Climate, biodiversity and dietary quality targets for Swedish food production and consumption

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Climate, biodiversity and dietary quality targets for Swedish food production and consumption
Klimat, biologisk mångfald och hälsa: Mål för svensk livsmedelsproduktion och konsumtion

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Denna rapport är framtagen inom forskningsprogrammet Mistra Food Futures. Det övergripande målet för programmet är att skapa en vetenskapligt baserad plattform som bidrar till att det svenska livsmedelssystemet kan transformeras till ett system som är ekonomiskt, socialt och miljömässigt hållbart samt resilient och kan leverera hälsosam mat. Målet uppnås genom att utveckla ett nära samarbete mellan akademin och ett antal nyckelaktörer i det svenska livsmedelssystemet. Den här rapporten utgör en del av Mistra Food Futures arbete med att beskriva produktionssystem som minskar klimatpåverkan. Detta utgör en av de centrala frågeställningarna inom Mistra Food Futures.

Mistra Food Futures leds och samordnas av Sveriges lantbruksuniversitet SLU i samarbete med forskningsinstitutet RISE och Stockholm Resilience Centre vid Stockholms universitet. Övriga partners inom programmet omfattar en bred representation av aktörer från akademi, näringsliv, branschorganisationer och regioner.

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1. Introduction

Targets can enable priorities, provide a framework for monitoring progress, and create a long-term common vision for societal actors. Accordingly, targets are key in the transition to sustainable food systems. The purpose of this report is to provide a discussion basis for developing Mistra Food Future (MFF) targets for a sustainable and resilient Swedish food system by 2045. The targets cover both territorial and consumption aspects, i.e., impacts of Swedish consumption both in Sweden and abroad.

The set of potential targets discussed in this report has been developed by Work Package (WP) 2 in tandem with WP3's production of scenario skeletons (Gordon *et al.*, 2022) and WP4's work on an indicator framework for measuring sustainability in the Swedish food system (Hansson *et al.*, 2023). More specifically, this work springs from the need expressed by WP3 for having target areas and levels to assess or benchmark the scenarios against. It should be noted that this report does not seek to arrive at a set of definite targets for what the Swedish food system should achieve by 2045, but rather provides a basis for further exploration and discussion.

In the process of identifying possible targets for a transformation of the Swedish food system, peer-reviewed scientific literature has been relied upon to the extent possible. Political and strategic documents, such as the Swedish Environmental Objectives (SEOs), have also proved useful in the process of mapping out potential indicators and formulating target suggestions. The target areas and levels suggested here are largely anchored in the planetary boundary framework, particularly the global targets for a safe operating space for food systems defined by the EAT-*Lancet* Commission on healthy diets from sustainable food systems (Willett *et al.*, 2019). Moreover, previous work on scaling down global planetary boundaries to targets for Swedish food production and consumption (Moberg *et al.*, 2020) has guided much of the work, especially when considering targets for climate change and biosphere integrity boundaries.

Several approaches for burden-sharing based on different allocation principles have been considered. A pertinent question related to setting quantitative targets based on global planetary boundaries is what responsibility Sweden should take in reducing the environmental footprint from food production and consumption. Another consideration was the political, social, and economic feasibility of different target levels. The approach to these dilemmas in this report has been to suggest multi-level targets for biodiversity, climate, and health based on different ways to allocate shares of the global safe operating space. The following allocation principles (drawing on e.g. Häyhä *et al.*, 2016) have been used to underpin different target levels:

A. *Historical accountability*. As a form of corrective justice, Sweden should assume greater responsibility for reducing the "environmental burden" per capita than low-income countries.

B. *Equal per-capita entitlements*. The budget for environmental damage from food production should be shared equally among all individuals on the planet.

C. *Grandfathering*. Sweden's current and historically large environmental footprint should increase future entitlements due to tradition, culture, and political feasibility.

Overall, the most ambitious levels suggested for the core targets build on egalitarian principles (historical accountability and/or equal per-capita entitlements) while the less ambitious alternatives build on grandfathering principles.

Climate change and biosphere integrity have been defined as core planetary boundaries since altering these significantly would drive the earth system to a new stage (Steffen *et al.*, 2015). In addition, human health is considered a key priority and the very basis for sustainable food systems. Biodiversity, Climate, and Diet quality & health are therefore suggested to be the three core target areas deemed most crucial to work toward for the Mistra Food Futures programme. This document also contains suggested targets for Freshwater use, Antibiotic use, Eutrophication, and Chemicals & pesticides. These represent important dimensions for food system sustainability and may have an impact on the suggested core boundaries. For instance, chemical and pesticide use can negatively impact biodiversity. Social and economic sustainability dimensions are beyond the scope of this report.

For most target suggestions, 2045 is the suggested year for target achievement, in line with the MFF programme's objective of long-term transformation of the food system. However, it is important to note that a slow target fulfilment likely would imply irreversible environmental and ecological damage and that targets rather should be reached as soon as possible. Going ahead, it would therefore be useful to develop mid-point targets to be reached by 2030. When not explicitly stated, the target starting year is 2024.

1.1. Overview of suggested Mistra Food Futures (MFF) targets

An overview of suggestions for all target areas is presented in Table 1 below. Two different ambition levels are suggested for the core target areas (Climate, Biodiversity, and Diet quality & health).

Table 1. Summary of suggested targets for all areas. The core target areas (Climate, Biodiversity, and Diet quality & Health) all have two target levels each with a slight variation in ambition level, where the darker shade of green (a) represents "high ambition" and the lighter shade of green (b) represents "ambition" in sustainability.

Target area	Territorial targets	Consumption targets
Biodiversity	*Overarching goals* **Function**: Ecosystems related to food production continue to deliver services and goods that support people in Sweden and elsewhere. **Culture**: The cultural values of biodiversity, contributing to health and wellbeing, are restored and safeguarded. **Composition**: Agriculture, aquaculture, and fisheries are managed sustainably, ensuring conservation of biodiversity.	*Overarching goals* **Function**: Swedish food consumption does not have a harmful impact on biodiversity and ecosystems' ability to deliver services and goods around the world. **Culture**: The cultural values of biodiversity, contributing to health and wellbeing, are restored and safeguarded. **Composition**: Agriculture, aquaculture, and fisheries for Swedish consumption are managed sustainably with no negative or minimised impact on biodiversity anywhere.
	1a) An increase in abundance and diversity of pollinators and birds in accordance with levels detected in a specific year (e.g., 1950).	1a) Cropland use is in line with an equal share per capita of the global land use boundary given by the EAT-*Lancet* Commission (0.12-0.16 ha), indicating no net expansion of current global cropland.
	1b) No further decrease in the abundance or diversity of pollinators and birds.	1b) Cropland use is slightly higher than the equal share per capita of the global land use boundary suggested by the EAT-*Lancet* Commission, indicating no net expansion of current global cropland.
	2a) Restoration of semi-natural grasslands at a substantial scale.	2a) Extinction rates are in line with an equal share per capita of the EAT-Lancet global extinction rate boundary (1.1 × 10−9 E/MSY).
	2b) No further reduction of semi-natural grasslands.	2b) Extinction rates are at most twice the equal share per capita of the EAT-Lancet global extinction rate boundary (2.2 × 10−9 E/MSY).
	3a) More than 10% of agricultural area is under high-diversity landscape features as defined in the EU biodiversity strategy.	
	3b) At least 10% of agricultural area is under high-diversity landscape features as defined in the EU biodiversity strategy.	
	4a) Substantially reduced use of pesticides and herbicides and an increase of farmland (ha) with no application of pesticides and herbicides.	
	4b) Reduced use of pesticides and herbicides.	
	5a) Sustainably utilized fish and shellfish stocks in the coast, sea and freshwater environments (under F_{MSY} and above $B_{TRIGGER}$), a shift to less harmful gear and at least 30% of ocean protected.	
	5b) Sustainably utilized fish and shellfish stocks in the coast, sea and freshwater environments (under F_{MSY} and above $B_{TRIGGER}$) and a shift to less harmful gear.	
Climate	*The territorial target levels below build on the perspective of climate neutrality by 2045 according to the Swedish national target, which allows for an 85% GHG emissions decrease and 15% supplementary measures.*	
	1a) Agriculture as a sector reaches net zero emissions by 2045, i.e., the land currently used needs to accomplish the negative emissions necessary to compensate for unavoidable emissions. Agriculture represents an equally large percentage of emissions decrease as the other sectors in the EU Effort Sharing Regulation (ESR), i.e., transport, buildings, waste, and small industry.	1a) Greenhouse gas emissions from food consumption are at most an equal share per capita of the global greenhouse gas emission boundary for food production given by the EAT-*Lancet* Commission (5 Gt CO_2e per year), equalling 0.53 ton CO_2e per capita/year.

