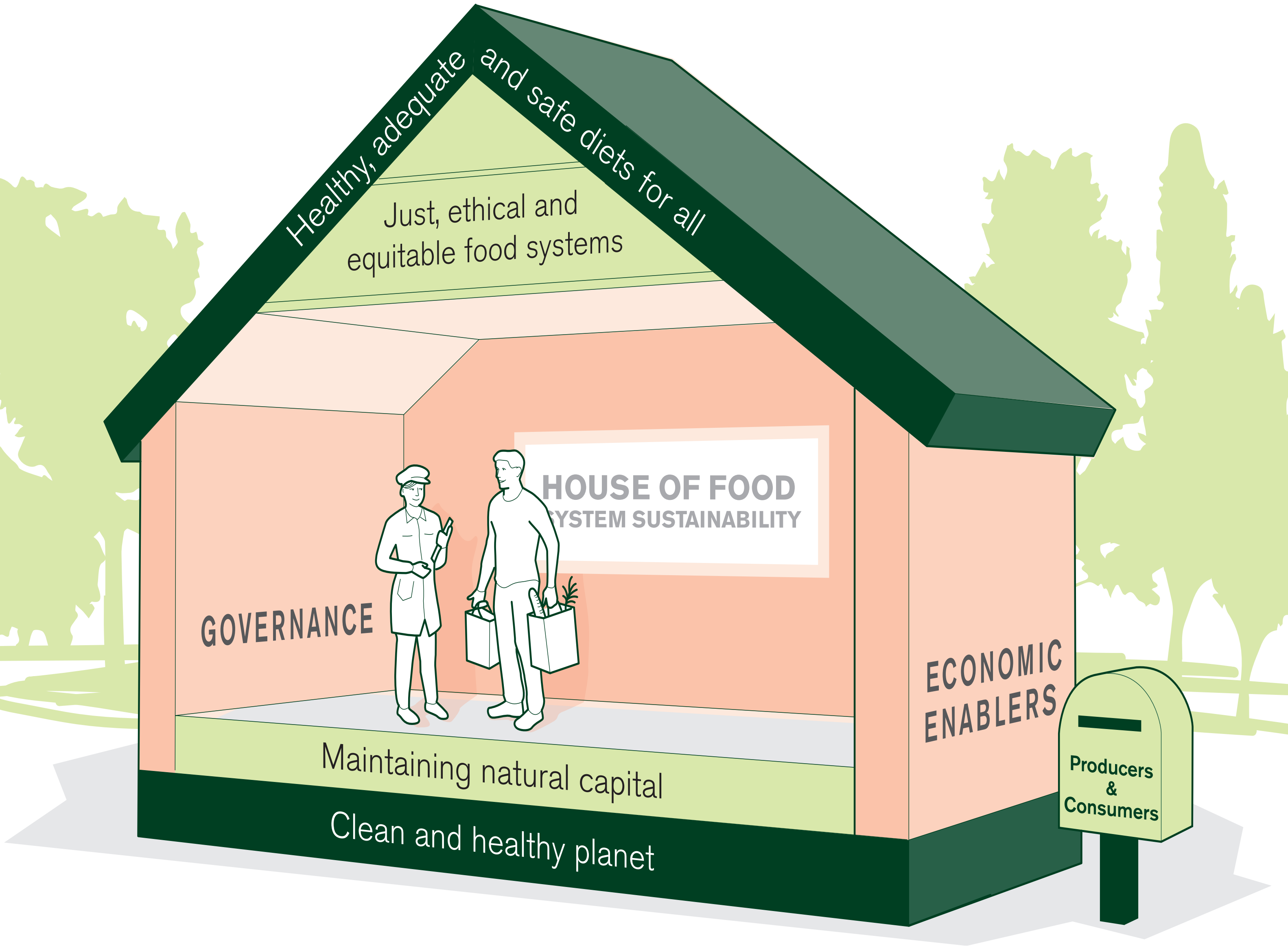

A framework for measuring sustainability in the Swedish food system

– indicator selection and justification

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A framework for measuring sustainability in the Swedish food system - indicator selection and justification
Ett ramverk för att mäta hållbarhet i det svenska livsmedelssystemet - val och motivering av indikatorer

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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 and RISE Research Institutes of Sweden.

