' (Swedish EPA, 2020) making the preservation of semi-natural grasslands a key nature conservation priority. We therefore use the area of semi-natural grasslands as an indicator of the contribution of Swedish food production to biodiversity conservation. In CIBUSmod, semi-natural grasslands are analogous to "Betesmark" in the areal statistics from the Swedish Board of Agriculture (2025e). This category includes grasslands with a long land use history of grazing and mowing without fertilisation or ploughing, alongside former arable fields that are no longer considered feasible to use for annual crop production. The biodiversity values of these grasslands vary considerably depending on pedo-climatic conditions and land use history (Glimskär et al., 2023). For Sweden's environmental goal of "a rich agricultural landscape" ("Ett rikt odlingslandskap") the area of semi-natural grasslands managed with environmental support payments are used as one of the indicators (Swedish EPA 2025a). This represents around 90% of semi-natural grasslands (as defined in CIBUSmod) and around 50% receive payments for nature conservation and cultural values (Swedish EPA, 2025a).

In terms of **climate impacts,** food systems have been estimated to account for 30-40% of global greenhouse gas emissions (Crippa et al. 2021). In national greenhouse gas accounting the greenhouse gas emissions allocated to the agricultural sector are dominated by methane from enteric fermentation and manure management as well as nitrous oxide emissions due to nitrogen fertilization. These emissions alone are responsible for 16% of Swedish domestic greenhouse gas emissions (Swedish EPA, 2024a). This figure excludes emissions from production of synthetic fertilizers and emissions from transports as well as energy use in for example food processing that are allocated to other sectors. The climate impact of the average Swedish diet has been estimated to around 2.2 t CO2eq per year, which is more than a three-fold transgression of the per capita boundary for climate impacts related to food (Hallström et al. 2022). Meat has been estimated to contribute with around 40% of total climate impacts from the average Swedish diet (Moberg et al 2020).

Ammonia (NH_3) is the main air pollutant linked to Swedish agriculture, which accounts for 90% of Sweden's territorial NH_3 emissions (Swedish EPA, 2023). NH_3 emissions are regulated under the National Emission Reduction Commitments Directive (NEC Directive, 2016/2284), and in 2020 NH_3 was the only air pollutant for which Sweden failed to meet its reduction target (EEA, 2023). In the atmosphere, ammonia contributes to the formation of fine particulate matter (PM2.5), which poses a risk to human health. When deposited in terrestrial and aquatic ecosystems, NH_3 can also lead to eutrophication and acidification.

Agricultural land is a limited resource globally and currently agriculture is occupying around one third of the land area and half of the habitable area on earth (Ritchie and Roser, 2024). Most of this land is used for livestock production (Ritchie and Roser, 2024). In sustainability assessments of diets, agricultural land area or cropland area are often used as indicators of resource use (i.e. use of the limited resource agricultural land) (Ran et al., 2024). Agricultural land occupation and transformation is also one of the main drivers to biodiversity loss (IPBES, 2019). However, as the area of agricultural land use is also indicative of the economic activity in the agricultural sector, we also use the agricultural land use in Sweden as an indicator of potential effects on the economic size of the agricultural sector in Sweden. Sweden and Europe have decreasing trends in agricultural land use (Ritchie and Rose, 2019, 2023; Swedish Board of Agriculture, 2021), which may pose challenges for rural livelihoods and self-sufficiency in food production. However, economic revenue per unit of crop land can vary greatly for different types of production.

Livestock numbers described in Livestock units (LSU) (Eurostat, 2025) are used in this report to indicate possible changes in animal herds and the economic size of the livestock sector as results of changes in demand.

3.1.2 Model description and methods

CIBUSmod is a mass flow model of the agriculture and food system, incorporating a detailed dataset for Sweden around the years 2016-2020. It does not include any economic or other decision-making logic and therefore cannot predict how actors in the system, such as farmers or consumers, might respond. Instead, the model relies on externally provided inputs, including consumption data and parameters for livestock and crop production. Using these inputs, CIBUSmod ensures a biophysically and agronomically feasible solution by distributing crop areas and livestock numbers across 106 regions ('harvest regions' or 'skördeområden' in Swedish) by minimising a combination of absolute and relative deviations from the current distribution of crop areas and animals, while adhering to various constraints, such as on mass flows, where different crops can be grown, crop rotations, and regional feed supply. From the resulting production, input requirements are calculated and emissions occurring in different parts of the system are calculated. The methods used for these calculations are mainly based on methods developed for territorial greenhouse gas and air pollution accounting (IPCC, 2019; EMEP/EEA, 2023).

The scenarios presented here are designed as counterfactual 'what-if' scenarios, which means that we do not explicitly account for time in the modelling but rather assess a possible alternative reality where some aspects of the system has changed (in this case red meat consumption and imports) while all other aspects remain constant. In reality, these changes would occur gradually over time alongside other changes in the system in terms of technology, agricultural practices, genetic material, etc., some of which may be interconnected with changes in demand. Here, agricultural productivity was held constant across the scenarios, with some exceptions for the SE-all scenarios (see section 3.3.3).

As this analysis builds on the one presented in Slijper et al. (2024), we refer to that report for a more detailed description of the model and dataset. Here, we focus on the aspects that differ from the previous assessment.

The model is available as open source on GitHub (https://github.com/SLU-foodsystems/CIBUSmod) and the data and scripts used to produce results presented in this report are also available on GitHub (https://github.com/SLU-foodsystems/CIBUSmod-SLV2025).

3.1.3 Constraints on land use

The maximum cropland use per region was constrained to cropland areas in 1981 according to national land use statistics on municipal level (Statistics Sweden, 2025) translated to harvest regions based on areal overlaps. For semi-natural grasslands, a dataset of potential semi-natural grasslands derived from historic land use maps (Swedish EPA, 2019) was used.

3.1.4 Constraints on use of semi-natural grasslands for grazing

In CIBUSmod, grazing is defined for each animal category as the proportion of total annual dry matter feed intake derived from grazed biomass. These proportions are multiplied by the number of animals in each category and their annual dry matter feed intake—calculated based on metabolizable energy requirements for cattle and horses or set as a fixed yearly dry matter intake for sheep—to determine the total grazing demand. The share of feed intake from grazing reflects current production systems, which could change into the future. Such changes were however not included in the scenarios studied here.

The demand for grazing can be met by either pastures on cropland (i.e. ley pastures) or semi-natural pastures. The proportion of grazed biomass sourced from cropland versus semi-natural grasslands is determined within the model via the optimisation algorithm that seeks to minimise deviations from existing land use patterns.

Due to technical and biological constraints on using semi-natural pastures for certain animal categories (e.g. too low energy density or practical restrictions on grazing semi-natural grasslands during lactation for dairy cows), CIBUSmod imposes animal category-specific limits on the maximum share of grazed biomass that can come from semi-natural grasslands. These limits were established based on data from previous literature on standardised feed rations for different animal categories (see Table 3). However, to avoid overestimating the potential for grazing on semi-natural grasslands, the values from the literature were reduced by 20%.

Table 3. Maximum share of grazed biomass from semi-natural grasslands for different animal categories in the literature and used in this study.

Animal category	Maximum share, % of dry matter		Source
	From source	Used here	
Dairy cows	28	22	Hessle & Danielsson (2023)
Suckler cows and calves	100	80	Ahlgren et al. (2022)
Bulls	No grazing assumed		
Other cattle	80	64	Ahlgren et al. (2022)
Lambs (autumn)	69	55	Ahlgren et al. (2022)
Other sheep (autumn)	66	53	Ahlgren et al. (2022)
Other sheep	100	80	Ahlgren et al. (2022)
Horses	15	12	Cederberg & Henriksson (2020)

3.1.5 Assumptions on productivity

As a general rule, productivity parameters in the model (i.e. crop yields, feed conversion ratios, animal growth rates, etc.) were held constant at their values in the 2016-2020 baseline across all scenarios. This implies that any increase or decrease in production leads to increased or decreased animal numbers and land use. However, large areas of cropland in Sweden are currently used extensively. For example, around 6% of cropland is currently in fallow and 5% of leys are not harvested (Swedish Board of Agriculture, 2025c). The yields of leys also differ substantially between different farm types, with per hectare yields on dairy farms being 25% higher than on non-dairy cattle farms (Swedish Board of Agriculture, 2023). While this is likely partly an effect of differences in soils across farm types, it also indicates room for intensifying ley production to increase biomass supply without expanding agricultural land. In the scenarios with 100% Swedish origin for all red meat consumed (SE-all), which imply significant increases in demand for Swedish production (especially for grazing and silages), we assume that intensified land use would contribute towards meeting the increased demand. This was implemented in the model by reducing the area of fallow and unharvested leys by 50% and 80%, respectively, and increasing the average ley yields for silage and grazing by 20%. In the other scenarios no changes in productivity were assumed.

3.1.6 Impacts of food and feed imports

In the previous assessment (Slijper et al., 2024), we analysed the impacts of changes in food imports separately and did not account for feed imports. Here, we extend the analysis by incorporating the effects of changes in both food and feed imports on cropland use, climate impacts, and ammonia emissions, using the database within the SAFAD tool (Röös et al. submitted manuscript). This tool contains a detailed trade database on the origin of various raw agricultural commodities, linked to a dataset on the environmental impacts of production in different countries.

In our scenarios, we only account for net changes in trade flows, including changes in red meat imports, imports of substitute products, and feed imports resulting from changes in Swedish production of red meat and chicken. Consequently, reductions in imports are presented as negative impact values (i.e. avoided impacts) in the results. To maintain consistency with the system boundaries of the current CIBUSmod version, we did not include processing emissions available in the SAFAD tool. For exporting countries where data on emissions in production were not available in the SAFAD database, an average for the countries with available data was used.

We here extended the SAFAD dataset to include beef production in Brazil, which was originally excluded due to a 10% market share cut-off (Röös et al. submitted manuscript). Brazil accounts for 5% of Swedish beef imports (Schwarzmueller & Kastner, 2022), making it the primary non-European supplier, and its beef production has a relatively high climate impact (Cederberg et al., 2011). Emissions data for Brazilian beef production was sourced from Cederberg et al. (2009) for carbon dioxide, methane, and nitrous oxide emissions.

Since the climate impact of changes in red meat imports depends heavily on the countries of origin and production systems of beef (i.e. dairy or suckler cow herds) considered, we conducted a sensitivity analysis assuming that changes in beef imports would solely affect Irish suckler cow production. This is motivated by Ireland being Sweden's largest beef supplier and the fact that dairy production systems are constrained suppliers of beef (i.e. beef is a by-product of milk production) that are unlikely to respond to changes in beef demand (Styles et al., 2018). Data on Irish suckler cow production were obtained from Moberg et al. (2019).

3.1.7 Accounting for land use change emissions

In the main text of this report, we present climate impacts excluding emissions from land use change. However, since land use change is a major contributor to the total climate impact of food production (Shukla et al., 2019), we also provide estimated emissions from land use change in Sweden in the supplementary materials.

To estimate land use change emissions in Sweden under the different scenarios, we used data from Sweden's national inventory reports on greenhouse gas emissions (Swedish EPA, 2024a). These emissions are based on national-scale sampling conducted through the Swedish National Forest Inventory and include carbon stock changes in living biomass, dead wood, litter, and soil carbon (Swedish EPA, 2024b). If land use change is detected at a sampling location, it is classified under the corresponding land use change category (e.g. forest converted to cropland) for 20 years, after which it is reassigned to the new land use category (e.g. cropland). This approach effectively sets an amortization period of 20 years, meaning that greenhouse gas emissions from land conversion are distributed over this timeframe when assessing their impact.

From these data, we derived per-hectare emission factors by averaging total net emissions over areas reported under the categories "4.B.2 Land converted to cropland" and "4.C.2 Land converted to grassland" for the most recent 10-year period 2013–2022 (Swedish EPA, 2024b). This resulted in emission factors of:

- 2.2 tCO_2/ha for land converted to cropland
- 3.6 tCO_2/ha for land converted to grassland

These emission factors were then multiplied by the net changes in cropland and semi-natural grassland areas modelled in CIBUSmod.

For imported products, emissions from land use change vary considerably depending on country of origin with generally limited land use change emissions attributed to red meat production in European countries (Pendrill et al., 2019). However, as the modelling for Sweden represent marginal effects of changed demand (i.e. any increase in demand must be met by areal expansion and/or intensified production), effects of changed imports should also ideally only affect the marginal suppliers. The SAFAD database includes emissions from land use change, but as this dataset represent land use changes averaged over current production, those are not comparable to emissions calculated here for Sweden. A thorough assessment of marginal suppliers on the Swedish market for the different imported red meats and feed commodities affected in the scenarios was however beyond the scope of this study. We therefore only present potential impacts on land use change emissions abroad from changes in beef imports using figures for Latin American beef production from Pendrill et al. (2019). Latin America, and more specifically Brazil, has been considered the global marginal exporter of beef in previous studies (Styles et al., 2018). Pendrill et al. (2019) employs a land-balance model coupled with a physical country-to-country trade model to attribute emissions from tropical deforestation to internationally traded agricultural and forestry commodities. This study used a 10-year amortization period. To align with the 20-year amortization period used for the Swedish emission factors we multiplied these emissions by a factor 0.5.

3.2 Modelling results

3.2.1 Cropland and semi-natural grasslands

The demand for cropland in Sweden reduced by 0.5% or 3% under 5% or 30% compliance with red meat recommendations when assuming maintained market shares for red meat (CMS; Figure 1). If those complying with recommendations only consume Swedish red meat (SE), demand for cropland instead increased by 0.4% or 2%. When assuming 100% Swedish origin for red meat consumed in Sweden (SE-all), cropland demand increased by 11% or 7% under a 5% or 30% compliance with recommendations.

The changes in cropland use between the 2016-2020 baseline and the 2023 baseline was small as reductions in red meat consumption between 2016-2020 and 2023 was accompanied by lower net imports of red meat in 2023 compared to 2016-2020 (see Table 1). Consequently, the changes in consumption observed between these two time-periods had limited impacts on Swedish production.