	1b) The agricultural sector is given a larger emission space than other ESR sectors. Agriculture could then continue to emit along its current trajectory or even increase emissions as a result of increased production.	1b) Greenhouse gas emissions from food consumption are slightly higher than the equal share per capita of the global greenhouse gas emission boundary for food production given by the EAT-*Lancet* Commission (5 Gt CO_2e per year), between 0.53 and 1 ton CO_2e per capita/year.
Diet quality & health	N/A	1a) The per capita food intake is in accordance with the optimal intake levels of key food groups as suggested by the Global Burden of Diseases (GBD), and/or the EAT-*Lancet* planetary health diet ranges.
		1b) The per capita food intake is inspired by the GBD optimal level intake of key food groups and/or the EAT-*Lancet* planetary health diet ranges but allows for a higher intake of food groups currently consumed in high quantities in Sweden (i.e., red meat and starchy vegetables). The quantity of red meat is aligned with the current dietary guidelines from the Swedish Food Agency.
		2. The average energy intake amounts to roughly 2400 kcal per person and day, depending on population group and physical activity level (in line with the Nordic Nutrition Recommendations).
Freshwater use	1. Food production and food industry in Sweden do not impact surface or groundwater levels in a way that limits the usage of groundwater for public or private drinking water supply or causes a negative impact on water supply, ground stability, or animal and plant life in nearby ecosystems. The surface and groundwater levels must be maintained at such volume that they can support freshwater consumption necessary for food production and industry.	1. Swedish food consumption does not create or exacerbate local, regional, or national water shortages in Sweden or in other countries.
Eutrophication	1. Food production does not contribute to eutrophication in springs, lakes, rivers, wetlands, and seas in Sweden. ○ Lakes, watercourses, coastal waters, and groundwater achieve at least good status for nutrients. ○ Land use for food production does not result in any substantial long-term harmful effects of eutrophying substances on Swedish ecosystems.	1. Swedish food consumption does not contribute to eutrophication in springs, lakes, rivers, wetlands, and seas in areas where food for Swedish consumption is produced.
Antibiotic use	1. Veterinary antibiotic use in Swedish food production is kept as low as possible while ensuring high animal welfare. 2. The need for antibiotic use is prevented, e.g., through comprehensive vaccination programmes and good animal health and welfare. 3. Emissions of antibiotics and antimicrobial substances to the environment are minimised.	1. Veterinary antibiotic use in food imported for Swedish consumption is kept as low as possible while ensuring high animal welfare. 2. Antibiotics particularly important for human health care (colistin, fluoroquinolones and 3rd or 4th generation cephalosporins) are only used when a veterinarian considers no other treatment option effective.
Chemicals & pesticides	1. Pesticide and agrochemical use is reduced so that the total exposure to chemical substances via food production is not harmful to human, animal or plant health, biodiversity, or water quality. 2. The levels of plant protection products in surface water and groundwater are reduced close to zero.	1. Pesticide and chemical use associated with Swedish food consumption does not have a harmful impact on human health, biodiversity, or water quality in Sweden or elsewhere.

2. Biodiversity

2.1. Background

The overall impact on biodiversity caused by the average Swedish diet represents a six-fold transgression of the per capita share of the global environmental boundary suggested by the EAT-*Lancet* Commission (Moberg *et al.*, 2020). It should however be noted that this estimate as well as the boundary against which it is benchmarked is associated with considerable uncertainty, due to the complexity of measuring impacts on biodiversity, especially for a complete diet that contains foods from many parts of the world and from many different production systems. The MFF-targets should take into account both production in Sweden and the impact of Swedish consumption on biodiversity elsewhere. Drawing on the IPBES conceptual framework, biodiversity targets are suggested to reflect the three different types of nature values: culture, function, and composition.

The proposal includes both overarching goals, covering areas which are important to recognize but not possible to assess, and quantitative, specific targets, which can be measured and operationalized. For the specific targets, two possible ambition levels are suggested. Possible overarching goals and specific targets, with associated indicators and levels, are presented in Table 2.

Identifying a set of potential targets for biological diversity has not been a straightforward process. A large number of possible indicators have been up for consideration for both the territorial targets and the consumption targets. Characteristics such as data availability, communicative appeal, and the ability to capture a range of biodiversity functions and values guide the suggested set of indicators. The reasoning behind why certain targets and indicators are suggested and not others is briefly accounted for below.

2.2. Territorial targets

A key consideration concerning the territorial biodiversity targets has been whether to focus solely on biodiversity in food production landscapes and seascapes, or on biodiversity in Sweden overall. Given the importance of certain food-producing landscapes and seascapes for maintaining ecosystem functions and species composition, the former approach was chosen. Thus, the central question is how food production affects the biodiversity of food-producing landscapes and seascapes in Sweden.

Arriving at a small set of useful indicators and specific target levels for biodiversity involves challenging trade-offs and delimitations. As a first step, the following four categories and associated target indicators are suggested: abundance and diversity of pollinators and farmland birds; total coverage of semi-natural grasslands; reduced use of pesticides and herbicides; and sustainable management and use of aquatic food resources.

2.2.1. Abundance and diversity of pollinators and farmland birds

Although general biodiversity indicators in agricultural landscapes are not yet agreed upon, there is evidence that indicators based on pollinators and birds would be among the most practical ones (Parliamentary Office of Science and Technology (POST), 2021). In the UK, for example, farmland birds are used as an indicator of the general quality of farmlands because trends and drivers of change for bird populations have been well-monitored for many decades and are better understood than for other species groups (ibid). Moreover, pollinators are known to be of importance for ecosystem services and crop production, and hence likely to indicate a general quality of agricultural landscapes. Pollinators, or the natural habitats they depend on, are also likely to be related to other organism groups, e.g., various insects. Finally, environmental monitoring programs on pollination or pollinators are planned for in many countries, including European Union (EU) member states, which means that data to monitor the quality of agricultural landscapes will soon become available (European Commission (EC), 2021; Parliamentary Office of Science and Technology (POST), 2021; Swedish Agricultural University (SLU), 2021; Swedish Environmental Protection Agency (SEPA), 2021d). Species diversity, functional diversity, and abundance (indicating pollination potential) are indicators that will be available for agricultural landscapes when these programs are in place. Benchmarks and baselines need to be developed, however.

2.2.2. Total coverage of semi-natural grasslands

It is well established that semi-natural grasslands are important for a large part of the biodiversity associated with agricultural landscapes (Eriksson, 2021). Furthermore, there are existing monitoring programs that follow the development of semi-natural grasslands in terms of area and quality, making this one of the most relevant indicators of general biodiversity in agricultural landscapes.

2.2.3. Small biotopes

Reduced landscape heterogeneity has been identified as a key driver of biodiversity loss and the establishment of vegetated strips and other small biotopes is one approach to improve biodiversity (Haddaway *et al*., 2018). These habitats within agricultural landscapes serve as refuges for native plants and wildlife, resilient against the encroachment of agriculture. Small biotopes encompass various elements such as buffer strips, fallow lands under both rotational and non-rotational systems, hedgerows, unproductive trees, terraced walls, and ponds. These components play a vital role in key ecosystem services, including mitigating soil erosion, preserving soil quality, purifying air and water, and facilitating pollination and pest response (Duarte *et al.*, 2018). However, they remain vulnerable to pesticides and isolation from other natural habitats. Within these patches, various species can thrive and venture into the more intensively cultivated areas that envelop them. The EU biodiversity strategy urges that at least 10% of agricultural area should be under high-diversity landscape features (European Commission (EC), 2020b) and the suggested targets therefore centre around this proposed level.

2.2.4. Reduced use of pesticides

The use of pesticides is a major threat to biodiversity, both in agricultural landscapes (Geiger *et al.*, 2010) and in aquatic environments in proximity to areas of chemical application (Relyea, 2005). In comparison to other countries, the level of pesticide use in Sweden is relatively low and when considering the pesticide footprint from Swedish consumption as a whole, only a minor portion (25% of the herbicides, 12% of the fungicides and 3% of the insecticides) comes from Swedish agriculture (Steinbach *et al.*, 2018). This is to a large extent driven by the crops produced in different countries, with much of the fruit and vegetables (crops high in pesticide use) being produced outside Swedish borders. The application of pesticides in Swedish agriculture is nonetheless substantial (Swedish Agricultural University (SLU), 2022) and can have negative impacts on various forms of biodiversity. A general reduction of pesticide application is therefore deemed beneficial for biodiversity.

2.2.5. Sustainable management of aquatic food resources

Exploitation from fishing is the most important driver of biodiversity loss in the oceans (Costello *et al.*, 2010; Brondizio *et al.*, 2019). Fishing can impact aquatic biodiversity negatively in two ways. First, by overexploitation of target and non-target species (bycatch), and second, through negative impacts on ecosystems, e.g., through the use of destructive gear types. Sustainable management of the targeted species can be considered to be the minimum level of protection of marine biodiversity. In essence, all legally caught seafood in Swedish should be within safe biological limits and no illegal fishing should be performed. In addition, negative impacts from harmful fishing practices, including the use of destructive gear types such as bottom trawling (Pommer, Olesen and Hansen, 2016) needs to be reduced to enhance biodiversity in marine environments.