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Introduction

Being able to assess the sustainability of food systems is central to evaluate policy implemented to remedy their sustainability problems, to monitor performance over time and to function as input to policy makers' decisions. This report introduces a catalogue of suggested themes, sub-themes and indicators for assessing food system sustainability in Sweden. The themes, sub-themes and indicators builds on previous work that developed food system sustainability frameworks, mainly Hebinck et al. (2021) who suggests an integrated framework for food system sustainability assessment building on a comprehensive review of the literature.

From a conceptual perspective, the report builds on a model developed by Mistra Food Futures researchers in 2022 - 23 (Hansson *et al.,* 2023), where a food system sustainability framework for Sweden is suggested to take the form of a *Food System Sustainability House* (Fig 1). The Food System Sustainability House is developed around the following key assumptions about a sustainable food system:

- The overall aim of a national food system (following Hebinck et al. (2021)) is to provide healthy, safe and adequate diets for all. In addition, the food system should be just, ethical and equitable. These two aspects form the ceiling of the food system.
- The environmental foundations for the food system activities are viewed as a floor, or as a foundation for the system, representing restrictions on human actions and behaviors within the system. The environmental foundations are central for future continuous food security, and the food system has to rest upon a functioning ecosystem foundation.
- The economic system takes the role of an enabler, which makes the system work. To this end, we need companies that can produce raw material and food, and policy that can ensure, that external effects by the food system actors are taken into considerations by actors in their decision-making. This implies that the external effects are internalized. The economic indicators developed for the Food System Sustainability House for Sweden are designed to measure performance in relation to this overall function of the system. The economic system, separated between enablers for producers and consumers on the one hand side and governance on the other hand side, functions as 'walls' in the system, connecting the floor with the ceiling.

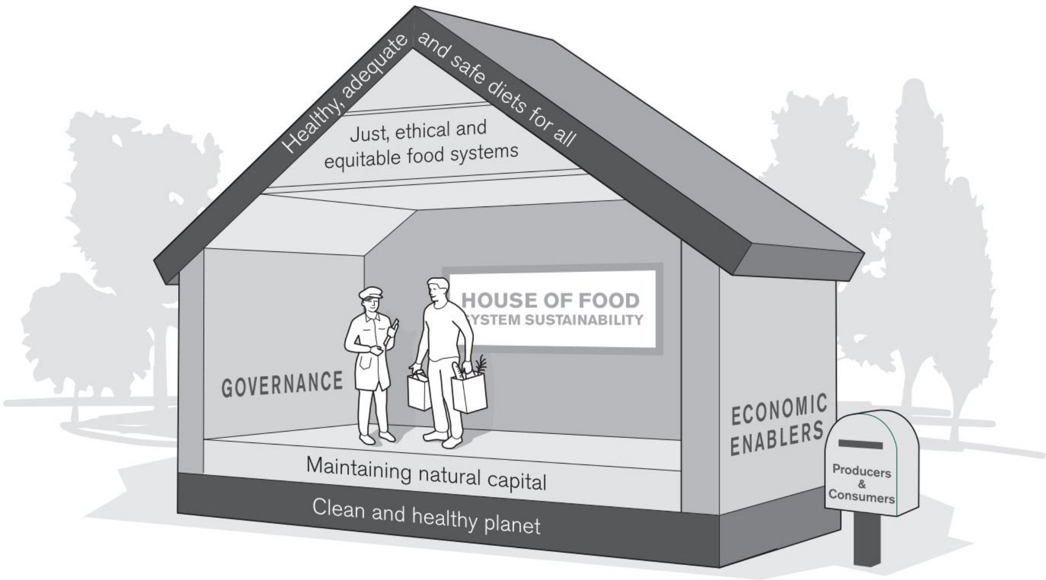

Figure 1: The Food System Sustainability House. Source: Hansson et al., (2023).