Changes in crop production were linked to corresponding shifts in fertiliser use. In the CMS scenarios, total nitrogen application—encompassing mineral fertilisers, animal manure, and other organic sources—declined slightly under the 5% compliance scenario and fell by around 3% under 30% compliance (Figure S3). In contrast, total nitrogen application increased in the SE and SE-all scenarios, regardless of compliance level. The SE scenarios resulted in up to 2% increase (30% compliance), while the SE-all scenarios resulted in up to a 22% increase (5% compliance). Scenarios assuming chicken as a substitute resulted in slightly higher nitrogen application than those using plant-based substitutes. Changes in mineral nitrogen fertiliser application were relatively smaller than overall nitrogen use, with increases of up to 9% in the SE-all scenarios under 5% compliance with red meat recommendations.

Accounting for changes in cropland demand abroad shows that the main contributor is changes in red meat imports, while changed feed and substitute imports have smaller effects. We can also note that increased cropland demand within Sweden is larger than estimated reductions in cropland use abroad in the scenarios with increased market share for Swedish red meat (i.e. going from the CMS to the SE and SE-all scenarios). This is however mainly an effect of diverging land use definitions. In Sweden, cropland is defined as land that is used to grow annual crops or that could be brought into annual crop production using conventional agricultural machinery. Therefore, croplands in Sweden include large areas of more or less permanent grassland (Karlsson et al., 2023). Internationally however, a cut-off, usually at 5 years in grass, is used to distinguish permanent grassland from cropland. This means that areas that would be defined as cropland in Sweden are defined as permanent grasslands (i.e. not cropland) internationally, which explains the lower cropland use for imported red meat.

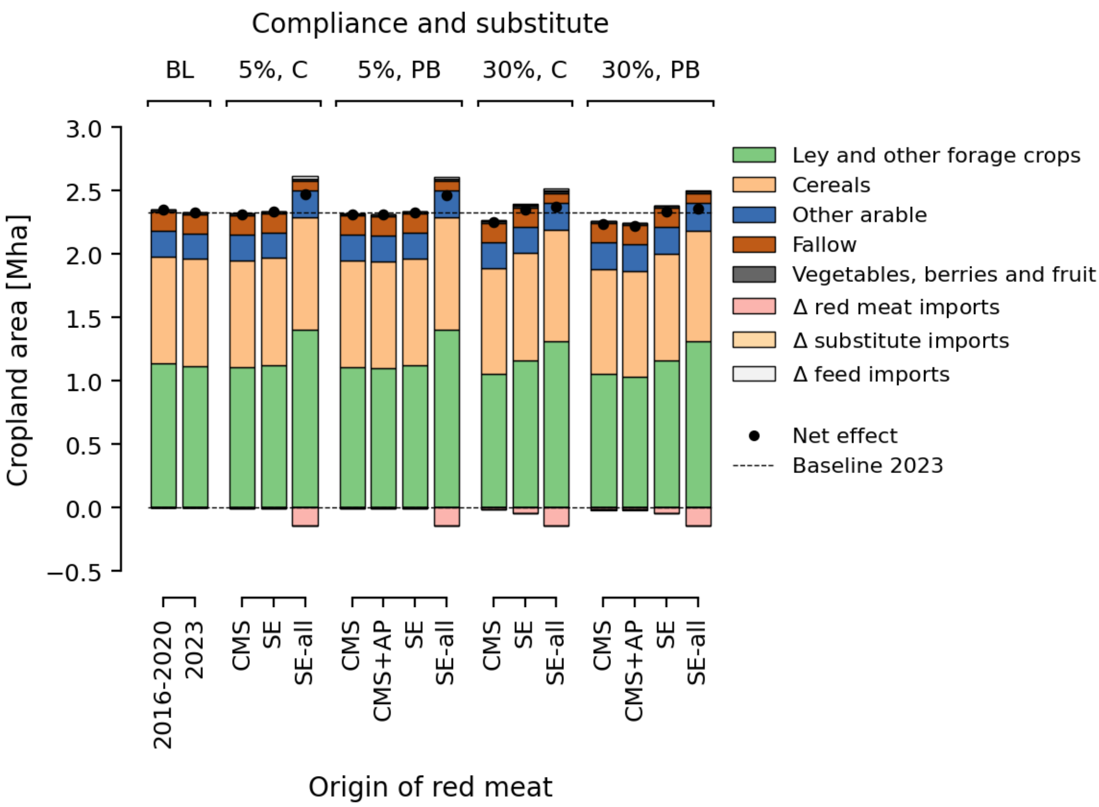

Figure 1. Swedish cropland use and changes in cropland use abroad due to changed food and feed imports. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP). Note: Due to diverging definitions of 'cropland' in Sweden and abroad, numbers for Swedish cropland use are not directly comparable to those of changed imports.

For the area of semi-natural grasslands (Figure 2a), results show a 1% or 7% reduction in area under a 5% or 30% compliance with red meat recommendations and unchanged market shares for red meat (CMS). When the group complying with recommendations are assumed to consume only Swedish red meat (SE), areas instead increase by 1% or 4%. The scenarios that assume improved incentives for grazing in semi-natural grasslands (+AP) show that animal numbers are enough to maintain semi-natural grassland areas also in the scenarios with reduced animal numbers (CMS). In the +AP scenarios the share of grazing in semi-natural grasslands increased from 53% in the baseline to up to 57% under 30% compliance with red meat recommendations (Figure 2b). The scenarios assuming 100% Swedish origin all for red meat consumed (SE-all) show a strong increase in semi-natural grassland area (+23% – +29%). It is however important to note here that the model minimises areal deviations from the baseline for both semi-natural grasslands and ley pastures on arable land. The higher yields for ley pastures assumed in the SE-all scenarios therefore explain the lower share of semi-natural grasslands in total grazed area (Figure 2b) as higher yields means that the model can meet increased demand for grazing with smaller changes in area for ley pastures compared to semi-natural pastures. This does not necessarily represent the on-farm decision making that would result from the changes imposed in the scenarios. The extent to which increased ruminant meat production would rely on ley pastures or restoration of semi-natural grasslands to meet increased demand for grazing is a question of availability of suitable areas for restoration and of economic incentives and relative profitability of different forms of production (Holmström et al., 2021), which are not fully captured in CIBUSmod.

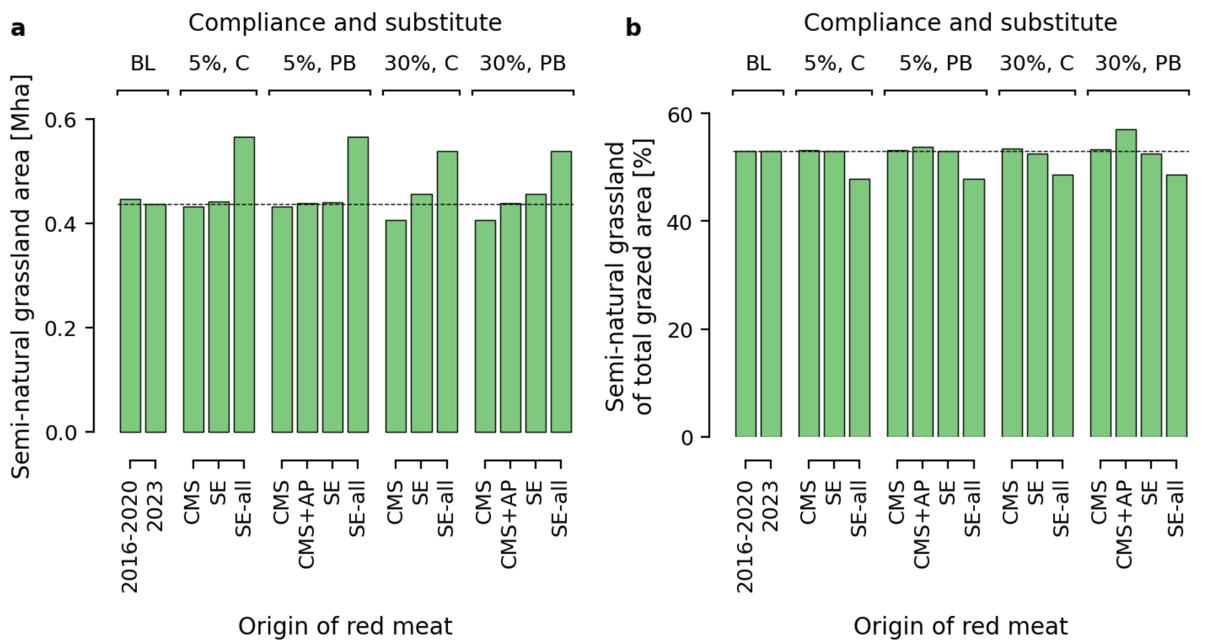

Figure 2. (a) Area of semi-natural grasslands in Sweden and (b) semi-natural grasslands as share of total grazed area, with the remainder being ley pastures on arable land. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP). The dashed line shows the area of semi-natural grasslands in the 2023 baseline.

Figure 3 shows how the changes in cropland and semi-natural grassland areas are distributed regionally in the model. The model minimises a combination of absolute and relative deviations from the current state, which results in larger absolute changes in regions that currently are dominated by red meat production and have large areas of ley and semi-natural grasslands. This includes the forested regions of south-central Sweden where changes in land-use are most pronounced. For some regions, such as the islands of Öland and Gotland and the north-eastern parts of Scania, the model reached the maximum allowed expansion of cropland (based on cropland areas in 1981) under the SE-all scenarios which constrained increases in production in these regions.

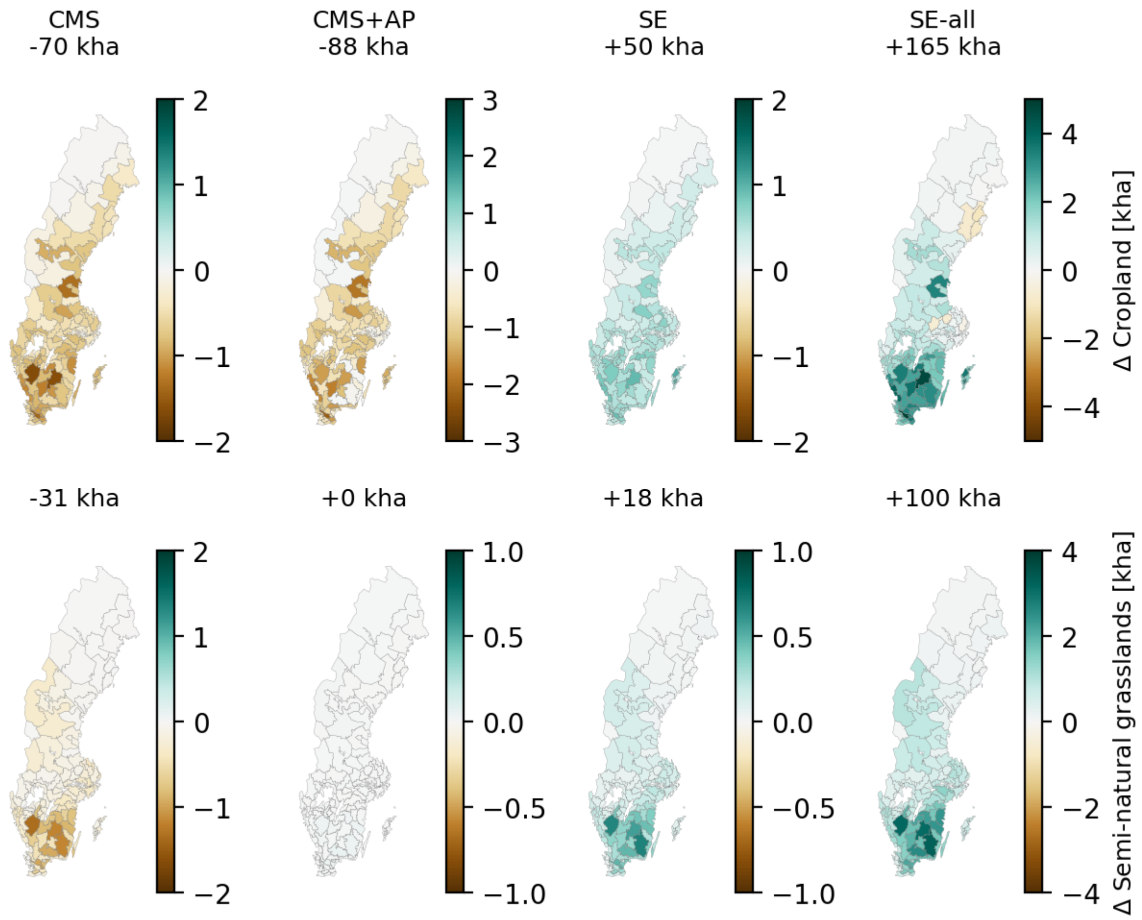

Figure 3. Changes in the area of cropland (top) and semi-natural grasslands (bottom) under the scenarios with 30% compliance with red meat recommendations and plant-based substitute. The columns show different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP).

The changes in cropland use are dominated by changes in the area of ley for grazing and silage (Figure 4) with a 60,000 ha reduction in area under the scenario with 30% compliance and unchanged market shares (CMS). Conversely, ley areas increase by 190,000 ha when assuming 100% Swedish market share for all red meat (SE-all). These changes are equivalent to a 6% decrease or 18% increase in total national ley areas, respectively. The latter figure despite the assumed increase in ley productivity in the SE-all scenarios.

For cereals, areas decreased by 600 – 2,200 ha (-0.1% – -0.3%) or 4,000 – 13,000 ha (-0.5 – -1.6%) in the CMS scenarios with 5% or 30% compliance, respectively. The ranges depend on the assumed substitute for red meat, where chicken as substitute resulted in a lower reduction in cereal area due to increased demand for feed cereals in chicken production. Conversely, in the SE-all scenarios, cereal areas increased by 30,000 – 46,000 ha (+3.5 – +5.5%) depending on compliance level and assumed substitute, due to increased demand for feed cereals for domestic red meat production.

Grain legume cultivation increased in all scenarios assuming plant-based substitute, while areas decreased in scenarios assuming chicken as substitute for red meat, with the exception of the SE-all scenarios where grain legume cultivation increased irrespective of assumed substitute due to increased demand for animal feed. The largest increase in grain legume cultivation was observed in the scenario with 30% compliance, 100% Swedish origin of red meat and plant-based substitute. There, grain legume area increased by 11,000 ha (+20%). This would imply that grain legumes are ultivated on 2.7% of Swedish cropland, which can be compared to grain legumes being cultivated on 2.4% of cropland in the baseline.

The changes in ley area are more pronounced in the less productive forest-dominated regions of Sweden, while changes in cereal, grain legume and rapeseed production mainly affect the agricultural plains districts where these crops are mainly grown currently.