Implementation of no-take marine protected areas (MPAs) is another strategy for improving marine biodiversity. Sweden currently protects around 15% of all marine areas, but scientific experts have recently stressed the need to protect at least 30% of the world's oceans in fully or highly protected areas by 2030 (O'Leary *et al.*, 2016). Accordingly, a sub-target on 30% marine protection is included for the more ambitious target level suggestion (3a).

2.2.6. Considered targets

In addition to the four categories mentioned above, the following indicators were identified as important to keep track of: soil biodiversity, crop rotation and landscape heterogeneity. However, as getting to concrete target levels is deemed to be more challenging for these dimensions, they are not suggested to be specific targets. Soil biodiversity is considered a relevant category as it covers the impact of biological diversity on soil fertility. This could be measured with three key organism groups, e.g. microbes, nematodes, and earthworms (El Mujtar *et al.*, 2019). However, deciding on certain threshold targets is presently challenging given the lack of data on the abundance and/or diversity of these organisms. Crop diversity is relevant since diversity in farmed species can lead to a more diverse production landscape, allowing a larger number of wild species to flourish in the landscape (Aguilera *et al.*, 2020; Beillouin *et al.*, 2021). However, it is difficult to set clear targets for these dimensions. First, there is poor knowledge of the consequences of different crop rotation practices for wild diversity in Sweden. Second, crop diversity is small in the northern part of Sweden for climatic reasons, but with crops, mainly leys, that are supporting some types of wild biodiversity. Comparisons with southern Sweden are therefore challenging and regional baselines and indicators are needed.

Various indicators are potentially relevant for blue food production. Fundamentally, the overarching target would ideally be higher biodiversity in Swedish waters, both in the ocean and in freshwater environments. The challenge, however, is that aquatic biodiversity is impacted by a suite of human activities, e.g., agriculture (leakage of nutrients), recreational activities such as boating other industries (emissions of chemicals) as well as climate change (ocean acidification and increased water temperatures). The approach taken was therefore to centre the target primarily on fishing activities, including the status of the stock type, use of harmful gear, and marine protected areas.

2.2.7. Consumption targets

While safeguarding territorial biodiversity related to food production in Sweden is highly relevant, the share of biodiversity loss caused by Swedish food consumption stemming from production systems outside Swedish borders must be considered (Brown *et al.*, 2022). Drawing on the boundaries for the global food system proposed by the EAT-*Lancet* Commission (Willett *et al.*, 2019), consumption-based targets on cropland use and extinction loss are proposed.

2.2.8. Land use

The key driver of biodiversity loss globally is the deforestation of ecologically valuable habitats, including tropical forests, and the largest driver of land conversion globally is food production (Willett *et al.*, 2019). It has been suggested that halting further land conversion (zero expansion) will allow humanity to protect half of the Earth's surface (Half-Earth strategy) and thereby maintain 80% of pre-industrial species richness (Wilson, 2016). In line with this thinking, a target on no further expansion of land used to farm the food needed for Swedish consumption is suggested. This proposal is based on the EAT-*Lancet* Commission boundary of global cropland use (thus not including grazing lands), downscaled to a per capita level (see also Moberg *et al.*, 2020). Moberg and colleagues (2020) base their global per capita boundary on a global population of 7.4 billion in 2015. For this report, however, the latest population projections of 9.48 billion people in 2045 according to the intermediate scenario by the UN Population Division (United Nations Department of Economic and Social Affairs, 2019) was used instead. The per capita boundary of global land use to use as a MFF-target would then be 0.12-0.16 ha per capita and year.[1]

We also considered including a consumption target for global pasture land use. Resare Sahlin *et al.* (2023) for instance suggest a global boundary of 2.3-2.5 billion hectares (depending on whether the reference year is 1700 or 1800) considering the biodiversity limits to the use of grazing lands for ruminant meat production. A key assumption is that in order for land to qualify as pasture land, there should either be a long historical tradition of grazing (such as Swedish semi-natural pasture land) or that the land naturally is a grassland (thus situated in a grassland biome). The assumption articulated above would result in a per capita pasture land availability for a global population 2045 of 0.24-0.26 ha per person. Given that this work is currently undergoing scientific peer review, the target is not suggested in this report but could be considered for future revisions of the MFF-targets.

[1] The chosen population projection represents the intermediate figure of the UN Population Division. The low and high scenarios vary between 8.8 - 10.1 billion people.

2.2.9. Extinction rate

In addition to halting any further destruction of natural ecosystems, it is important to acknowledge that some crops and livestock products currently have more negative impacts on biodiversity than others. Some examples include soy and beef from Brazil and palm oil from Indonesia. Therefore, the suggestion is an indicator through which food consumed in Sweden can be translated to the potential species loss (PSL) per kg of food. The target (ten extinctions per million species-years) is gathered from the EAT-*Lancet* Commission and, through the methodology described by Moberg *et al.* (2020) the PSL per kg of food can be related to the set boundary. Note that the per capita boundary ($1.1 \times 10{-}9$ E/MSY) is based on a 2045 population of 9.48 billion people. We acknowledge that from a justice perspective, more resource space could be allocated to developing, export-driven countries in areas with high biodiversity value. It could be argued that Swedish contributions to species loss should be smaller than the per capita share given that we mainly eat food from non-critical areas with respect to biodiversity loss. In this report, however, no such adjustment of the per capita boundary is attempted.

2.3. Suggestion of targets

Table 2. Biodiversity: suggestion of territorial and consumption targets with relevant input from literature. The darker shade of green (a) represents the "more ambitious" level and the lighter shade of green (b) the "ambitious" level.

Territorial targets	**Literature**	**Consumption targets**	**Literature**
Overarching goals **Function**: Ecosystems related to food production continue to deliver services and goods that support people in Sweden and elsewhere. **Culture**: The cultural values of biodiversity, contributing to health and wellbeing, are restored and safeguarded. **Composition**: Agriculture, aquaculture, and fisheries are managed sustainably, ensuring conservation of biodiversity.	Brondizio *et al.,* 2019	Overarching goals **Function**: Swedish food consumption does not have a harmful impact on biodiversity and ecosystems' ability to deliver services and goods around the world. **Culture**: The cultural values of biodiversity, contributing to health and wellbeing, are restored and safeguarded. **Composition**: Agriculture, aquaculture, and fisheries for Swedish consumption are managed sustainably with no negative or minimised impact on biodiversity anywhere.	Brondizio *et al.,* 2019
1a) An increase in abundance and diversity **of pollinators and birds** in accordance with levels detected in a specific year (e.g., 1950).	POST, 2021	1a) **Cropland use** is in line with an equal share per capita of the global land use boundary given by the EAT-Lancet Commission (0.12-0.16 ha), indicating no net expansion of current global cropland.	Willett *et al.,* 2019 Wilson, 2016
1b) No further decrease in the abundance or diversity of **pollinators and birds.**		1b) **Cropland use** is slightly higher than the equal share per capita of the global land use boundary suggested by the EAT-Lancet Commission, indicating no net expansion of current global cropland.	
2a) Restoration of previous **semi-natural grasslands** at a substantial scale.	Moberg *et al.,* 2020 Eriksson, 2021	2a) **Extinction rates** in line with an equal share per capita of the EAT-Lancet global extinction rate boundary (1.1 × 10−9 E/MSY).	Willett *et al.,* 2019 Moberg *et al.,* 2020
2b) No further reduction of **semi-natural grasslands**.		2b) **Extinction rates** at most twice the equal share per capita of the EAT-Lancet global extinction rate boundary (2.2 × 10−9 E/MSY).	
3a) More than 10% of agricultural area is under **high-diversity landscape features** as defined in the EU biodiversity strategy.	EC, 2020b		
3b) At least 10% of agricultural area is under **high-diversity landscape features** as defined in the EU biodiversity strategy.			
4a) Substantially reduced use of **pesticides and herbicides** and an increase of farmland (ha) with no application of pesticides or herbicides.	Geiger *et al.,* 2010 Relyea, 2005		
4b) Reduced use of **pesticides and herbicides**.			
5a) Sustainably exploited fish **and shellfish stocks** in the coast, sea and freshwater environments (under F_{MSY} and above $B_{TRIGGER}$), a shift to less **harmful gear** and at least 30% of **ocean protected**.	Costello *et al.,* 2010 Brondizio *et al.,* 2019 Sveriges Miljömål, no date O'Leary *et al.,* 2016		
5b) Sustainably exploited **fish and shellfish stocks** in the coast, sea and freshwater environments (under F_{MSY} and above $B_{TRIGGER}$) and a shift to less **harmful gear**.			
Considered targets **Soil biodiversity** Diversity and abundance of three key organism groups (e.g., microbes, nematodes and earthworms). **Crop diversity** Diversity in crops produced.	El Mujtar *et al.,* 2019 Aguilera *et al.,* 2020 Beillouin *et al.,* 2021	Considered targets **Global pasture use**	Resare Sahlin *et al.,* 2023

3. Climate

3.1. Background

3.1.1. Territorial climate targets

In 2021, the Swedish agricultural sector emitted about 6.7 $MtCO_2e$ (mainly methane and nitrous oxide), representing 14% of the territorial emissions (Swedish Environmental Protection Agency (SEPA), 2023). This does not include emissions related to e.g., agricultural machinery or electricity for facilities, which are reported under the energy sector, or emissions related to land use, which are reported under the LULUCF sector (ibid). The Swedish Board of Agriculture (SBA) states that emissions from fisheries and aquaculture are relatively low compared to agriculture (Swedish Board of Agriculture (SBA), 2021b).