The report now continues by introducing and motivating themes and indicators to assess food system sustainability based on the Food System Sustainability House. The themes and indicators are adapted for the Swedish food system.

For each indicator, we give suggestions for official and what we call science-based targets. Official targets are targets currently reflected in official policy documents. Such are currently lacking for most of the indicators.

Each indicator are also classified using the Driver (D)-Pressure (P)-State (S)-Impact (I)-Response (R) framework (Kristensen, 2004). This framework illustrate where along the cause-effect chain indicators are located. *Drivers* include the human activities that drive *pressures* (e.g. natural resource use, emissions) that lead to a change in the socioeconomic and ecological *state* and *impacts* on these systems that eventually lead to societal responses (e.g. policy responses).

Catalogue of themes and indicators for the Food System Sustainability House for Sweden

1. CEILING: Healthy, adequate and safe diets for all

Healthy, adequate and safe diets are central to human health as well as to food system sustainability. In the latest update of The Global Burden of Disease project (GBD 2019), low-quality, non-diverse diets were the second (women) or third (men) leading risk factors for premature death, causing 3.48 and 4.47 million premature deaths per year among women and men, respectively.

The theme healthy, adequate and safe diets is divided into three sub-themes focusing on healthy and adequate diets (1.1), food safety (1.2) and food availability (1.3). The selection of indicators was based on indicators previously proposed to monitor nutrition, health, food safety and availability aspects in food sustainability frameworks (Fanzo et al., 2021; Hebinck et al., 2021; Bené et al., 2019; Chaudhary et al., 2018), which were also judged to be relevant for the Swedish population.

1.1 Theme: Healthy and adequate diets

Poor diets are identified as one of the largest behavioral risk factors for disease and premature death globally and in Sweden. Adoption of healthier diets could substantially reduce the risk of morbidity and mortality from non-communicable diseases. For example, 46% of ischaemic heart disease cases and 15% of stroke cases are estimated to be associated with poor dietary habits in Sweden (IHE, 2021).

1.1.1 Diet quality

Territorial-based indicator(s)

NA

Consumption-based indicator(s)

Mean population intake of critical food groups per day or week.

Description: The indicator measures mean food intake levels in the Swedish population in relation to recommended intake levels in Swedish food-based dietary guidelines.

Indicator:	Mean population intake of critical food groups per day or week.
Indicator label:	T - 1.1.1a-e
Type according to DPSIR:	S
Target:	Recommended intake levels in Swedish food-based dietary guidelines (SFA, 2022a; NCM, 2014)
Data source:	National dietary surveys by the Swedish Food Agency (SFA, 2012; 2018).

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Poor diets are identified as one of the largest behavioral risk factors for disease and premature death in Sweden. Adoption of healthier diets could substantially reduce the risk of morbidity and mortality from non-communicable diseases.	Well established indicator proposed in previous sustainability frameworks. Data from national dietary surveys allow for detailed assessments of food intake. Self-reported food intake data is hampered by uncertainty e.g., underreporting of unhealthy foods. Quality of food intake data is hampered by national dietary intake surveys on adults being performed only every 10 years.	Quantitative indicator. Easy and intuitive to interpret. Clearly reflects trends in intake of specific foods and food groups. Available data allow for assessment of differences in food intake between population groups. Intake of specific food groups are easier to interpret and communicate compared to aggregated indicators such as dietary quality or diet diversity scores.	Straight-forward in evaluating the sustainability of current intake levels and follow trends based on national food intake data. Official food-based dietary guidelines are only available for a limited selection of food groups. These are often based on maximum or minimum levels of intake, which may be difficult to translate into targets that are more specific.