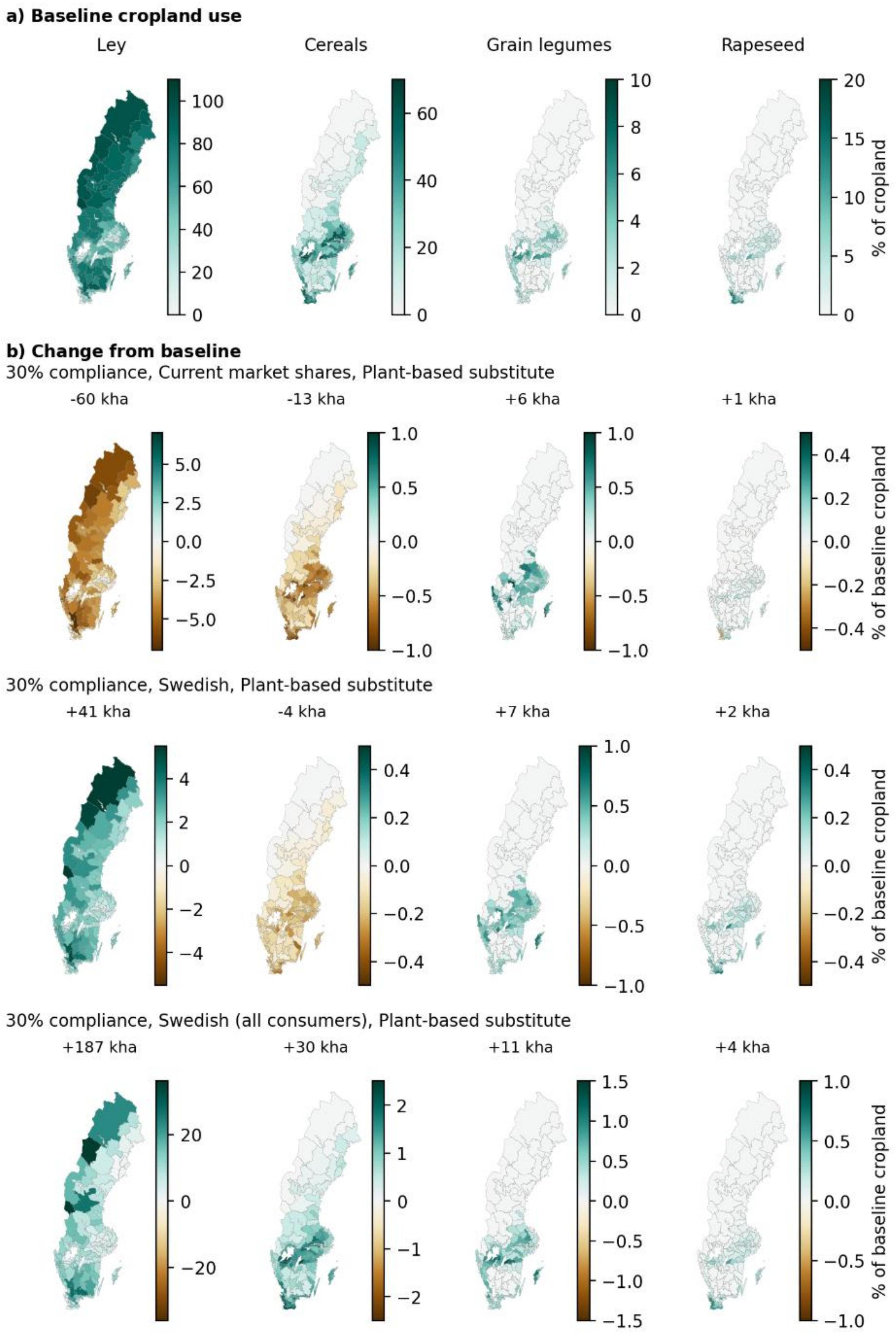

Figure 4. a) Share of cropland used for ley, cereals, grain legumes and rapeseed in the baseline. b-c) Change in cropland use for scenarios with 30% compliance, plant-based substitutes and either current market share for red meat (b) or 100% Swedish red meat for those complying with recommendations (c). Changes are shown as percentage of total cropland in each region in the baseline for the cases when plant-based food is assumed to substitute red meat in the diet (b) and for poultry as a substitute for red meat (c). The numbers on top of each map show the absolute change in Swedish cropland use for that crop in thousands of hectares (kha).

3.2.2 Livestock production in Sweden

In the scenarios assuming maintained market shares for red meat, the total number of livestock units in Sweden decreased by 0.9-1% or 5-6% under 5% or 30% compliance with red meat recommendations. The differences within compliance levels are explained by the assumption on substitute. When chicken is assumed to substitute red meat consumption the number of animals in broiler production increased by 3% or 18% under the 5% or 30% compliance level, respectively. The largest changes were observed for the self-recruiting beef production systems (i.e. suckler cow herds) where animal numbers reduce by 3% (5% compliance) or 20% (30% compliance) when assuming unchanged market shares (CMS). Conversely, the number of animals in suckler cow herds increase by 2% or 11% when assuming that those complying with red meat recommendations consume 100% Swedish red meat (SE). The reason that suckler cow herds are disproportionately affected is that consumption of dairy products is assumed unchanged across the scenarios. The number of dairy cows therefore remain unchanged at baseline numbers required to meet demand for Swedish raw milk production. In all scenarios, demand for Swedish beef production was more than enough to cover the beef generated as a by-product from the dairy systems.

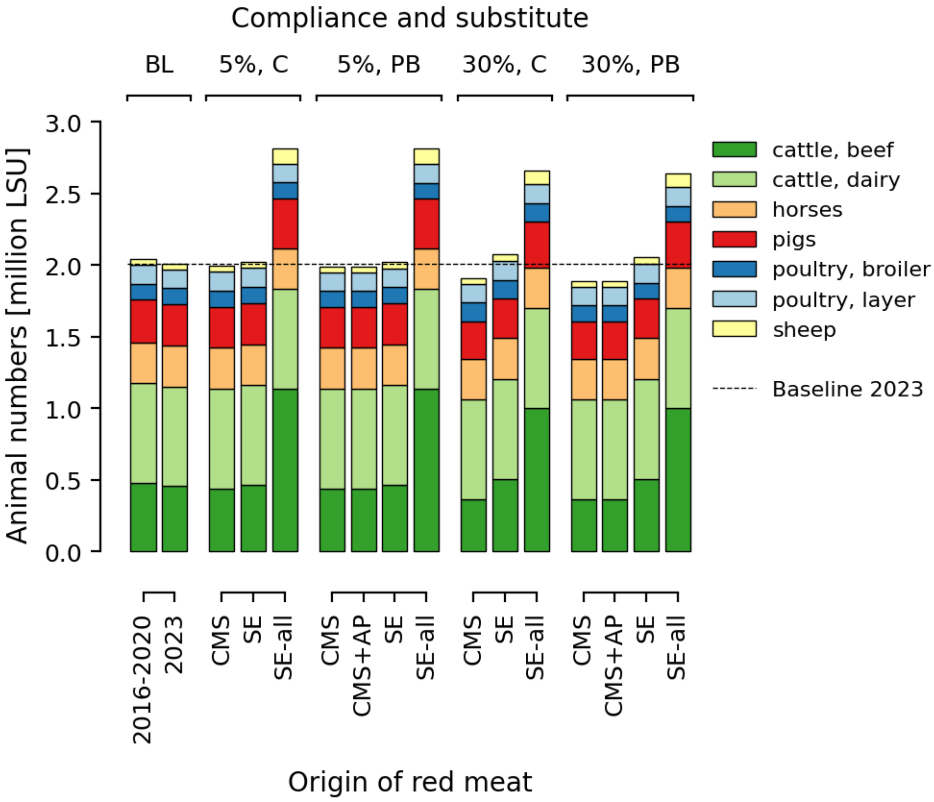

Figure 5. Animal numbers in Sweden expressed as livestock units (LSU) where one dairy cow equals one livestock unit and other animals are weighted in proportion to their feed intake relative to a dairy cow. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP).

3.2.3 Climate impact

The climate impact from Swedish agriculture was reduced by 0.7% under the 5% compliance level and by 4% under the 30% compliance level when assuming current market shares (CMS). When those complying with recommendations were assumed to consume only Swedish red meat (SE) climate impact increased by 0.5% or 2-3% under 5% or 30% compliance, respectively. In the SE-all scenarios, the climate impact of Swedish agriculture increased by up to 32% with the highest emissions in the 5% compliance scenarios.

Accounting for changes in climate impact abroad due to changes in imports of red meat, substitute products and animal feed show that net climate impacts (i.e. greenhouse gas emissions within Sweden minus reduced emissions abroad) increase slightly as the share of red meat produced in Sweden increases (i.e. going from CMS through SE to SE-all). This net effects however largely depends on the emissions intensity assumed for the imports. The dataset used here reflect average production in the countries from where Sweden currently imports red meat, which for beef includes a large share of beef from dairy systems where a large share of total impacts is allocated to milk products, resulting in relatively low climate impact per kg beef. In Sweden on the other hand, marginal effects are modelled (i.e. increased climate impact reflect the emissions associated with the additional production introduced, which is production in self-recruiting suckler herds in the case of beef). If assuming that changes in beef imports would only affect Irish suckler cow production (Figure S1) results are reversed, and the scenarios assuming 100% Swedish origin for red meat results in the strongest reductions in net climate impact. It is however important to note here that the SE-all scenarios include assumed productivity improvements in ley production and reduced areas in fallow, which reduces the overall climate impact per unit product in these scenarios.

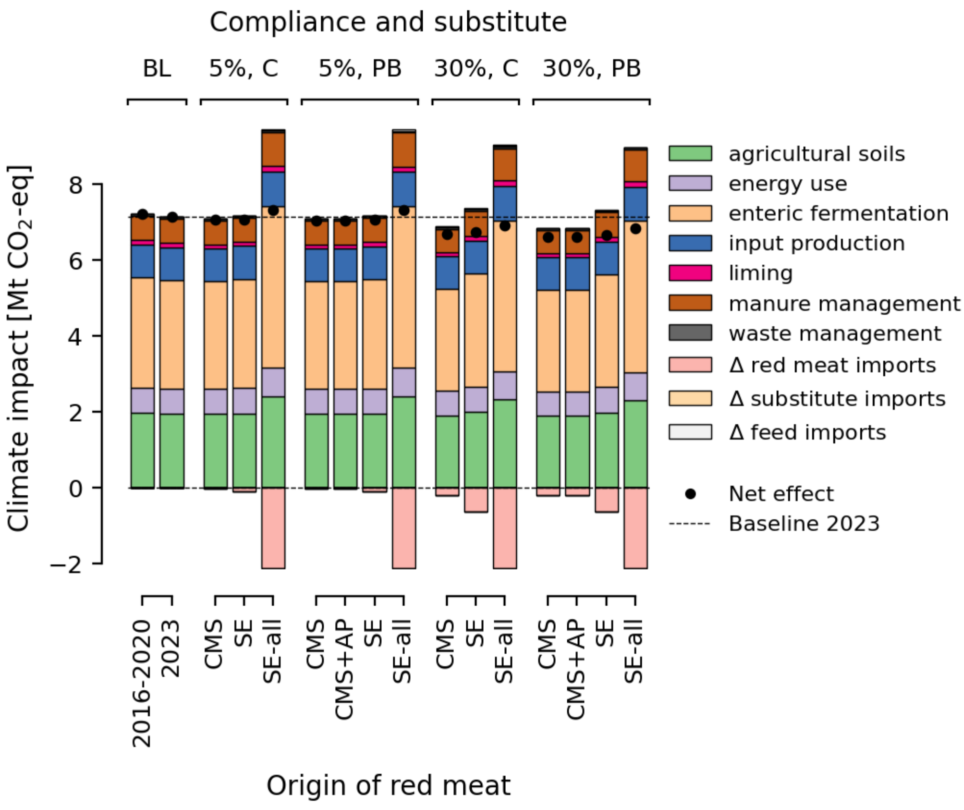

Figure 6. Climate impact of Swedish agricultural production and changes in climate impact due to changed food and feed imports. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP).

Accounting for carbon dioxide emissions from land-use changes, the SE-all scenarios result in significant emissions—around 1 Mt CO_2 under 5% compliance or 0.7 Mt CO_2 with 30% compliance (Figure S2) due to expansion of agricultural land use. This equates to 8-11% of the climate impact of greenhouse gas emissions from Swedish agriculture in these scenarios. For the other scenarios land-use change emissions were smaller, ranging from a 0.3 Mt CO_2 uptake in the CMS scenarios to 0.2 Mt CO_2 emissions in the SE scenarios, under 30% compliance with red meat recommendations.

However, these results are highly sensitive to underlying assumptions. Firstly, the amortisation period (set to 20 years here) has a strong influence on how land-use change emissions compare to other emissions. Secondly, assumptions about how increased demand is met—either through intensified use of existing agricultural land, changes in trade balance or through agricultural expansion into other land types—affect the extent of land-use change and, consequently, emissions. In this analysis, we assumed a relatively ambitious intensification of ley use (+20% yield per hectare) but no intensification for other crops. The way these processes would unfold under large shifts in demand for Swedish agricultural production remains highly uncertain.

Finally, we relied on historical data to estimate emission factors for land-use changes, which may not accurately represent future trends. The emissions associated with land conversion depend on the carbon stocks of the affected land. These stocks can vary significantly depending on whether the land that is converted into agricultural land was recently abandoned arable land with relatively low carbon stocks or land that had been left fallow for a long time or had been converted to plantation forests with substantial carbon stocks.

Considering the complexity in global land use changes and the commodities that drive them, it was beyond the scope of this study to conduct a thorough assessment of potential impacts abroad from changed red meat imports to Sweden. Potentially avoided land use change emissions could vary greatly depending on where production is assumed to respond to changes in global demand. For example, assuming that changes in beef imports would only affect Latin American beef production to which Pendrill et al. (2019) attribute 43 kg CO_2/kg carcass weight, these figures would range from 0.2 Mt CO_2 (CMS) to 2.1 Mt CO_2 (SE-all) of avoided land use change emissions under the 30% compliance level scenarios.

3.2.4 Ammonia emissions

Ammonia emissions from Swedish agriculture were reduced by 1% (5% compliance) or 5-6% (30% compliance) under the CMS scenarios (Figure 7). In the SE scenarios ammonia emissions increased marginally, while the SE-all scenarios resulted in substantial increases in emissions of up to 35%. The assumed substitute for red meat did not have a strong influence on ammonia emissions, but emissions were slightly lower in scenarios assuming a plant-based substitute.