According to Sweden's Climate Act and Climate Policy Framework (Ministry of the Environment, 2017), the long-term territorial target for the country, i.e. not limited to food production, is net zero GHG emissions by 2045. After 2045, Sweden is to achieve negative net emissions. The target implies that emissions should be at least 85% lower in 2045 compared to 1990, with the remaining reductions to be achieved through supplementary measures. Calculations of territorial Swedish emissions do not encompass emissions and uptake from land use, land use change and forestry (ibid).

On an EU level, a binding target of a climate-neutral European economy and society by 2050 is set by the European Climate law (European Union (EU), 2021). The intermediate target, as posited by the 2030 Climate Plan, is to reduce net GHG emissions to at least 55% below 1990 levels by 2030. There are no specific EU or Swedish national targets for the reduction of GHG emissions in the agricultural sector. Agricultural emissions are accounted for together with emissions from transports, buildings, waste and small industries under the Effort Sharing Regulation (ESR). These are the sectors not covered by the EU Emissions Trading System (EU ETS). As presented by the Swedish Environmental Protection Agency (Swedish Environmental Protection Agency (SEPA), 2021b), Sweden has set a few milestone targets toward the long-term net-zero 2045 target specifically for these sectors:

- By 2020 emissions are to be 40% lower than in 1990.
- By 2030 emissions are to be 63% lower than in 1990.
- By 2040 emissions are to be 75% lower than in 1990.

As with the national long-term 2045 target, it is also possible to achieve some of the targets by 2030 and 2040 through supplementary measures (up to 8% of the 2030 target and 2% of the 2040 target) (ibid). Since emissions from all sectors covered under the ESR are accounted for together, the territorial targets of Swedish agriculture could be met by reductions in other sectors, such as transport.

In addition to agricultural emissions, the MFF-targets should ideally encompass the whole food sector. The remaining areas include fisheries, aquaculture, processing, packaging, distribution, retail, and potentially food waste. The suggested territorial targets (Table 3) build on the assumption of climate neutrality by 2045 according to the Swedish national target, thereby allowing for an 85% emission decrease and 15% supplementary measures for all sectors under the Effort Sharing Regulation (ESR). Zero net greenhouse gas emissions are defined according to GWP100, global warming potential over 100 years. An 85% decrease corresponds to a remaining total emission space (of all sectors) of around 10.7 $MtCO_2e$ in 2045. The rest of the food system - encompassing sectors such as processing and retail - is assumed to be climate neutral by 2045. Going ahead, an additional territorial climate target for 2030 could be structured similarly to the targets suggested in Table 3, but instead use the milestone target of 63% lower ESR emissions than in 1990.

3.1.2. Consumption targets for climate

Estimates of the greenhouse gas emissions from current Swedish food consumption range between 1.4 - 2.2 tons per capita and year (Röös *et al.*, 2015; Steinbach *et al.*, 2018; Moberg *et al.*, 2020; Hallström *et al.*, 2021; Swedish Environmental Protection Agency (SEPA), 2021a). Recent work by Hallström *et al.* (2021) demonstrates a broad distribution of emissions, with about a threefold variation in CO_2e/person/year between high and low impact individuals, suggesting a great potential to radically lower the average carbon footprint of the population. These estimated figures of diet-related emissions differ somewhat due to different methods (e.g., input-output analysis vs. a review of LCA studies) and figures used. Moberg *et al.* (2020) found that the average Swedish diet transgressed the global emission boundary, as suggested by the EAT-*Lancet* Commission, by more than three-fold.

For the consumption targets, both national climate territorial goals and the total impact of Swedish food consumption should be taken into consideration. A national process is underway to develop a strategy to reduce the climate impact of consumption (Miljömålsberedningen, 2022). Food consumption is also guided by the national generational goal, positing that environmental issues in Sweden are to be solved without resulting in increased problems for environmental and human health outside of the country's borders (Swedish Environmental Protection Agency (SEPA), 2021c). As around 60% of the greenhouse gas emissions of Swedish food consumption occur outside the borders (Steinbach *et al.*, 2018), the MFF consumption targets must carefully consider the total impact of food consumption, including both food produced in Sweden, imported food products, and inputs for the national food supply chain.

The EAT-*Lancet* Commission boundary of food consumption emissions downscaled to a per capita level is suggested as the consumption target, following the methodology of Moberg *et al.* (2020). The same figure for emission space of food production as established by the EAT-*Lancet* Commission (5 Gt CO_2e per year in 2050) is applied, but instead of using the global population of 7.4 billion in 2015 as Moberg *et al.* (2020), the targets are based on the latest population projections of 9.48 billion people in 2045 (United Nations Department of Economic and Social Affairs, 2019). The per capita boundary of food consumption emissions would then be 0.53 tons of CO_2e per capita and year.[2] This target includes CH_4, N_20 and CO_2. While the EAT-*Lancet* target assumes that CO_2 emissions are reduced to zero (an ambition shared by the authors of this report), all GHG emissions are included here to capture the actual contribution of CO_2. This makes it possible to model points in time before 2050 when exploring pathways to reach the Mistra Food Future scenarios (Gordon *et al.*, 2022).

The most ambitious target level of the consumption target (1a, marked in Table 3) follows the egalitarian allocation principle. As the per capita consumption emissions should be *maximum* the equal global share, the target level also leaves space for lower consumption levels in line with the principle of historical accountability/climate justice. A

[2] The chosen population projection represents the intermediate figure of the UN Population Division. The low and high scenarios vary between 8.8 - 10.1 billion people and would have resulted in a consumption boundary of between 0.57 - 0.5 ton CO_2e per capita and year, respectively.

lower per capita emission space could also be justified according to the principle of "common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" of the Paris Agreement within the United Nations Framework Convention on Climate Change (UNFCCC) as well as other considerations (Anderson *et al.*, 2018; Anderson, Broderick and Stoddard, 2020). The second target level (1b, marked in light green) allows for slightly higher per capita emissions, following the logic of emissions grandfathering (Knight, 2013). For this allocation, Sweden's current and historical food consumption and production trends with relatively high emissions could justify a future higher emission entitlement, since for instance keeping livestock and having relatively meat-heavy diets are considered deeply ingrained in Swedish culture, customs, and food industry. It can be argued that other countries may have less difficulty in reducing their emissions due to this. This line of thought may also be supported by the argument that Sweden also has a favourable climate and landscapes to support livestock, with suitable conditions for feed and grazing. Important to note, however, is that meat consumption in Sweden today is considerably higher than in the 1980s (Swedish Board of Agriculture (SBA), 2023) and that the dramatically increased appetite for poultry can not be explained by historical consumption levels.

3.1.3. Considerations

One of the issues to consider concerning the suggested MFF climate targets is whether the Swedish national target (territorial climate neutrality by 2045) and the EAT-*Lancet* boundary (keeping global warming to well below 2°C, aiming for 1.5°C) are ambitious enough to base Swedish food system targets on. One option that was considered for both consumption and territorial emissions was to suggest more ambitious targets based on the need for rich countries to assume greater responsibility and reach net zero by e.g. 2030, similar to the argumentation of Anderson and colleagues (Anderson *et al.*, 2018; Anderson, Broderick and Stoddard, 2020). However, this report instead uses the territorial climate neutrality target as a basis. Note that the Swedish policy target is to reach net zero by 2045 *by the latest*, which leaves room in interpretation to set an earlier goal.

Another issue of relevance is how to consider that the emissions from agriculture consist of a mixture of three main gases, methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2), all with different temperature change profiles. The challenge lies in differences in strength and atmospheric lifetime with fossil methane and nitrous oxide being more powerful than carbon dioxide (around 30 and 273 times more potent, respectively, measured with the GWP100 method) but where methane is much more short-lived. While CO_2 emissions need to be completely stopped for climate stabilisation as a large part of the gas stays in the atmosphere close to indefinitely, this is not the case for e.g. CH_4 or N_2O. Moving from a single-basket approach to a multi-basket approach, thus having separate targets for long-term and short-term gases, is one suggestion to get around that the three main gases have different properties and that reducing them may need different policy approaches (Allen *et al.*, 2022). This suggestion has not been taken into consideration for this report, but a continued discussion on this topic is encouraged for future revisions.

3.2. Suggestion of climate targets

Table 3. Climate: suggestion of territorial and consumption targets with relevant input from literature. The darker shade of green (a) represents the "more ambitious" target level and the lighter shade of green (b) the "ambitious" target level.