Background

The indicator proposed for diet quality in previous sustainability frameworks (Fanzo et al., 2021; Hebinck et al., 2021; Bené et al., 2019; Chaudhary et al., 2018) are primarily based on food intake levels, adherence to dietary guidelines or aggregated diet scores reflecting the overall diet quality or diversity. In this framework, diet quality is proposed to be measured by the mean population intake of food groups identified as critical for the Swedish population. In the literature, several diet scores for the total diet are described and have to some extent also been developed based on the Swedish dietary guidelines (Moreaus et al., 2020; Gonzales-Padilla et al., 2022; Drake et al., 2011). These are not suggested as indicators in this framework because aggregated scores are often considered more difficult to interpret compared to indicators for specific food groups and often lack defined thresholds and goals for benchmarking. In this framework, diet diversity is assumed to be captured by including a combination of indicators on different food groups and adequacy of critical nutrients.

For diet quality, there are few examples of defined absolute limits to use as goals or thresholds for healthy intake levels. Dietary guidelines in general emphasize the importance of diet diversity to support health. However, to define healthy intake levels within a specific food group is difficult as this depends on the overall diet composition and will vary depending on individual characteristics and the cultural and regional context. Due to this, it is challenging to set general goals for healthy food intake levels that are scientifically based and useful at the national level. In Sweden, food-based dietary guidelines exist for some food categories and provide an indication of recommended intake levels from a health perspective (SFA, 2022a).These guidelines are often described as a minimum (e.g., fruits and vegetables) or maximum (e.g., red meat, added sugar, alcohol) level of intake. Others have suggested targets for dietary intake developed from a broader sustainability perspective considering more aspects than health (Willet et al., 2019; SFA 2021a). To monitor public health in Sweden, several indicators are used of which "risk consumption of alcohol" and "daily intake of vegetables" are food-based indicators (The Public Health Agency of Sweden, 2022a).

The national dietary surveys that provide information on food intake in the Swedish adult population are performed approximately every ten years (SFA, 2022b) complemented by surveys focusing on other age groups, e.g., children and adolescents performed at regular basis (SFA, 2018). In addition, a national health survey is performed every second year which includes questions on the frequency and intake levels of fruits and vegetables, sweetened beverages, seafood and alcohol (The Public Health Agency of Sweden, 2022b). The per capita food supply data are provided by the Swedish Board of Agriculture on a yearly basis. The per capita food supply data are useful to follow dietary trends in the population but are less appropriate for benchmarking against targets based on food intake e.g., food-based dietary guidelines, since the supply data includes food that is available but not eaten, e.g., food waste. Another limitation of per capita supply data is their inability to capture differences in dietary habits between population groups. In this framework, food intake data from the national dietary surveys (SFA, 2012; 2018) are suggested as the most suitable source of food intake data to measure diet quality in Sweden. These data have several advantages, e.g., the level of detail in the dietary data from a wide variety of food groups and the possibility to estimate mean intake levels of different population groups. Although it is well known that self-reported dietary data often suffer from misreporting and that it would be desirable for the indicator to be based on data that were updated more frequently, this is the most comprehensive source on food intake in the Swedish population which can also be benchmarked against the food-based dietary guidelines. To monitor food consumption trends more regularly, these data could be complemented with food intake and supply data from other sources that are updated more frequently.

Food-based dietary guidelines can be used to benchmark food intake in a population either by comparing the mean intake levels of a specific food group within a population group to a recommended level of intake (e.g., 500g fruits and vegetables per day) or by estimating the percentage adherence to dietary guidelines within the population (e.g., 20% adherence of recommended intake of fruits and vegetables in the adult population). In this framework, the approach of comparing current intake levels to recommended intake levels is suggested to be most useful as it provides information on how close or far dietary patterns are compared to the recommendations. To capture risk groups in the population, the indicator should preferably measure the diet quality both at an aggregated level, e.g., mean intake of the total adult population, and in specific population groups that differ in terms of gender, age and socioeconomic characteristics.