For the net effects on ammonia emissions, including changes in imports, the same caveats apply here as for the climate impact in that the figures used for imported red meat reflect average production and not the marginal producers that are likely to respond to changes in demand on the global market.

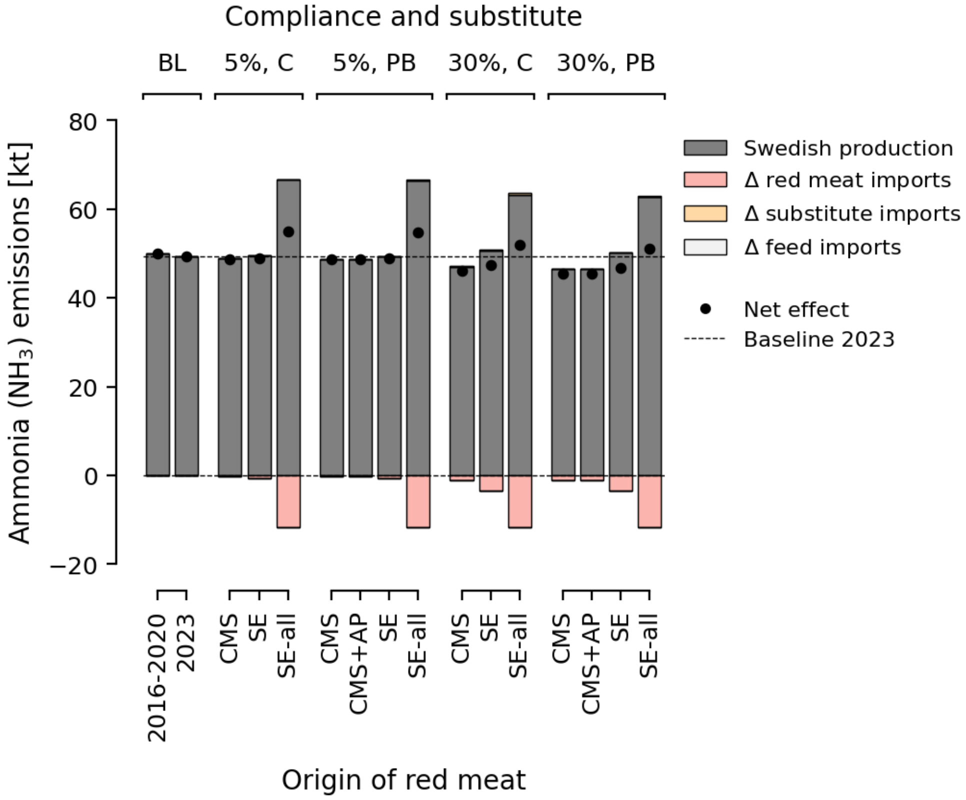

Figure 7. Ammonia emissions in Swedish agricultural production and changes in emissions due to changed food and feed imports. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP).

3.3 Discussion on model results and assumptions

The modelling results highlight that the assumptions on how Sweden's trade balance for red meat responds to changes in red meat consumption is highly influential on the final results in terms of Swedish production and associated greenhouse gas and ammonia emissions. The assessed changes in red meat consumption can accommodate both reduced and increased production in Sweden depending on how market shares develop.

Net climate impact and ammonia emissions (including reduced emissions abroad) were generally reduced following reduced red meat consumption, but exact effects depend on the production systems assumed to respond to changes in demand on the global market, which is highly uncertain. It is also implicitly assumed here that changed imports result in equivalent reductions in production on a mass basis. This is however not necessarily the case as changes in Sweden's trade balance influence supply and demand on the global market and thereby prices, with potential rebound effects on demand elsewhere, which is not captured in the analysis presented here.

A reduction in red meat consumption was associated with net reductions in crop land use both in Sweden and abroad (Figure 1). Especially beef and lamb are land demanding products (Poore and Nemecek, 2018). Global food trade is associated with large carbon losses due to deforestation, driven mainly by beef from South America and oil seeds from Southeast Asia (Pendrill et al., 2019). In general, decreasing the overall land use requirements for food production could decrease the risk of deforestation and associated carbon losses.

Market shares are input variables in the model, meaning that we do not model how changes in demand affect markets shares. In the scenarios, market shares were assumed to be unchanged (CMS-scenarios), or that consumers would choose Swedish red meat in line with the qualitative recommendation in the proposed FBDG (SE and SE-all-scenarios), which would increase the Swedish market shares for red meat (Table 1). The scenarios are thus examples of possible, more or less likely, outcomes.

As the model cannot predict how market shares are likely to respond under changes in consumption, it is interesting to study how changes in consumption of meat has affected domestic production historically. Figure 8 presents statistics on Swedish production, consumption and import of beef, pork and chicken. During this time period beef consumption has increased significantly, while production has remained rather stable or decreased. The increase in consumption from the beginning of the 1990's has thus been met by imports. For pork, domestic production has decreased while maintained or increased consumption has been met through imports. For chicken on the other hand, domestic production has increased in relation to increased domestic demand. Thus, there seems to be a weak connection between consumption demand and Swedish production volumes of beef and pork, while chicken production on the other hand seem to have been able to scale up in response to increased domestic demand. Although consumption has generally increased, there are also examples of decreased consumption. Since 2010, pork consumption has declined around 10%, nearly all of that decreased demand affected imports and Swedish market shares are now around 80% as opposed to 76% in 2010. For beef, total consumption and production is similar today as in 2010. However, there are examples of decreases in consumption during the period from 2010, for example, from 2015 to 2020 consumption decreased around 8%, in the same period production increased around 6%. These examples indicate that a decrease in demand for pork and beef seems more likely to affect imported quantities than domestic production. From this perspective, the scenarios with a consumption decrease and maintained market (CMS) seem less likely.

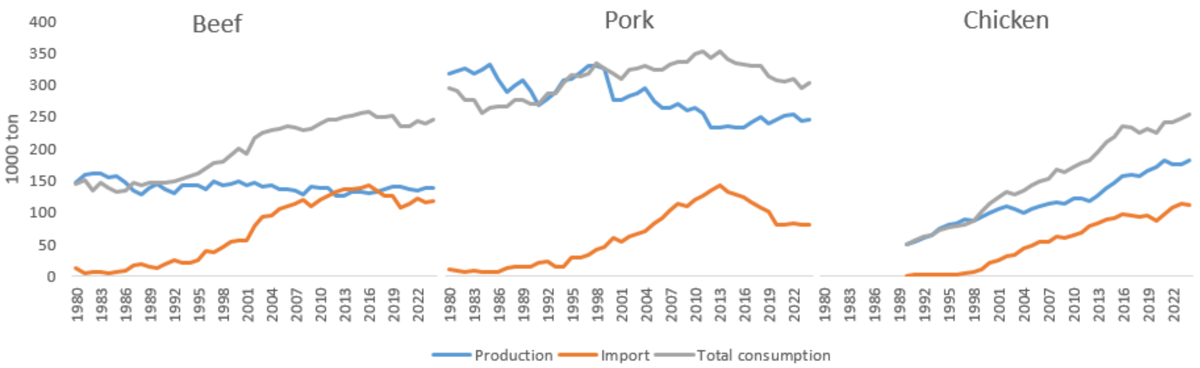

Figure 8. Swedish production, total consumption and import of beef, pork and chicken from 1980-2024 (data for chicken is missing from 1980-1989).

3.3.1 Using semi-natural grassland area as an indicator for biodiversity impact

We use area grazed semi-natural grassland as an indicator of the contribution of Swedish food production to biodiversity conservation. Preserving semi-natural grasslands are important for national environmental targets. However, food production also has negative effects on biodiversity in Sweden and abroad through for example land occupation and transformation, pesticide use, emissions of greenhouse gases as well as eutrophying and acidifying emissions. Agricultural land use is one of the main drivers behind biodiversity loss globally (Benton et al., 2021).

Consequently, biodiversity extends beyond semi-natural grasslands and must be considered in a broader context. One key concern in relation to the scenarios and the impact from the Swedish agricultural sector is the potential increase in land use in Sweden, which in itself can have a negative impact on biodiversity. Additionally, scenarios with higher production levels show increased ammonia emissions and greater application of mineral fertilizers and manure, posing risks to biodiversity. Excess reactive nitrogen can reduce terrestrial plant diversity and trigger algal blooms in aquatic ecosystems, leading to oxygen-deficient dead zones (De Vries, 2021). Ultimately, some of these nutrient emissions reach the Baltic Sea, an already polluted ecosystem. This increase contradicts environmental goals such as "zero eutrophication" and "a balanced marine environment, flourishing coastal areas, and archipelagos," as well as commitments in the HELCOM agreements.

Assessing biodiversity impacts is challenging. Several methods with global coverage have been developed to estimate impact on biodiversity loss from land use (Chaudhary et al., 2015; Scherer et al., 2023), which enables comparing biodiversity impacts from agricultural production in different regions of the world. However, since these assessments are associated with uncertainties, the results should be interpreted with care. Mazac et al. (submitted manuscript) assessed biodiversity loss (using the method developed by Scherer et al. 2023) from the current Swedish diet (for the year 2020) and for four future scenarios with varying degree of self-sufficiency. The results show that scenarios relying more on domestic production are associated with lower biodiversity loss than scenarios relying more on import (Mazac et al., submitted manuscript). This is because agricultural production in Sweden generally has a lower impact on biodiversity loss than production in biodiversity rich regions such as South America and the Mediterranean. However, all four future scenarios analyzed were associated with lower biodiversity loss than the current diet, which was primarily an effect of lower consumption of meat as well as coffee and chocolate in the future scenarios (Mazac et al., submitted manuscript). The biodiversity impact from the current diet is largely associated with two product groups: meat and “stimulants” (coffee and chocolate). Meat (red meat and chicken) is responsible for approximately 30% of current impacts. Biodiversity impacts from meat production is a result of the high land use for this production, but also the use of feed from biodiversity rich regions such as soy from South America. In addition, the current diet has high consumption of for example coffee and chocolate that are generally grown in biodiversity rich regions and hence are large contributors to the total biodiversity impact of the average Swedish diet (Mazac et al., submitted manuscript).

3.3.2 Substitution product and origin

Substitutes for the reduction in red meat was assumed to be plant-based or chicken. Product origin was assumed to follow current market shares. How a consumption change in red meat would affect the consumption of other food products is however difficult to know. Below we discuss possible effects if a decrease in red meat consumption would result in an increase in: soy-based plant-based foods or dairy foods (such as cheese). For a discussion on fish in relation to NNR2023 see Slijper et al. (2024).

Soy-based food

The plant-based substitute in the scenarios were assumed to be grain legumes (pea and broad bean) and rapeseed oil. For these products we assumed current market shares, meaning that the plant-based substitute was largely domestically produced. Although there is a growing supply of Swedish produced plant-based protein rich foods there are several soy-based foods on the market. A decrease in meat consumption could therefore lead to an increase in import of soy for food. One person complying with the recommendation on red meat to consume 350 g per week (equivalent to 438 g raw weight), would decrease red meat consumption with 161 g per week (equivalent to 192 g raw weight). Substituting all of this decrease in red meat with a soy-based product based on raw weight would mean a consumption of soy-based protein foods of around 10 kg per person per year. To produce 1 kg of ready-to eat soy-based meat analogue (with 17% protein) 0.53 kg soybeans are needed (with no allocation to soybean oil which is a by-product from the production of soy-based meat analogues) (Karlsson Potter et al 2020). Yearly demand for soybeans would then be around 6.7 kg per person after accounting for losses from processing to consumption. For the whole population this means that if the whole reduction in red meat (under the 30% compliance scenario) were replaced with a soy-based product it would require around 21,000 tonnes of soybeans.

However, the reduction in red meat would mean a reduced demand for soy as feed (for imported as well as Swedish meat). CIBUSmod estimates use of imported feed for the Swedish production. In the 30% compliance scenario with CMS, demand for soybean meal decreases with around 4,000 tonnes (for which approx. 4,800 tonnes soybeans are needed, around 20% of the soybean is soybean oil). This feed demand is only for the Swedish part of the production and decreasing meat consumption would affect also soy used as feed for the imported red meat, meaning that the actual figure of avoided soy as feed is larger than 4,800 tons per year.

Chicken is the livestock sector that uses the most soy per kg edible meat produced, in Sweden (Rundgren, 2023) and in Europe (Karlsson et al., 2021). If all the reduction in red meat is replaced with chicken produced in Sweden the additional demand for soybean meal as feed increases with around 16,300 tonnes (equivalent to 19,600 tonnes soybeans). Consequently, substituting red meat with soy-based meat analogies or Swedish produced chicken has a similar effect on the demand for soybeans. In addition, soy is not the only feed for chicken and apart from the increased use of soy a transition to more chicken would also imply an increased demand for other feeds.

Dairy products

A reduction in red meat could result in a higher consumption of dairy products (Slijper et al., 2024). For the Swedish agricultural sector an increased demand for dairy, instead of the assumed substitution products chicken and plant-based, would increase domestic greenhouse gas emissions, ammonia emissions and crop land use.

3.3.3 Qualitative recommendation on meat choice in the proposed FBDG

In the scenarios, the reduction in red meat consumption was assumed to equally affect consumption of beef, pork and lamb (Table 1). However, there are some additional qualitative recommendations in the FBDG that could influence consumption, that were not accounted for in the scenarios. For example, the FBDG recommends that consumption of processed meat products should make up a "low share” of total red meat consumption. Consumption of processed meat products is around one third of the total red meat consumption (Swedish Board of Agriculture 2024a). We decided not to consider this recommendation in the scenarios, since the share of different types of meat in the “processed meat” category in available statistics is unknown. However, since this category contains sausages and ham, it is reasonable to assume that the proportion of pork is higher in the processed meat category compared to total red meat consumption. Consequently, a person following the recommendation to decrease consumption of primarily processed meat products would likely lower pork consumption to a larger extent than beef and lamb and consequently have a lower impact on the demand for beef and a higher impact on pork than assumed in the scenarios (Table 1).