Overarching goal: Swedish food production and consumption should have a net zero or limited negative impact on climate change.			
Territorial target	**Literature**	**Consumption target**	**Literature**
1a) Agriculture as a sector reaches **net zero emissions** by 2045, i.e., the land currently used needs to accomplish the negative emissions necessary to compensate for unavoidable emissions. Agriculture represents an equally large percentage of emissions decrease as the other sectors in the EU Effort Sharing Regulation (ESR), i.e., transport, buildings, waste, and small industry.	Ministry of the Environment, 2017	**1a)** Greenhouse gas emissions from food consumption are at most an equal share per capita of the global greenhouse gas emission boundary for food production given by the EAT-*Lancet* Commission (5 Gt CO_2e per year), equalling 0.53 ton CO_2e per capita/year.	Willett *et al.*, 2019 Moberg *et al.*, 2020
1b) The agricultural sector is given **a larger emission space** than other ESR sectors. Agriculture could then continue to emit along its current trajectory or even increase emissions as a result of increased production.		**1b)** Greenhouse gas emissions from food consumption are slightly higher than the equal share per capita of the global greenhouse gas emission boundary for food production given by the EAT-*Lancet* Commission (5 Gt CO_2e per year), between 0.53 and 1 ton CO_2e per capita/year.	

4. Diet quality and health

4.1. Background

Dietary habits in Sweden are not in accordance with the national recommendations (Swedish Food Agency, 2021a). Unhealthy diets are the second leading behavioural risk factor for poor health, causing a significant part of the total burden of disease in Sweden (GBD 2019 Risk Factors Collaborators, 2020; Swedish Food Agency, 2021a). According to the Global Burden of Disease (GBD) study, the greatest dietary risk factors for poor health in Sweden in 2019 were low intake of whole grains, high intake of red meat, and low intake of legumes (GBD 2019 Risk Factors Collaborators, 2020). One in four Swedes is at risk of falling ill or dying prematurely from lifestyle diseases such as cardiovascular disease, diabetes, and cancer due to their eating habits. Moreover, about half of the adult population is overweight or obese (Public Health Agency of Sweden, 2022). The supply of energy available for consumption in Sweden has increased since the 1990s, at the same time as the prevalence of overweight and obesity has grown (Swedish Food Agency, 2021b). In short, the combined burden of poor diet quality and overconsumption contributes to obesity and diet-related non-communicable diseases in Sweden.

An overview of potential target indicators to measure the performance of the Swedish food system within the domain of nutrition and health is provided in Table 4, drawing on the work of Mistra Food Futures WP4 (Hansson *et al.*, 2023). The indicators included in the target suggestions are marked in bold.

Table 4. Overview of potential indicators for diet quality and health (Hansson et al., 2023).

Category	**Potential indicators for diet quality and health** (indicators included in suggested targets in **bold**)
Diet quality	**Food intake level (e.g., adherence to food-based dietary guidelines)** *Diet quality scores* *Diet diversity*
Nutrient adequacy	**Balanced energy intake** *Intake levels of individual nutrients in relation to reference values* *Nutrient quality scores*
Dietary health effects	*Deaths and DALYs caused by nutritional deficiencies* *Overweight and obesity prevalence* *Metrics focusing on undernutrition*

4.2. Suggestion of intake levels

The suggested set of targets includes one target category on diet quality and one target on energy intake, each with two proposed ambition levels. Moreover, an overarching goal of increasing the share of the population with healthy dietary habits is proposed, including a balanced energy intake. The targets are focused on human health and do not take into account the impact of diets on e.g., climate, biodiversity, or freshwater as these dimensions are covered by other targets.

Existing guidelines and ongoing work on food consumption targets are of relevance to this work. The Swedish food-based dietary guidelines (Swedish Food Agency, 2015), based on the Nordic Nutrition Recommendations (NNR) (Nordic Council of Ministers, 2014) provide useful guidance on intake levels of several foods deemed particularly important for human health (e.g. fruits and vegetables, seafood and whole grains) or associated with a risk for negative health effects (e.g. red meat and salt). The diet quality targets in this report are however not based on these recommendations for the following reasons (i) the recommendations are not covering all food groups (needed for WP3 modelling of scenarios), and (ii) they take feasibility into account, i.e., current consumption levels are guiding recommended intakes. In 2023, updated NNRs were launched providing guidance for nutrient and dietary intake (Blomhoff *et al.*, 2023). The recommendations are scientifically based and provide very useful guidance for healthy and environmentally sustainable food. However, given that the NNRs are not presenting the quantitative recommendations needed for modelling food system impacts for all food groups (e.g potatoes and pulses) they were not used in this report.

The Swedish Food Agency recently published a draft proposal for food consumption goals at the population level for environmental, social, and economic sustainability (Swedish Food Agency, 2021b). These goals have not been used to inform the target for this report here since they a) cover a small set of food groups and not all diet components, and b) to some extent also consider environmental and economic sustainability. However, the proposed goals from the Swedish Food Agency are still of relevance to the work of Mistra Food Futures and are generally aligned with the suggestion presented in this document.

For food groups where current dietary patterns differ considerably from dietary recommendations, feasibility has been accounted for in the lower ambition target level values. In these cases, we used Riksmaten, the most recent national dietary survey in adults performed approximately every ten years (Swedish Food Agency, 2012), to identify whether individuals are typically over- or under consuming a food, which informed our thinking on whether relaxed upper or lower boundaries were needed. Despite the known errors in self-reporting of dietary patterns, food intake diet data from Riksmaten is used because it is the most comprehensive source on food intake in the Swedish population which can also be benchmarked against existing food-based dietary guidelines.

4.2.1. Target 1a on diet quality

Since what we eat is one of the largest behavioural risk factors for disease and premature death, diet quality is of high priority from a Swedish food system perspective. A diet quality target based on intake levels of key food groups is therefore proposed. The most ambitious target level, marked in dark green in Table 5, originates from the EAT-*Lancet* planetary health diet (Willett *et al.*, 2019) and the GBD optimal intake levels (GBD 2017 Diet Collaborators, 2019). EAT-*Lancet* defined intake levels based on evidence of dietary risk factors and nutritional adequacy. GBD defines the optimal level of intake as the level of risk exposure that minimises the risk from all causes of death.

For the GBD diet, only the recommendations for specific food groups with amounts in grams per day stated were included, i.e., not nutrient intake recommendations (e.g., fibre, calcium, and sodium) or fatty acids. In EAT-*Lancet*, recommended intake levels of red meat and processed meat are grouped together whereas they are reported as two separate categories by the GBD. However, both diets recommend that the consumption of processed meat should be minimised.

4.2.2. Target 1b on diet quality

A second target level (1b, marked in light green) is also suggested with adapted intake levels for the food groups where current consumption levels in Sweden differ considerably from the GBD and EAT-*Lancet* Commission targets (1a). Following the principle of "emissions grandfathering" (Knight, 2013), target 1b allows for a slightly higher intake of red meat and starchy vegetables (such as potatoes) and a slightly lower intake of nuts, whole grains, and legumes than what the GBD and EAT-*Lancet* diets stipulate as optimal. In essence, target 1b represents a diet closer to current national consumption levels. These adaptations are warranted given the current food consumption patterns and the rootedness of this diet in Swedish cuisine and culture. Even so, since the greatest dietary risk factors for poor health in Sweden in 2019 were low intake of whole grains, high intake of red meat, and low intake of legumes (Swedish Food Agency, 2021a), target 1b aims for an improvement from the current consumption levels of these food groups.

Based on the most recent self-reported data, the intake of red meat in Swedish adults is estimated to be on average 77.5 g/day in cooked weight (Swedish Food Agency, 2012),[3] significantly higher than the intake recommended by both the GDB, i.e. 23 g (18-27), and the EAT-*Lancet* Commission, i.e. 10 g (0-20) when adjusted to the "as consumed" weight.[4] For the 1b target level, the suggested intake level of red and processed meat is instead in line with the current national recommendation of a maximum of 70 g/day of cooked red meat (Swedish Food Agency, 2015).[5] For starchy vegetables (root vegetables and potatoes), the current Swedish consumption in adults is estimated to be approximately 121 g/day (Swedish Food Agency, 2012). The 1b target level, therefore, allows for a slightly larger range of 0-120 g of starchy vegetables per day, compared with the EAT-*Lancet* target value of 40 (0-80) g/day (see appendix 1). Moreover, estimates indicate that the adult Swedish population eat very small amounts of nuts, on average 5 g/day (Swedish Food Agency, 2012). In target 1b, an intake of 5-25 g/day is suggested. The current intake of whole grains, on average 42 g/day according to self-reported dietary data in adults (Swedish Food Agency, 2012), is also far below both the national recommendations of 70 g/day for women and 90 g/day for men (Swedish Food Agency, 2015). Moreover, the EAT-*Lancet* Commission recommends a whole grain intake of 462 g/day (adjusted to cooked weight). Worth noting, however, is that the EAT-*Lancet* Commission assumes all cereals to be whole grain and the value of 462 g/day is thus also the value for total cereal intake. The GBD, on the other hand, recommends a wholegrain intake of 125 g/day and does not assume all cereals consumed to be of whole grain type. Based on this, an intake range of 70-462 g/day is suggested for the 1b target level. According to Swedish dietary survey data (Swedish Food Agency, 2012), the intake of legumes was 12 g/day - an enormous difference from the EAT-*Lancet* Commission recommendation of 188 (0-375) g/day (adjusted to cooked weight, see appendix 1) and the GBD optimal intake of 60 (50-70) g/day.[6] As noted above, a too-low intake of legumes is one of the greatest dietary risk

[3] Assuming that sausages contain 50% red meat.