Food groups measured by the indicator

Diet quality should preferably be measured by intake levels of food groups identified as critical for achieving healthy diets in the Swedish population.

The food groups proposed to be measured by the indicator are intake of:

- Fruits and vegetables (including legumes)
- Whole grains
- Red and processed meat
- Seafood
- Discretionary foods

The selection of critical food groups proposed was guided by the following criteria (1-3). The food groups selected fulfill all or most of the criteria outlined.

1) Specification of recommended intake levels in food-based dietary guidelines

The indicator for diet quality aims to measure the adherence to dietary guidelines within the Swedish population. For the food groups proposed, the recommended quantitative intake levels are specified in the Swedish dietary guidelines (SFA, 2022a; NCM, 2014). The food groups proposed are also included in the diet quality scores developed based on the current Swedish dietary guidelines (Gonzales-Padilla et al., 2022; Moreaus et al., 2020).

According to the Swedish dietary guidelines, the recommended intake levels of fruits and vegetables (including legumes) are at least 500 g per day. The recommended intake level of whole grains is 75 g per 10 MJ, equivalent to about 70 g per day for women and 90 g per day for men. The intake of red and processed meat is recommended to be a maximum of 500 g of cooked meat per week, with processed meat intake limited to a minor share of the total red meat intake. The seafood intake is recommended to be 2-3 times per week, equivalent to about 45 g seafood per day (Moraeus et al., 2020) The discretionary foods, as defined in the proposed indicator, include several food groups that contribute substantially to the total energy intake in the Swedish population while providing a small nutritional contribution. For example, in the Swedish dietary survey of adults (SFA, 2012), intake of an aggregated food group consisting of soda, cordial, energy drinks, sweetened soups, desserts, fruit puré, marmelades, pastries, ice cream, sugar, honey and snacks was estimated. No official recommended intake level is available for the broader category of discretionary foods in the Swedish dietary guidelines. However, such recommendations exist for some of the food groups (i.e., added sugar and alcoholic drinks) included in the broader category of discretionary foods, which justifies the selection of the indicator. The intake levels of added sugar are recommended to be limited to maximum 10% of the total energy intake, equivalent to about 50-75 g per day for adults. The intake levels of alcoholic drinks are recommended to a maximum of 10 g and 20 g of alcohol per day for men and women, respectively. In addition, an indicator to monitor consumption of discretionary foods in Sweden was recently proposed by the Swedish Food Agency (2021a). The indicator proposed, which also is potentially useful as a complementary indicator in this framework, is based on national statistics of direct consumption from the Swedish Board of Agriculture for the following foods: alcoholic beverages, soda, sugar, syrup, coffee, tea, cacao, honey, chocolate, confectionery, ice cream and pastries.

2) Low adherence of dietary guidelines in the average Swedish population

The indicator for diet quality aims to measure the intake of food groups where changes in the Swedish diet is most needed. The adherence of current dietary guidelines was judged based on data from the most recent national dietary survey of adults in Sweden (SFA, 2012). The food groups for which mean intake levels in the adult Swedish population were below the recommended levels or above maximum recommended levels were considered of special relevance to include as indicators for diet quality.

According to the most recent self-reported data available on national level, the mean intake levels of fruits and vegetables, whole grains, and seafood are below recommended levels in the Swedish adult population. The mean intake levels of red and processed meat are above the maximum recommended levels and the intake of added sugar reach the maximum recommended intake levels.

3) High significance for diet-related health outcomes in the Swedish population

The indicator for diet quality aims to measure the intake of food groups with highest relevance for preventing negative diet-related health effects and promoting positive diet-related health effects in the Swedish population. The evidence for diet-related health effects differs between the different food items and food groups. In addition, the diet-related health effects of a specific food will vary depending on the intake level. The food groups ranked as the top dietary risk factors in the Swedish population were considered of special relevance to capture by the indicator for diet quality. For this criterion, risk factors based on data from the Global Burden of Disease were used (IHME, 2022). The dietary risk factors were measured by the number of deaths per 100 000 individuals in Sweden, including both sexes and all ages in 2019.