Another recommendation in the proposed FBDG is to choose red meat that could contribute with positive environmental aspects such as meat from production systems that use semi-natural grasslands and thereby preserve biodiversity. This recommendation could favor beef and lamb consumption over pork, as the latter is not associated with these potential benefits for biodiversity conservation. However, the FBDG also explicitly mentions the higher climate impact associated with ruminant meat production, so the final effects will depend on how consumers and practitioners interpret the recommendations.

3.3.4 Demand for non-food grade cereals

In the 2023 baseline around 16% of cereals produced in Sweden were used directly for domestic food production (e.g. bread, pasta and beer) while 42% were used for animal feed, 26% were exported, 12% ware used for non-food purposes (mainly bioethanol production) and 3% were required for next year's seeds. In some cases, cereals intended for direct food applications do not meet the quality criteria required for e.g. baking or beer brewing. This can be due to weather conditions, fungi, pests, or diseases (Tillgren, 2021). However, Tillgren (2021) found that most cereals intended for food applications in Sweden do reach the quality standards, and that a large share of cereals currently used for animal feed would also meet the quality criteria for food applications. Nonetheless, 100% utilization of cereals in food applications is likely challenging under current quality criteria and processing methods. In the scenarios with decreased demand for Swedish meat, direct food applications of cereals increased marginally, from 42.7% to up to 43.4% if including both domestic use and exports. Consequently, large quantities are still used as feed which means that a surplus of cereals not meeting current quality standards for food is very unlikely in these scenarios.

3.3.5 Changes in ley area

The largest changes in cropland use in the scenarios were for ley cultivation. Ley area decreased by 6% in the 30% compliance scenario or increased by 19% when 100% Swedish origin of red meat was assumed. In these two scenarios ley was cultivated on 43% and 49% of total cropland, respectively. Ley is today the dominating crop in Sweden, in 2023 it occupied around 46% of the total cropland. Total ley area has increased the last 40 years with around 100 000 ha and in the 1980's it was not ley, but spring-sown cereals, that dominated the cropland use (in the 1980's ley occupied around 35% of the total crop land area) (Swedish Board of Agriculture, 2025d).

Ley is grown all over Sweden and is especially dominating in the north and in forest dominated areas. Ley cultivation is associated with several positive crop rotation effects, which include for example maintaining or increasing soil organic carbon content (Henryson et al., 2022) and fixing nitrogen as well as improving weed and pest management (Martin et al., 2020). However, for some of these benefits to be fully utilized, ley cultivation needs to be integrated in crop rotations. Recent estimates suggest that a large proportion of ley is not integrated in crop rotations, indicating that there is room for a better utilization of crop rotation benefits by better incorporation of ley in crop rotations (Karlsson et al. 2023).

3.3.6 Trade balance for red meat in the model

Export of red meat was not explicitly included in the model but handled implicitly in the net import shares. In 2023 Sweden exported around 12.6% of the pork produced and 11.7% of the beef (Swedish Board of Agriculture, 2023). One alternative would have been to model the exports as a separate demand and to adjust the Swedish market share in consumption of red meat accordingly. In both cases it is difficult to know how a change in domestic demand may affect exports. The way it was modelled here might underestimate the demand for meat for exports in the scenarios if assuming that these are unaffected. For example, including current export volumes in the SE-all scenarios where all red meat consumed in Sweden is produced in Sweden would further increase cropland demand, animal numbers and emissions from Swedish agriculture in these scenarios.

4 Possible impacts on the food value chain

In this section, we discuss potential implications of the results presented in Section 4 for Swedish food value chains. It is important to note that CIBUSmod does not account for economic decision-making, meaning that our discussion should be interpreted with caution and viewed as a speculative analysis of the economic consequences of the findings. We examine potential implications on the food value chain by considering three key aspects. We first discuss implications for primary production (Section 4.1). Then, we discuss implications for the value chain (Section 4.2). Finally, we discuss implications for consumers (Section 4.3).

4.1 Implications for primary production

Across the scenarios analysed with CIBUSmod, the ones assuming constant market shares for red meat (CMS) implied reduced livestock production in Sweden, while scenarios assuming 100% Swedish origin of red meat consumed by those complying with recommendations (SE) or by all consumers (SE-all), resulted in increased livestock production. The scenarios resulting in reduced livestock production in Sweden may pose both threats and opportunities for primary producers (i.e. Swedish farmers). We discuss the importance of entrepreneurship in leveraging opportunities.

The economic implications of reducing the overall number of livestock units on farms, rural economies, and food supply chains are not investigated in CIBUSmod. We highlight that economic implications depend on many exogenous factors (e.g. policies), which usually require a long-term time-horizon to be addressed. Such a long-term time-horizon is not included in CIBUSmod. A possible implication of reducing the number of animals could be that regions specializing in livestock production will have a lower income in the short run (Sørensen et al. 2025; Rieger et al., 2023). In the long run, we expect that the economic implications of reduced livestock production may be limited for the Swedish agricultural sector, as there is time to change towards more production of crops such as vegetables with opportunities, given increased demand for these vegetable products, to increase production to compensate income losses in livestock production (Geibel & Freund, 2023).

We discuss some opportunities for adapting Swedish production in the long run. The analysed scenarios revealed a lower cropland demand, with varying numbers across scenarios. Some of the available cropland may become available for other production opportunities. These opportunities to increase Swedish production should also consider whether it is practically feasible to implement them, as it remains uncertain how the production system for different crops responds to increased demands and how to integrate it into the crop rotation.

We also note that the long-run implications on the livestock sector depend heavily on what future role meat consumption plays. For instance, a "less but better meat" future (Resare Sahlin and Trewern 2022) could offer viable business models for livestock farms (e.g. organic, extensive or grass-fed), without relying on current animal numbers for having profitable farms. The willingness of a farmer to shift towards a new production system depends on several factors, including farmer identity, entrepreneurial characteristics (Vesala and Vesala 2010), and the willingness to pay among consumers (Carlsson et al. 2005).

Farm businesses, like other entrepreneurial ventures, must navigate a landscape of ongoing challenges. What adaptations farmers will adopt depends on several factors, including market demands, policy shifts and environmental conditions, which cannot be assessed based on the model outputs described in Section 3. These factors will guide farmers' decisions, but the need for major adjustments may vary depending on individual circumstances.

Agricultural conditions in Sweden vary significantly, influencing how different areas can adapt to these shifts. As Welter (2011) emphasizes, context plays a crucial role in determining how businesses – including farms – adapt to change, as environmental, economic, institutional, and social factors influence their opportunities and constraints. In this context, while farm businesses are responding to changes in the external environment, their decisions are not solely driven by markets or policies. The deep connection to the place and community plays a significant role in shaping farmers' entrepreneurial choices (Korsgaard et al., 2015) and identities as producers or entrepreneurs (Vesala and Vesala, 2010). The entrepreneurial decisions farmers make, in light of these recommendations, are influenced by both external opportunities and personal, familial ties to their farms and communities. This dual influence of opportunity and place underscores the complexity of decisions in farm businesses. The impact of these recommendations will likely require some farmers to adjust their practices, but for others, it may reinforce existing strategies.

We expect adaptations to be tailored to geographic regions. In the southern parts of the country, where climate and soil conditions resemble those in Denmark, farmers benefit from favorable conditions for crop production, allowing for a broader range of adaptation strategies. In contrast, agriculture in northern Sweden faces Arctic conditions, where shorter growing seasons and lower temperatures limit crop options and increase dependency on livestock farming. Additionally, terrain, zoning, and soil quality differ across the country, further shaping the feasibility of different production models. For example, crop cultivation is mainly concentrated in the fertile plains of southern and central Sweden, while cattle farming for beef and dairy are more prevalent in northern and forested areas, where agricultural conditions are less favorable (Swedish Board of Agriculture, 2024b). These regional differences play a critical role in determining the adaptability of different farms to changing consumer demands (Barth et al., 2021). For instance, farms relying on grazing animals in forested areas and coastal meadows do not have the same conditions for transition as those with fertile and well-structured farmland.

Overall, the modelling results described in Section 3 indicate opportunities to expand the production of cereals, rapeseed, and legumes because of reduced meat consumption. This shift could benefit Sweden's primary producers in multiple ways. Among Sweden´s key agricultural exports, cereals have a high protein content that can partially replace protein intake from meat. Additionally, they are easily storable, enhancing food security and preparedness.

Currently, Sweden import half of e.g. the consumed rape seed oil, and fat is one of the macro nutrients where domestic supply might not be sufficient for the population needs. An increase in rapeseed cultivation could therefore reduce reliance on imports and strengthen self-sufficiency. Similarly, expanding legume production (and demand) would contribute to protein availability, support food preparedness, and improve agricultural sustainability by reducing the need for fertilizers through more legumes in the crop rotation (e.g. Weiner et al., 2024). Furthermore, increased domestic legume production could encourage investments in infrastructure for processing. At present, a share of dried Swedish beans is transported to Italy for boiling and packaging (GoGreen, 2025). Expanding production could facilitate the development of local processing facilities, thereby enhancing the value chain within Sweden.

Preparedness and exports

The Swedish National Food Strategy focuses on increased Swedish food production and exports. The export of red meat, however, is relatively small. In 2023, total beef consumption amounted to 239.8 kiloton, with domestic production reaching 138.2 kiloton and exports totalling 16.1 kiloton (Swedish Board of Agriculture, 2023). The primary export destinations were the United Kingdom, followed by Belgium, Denmark, and Finland. A relatively small proportion of domestically produced beef is thus exported. To increase exports, there must be potential buyers. However, most consumers prefer domestic beef (Felderhoff et al., 2020; Cubero et al., 2021), and both Finland and Denmark adhere to the same NNR as Sweden, which advocates for a reduction in meat consumption. Similarly, beef consumption in the United Kingdom is in decline (Vonderschmidt et al., 2024). This makes it questionable whether increasing the export of Swedish beef to these countries will happen.

Grazing animals can utilize feed sources that are inedible to humans, allowing them to contribute to agricultural resilience by grazing in areas unsuitable for crop production (Battheu-Noirfalise et al. 2023). However, the unanticipated drought of 2018 demonstrated a lack of preparedness. During the unusually dry conditions, pasture availability in the warm season and the ability to harvest winter feed were severely restricted. As a result, feed prices increased, and slaughterhouses became fully booked for months, and farmers were forced to cull animals they could no longer sustain (SVT 2018, SR 2018).

It is worth noting that keeping animals is resource intensive. In times of crisis, grain and agricultural land currently used for animal feed could instead feed more people (e.g. Poore & Nemecek, 2018). While cattle can consume straw-based feed, pigs and chickens primarily rely on crops, which consist mainly of products that could often be consumed directly by humans.

4.2 Broader implications for the food value chain

We discuss broader implications for the food value chain, which go beyond either the producer (section 4.1) or consumer (section 4.3) level. Implications of the FBDG are expected to arise for several value chain actors, but we tailor our discussion to the actors most affected. These actors are: (i) slaughterhouses and red meat processors, (ii) supply chains of other protein producers (e.g. plant-based, fish, poultry), and (iii) retailers.

Implications for slaughterhouses and red meat processors

Especially in the scenarios with 30% compliance of the FBDG and current market shares, we observe an average reduced demand for Swedish red meat of 9.5% per capita, which would result in 6.0% reduction in livestock units. Such changes have economic implications for various actors within the food value chain, although the extent of the impact will depend on the pace and scale of changing consumer preferences. For meat processors, a gradual decline in demand for red meat may lead to adjustments in production volumes, requiring businesses to adapt rather than face immediate large-scale disruptions. Some companies, particularly those heavily reliant on red meat processing, may experience profitability challenges, prompting them to explore diversification strategies. Slaughterhouses, meat packaging facilities, and distribution networks specializing in red meat may need to reassess their operations, but the overall effects will likely unfold over time rather than as a sudden shift. Suppliers of inputs such as animal feed, packaging materials, and processing additives tailored for the red meat industry may also see a gradual change in demand rather than an abrupt downturn.

One suggested adaptation is to consider the implementation of more accessible and flexible slaughtering facilities (Riksdagen, motion 2018/19:257). Currently, there are eight major slaughterhouses in Sweden, which limits the availability of emergency slaughter services (SvensktKött, 2025). Expanding local or mobile slaughter options allows animals to be slaughtered in case of emergency on short notice and ensures that the meat reaches the consumer market. This could increase the share of animals utilized for food while also improving efficiency for farmers and increasing emergency preparedness.

For businesses focused on red meat processing, flexibility will be key. Some may look to diversify their offerings, incorporating plant-based options or expanding into poultry and seafood. This shift may involve investments in new equipment, product development, and marketing strategies aimed at reaching different consumer segments. Government policies and incentives supporting sustainable food production could also play a role in facilitating the transition for affected businesses.

Implications for the value chains of alternative protein sources

Companies involved in the production and processing of alternative protein sources, such as plant-based foods, poultry, fish, and seafood, may find growth opportunities if the demand for red meat decreases. A steady increase in demand for these products could encourage investments in new production technologies, expanded processing capacity, and supply chain development. Food manufacturers willing to innovate may benefit from shifting consumer preferences, particularly if they can develop products that meet expectations for taste, texture and nutritional value. However, this transition requires time, investment, and adaptation to evolving market conditions.

Implications for retailers

Retailers will need to adjust by refining their product assortments and responding to evolving demand. While red meat is likely to remain an important product category, supermarkets and food service providers may gradually reallocate shelf space and marketing efforts to reflect the increasing popularity of alternative protein products. However, consumer acceptance remains a crucial factor – while some shoppers may readily adopt new dietary patterns, others may be slower to change due to cultural preferences, taste, or price considerations (e.g. SAPEA, 2023).

4.3 Implications for consumption

The updated nutritional recommendations are unlikely to significantly influence the average Swede's dietary choices in the short term (SAPEA, 2023). The scenarios with the smallest considered impacts of the proposed FBDG seem by far most realistic, while the only Swedish consumption scenario is fairly hypothetical and unlikely to occur. However, even if individual choices are only marginally influenced, the guidelines play an important role in shaping public meal compositions. Public meals, which account for 4% of the food sector's turnover and serve approximately 3 million meals per day (Krewer & Florén, 2020), are expected to gradually incorporate more sustainable options in line with the FBDG. This exposure to a broader variety of foods, particularly among younger generations, may lead to long-term changes in dietary habits.

Beyond individual consumption, the FBDG also serves as a benchmark for the food industry and producers, incentivising a gradual transformation of the food supply chain towards healthier and more sustainable food. Retailers, food processors and primary producers may respond to the FBDG by adjusting product offerings, investing in innovation, and aligning their marketing strategies with evolving dietary trends.