[4] The original EAT-*Lancet* intake recommendations are provided in raw/dry weight for a number of food groups, including for meat and starchy vegetables. To compare these with the "as consumed" intake values given by GBD and Riksmaten, EAT-*Lancet* values are adjusted using the raw-to-cooked ratios presented in Appendix 1.

[5] The sixth edition of the Nordic Nutrition Recommendations, NNR 2023, was published in June 2023 (Blomhoff *et al.*, 2023). For health reasons, it is recommended that consumption of red meat should be low and not exceed 50 gram/day (350 gram/week). The Swedish Food Agency has been commissioned to update the Swedish dietary guidelines based on the scientific basis in NNR 2023, while also considering national conditions. Updated national recommendations are expected during 2024 and are not used to inform the intake targets in this report.

[6] The lowest part of the EAT-*Lancet* range for legumes exists to allow for substituting legumes with interchangeable foods, i.e., peanuts, tree nuts, seeds, and soy (Willett *et al.*, 2019).

factors for poor health in Sweden. For the adapted recommendations for legumes in target 1b, an intake of 40-375 g/day is therefore suggested, where the lower end of the range is based on potential feasibility and current intake (12 g/day according to Riksmaten).

Finally, the current intake of egg, poultry, fish and seafood, and unsaturated oils in Swedish adults, as reported in the most recent national dietary survey (Swedish Food Agency, 2012), is in line with EAT-*Lancet* recommendations. Recommended intake levels for these food groups are thus not adjusted for target 1b. To allow for a higher intake of food groups with a high protein/kcal content (e.g., red meat) in target 1b, the intake of other food groups would need to be adapted to assure that the total average energy intake does not surpass 2500 kcal per person and day.

4.2.3. Target 2 on energy intake

The current overconsumption of food in Sweden contributes to the high prevalence of overweight and obesity and related poor health outcomes (Swedish Food Agency, 2021b). Reducing excess caloric intake is thus central for improving health. In the most recent national dietary survey of Swedish adults, ”Riksmaten”, the daily energy intake was reported to be on average around 2000 kcal/d (Swedish Food Agency, 2012). Underreporting is however a common issue of self-reported data, particularly for total energy intake (Black, 2000). Riksmaten estimates that there is an underreporting error of about 25%, signifying a total energy intake of approximately 2500 kcal/d on average. The Nordic Nutrition Recommendations 2012 and 2023 provide a reference value for adults of roughly 2400 kcal (10 MJ) per person and day, depending on population group and physical activity level (Nordic Council of Ministers, 2014; Blomhoff *et al.*, 2023). The energy intake value of the EAT-*Lancet* planetary health diet is similar to that of the NNR, with a recommendation of 2500 kcal per person and day (Willett *et al.*, 2019). Based on this, a daily energy intake of 2400 kcal is proposed. This is in line with science-based recommendations and leaves room for public health goals to increase physical activity. The recommended energy intake refers to individual calorie consumption and does not include food waste and loss.

4.2.4. Considered targets

A target on dietary health effects, e.g., using the disability-adjusted life year (DALY) measure or obesity prevalence, was considered but in the end not included in the present suggestion since using recommended intakes of key food groups demonstrates a clearer connection between food systems, dietary patterns, and health. Moreover, basing targets on food groups instead of e.g., indices, scores, or intake levels of individual nutrients is in this context preferred due to the clear link to food production, making it the most suitable for WP3’s scenario development which this work partly sought to feed into.

4.2.5. Suggestion of consumption targets for diet quality and health

Table 5. Diet quality and health: suggestion of consumption targets. The darker shade of green (a) represents the "more ambitious" target level and the lighter shade of green (b) the "ambitious" target level.

	Consumption target intake levels		
	Overarching goal: Increasing the share of the population with healthy dietary habits, including a balanced energy intake.		
	1a) The per capita **food intake** is in accordance with the optimal level intake of key food groups, including red meat, as suggested by the Global Burden of Disease (GBD), and/or the EAT-*Lancet* planetary health diet ranges.		**1b)** The per capita **food intake** is inspired by the GBD optimal level intake of key food groups, including red meat, and/or the EAT-*Lancet* planetary health diet ranges but allows for a higher intake of food groups currently consumed in high quantities in Sweden (i.e., red meat and starchy vegetables).
	EAT-*Lancet* g/day	**GBD optimal intake g/day**	***Adapted* recommendations g/day****
Whole grains	462 * refers to the total consumption of grains	125 (100-150) refers to whole grains only	70-462
Starchy vegetables	40 (0-80) *	*Not specified*	0-120
Vegetables	300 (200-600)	360 (290-430)	Same as Target 1a
Fruit	200 (100-300)	250 (200-300)	Same as Target 1a
Dairy products expressed in terms of milk equivalents	250 (0-500)	435 (350–520) *refers to milk only*	Same as Target 1a
Red meat	10 (0-20) *	23 (18-27)	0-70
Processed meat		2 (0-4)	
Chicken and other poultry	20 (0-40) *	*Not specified*	Same as Target 1a
Eggs	12 (0-23) *	*Not specified*	Same as Target 1a
Fish and seafood	28 (0-100)	*Not specified*	Same as Target 1a
Legumes	188 (0-375) *	60 (50-70)	40-375
Nuts	50 (0-100)	21 (16-25)	5-25
Unsaturated oils	40 (20-80)	*Not specified*	Same as Target 1a
All sweeteners	31 (0-31)	*Not specified*	Same as Target 1a
	2) The average energy intake amounts to roughly 2400 kcal per person and day, depending on population group and physical activity level (in line with the Nordic Nutrition Recommendations).		

* GBD and dietary survey data (Riksmaten) provide recommended values "as consumed", i.e., cooked, whereas EAT-*Lancet* generally are provided in raw weight. To enable comparison, EAT-*Lancet* intake levels for a number of food groups are adjusted using the raw-to-cooked ratios presented in Appendix 1.

** To allow for increased intake of red meat and starchy vegetables without surpassing 2500 kcal per person/day, the intake of other food groups must decrease.

5. Freshwater use

5.1. Background

Freshwater is integral to food systems and a vital resource for agriculture and aquaculture, as well as for other parts of the food supply chain, such as processing. Moreover, water bodies can be negatively impacted by food production both in terms of quality (by pollution/overfertilization) and quantity (by withdrawal for irrigation). In this section, targets focusing on water quantity are suggested. The impact of the food system on water quality and marine environments is addressed in separate categories on eutrophication, pesticides and chemicals, antibiotics, and biodiversity.

Sweden generally enjoys ample water availability, albeit with significant yearly and regional differences. Sweden does not have specific official goals regarding water usage, except for SDG target 6.4, which emphasises improving water-use efficiency and guaranteeing sustainable water withdrawals. The assessment of water usage in Sweden is an intricate process that relies on various data sources, with Statistics Sweden regularly evaluating total water use across different sectors (Statistics Sweden, 2021b)

The consumption-based targets must take into account both global, regional and local aspects of freshwater consumption and availability. Around 60% of the freshwater used for Sweden's total consumption (not only food) occurs abroad, particularly outside of the EU (Steinbach *et al.*, 2018). From a perspective of global per capita shares of freshwater consumption for food production, Moberg *et al.* (2020) show that the current average Swedish consumption of 55 m3/year is well below the downscaled global EAT-*Lancet* Commission boundaries of 339 m3/year per capita (for 2050). However, while the global per capita share of freshwater use is one important measure, it does not capture the local impacts that may arise in both Sweden and abroad, overlooking regional variations in water scarcity. Freshwater scarcity often manifests itself differently in different places, and it is useful to also consider impacts in specific locations suffering from water scarcity. The lack of regional context with a global consumption boundary is further underlined by Moberg *et al.* (2020). In addition, other potential allocation principles of freshwater may be considered, such as alternatives based on rights and the responsibility of different groups (Zipper *et al.*, 2020).