The low intake of vegetables (ranked as number 8 by IHME), fruit (Nb 7) and legumes (Nb 2) are ranked among the top dietary risk factors in the Swedish population by IHME (2022). The low intake of whole grains is identified as the number one dietary risk factor and the high intake of red (Nb 3) and processed meat (Nb 4) are also identified among the top dietary risk factors. The low intake of seafood is not ranked among the top 15 dietary risk factors in the Swedish population. However, the low intake of omega-3 fatty acids (Nb 12) is identified among the top dietary risk factors and seafood is a main source in the

Swedish diet (SFA, 2012). Within the category of discretionary foods, the high intake of sweetened beverages (Nb 13) is ranked among the top dietary risk factors. The high intake of alcoholic drinks is not classified as a dietary risk factor but is identified as the third most important behavioral risk factor in the Swedish population after tobacco and dietary risks (IHME, 2022). In addition to the food groups proposed to be measured by the indicator for diet quality, the low intake of milk (Nb 14) and nuts and seeds (Nb 10) are identified among the top 15 dietary risk factors in the Swedish population. These were not proposed to be measured by the diet quality-indicator in this framework as they did not fulfill the other criteria defined. However, the intake of nutrients mainly provided by these food groups (e.g., calcium for which milk is the main source in the Swedish diet [SFA, 2012]) are suggested as nutrients to measure by the indicator for nutrient adequacy.

1.1.2 Nutrient adequacy

Territorial-based indicator(s):

NA

Consumption-based indicator(s):

Mean population intake of critical nutrients per day

Description: The indicator measures mean nutrient intake in the Swedish population in relation to the reference values for nutrient intake in the Nordic Nutrition Recommendations (NCM, 2014).

Indicator:	Mean population intake of critical nutrients per day.
Indicator label:	T - 1.1.2a-e
Type according to DPSIR:	S
Target:	Reference values for nutrient intake (e.g., average requirement [AR]) (NCM, 2014)
Data source:	National dietary surveys by the Swedish Food Agency (SFA, 2012; 2018).

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Nutrition adequacy is fundamental to maintain health. The indicator can, together with indicators on diet quality, serve as a proxy for diet diversity.	Well established indicator proposed in previous sustainability frameworks. Data from national dietary surveys allow for detailed assessments of nutrient intake. Self-reported food intake data are hampered by uncertainty e.g., underreporting of unhealthy foods. Quality of food intake data are hampered by the national dietary intake surveys on adults being performed only every 10 years.	Quantitative indicator that is easy and intuitive to interpret. Clearly reflects trends in intake levels of specific nutrients. Available data allow for assessment of differences in nutrient intake between population groups. Intake of specific nutrients is easier to interpret and benchmark compared to aggregated indicators such as nutrient quality scores.	Challenging to select the nutrients most relevant to monitor. Relevance of individual nutrients may differ between population groups. Bioavailability of nutrients and nutritional status in the population is not fully captured by the indicator.

Background

Nutrition adequacy is fundamental to maintain health and body functions. In Sweden, diet-related health problems are mainly associated with excessive energy intake and poor diet quality. Undernutrition in the Swedish population is related mainly to specific micronutrients and to specific groups of the population with special requirements (SFA 2012; 2018). Measuring nutrient adequacy is of large importance in interdisciplinary food sustainability frameworks to capture the nutritional effects from dietary changes driven by other sustainability perspectives (e.g., ecologic or economic perspectives).