Since Sweden's accession to the EU in the mid-1990s, rising red meat consumption has been largely met through imports, while domestic production has remained rather stable (see Figure 8). The domestic beef production increased in the mid 2010´s when consumption declined. Recently, the numbers for 2024 were released, and while consumption now increases again, production decreases. The relationship between red meat consumption and domestic red meat production in Sweden is thus weak. A reduction in red meat consumption to align with the new FBDG recommendations would likely bring Swedish consumption levels closer to those seen in the 1990´s while the implications for domestic production would depend on how and if import shares will change.

Finally, we underline that meat consumption in Sweden varies across different market channels. For instance, major grocery retailers primarily sell Swedish meat, ensuring a strong presence of domestic products in supermarkets. In contrast, a significant share of imported meat is consumed in restaurants and food service establishments. Since March 1st 2025, restaurants are required to disclose the country of origin for the meat they serve, which may increase consumer awareness and influence purchasing decisions. Rather than overall consumption levels, factors such as competitive prices and effective marketing of Swedish meat are likely to play a more crucial role in sustaining domestic production.

5 Possible implications for grazing in semi-natural grasslands

One of the environmental indicators considered is the area of semi-natural grasslands, as indicator for biodiversity conservation. The demand for grazing in semi-natural grasslands is modelled in CIBUSmod based on animal numbers and animal-category specific rates of grazing and maximum allowed share of semi-natural pastures in total grazing. This means that as animal numbers decrease in the model, so does the area of semi-natural grasslands.

However, the use of semi-natural pastures is largely governed by factors other than total production volumes. In the modelling work, we show that it is technically possible to maintain the area of grazed semi-natural grasslands with current rates of grazing and within the assumed maximum shares of grazing from semi-natural grasslands, also in the scenarios implying reduced livestock numbers. Earlier studies have estimated the number of animals needed to make full use of semi-natural pastures in Sweden and in the Nordics and the associated production of meat and milk (Röös et al. 2016; Karlsson et al. 2018). Total production varies depending on the areas of semi-natural pastures utilized, but also depending on which production systems are prioritized (i.e. self-recruiting beef production or dairy production systems). For example, Röös et al (2015) estimated a production of beef of around 32-120 g cooked beef per person per week in scenarios where the current area of semi-natural pastures is maintained. These consumption levels are significantly lower than the ones assessed here.

The environmental model used in our analysis and previous studies cited does not incorporate any economic or other behavioural modelling. As such, they cannot answer questions regarding what is needed to achieve this technical potential. Previous studies found that the primary obstacle to expanding semi-natural pasture areas is low profitability (Larsson et al., 2020). While there are sufficient grazing animals to maintain and even increase the extent of semi-natural pastureland, the financial compensation provided does not adequately cover increased costs for cattle owners. Furthermore, Larsson et al. (2020) emphasize that compensation rates remain the same regardless of the actual biodiversity present on pasturelands. As a result, pastures with high biodiversity are not sufficiently supported, while those with lower biodiversity levels receive relatively more support payments, leading to inefficient use of public funds. To encourage increased grazing of semi-natural pastures, cattle owners likely require higher compensation that accounts for both the ecological benefits of biodiversity and the logistical challenges of maintaining livestock on high-biodiversity land. Compensations that reflect the biodiversity level on the margin is one suggestion from Larsson et al., (2020) that could increase the usage of the most biodiversity-rich pasture areas.

Jamieson and Hessle (2021) examine factors beyond the level of agricultural support payments that can either encourage or hinder increased grazing in semi-natural grasslands from a farmer's perspective. They emphasize the need for long-term market stability and predictable support schemes to enable necessary investments as well as the importance of viable rural communities that provide support and essential services for farmers. Another key challenge they identify is the difficulty in establishing sales channels that effectively communicate the biodiversity benefits of pasture-based production to consumers, which could justify a price premium.

Since 2019, the number of farms offering certified semi-natural pasture-based beef has doubled, covering an increase in demand (Svenskt Sigill, 2020). Some consumers are thus willing to pay a premium for such products. However, this alone is unlikely to drive a significant expansion of grazed areas. During the price inflation that has taken place in previous years, the trend has been decreasing market shares of organic products and domestic shares of beef (Swedish EPA, 2025b; Swedish Board of Agriculture, 2025). This highlights the risks involved in relying on consumers' willingness to pay premium prices for more environmentally benign forms of production as a strategy to increase the areas of semi-natural grasslands.

Greater public support for semi-natural grasslands is thus likely essential and could receive an additional push following the EU Nature Restoration Law, which entered into force in 2024. The biodiversity these lands sustain is a public good, which, like all public goods, cannot be sufficiently provided through private market solutions alone. Market pricing is based on marginal costs, and beef from semi-natural pastures generally entails higher production costs than conventionally raised beef. Integrating the societal value of biodiversity into pricing, by ensuring farmers receive adequate compensation for biodiversity conservation as suggested by Larsson et al., (2020), could help lower consumer prices, increase demand and expand the areas under grazing. However, support should be connected to the actual biodiversity benefits provided rather than the specific species being grazed (it can be cattle, sheep, horses or e.g. alpacas), allowing farmers the flexibility to determine their production method.

6 Conclusions

This report analyzed the implications of the proposed FBDG for production and environmental outcomes. We analyzed potential outcomes of the dietary recommendation on red meat in the proposed FBDG using twelve scenarios. These scenarios differ regarding compliance rate (5% and 30% compliance), assumed substitute for red meat (chicken or plant-based) and origin of the red meat (current market shares, compliant group choose Swedish produce, and 100% Swedish red meat for all consumers). A strictly biophysical model (CIBUSmod) was used for the analysis. This model does not incorporate the economic dimension or decision-making processes of food system actors, meaning that economic variables that could be affected by changes in demand, such as efficiency changes, are not included, except for an assumed intensification in ley production in the scenarios assuming a 100% Swedish market share for all red meat consumed.

Assumptions on the origin of red meat consumed have a large impact on how changes in consumption affect domestic production and emissions in the modeling work. The scenarios consider a range of potential outcomes depending on how market shares for Swedish red meat develop. However, these scenarios are assumed, meaning that we cannot assess the likelihood of these scenarios. Literature suggests that the standalone impact of dietary guidelines on consumption is low, so the scenarios considering the smaller changes in red meat consumption seem most likely to occur. Further, historical trends in red meat production, consumption and imports indicate that changes in consumption might affect imports the most if domestic prices are competitive.

The results show that for the 30% compliance scenarios, when all of the compliant group choose Swedish red meat (i.e. the SE scenarios), there are marginal increases in land use, semi-natural pasture area and animal numbers in Sweden. This results in an increase in national greenhouse gas and ammonia emissions of 2-3%. When market shares are maintained (i.e. the CMS scenarios), cropland use and semi-natural grassland area decrease by 3% and 7%, respectively. Animal numbers reduce too, with 5-6% when the 30% compliance scenario is considered. Domestic emissions of greenhouse gases then decrease by 4% and ammonia emissions by 4-6%.

Unsurprisingly, in the scenarios where all consumers choose Swedish red meat, the demand for products from the Swedish agricultural sector increases, both in the 5% and 30% compliance scenarios. In these scenarios, demand for Swedish cropland increases by 8-12% and semi-natural grassland area increases by 23-30%. However, this results in large increases in domestic emissions of greenhouse gases (+26%) and ammonia (+28%).

After accounting for changes in imports of food and feed, the net effects showed that the 30% compliance scenarios were associated with the largest net decrease in climate impact. However, we emphasize that the exact effects are sensitive to assumptions regarding which production systems are assumed to respond to changes in imports to Sweden.

The demand for semi-natural pastures in the model is a result of animal numbers, assumed feed rations, and limits set for the maximum share of semi-natural grasslands in grazing. Modelling results show that it is technically feasible to maintain current areas of semi-natural grassland, also in scenarios with reduced animal numbers. The link between the number of cattle in Sweden and areas of semi-natural grasslands is thus weak. Larsson et al., (2020) showed that grazing in semi-natural pastures is mainly influenced by the level of economic support and other external factors influencing the economic viability of semi-natural grassland-based production. Maintaining semi-natural pastures thus mostly depends on the financial structure and the incentives for upholding biodiversity. If the economic compensations are high enough, producers will keep animals in biodiverse areas.

Increased demand for agricultural land can lead to land use changes and associated carbon losses. However, these correlations are difficult to predict (i.e. to what extent a change in demand leads to land use change and where), and carbon losses due to land use change are difficult to estimate. Therefore, this effect could not be thoroughly analyzed within the scope of this report. In the scenarios where more consumers choose Swedish meat, the area of cropland and semi-natural grassland increased in Sweden. The results indicate that a large increase in agricultural land use in Sweden could lead to substantial carbon losses. Potentially avoided land use change emissions from a decrease in imports are highly uncertain and largely depend on where production changes may happen, as a result of a decreased demand for imported meat.

The updated FBDG are unlikely to lead to immediate and significant changes in individual dietary choices. Nevertheless, the FBDG may gradually influence food consumption patterns, particularly through their integration into public meals and the food industry’s product development. Over time, this may contribute to more sustainable and diverse diets. While the direct impact on domestic red meat production will depend on evolving market dynamics and trade patterns, rather than consumption levels alone, these changes in consumption may still set the stage for longer-term transformations in the food value chain.

In terms of primary production, a reduction in livestock production in Sweden could present both challenges and opportunities for farmers, particularly red meat producers. Farmers in this sector may face economic and operational challenges as they adjust to declining demand for red meat, which could involve reduced income and the need for investment in new production systems. However, in the long run, there may be potential to shift towards more crop production, such as legumes and rapeseed, which could contribute to food security and self-sufficiency. The economic implications of such transitions depend on regional conditions, market developments, and the ability of individual farmers to adapt to changing circumstances. However, we note that some scenarios show an increase in Swedish meat production. How the FBDG may influence Swedish production thus remains uncertain, and we again highlight the weak correlation between domestic demand for red meat and domestic supply.

Finally, concerning the broader food value chain, the shift in consumption patterns in line with FBDG may gradually reshape the Swedish food value chain. For slaughterhouses and red meat processors, a reduced demand for red meat could require adaptation and diversification over time. At the same time, growing demand for alternative protein sources may create new business opportunities across the value chain. Retailers will also play a key role in responding to shifting consumer preferences. Overall, these changes are likely to unfold gradually, giving actors time to adjust, but will require flexibility, innovation and strategic decisions across the chain.

References

Ahlgren, S., Behaderovic, D., Wirsenius, S., Carlsson, A., Hessle, A., Toräng, P., Seeman, A., den Braver, T. & Kvarnbäck, O. (2022). Miljöpåverkan av svensk nöt-och lammköttsproduktion.

Barth, H., Ulvenblad, P., Ulvenblad, P. O., & Hoveskog, M. (2021). Unpacking sustainable business models in the Swedish agricultural sector–the challenges of technological, social and organisational innovation. *Journal of Cleaner Production*, *304*, 127004.

Battheu-Noirfalise, C., Mertens, A., Froidmont, E., Mathot, M., Rouillé, B., & Stilmant, D. (2023). Net productivity, a new metric to evaluate the contribution to food security of livestock systems: The case of specialised dairy farms. Agronomy for Sustainable Development, 43(4), 54. https://doi.org/10.1007/s13593-023-00901-z

Benton, T. G., Bieg, C., Harwatt, H., Pudasaini, R., & Wellesley, L. (2021). Food system impacts on biodiversity loss. Three levers for food system transformation in support of nature. Chatham House, London, 02-03.

Brandt, M., Ejhed, H., Rapp, L., 2008. Näringsbelastning på Östersjön och Västerhavet 2006. Swedish EPA Report 5815

Carlsson, F., Frykblom, P., & Lagerkvist, C. J. (2005). Consumer preferences for food product quality attributes from Swedish agriculture. *AMBIO: A Journal of the Human Environment*, *34*(4), 366-370.

Cederberg, C. & Henriksson, M. (2020) Gräsmarkernas användning i jordbruket. Institutionen för Rymd-, geo- och miljövetenskap, Chalmers tekniska högskola. https://research.chalmers.se/publication/517805

Cederberg, C., Persson, U.M., Neovius, K., Molander, S. & Clift, R. (2011). Including carbon emissions from deforestation in the carbon footprint of Brazilian beef. ACS Publications.

Cederberg, C., Meyer, D. & Flysjö, A. (2009). Life cycle inventory of greenhouse gas emissions and use of land and energy in Brazilian beef production: SIK Institutet för livsmedel och bioteknik.

Chaudhary, A., Verones, F., De Baan, L. & Hellweg, S. (2015). Quantifying land use imapcts on biodiversity: combining species-area models and vulnerability indicators. *Environmental science & technology,* 49(16), pp. 9987-9995.

Christensen, J. J., Arnesen, E. K., Andersen, R., Eneroth, H., Erkkola, M., Høyer, A., Lemming, E. W., Meltzer, H. M., Halldórsson, Þ. I., Þórsdóttir, I., Schwab, U., Trolle, E., & Blomhoff, R. (2020). The Nordic Nutrition Recommendations 2022 – principles and methodologies. Food & Nutrition Research, 64. https://doi.org/10.29219/fnr.v64.4402

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N. & Leip, A. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature food*, 2(3), pp. 198-209.

Cubero Dudinskaya E, Naspetti S, Arsenos G, Caramelle-Holtz E, Latvala T, Martin-Collado D, Orsini S, Ozturk E, Zanoli R. European Consumers' Willingness to Pay for Red Meat Labelling Attributes. Animals (Basel). 2021 Feb 20;11(2):556. doi: 10.3390/ani11020556. PMID: 33672549; PMCID: PMC7923784.

Deaton, A., & Muellbauer, J. (1980). An Almost Ideal Demand System. The American Economic Review, 70(3).

De Vries, W. (2021). Impacts of nitrogen emissions on ecosystems and human health: A mini review. Current Opinion in Environmental Science & Health, 21, p. 100249.

EEA. (2023). National Emission reduction Commitments Directive reporting status. https://www.eea.europa.eu/publications/national-emission-reductioncommitments-directive-2022/national-emission-reduction-commitmentsdirective

EMEP/EEA (2023). EMEP/EEA air pollution emission inventory guidebook 2023 Technical guidance to prepare national emission inventories. EEA Report 06/2023. European Environmental Agency. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

Eriksson, O. & Cousins, S.A. (2014). Historical landscape perspectives on grasslands in Sweden and the Baltic region. *Land,* 3(1), 300-321.