Since Swedish food consumption and production are well below the global average boundary, the purpose here is not to set a globally relevant target per capita measurement. To examine how Swedish consumption aggravates water stress across the world, the suggestion is instead to use one of the available water scarcity indexes. The analysis could consider regions where Swedish food consumption has the largest water footprint and regions with the greatest risk of water scarcity. These analyses could be derived by a scarcity-weighted water footprint metric. Other applications of the freshwater planetary boundary in a regional context also exist, although these methods are likely to be too resource-demanding in this case. Zipper *et al.* (2020), for example, have identified both a "fair share" from a global perspective as well as a "locally safe operating space". While water quantity levels are not considered a current issue for overall national levels of Swedish food production, it is projected that climate change will contribute to increased competition for freshwater between Swedish agricultural production and other activities, particularly in certain regions (Swedish Board of Agriculture (SBA), 2021b).

5.2. Suggestion of targets

The proposed targets below (Table 6) focus on blue water, in line with Moberg *et al.* (2020) and Willett *et al.* (2019). Specific quantitative boundaries are not set for local water impact but may be developed at a later stage, e.g., using a scarcity-weighted water footprint metric on regions most impacted by Swedish food consumption. The territorial targets are primarily based on Sweden's Environmental Objectives (Sveriges Miljömål, no date) and on the suggested indicators by Mistra Food Futures, WP4 (Hansson *et al.*, 2023).

Table 6. Freshwater use: suggestion of territorial and consumption targets.

Territorial target	Consumption target
1. Food production and food industry in Sweden do not impact surface or groundwater levels in a way that limits the usage of groundwater for public or private drinking water supply or causes a negative impact on water supply, ground stability, or animal and plant life in nearby ecosystems. The surface and groundwater levels must be maintained at such volume that they can support freshwater consumption necessary for food production and industry.	**1.** Swedish food consumption does not create or exacerbate local, regional, or national water shortages in Sweden or in other countries.
Considered targets/indicators ○ Total blue water used in food production (m^3 $year^{-1}$) ○ Level of water stress – freshwater withdrawal as a proportion of available freshwater ○ Geographically explicit estimates of water stress (or similar), considering the volume of freshwater consumption of food production and industry (m^3). ○ Status of groundwater. ○ Conservation status for groundwater-dependent habitats. ○ Water protection areas. ○ Indicator of the resilience of water levels.	*Considered targets/indicators* ○ 105-422 m2 of consumptive freshwater use per capita and year (i.e. the downscaled EAT-*Lancet* boundary, based on a projected global population of 9.48 billion people in 2045) ○ Total blue water used in food production (m^3 $year^{-1}$) ○ Scarcity adjusted blue water use

6. Eutrophication

6.1. Background

Reducing eutrophication is key to conserve aquatic environments (marine and freshwater) and sustainably using marine and freshwater food resources. The EAT-*Lancet* Commission set a boundary based on maximum inputs that do not lead to the eutrophication of terrestrial and aquatic systems, using the application of nitrogen and phosphorus as indicators (Willett *et al.*, 2019). Applying the downscaled global EAT-*Lancet* boundaries on Sweden indicate that the average Swedish diet currently transgresses the EAT-*Lancet* boundary (for 2050) for both nitrogen and phosphorus by more than four-fold (Moberg *et al.*, 2020).

The territorial targets suggested in this report (Table 7) draw upon the Swedish Environmental Objectives (SEOs) (Sveriges Miljömål, no date) and Hansson *et al.* (2023). Agreements and maximum nutrient input levels decided under the Baltic Sea Action Plan adopted by the Helsinki Commission (Helsinki Commission HELCOM, 2021) have also been considered. It is important to note that although boundaries have been set to benchmark Sweden's overall territorial performance, no specific limit has been set for the maximum emissions load from specific sectors such as agriculture (Moberg *et al.*, 2020). Current SEO indicators are designed to measure overall emission loads from Sweden and neighbouring countries and are thus difficult to link to agriculture and aquaculture, or specific foods and diets. The EU Farm to Fork strategy aims to reduce nutrient losses by 50% and the use of fertilisers by at least 20% by 2030 (European Commission (EC), 2020a). Sweden's position, as posited in a report by the Swedish Board of Agriculture (2021c) is that this target is "very ambitious" and that reducing nutrient losses by 50% on a national level solely through more efficient fertiliser use is unlikely. This is because the efficiency of fertiliser use in Sweden is deemed to be relatively high already (ibid). N and P surpluses on Swedish agricultural land expressed in total and per ha could be another relevant indicator for territorial targets given available high-quality data from Statistics Sweden (2021a)

Further work is needed to develop indicators to assess eutrophication caused by Swedish consumption of imported food (Steinbach *et al.*, 2018; Moberg *et al.*, 2020). Official statistics for nitrogen and phosphorus emissions to water are available for the Swedish territory (Swedish Board of Agriculture (SBA), 2020), but the calculation models in EXIOBASE for emissions in the rest of the world are highly simplified (Steinbach *et al.*, 2018). However, analyses show that the size of emissions of nitrogen and phosphorus to water and air caused by Swedish food consumption is likely to be greater outside Sweden than within the country's borders (Steinbach *et al.*, 2018).

6.1.1. Considered targets

Future discussions on how to develop the suggested targets could consider the concept of circularity, for instance whether Sweden should improve the capacity of phosphorus and nitrogen recycling from e.g. animal manure, food waste, and sewage (Metson *et al.*, 2020). A target on ammonia emissions from agriculture is another potential addition. For production, losses from fields (that could be modelled) as well as indicators like nitrogen use efficiency and nitrogen balances for which targets can be set could be used. The EAT-*Lancet* boundaries are based on "added nutrients", the amount of new reactive nitrogen and phosphorus added to ecosystems (Moberg *et al.*, 2020). For the consumption-based targets, the level of specificity needs to be further discussed.

Some of the potential target areas are listed below:

- Maximum allowable nutrient pollution inputs (from agriculture or fields) into Swedish sea basins. See the Swedish Environmental Objectives (Sveriges Miljömål, no date) for current phosphorus and nitrogen levels and Baltic Sea Action Plan limits. However, targets for agriculture need to be developed specifically.
- Achieving and maintaining that by 2045, Swedish water bodies should have a maximum annual input of xx tons of phosphorus and xx tons of nitrogen from agriculture and aquaculture runoff.
- Reduce nutrient losses from agriculture by xx%.

With respect to consumption targets, one potential target category could be downscaled EAT-*Lancet* boundaries (Willett *et al*., 2019), based on a projected global population of 9.48 billion in 2045:

- Nitrogen application: 9.49 kg, uncertainty range 6.86-13.71 kg per capita and year
- Phosphorus application: 0.84 kg, uncertainty range 0.63-1-69 kg per capita and year

6.2. Suggestion of targets

Territorial and consumption targets for eutrophication are suggested in Table 7. Due to the lack of data, no quantified target levels are specified.

Table 7. Eutrophication: suggestion of territorial and consumption targets.

Overarching goal: Nutrient runoff caused by agriculture for Swedish consumption and production should not have any negative impact on human health or conditions for biodiversity, i.e., cause eutrophication in aquatic environments - in Sweden or the rest of the world.	
Territorial target	**Consumption target**
1. Food production does not contribute to eutrophication in springs, lakes, rivers, wetlands and oceans in Sweden. ○ Lakes, watercourses, coastal waters, and groundwater achieve at least good status for nutrients. ○ Land use for food production does not result in any substantial long-term harmful effects of eutrophying substances on Swedish ecosystems.	**1.** Swedish food consumption does not contribute to eutrophication in springs, lakes, rivers, wetlands and seas in areas where Swedish food is produced.
Considered targets/ indicators ○ Maximum allowable nutrient pollution inputs (from agriculture or fields) into Swedish sea basins. ○ Achieving and maintaining that by 2045, Swedish water bodies should have a maximum annual input of xx tons of phosphorus and xx tons of nitrogen from agriculture and aquaculture runoff. ○ Reduce nutrient losses from agriculture by xx%. ○ N and P surpluses on Swedish agricultural land expressed in total and per ha. ○ Nitrogen use efficiency ○ Nitrogen balances ○ Environmental status for eutrophication, following the Ecological Quality Ratio (EQR value) from the Water Framework Directive ○ Oxygen levels (extent of low oxygen or oxygen-free deep waters) ○ Algal blooms	*Potential targets/ indicators* ○ Nitrogen application 9.49 kg, uncertainty range 6.86-13.71 kg per capita and year (Eat-*Lancet*-commission). ○ Phosphorus application: 0.84 kg, uncertainty range 0.63-1-69 kg per capita and year (Eat-*Lancet*-commission). ○ Amount of P fertiliser used on arable land per year to produce the food in the Swedish diet (thousands of tons) ○ Total new reactive kg N (synthetic fertiliser+N-fixation) to arable land per year (thousand tons) ○ Nitrogen use efficiency ○ Nitrogen balances

7. Antibiotic use

7.1. Background

The use of antibiotics in Swedish food production is small in comparison to Europe and the rest of the world and the antibiotic resistance situation in Sweden is considered relatively favourable (Ministry of Health and Social Affairs, 2020). In 2013, the Swedish antimicrobial veterinary medicine products (VMPs) footprint was 5 grams of active ingredients per capita. 17% of VMP use came from domestic production, 70% from European production, and a smaller share from the rest of the world (Steinbach *et al.*, 2018; Cederberg *et al.*, 2019). Proposals to e.g., tax and regulate the import of certain foods are not included in the consumption targets below seeing as safe international trade is considered a way to reach the target rather than a target in itself.