In previous sustainability frameworks (Fanzo et al., 2021; Hebinck et al. ,2021; Bené et al., 2019; Chaudhary et al., 2018), indicators proposed for nutrient adequacy are primarily based on nutrient intake levels related to reference values (e.g., population share with adequate nutrients), aggregated nutrient quality scores, or metrics focusing on undernutrition (e.g., prevalence of stunting in children or nutritional deficiencies). In this framework, undernutrition is not measured per se, instead an indicator of the adequacy of critical nutrients is proposed because if intake of these nutrients is insufficient then deficiency and undernutrition will later occur. While several nutrient quality scores exist and provide the opportunity of using an aggregated nutrition indicator accounting for nutrient adequacy of multiple nutrients (e.g., the Swedish-adapted Nutrient Rich Food index: (Bianchi et al., 2020; van den Bergh, 2010; Strid *et al.*, 2021) they were not proposed as indicators in this framework due to some limitations of their use. For example, nutrient quality scores are often considered difficult to interpret, may hide information about specific nutrients, and lack defined thresholds/goals for benchmarking.

In the Nordic Nutrition Recommendations (NCM, 2014) reference values are defined for a large number of nutrients. A food sustainability framework could either include all these or a selection of the nutrients. The selection of which nutrients to monitor, and what such prioritizing should be based on, may differ between population groups. In this framework we suggest a selection of nutrients identified as the most critical in the Swedish population. For nutrition adequacy, the reference values for individual nutrients could be used as a basis to develop goals and thresholds values. For example, the average requirement (AR) is the reference value primarily used to assess the risk for inadequate intake of micronutrients in a certain group of individuals whereas the recommended intake (RI) refers to the amount of a nutrient that meets the requirements and maintains the nutritional status among practically all healthy individuals of a certain age and gender group (NCM, 2014).

The national dietary surveys that provide information on the average nutrient intake levels in the Swedish adult population are performed approximately every ten years (SFA, 2012), complemented by surveys focusing on other age groups, e.g., children and adolescents performed at regular basis (SFA, 2018). The supply of selected nutrients based on per capita food supply data are provided by the Swedish Board of Agriculture on yearly basis. The supply data could be useful to follow trends in the Swedish population but are not appropriate for benchmarking the nutrient intake levels against the existing reference values. Another limitation of per capita supply data is their inability to capture differences between population groups. In this framework, the nutrient intake data from the national dietary surveys (SFA, 2012; 2018) are suggested as the most suitable data to measure nutrient adequacy in Sweden. These data have several advantages, e.g., the level of detail and possibility to estimate the mean intake levels of different population groups. Although it is well known that self-reported dietary data often suffer from misreporting and it would be desirable for the indicator to be based on data that were updated more frequently, this is the most comprehensive data source on nutrient intake in the Swedish population which also can be benchmarked against existing reference values. To monitor trends in nutrient intake more regularly, these data could be complemented with food intake data from other sources that are updated more frequently e.g., Swedish food basked dietary surveys (SFA, 2022b). Complementary data may also be needed to capture specific risk groups of the population, e.g., pregnant women and the elderly. Several population-based epidemiological studies are ongoing in Sweden which could be another source of information on nutrient content and the nutritional status of specific nutrients in certain groups of the population. When considering the use of these data, it should however be considered that these studies are supported by research funding which may affect the availability of continuous updated data in the future.

The reference values for nutrients can be used to benchmark the nutrient intake in a population either by direct comparison of the mean intake levels of a specific nutrient within a population group to the reference value, or by estimating the population share with the adequate nutrient intake. In this framework, the approach of comparing the current intake levels to reference values is suggested to be the most useful as it provides information on how close or far current intake levels are compared to the recommendations. To capture risk groups in the population, the indicator should preferably measure nutrient adequacy at different levels, e.g., as the mean intake of total adult population, and in specific population groups that differ in terms of gender, age and socioeconomic characteristics.