Eurostat (2025). Glossary: Livestock units (LSU). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Livestock_unit_(LSU). Accessed: 20250313

FAO. (2023). *SDG Progress report 2023: Tracking progress on food and agriculture-related SDG indicators 2023*. https://doi.org/10.4060/cc7088en

Felderhoff C, Lyford C, Malaga J, Polkinghorne R, Brooks C, Garmyn A, Miller M. Beef Quality Preferences: Factors Driving Consumer Satisfaction. Foods. 2020 Mar 4;9(3):289. doi: 10.3390/foods9030289. PMID: 32143411; PMCID: PMC7143558.

Geibel, I., & Freund, F. (2023). The effects of dietary changes in Europe on greenhouse gas emissions and agricultural incomes in Ireland and Denmark. *Environmental Research Letters*, *18*(12), 124026.

Glimskär, A., Hultgren, J., Hiron, M., Westin, R., Bokkers, E.A. & Keeling, L.J. (2023). Sustainable grazing by cattle and sheep for semi-natural grasslands in Sweden. Agronomy, 13(10), p. 2469.

GoGreen (2025). Svenskodlat ja! Men varför sker produktionen i Italien. https://www.gogreen.se/om-oss/produktion-utomlands/. Accessed: 20250423

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R. & Meybeck, A. (2011). *Global food losses and food waste*. FAO Rome. http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

Hallström, E., Davis, J., Håkansson, N., Ahlgren, S., Åkersson, A., Wolk, A., & Sonesson, U. (2022). Dietary environmental impacts relative to planetray boundaries for six environmental indicators- a population based study. *Journal of Cleaner Production,* 373, p. 1333949

Henryson K., Meurer K.H.E., Bolinder M.A., Kätterer T. och Tidåker P. (2022) Higher carbon sequestration on Swedish dairy farms compared with other farm types as revealed by national soil inventories. Carbon Management 13(1), 266–278. https://doi.org/10.1080/17583004.2022.2074315

Hessle, A. och Danielsson, R. 2023. Antal nötkreatur som krävs för att nå gynnsam bevarandestatus i svenska naturbetesmarker och djurens metanutsläpp. Rapport 60, Institutionen för husdjurens miljö och hälsa, Sveriges lantbruksuniversitet.

Holmström, K., Kumm, K.-I., Andersson, H., Nadeau, E., Segerkvist, K.A. & Hessle, A. (2021). Economic incentives for preserving biodiverse semi-natural pastures with calves from dairy cows. Journal for Nature Conservation, 62, 126010. https://doi.org/10.1016/j.jnc.2021.126010

IPBES (2019): Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages

IPCC. (2019) 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

Jamieson & Hessle (2021). Hinder och möjligheter för ökad naturbetesdrift ur ett landskapsperspektiv- en kunskapsöversikt. SustAnimal Repports #1, 2021

Karlsson, J.O., Einarsson, R. & Tidåker, P. (2023). Vallens Roll i Hållbara Livsmedelssystem—Hur Välintegrerad Är Vallen i Växtodlingssystemen? *Vallkonferens 2023,* Uppsala. https://doi.org/10.54612/a.5l50sdfpvh

Karlsson, J. O., Parodi, A., Van Zanten, H. H., Hansson, P. A., & Röös, E. (2021). Halting European Union soybean feed imports favours ruminants over pigs and poultry. *Nature Food*, *2*(1), 38-46.

Karlsson, J. O., Carlsson, G., Lindberg, M., Sjunnestrand, T., & Röös, E. (2018). Designing a future food vision for the Nordics through a participatory modeling approach. *Agronomy for Sustainable Development*, *38*, 1-10.

Karlsson, J.O., Karlsson-Potter, H., Lagnelöv, O., Ericsson, N., Einarsson, R., Hansson, P-A. CIBUSmod: A spatially disaggregated biophysical agri-food systems model for studying national-level demand- and production-side intervention scenarios. *Manuscript in preparation.*

Korsgaard, S., Müller, S. and Tanvig, H.W. (2015), "Rural entrepreneurship or entrepreneurship in the rural – between place and space", International Journal of Entrepreneurial Behavior & Research, Vol. 21 No. 1, pp. 5-26. https://doi.org/10.1108/IJEBR-11-2013-0205

Krewer, C. & Florén, B. (2020). Hållbarhetsmål i offentliga måltider. RISE Rapport 2020:55 ISBN: 978-91-89167-38-4

Larsson, C., Boke Olén, N., Brady, M. 2020. Naturbetesmarkernas framtid - en fråga om lönsamhet. AgriFood Economics Centre, RAPPORT 2020:1

Lazaric, N., Le Guel, F., Belin, J., Oltra, V., Lavaud, S., & Douai, A. (2020). Determinants of sustainable consumption in France: The importance of social influence and environmental values. *Journal of Evolutionary Economics*, *30*(5), 1337–1366.

Martin G., Durand J.-L., Duru M., Gastal F., Julier B., Litrico I., Louarn G., Médiène S., Moreau D., ValentinMorison M., Novak S., Parnaudeau V., Paschalidou F., Vertès F., Voisin A.-S., Cellier P. och Jeuffroy M.-H. (2020) Role of ley pastures in tomorrow's cropping systems. A review. Agronomy for Sustainable Development 40(3), 17. https://doi.org/10.1007/s13593-020-00620-9

Martini, D., Tucci, M., Bradfield, J., Di Giorgio, A., Marino, M., Del Bo', C., Porrini, M., & Riso, P. (2021). Principles of Sustainable Healthy Diets in Worldwide Dietary Guidelines: Efforts So Far and Future Perspectives. *Nutrients*, *13*(6), Article 6. https://doi.org/10.3390/nu13061827

Mazac, R., Karlsson Potter, H., Persson, M., Einarsson, R., Carlsson, H., Bengtsson, J., Karlsson, J., Peterson, G., Gordon, L. & Röös, E. National pathways to global boundaries: Environmental and health outcomes of diets in four food futures. in review in Nature Communications.

Moberg, E., Karlsson Potter, H., Wood, A., Hansson, P.-A., & Röös, E. (2020). Benchmarking the Swedish Diet Relative to Global and National Environmental Targets—Identification of Indicator Limitations and Data Gaps. *Sustainability*, *12*(4), 1407. https://doi.org/10.3390/su12041407

Moberg, E., Walker Andersson, M., Säll, S., Hansson, P.-A. & Röös, E. (2019). Determining the climate impact of food for use in a climate tax—design of a consistent and transparent model. *The International Journal of Life Cycle Assessment,* 24(9), 1715-1728. 10.1007/s11367-019-01597-8

Pendrill, F., Persson, U. M., Godar, J., Kastner, T., Moran, D., Schmidt, S., & Wood, R. (2019). Agricultural and forestry trade drives large share of tropical deforestation emissions. *Global environmental change*, *56*, 1-10.

Poore, J. & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), pp. 987-992.

Ran, Y., Cederberg, C., Jonell, M., Bergman, K., De Boer, I. J., Einarsson, R., ... & Röös, E. (2024). Environmental assessment of diets: overview and guidance on indicator choice. *The Lancet Planetary Health*, *8*(3), e172-e187.

Resare Sahlin, K., & Trewern, J. (2022). A systematic review of the definitions and interpretations in scientific literature of 'less but better' meat in high-income settings. *Nature food*, *3*(6), 454-460.

Rieger, J., Freund, F., Offermann, F., Geibel, I., & Gocht, A. (2023). From fork to farm: Impacts of more sustainable diets in the EU-27 on the agricultural sector. *Journal of Agricultural Economics*, *74*(3), 764-784.

Riksdagen, motion 2018/19:257. Gårdsnära slakt. https://www.riksdagen.se/sv/dokument-och-lagar/dokument/motion/gardsnara-slakt_h602257/

Ritchie, H. & Roser, M. (2024). Half of the world's habitable land is used for agriculture. https://ourworldindata.org/global-land-for-agriculture

Hannah Ritchie and Max Roser (2019) - "Land Use" Published online at OurWorldinData.org. Retrieved from: https://ourworldindata.org/land-use

Rundgren, G., (2023). The use of feed for the production of meat, egg and cheese in Sweden. WWF Sweden

Röös, E., Jacobsen, M., Karlsson, L., Wanecek, W., Spångberg, J., Mazac, R. , Rydhmer, L. Introducing a Comprehensive and Configurable Tool for Calculating Environmental and Social Footprints for use in Dietary Assessments. In review in Journal of Cleaner Production

Röös, E., Patel, M., Spångberg, J., Carlsson, G., Rydhmer, L. (2015). Kött och mjölk från djur uppfödda på bete och restprodukter-ger det en hållbar kost? SLU framtidens lantbruk.

Röös, E., Patel, M., Spångberg, J., Carlsson, G., & Rydhmer, L. (2016). Limiting livestock production to pasture and by-products in a search for sustainable diets. *Food policy*, *58*, 1-13.

SAPEA. (2023). *Towards sustainable food consumption: Evidence review report* (1.0). Zenodo. https://doi.org/10.5281/ZENODO.8031939

Scherer, L., Rosa F., Sun, Z., Michelsen, o., De Laurentiis, V., Marques, A., Pfister, S., Verones, F. & Kuipers, K.J. (2023). Biodiversity impacts assessment considering land use intensities and fragmentation. *Environmental science & technology,* 57(48), pp. 19612-19623.

Schwarzmueller, F., & Kastner, T. (2022). Agricultural trade and its impacts on cropland use and the global loss of species habitat. *Sustainability Science*, *17*(6), 2363-2377.

P.R. Shukla, J. Skea, R. Slade, R. van Diemen, E. Haughey, J. Malley, M. Pathak, J. Portugal Pereira (eds.) Technical Summary, 2019. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M, Belkacemi, J. Malley, (eds.)]. https://doi.org/10.1017/9781009157988.002

Slijper, T., Karlsson, J., Karlsson Potter, H., Säll, S., & Hansson, H. (2024). Introducing environmental considerations to the Nordic Nutrition Recommendations 2023. *Mistra Food Futures Report*, (21).

Statistics Sweden (2025). Statistikdatabasen. Jordbruksmark och skogsmark efter region och markanvändningsklass. År 1951-2020. Jordbruksmark och skogsmark efter region och markanvändningsklass. År 1951 - 2020. PxWeb

Styles, D., Gonzalez-Mejia, A., Moorby, J., Foskolos, A. & Gibbons, J. (2018). Climate mitigation by dairy intensification depends on intensive use of spared grassland. *Global Change Biology,* 24(2), 681-693. https://doi.org/10.1111/gcb.13868

SR (2018). https://www.sverigesradio.se/artikel/7079634

SvensktKött, 2025. Hur går slakt till i Sverige? https://svensktkott.se/om-kott/djuruppfodning/slakt/

Svenskt Sigill (2020). Pressmeddelande. Efter Coops satsning- nu dubblades antalet gårdar med naturbeteskött. https://www.mynewsdesk.com/se/svensktsigill/pressreleases/efter-coops-satsning-nu-dubbleras-antalet-gaardar-med-naturbeteskoett-2962810

SVT (2018) Torkan: Bönderna tvingas nödslakta sina djur. https://www.svt.se/nyheter/lokalt/jonkoping/torkan-leder-nodkris-for-bonderna

Swedish Board of Agriculture (2021). Långa tidsserier- Basstatistik om jordbruket åren 1866-2020. https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2021-08-16-langa-tidsserier---basstatistik-om-jordbruket-aren-1866-2020

Swedish Board of Agriculture (2023). Marknadsrapport animalieprodukter- utvecklingen i Sverige till och med 2023. Marknadsrapport animalieprodukter 2023

Swedish Board of Agriculture (2025a). Konsumtion animalieprodukter. Priser och marknadsinformation för livsmedel - Jordbruksverket.se. Accessed: 250312

Swedish Board of Agriculture (2025b). Marknadsbalans gris, nöt, får och fågel. https://jordbruksverket.se/mat-och-drycker/handel-och-marknad/priser-och-marknadsinformation-for-livsmedel,. Accessed 250312

Swedish Board of Agriculture (2025c) Jordbruksverkets statistikdatabas. https://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets%20statistikdatabas/

Swedish Board of Agriculture (2025d). Åkerarealens användning efter år och gröda. https://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets%20statistikdatabas/Jordbruksverkets%20statistikdatabas__Aldre%20statistik__Langa%20tidsserier/HISTA01.px/table/tableViewLayout1/?loadedQueryId=b3f38035-edb6-4f1b-9b9b-a0402466650d&timeType=from&timeValue=0

Swedish Board of Agriculture (2025e). Jordbruksmark och skogsmark efter region och markanvändningsklass. År 1951-2020. Jordbruksmark och skogsmark efter region och markanvändningsklass. År 1951 - 2020. PxWeb

Swedish Board of Agriculture (2023) Skörd av spannmål, trindsäd, oljeväxter, potatis och slåttervall 2022. Slutlig statistik. JO0601 https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2023-04-21-skord-av-spannmal-trindsad-oljevaxter-potatis-och-slattervall-2022.-slutlig-statistik

Swedish Board of Agriculture (2024a). Konsumtion av kött. https://jordbruksverket.se/mat-och-drycker/hallbar-produktion-och-konsumtion-av-mat/konsumtion-av-kott

Swedish Board of Agriculture (2024b). Jordbruksmarkens användning 2024. Slutlig statistik. Jordbruksverket. Hämtad från https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2024-10-22-jordbruksmarkens-anvandning-2024.-slutlig-statistik

Swedish EPA. (2020). Sveriges arter och naturtyper i EU:s art och habitatdirektiv – Resultat från rapportering 2019 till EU av bevarandestatus 2013-2018. https://www.naturvardsverket.se/4ac60f/globalassets/media/publikationerpdf/6900/978-91-620-6914-8.pdf

Swedish EPA. (2024a). Jordbruk, utsläpp av växthusgaser Jordbruk, utsläpp av växthusgaser

Swedish EPA. (2024b). National Inventory Report Sweden 2024. Greenhouse Gas Emission Inventories 1990-2022 Submitted under the United Nations Framework Convention on Climate Change. Swedish Environmental Protection Agency

Swedish EPA. (2023). Informative Inventory Report Sweden 2023 – Submitted under the Convention on Long-Range Transboundary Air Pollution.

https://www.naturvardsverket.se/494814/contentassets/a793266c97e54f95806a9 793fad82217/informative-inventory-report-sweden-2023.pdf

Swedish EPA (2025a). Sveriges miljömål. Betesmarker och slåtterängar. https://www.sverigesmiljomal.se/miljomalen/ett-rikt-odlingslandskap/betesmarker-och-slatterangar/

Swedish EPA (2025b). Sveriges miljömål. Andel ekologisk försäljning av livsmedel och alkoholfria drycker. https://sverigesmiljomal.se/miljomalen/generationsmalet/ekologisk-mat/

Swedish EPA (2019). Mer naturbetesmarker och ekonomiskt bärkraftiga företag - Ett samverkansprojekt inom miljömålsrådets gemensamma åtgärdslista 2019. https://www.naturvardsverket.se/4ac403/contentassets/260e782f99c948a0a23977ba43cd66d0/naturbetesmarker-o-barkraftiga-foretag.pdf

Swedish Food Agency (2025b) Livsmedelsdatabasen. https://soknaringsinnehall.livsmedelsverket.se/

Swedish Food Agency (2025a) Livsmedelsverket. Regeringsuppdrag 2025. Fördjupad konsekvensanalys av kostrådet om rött kött och chark. Livsmedelsverket Uppsala

Sørensen, P. B., Beck, U. R., Berg, A. K., Christiansen, S., Jørgensen, C. L., Kirk, J. S., ... & Stephensen, P. P. (2025). The effects of unilateral climate policy towards agriculture: A case study of Denmark. *Journal of Agricultural Economics*.