The EU Farm to Fork 2030 strategy aims to reduce EU sales of antimicrobials for farmed animals in agriculture and aquaculture by 50% (European Commission (EC), 2020a). It is unclear whether the goal to reduce antimicrobial sales by 50% is expected to apply to each member state or the EU as a whole (Swedish Board of Agriculture (SBA), 2021a). The Swedish Board of Agriculture wishes to see clarity on this issue and posits that halving Sweden's comparatively very low use of antibiotics is unrealistic (ibid). Moreover, the SBA would like for the definition of EU targets to be linked to the dosage of drugs and the number of animals treated rather than kilograms of antibiotics used, ideally specified for each animal species. The amount of used antibiotics in kgs can be reduced by using antibiotics that require a lower dose per kg, without improving animal health or the resistance situation.

Also worth noting is the set of new EU regulations on veterinary medicinal products and medicated feed, to apply as of 2022 (European Union (EU), 2018):

- ⇒ a ban on the preventive use of antibiotics for group treatments of healthy animals;
- ⇒ a ban on the preventive use of antimicrobials via medicated feed;
- ⇒ restrictions on the use of antimicrobials as a control treatment to prevent a further spread of infection;
- ⇒ a reinforced ban on the use of antimicrobials for promoting growth and increasing yield (in addition to the 2006 prohibition of using antibiotics as growth promoters in feed);
- ⇒ the possibility to reserve certain antimicrobials for humans only;
- ⇒ the obligation for EU countries to collect data on the sale and use of antimicrobials;
- ⇒ science-based maximum limits for cross-contamination of feed with antimicrobials.

In addition, products of animal origin imported into the EU from non-EU countries will have to comply with the ban on antimicrobials for promoting growth and increasing yield, as well as the restrictions on antimicrobials designated as reserved for human use in the EU (European Union (EU), 2018).

Other documents of relevance to the targets for antibiotic use include the Swedish Strategy to Combat Antibiotic Resistance 2020-2023 (Ministry of Health and Social Affairs, 2020) and Axfoundation's criteria for responsible use of antibiotics for farmed animals (Smith *et al.*, 2020). In addition, Hansson *et al.* (2023) suggest several potential indicators for antimicrobial resistance in the Mistra Food Futures' report on indicators.

7.2. Suggestion of targets

Qualitative targets on minimising the footprint of veterinary antibiotic use and focusing on preventive work for animal health and welfare are proposed in Table 8. No quantitative targets are suggested at this stage.

Table 8. Antibiotic use: suggestion of territorial and consumption targets.

<table>
<tr><td colspan="2">Overarching goal: The possibility of effective treatment of bacterial infections in people and animals is preserved (in line with the Swedish Strategy to Combat Antibiotic Resistance 2020-2023).</td></tr>
<tr><th>Territorial target</th><th>Consumption target</th></tr>
<tr><td>1. Veterinary antibiotic use in Swedish food production is kept as low as possible while ensuring high animal welfare.
2. The need for antibiotic use is prevented, e.g., through comprehensive vaccination programmes and good animal health and welfare.
3. Emissions of antibiotics and antimicrobial substances to the environment are minimised.</td><td>1. Veterinary antibiotic use in food imported for Swedish consumption is kept as low as possible while ensuring high animal welfare.
2. Antibiotics particularly important for human health care (colistin, fluoroquinolones and 3rd or 4th generation cephalosporins) are only used when a veterinarian considers no other treatment option effective.</td></tr>
<tr><td>Potential indicators
○ Antimicrobial veterinary medicine product (VMP) footprint (see Steinbach et al., 2018; Cederberg et al., 2019),
○ Number of vaccinated animals.
○ Sales of antibiotics for different animal species used for food production, in mg/PCU. PCU (population corrected unit) is a measure of use standardised for the total amount (biomass) of animals.</td><td>Potential indicators
○ Antimicrobial veterinary medicine product (VMP) footprint (see Steinbach et al., 2018; Cederberg et al., 2019).
○ Number of vaccinated animals.
○ Sales of antibiotics for different animal species used for food production, in mg/PCU. PCU (population corrected unit) is a measure of use standardised for the total amount (biomass) of animals.
○ If data on the sales of antibiotics are missing for the country, the existence of national laws regulating the use of antibiotics for animals can be used as an indicator for countries not reporting sales of antibiotics.</td></tr>
</table>

8. Chemicals and pesticides

8.1. Background

The pesticide footprint associated with Swedish consumption in 2013 was estimated to be 0.30 kg active ingredients (a.i.) of herbicides, 0.17 kg a.i. of fungicides and 0.07 kg a.i. of insecticides per capita (Cederberg *et al.*, 2019). Sweden's consumption-based fungicide and insecticide footprint is slightly below the EU average, while the herbicide footprint is slightly above average. The largest impact of chemical and pesticide use associated with Swedish food consumption occurs abroad, with 75-97% of it embedded in imports (Cederberg *et al.*, 2019).

Use of three major pesticide groups - herbicides, insecticides, and fungicides & bactericides - are used by Cederberg *et al.* (2019) as indicators to monitor the potential environmental and health impacts of pesticide use associated with Swedish food consumption. They argue that the most suitable indicator is *use* due to the available, regularly updated databases such as FAOSTAT, with international coverage and the possibility to link data to different economic sectors. Still, country coverage and time series are incomplete. A key limitation for setting quantitative targets is the lack of inventory data and poor traceability for imported food.

The EU Farm to Fork strategy sets out to reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030 (European Commission (EC), 2020a). It is unclear whether these goals are expected to apply to each member state or the EU as a whole.

8.2. Suggestion of targets

Qualitative targets on minimising the harmful impact of chemicals and pesticides are proposed in Table 9. The indicators correspond with those suggested in the Mistra Food Future's report on indicators (Hansson *et al.* 2023). No quantitative targets are suggested at this stage.

Table 9. Chemicals and pesticides: suggestion of territorial and consumption targets.

Territorial target	Consumption target
1. Pesticide and agrochemical use is reduced so that total exposure to chemical substances via food production is not harmful to human, animal or plant health, biodiversity, or water quality. **2.** The levels of plant protection products in surface water and groundwater are reduced close to zero. *Potential indicators* ○ Use of virgin P per year (Mt) ○ Pesticide risk index for health and environment ○ Pesticide use/footprint ○ Plant protection residue in surface water	**1.** Pesticide and chemical use associated with Swedish food consumption does not have a harmful impact on human health, biodiversity, or water quality in Sweden or elsewhere. *Potential indicators* ○ Use of virgin P per year (Mt) ○ Pesticide use/footprint

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Appendix 1. Raw-to-cooked ratios

Table 10. Raw-to-cooked ratios used to adjust EAT-Lancet intake levels. Adjusted values for seven food groups are given, along with the reasoning behind the chosen ratio as well as the original amounts in dry/raw weight. Food groups not included below are not adjusted as they are already expressed in as-consumed weight in Willett et al. *(2019).*

Food group	Amount (g/day), original	Amount as consumed (g/day), adjusted	Raw-to-cooked ratio	Reasoning
Whole grains	232	462	2.0	The as-consumed weight of grains varies extremely, from 0.90 for bread to 4.1 for oatmeal (Bognár, 2002). To translate the EAT-*Lancet* whole grains subgroup from dry to as-consumed, Blackstone and Conrad (2020) calculated an average conversion factor of 2.13, weighted by proportion of recommended servings. Due to uncertainty, we use an estimated average weight change of 2.0.
Starchy vegetables	50 (0-100)	40 (0-80)	0.80	With reference to the ratio in Bognár (2002) for boiled/steamed potatoes with peel, 0.80 is used.
Beef and lamb	7 (0-14)	5 (0-10)	0.70	Conversation factors found in the literature generally range somewhere between 0.60-0.80 (Bognár, 2002; Wood *et al.*, 2019), depending on the type of meat, part, and cooking method. Based on this, we estimate a weight loss of around 0.70 for beef, lamb, pork and poultry when cooked.
Pork	7 (0-14)	5 (0-10)		
Chicken and other poultry	29 (0-58)	20 (0-40)		
Eggs	13 (0-25)	12 (0-23)	0.90	Based on an approximate average of raw-to-cooked factors for eggs (boiled, scrambled, fried) found in Bognár (2002), we estimate a weight change of 0.90.
Legumes (beans, lentils, peas, soy)	75 (0-150)	190 (0-375)	2.5	The estimated weight change of 2.5 is based on an approximate average of raw-to-cooked ratios used in the literature (Bognár, 2002; Wood *et al.*, 2019; Blackstone and Conrad, 2020).

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MISTRA
FOOD FUTURES