Tillgren, B. (2021). Cereals as “leftover biomass” An analysis of Swedish cereal production from the perspective of feed-food competition. Master thesis. Swedish university of Agricultural Sciences. Agricultural Programme-food sciences, Molecular Sciences, 2021:05

Vesala, H. T., & Vesala, K. M. (2010). Entrepreneurs and producers: Identities of Finnish farmers in 2001 and 2006. *Journal of Rural Studies*, *26*(1), 21-30.

Vonderschmidt, A., Jaacks, L.M., Alexander, P. *et al.* Smaller meat portions contribute the most to reducing meat consumption in the United Kingdom. *Nat Food* **5**, 982–987 (2024). https://doi.org/10.1038/s43016-024-01070-2

Weiner, M., Moakes, S., Raya-Sereno, M.D., Cooper, J. Legume-based crop rotations as a strategy to mitigate fluctuations in fertilizer prices? A case study on bread wheat genotypes in northern Spain using life cycle and economic assessment, European Journal of Agronomy, Volume 159,2024,127267,ISSN 1161-0301,https://doi.org/10.1016/j.eja.2024.127267.

Welter, F. (2011). Contextualizing Entrepreneurship-Conceptual Challenges and Ways Forward. Entrepreneurship Theory and Practice, 35 (1), 165–184. https://doi.org/10.1111/j.1540-6520.2010.00427.x

Supplementary materials

Data presented in bar-charts in this report are available in tabular form in the GitHub repository here:

https://github.com/SLU-foodsystems/CIBUSmod-SLV2025/raw/refs/heads/main/output/Result%20tables.xlsx

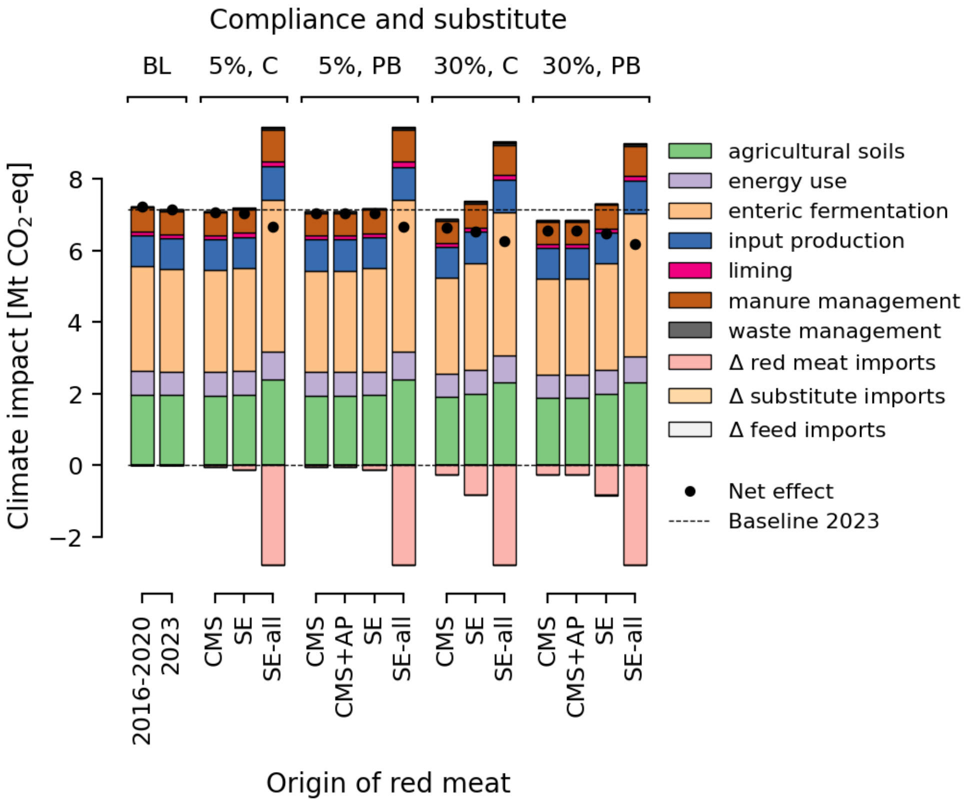

Figure S1. Climate impact of Swedish agricultural production and changes in climate impact due to changed food and feed imports using values for Irish suckler cow production from Moberg et al. (2020) for all beef imports. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP).

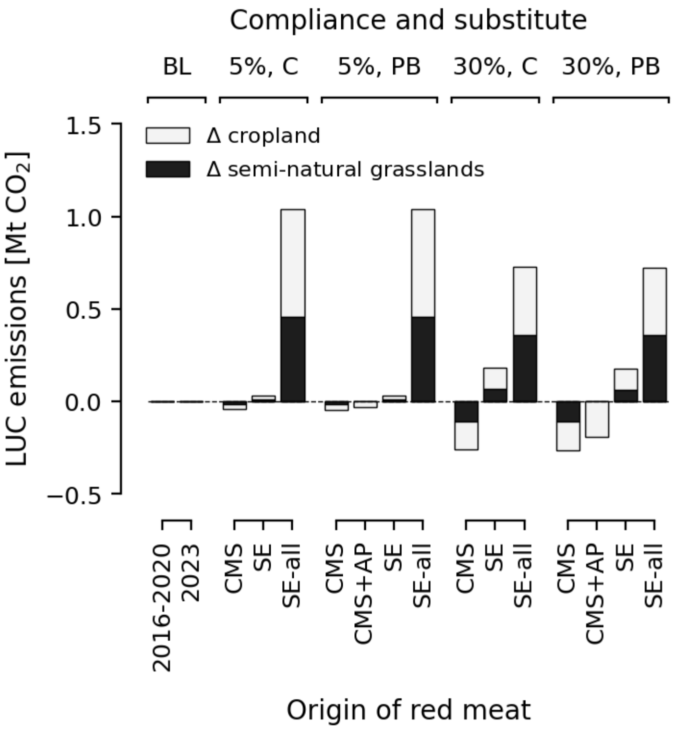

Figure S2. Land-use change emissions in Sweden. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland-based production are assumed (+AP).

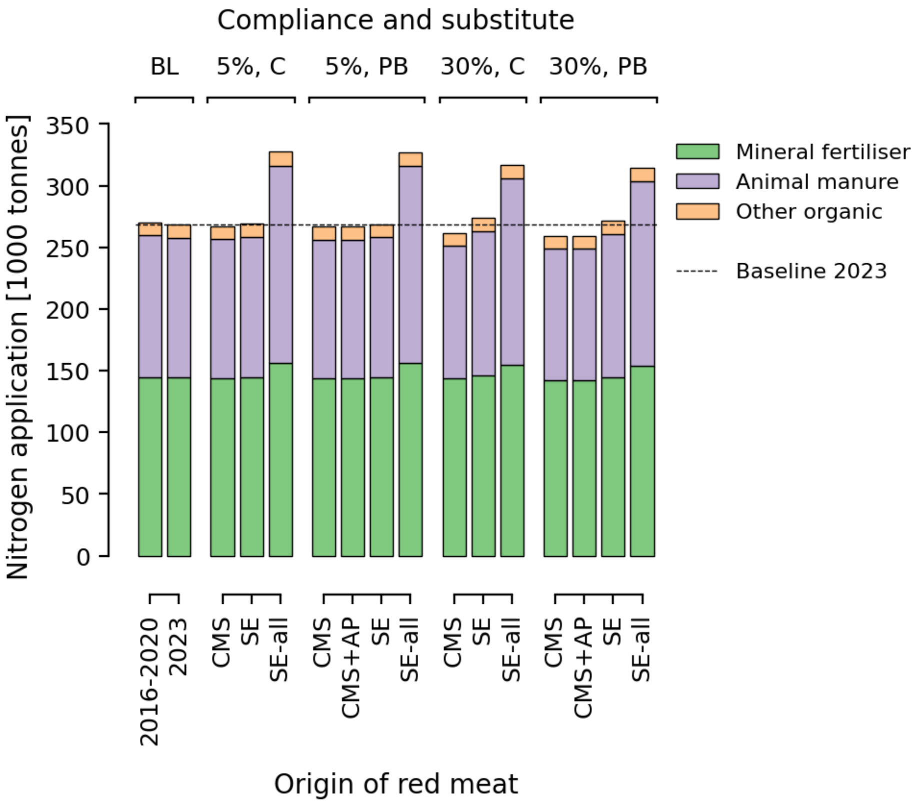

Figure S3. Application of nitrogen on Swedish cropland subdivided on mineral fertilisers, animal manure, and other organic fertilisers. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat *recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland-based production are assumed (+AP).*

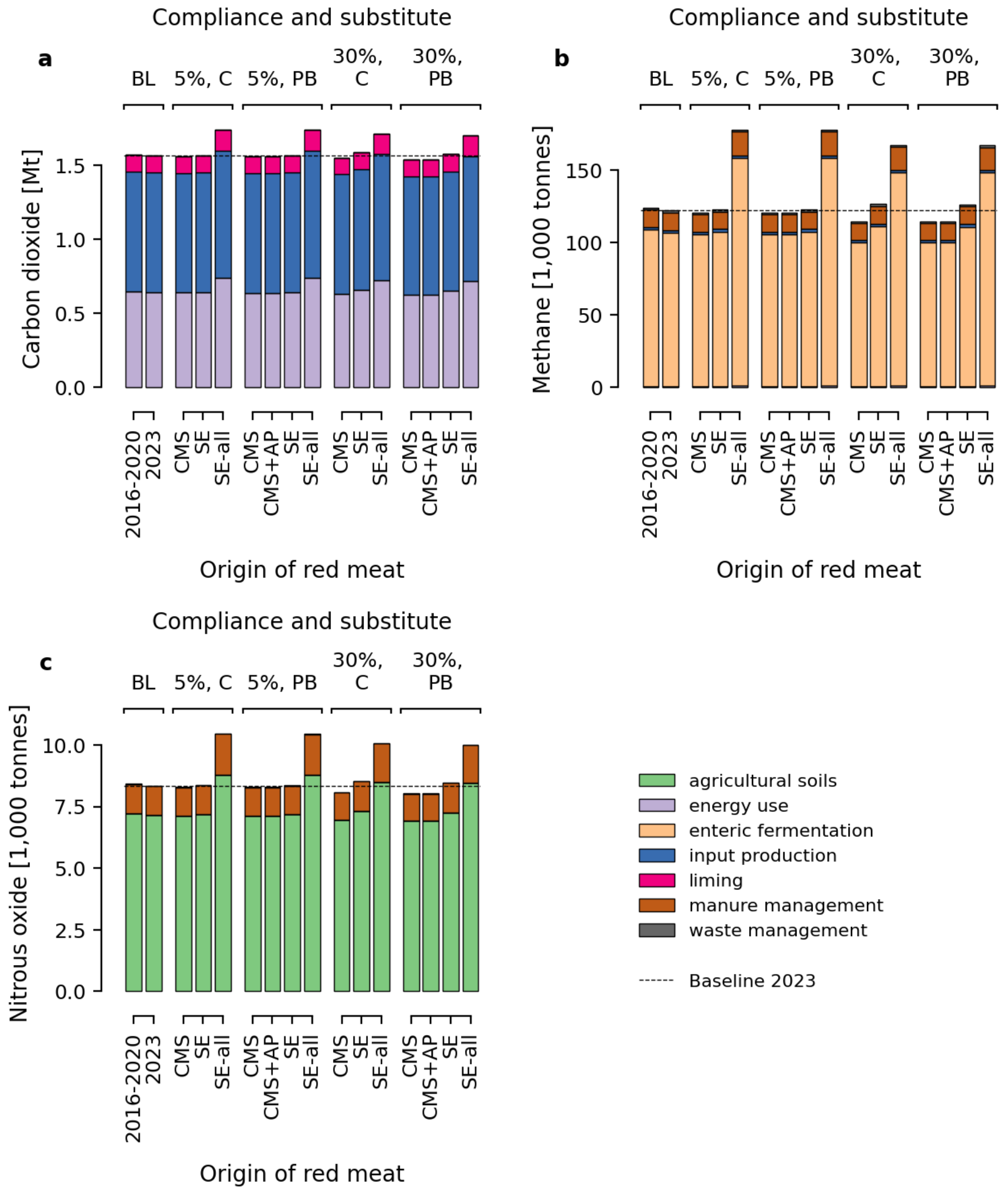

Figure S4. Emissions of (a) carbon dioxide, (b) methane and (c) nitrous oxide from Swedish agricultural production. Results are shown for the baseline (BL) and the scenarios with 5% or 30% compliance to red meat recommendations and chicken (C) or plant-based foods (PB) as substitute. The x-axis shows different assumptions on the origin of red meat consumed (CMS = According to current market shares, SE = 100% Swedish for those complying with recommendations, and SE (all) = 100% Swedish for all consumers) and if agricultural policies to support semi-natural grassland based production are assumed (+AP).

MISTRA

FOOD FUTURES