When assessing the nutrient adequacy, it is important to distinguish between nutrient intake and nutritional status. Most data available to assess nutrient adequacy are based on the content of nutrients in the food ingested. However, to provide nutrition and thereby contribute to body function and health, nutrients need to be bioavailable, i.e., they need to be digested, absorbed and metabolized (FAO, 2021). The bioavailability of nutrients is affected by various factors (e.g., content of antinutrients in the food, meal effects, nutritional status) and is therefore difficult to assess. The effect of bioavailability is to some extent accounted for in the official reference values for nutrient intake. However, to assess the nutritional status for individuals or population groups with greater accuracy, biomarkers such as blood samples are required. For this purpose, it may be possible to use data from the health care sector to follow up the nutritional status of specific nutrients in risk groups of the population (e.g., iron status in pregnant women).

Nutrients measured by the indicator

Nutrient adequacy is suggested to be measured by the intake levels of nutrients identified as most critical for achieving nutritious diets in the Swedish population. The nutrients proposed to be measured by the indicator are intake of:

- Sodium
- Saturated fat
- Calcium
- Vitamin D
- Iron

Only nutrients for which recommended intake levels are defined in the Nordic Nutrition recommendations (NCM, 2014) were proposed to be measured by the indicator for nutrient adequacy. The selection of nutrients was further guided by the following criteria (1-2). The nutrients proposed fulfill all or most of the criteria outlined. When selecting nutrients, non-redundancy of indicators was also considered, i.e., nutrients mainly provided by food groups measured by the indicator for diet quality were not proposed to be measured by the indicator for nutrient adequacy.

1) Low adherence of nutrition recommendations in the average Swedish population

The indicator for nutrient adequacy aims to measure the intake of nutrients where the need for changes in the Swedish diet is most needed. The adherence to the current nutrition recommendations was judged based on data from the most recent national dietary survey of adults in Sweden (SFA, 2012). The nutrients for which mean intake levels in the Swedish population were below recommended levels or above maximum levels were considered of special relevance to capture by the indicator for nutrient adequacy.

According to the latest Swedish dietary survey of adults (SFA, 2012), the mean intake levels of sodium and saturated fat are above the maximum recommended levels, whereas the mean intake of vitamin D and iron are below the recommended levels in the adult population. The mean intake levels of calcium are in line or above the recommended levels.

Fibre, folate, potassium and carbohydrates are additional nutrients for which the mean intake levels in the Swedish adult population are estimated to be below the recommended levels. These nutrients were not proposed to be measured either because they did not fulfill the other criteria defined, and/or because the food groups mainly providing these nutrients in the Swedish diet were proposed to be measured by the indicator for diet quality (e.g., intake of fibre from whole grains, fruits and vegetables including legumes).

In the latest national dietary survey of adults (SFA, 2012), the nutrient intake in the Swedish population was compared with the Swedish dietary guidelines from 2005. A recent assessment (Lemming and Pitsi, 2022) updated the comparison based on the Nordic Nutrition Recommendations 2012 (NCM, 2014) and showed similar results.

2) High significance for diet-related health outcomes in the Swedish population

The indicator for nutrient adequacy aims to measure the intake of nutrients with the highest relevance for preventing negative diet-related health effects and promoting positive diet-related health effects in the Swedish population. In line with the method used for selecting the food groups to measure by the indicator for diet quality, risk factors based on data from the Global Burden of Disease study were used for this criterion (see section 1.1.1).

The high intake of trans-fatty acids (ranked as number 9) and the low intake of polyunsaturated fatty acids (Nb 11), omega-3 fatty acids (Nb 12) and calcium (Nb 15) are nutrients ranked among the top dietary risk factors in the Swedish population by IHME (2022). Among these, only calcium was proposed to be measured by the indicator for nutrient adequacy. The other nutrients were not selected as they did not fulfill the other criteria defined and/or because the food groups mainly providing these nutrients in the Swedish diet were proposed to be measured by the indicator for diet quality (e.g., intake of omega-3 fatty acids from seafood).

1.1.3 Energy balance

Territorial-based indicator(s):

NA

Consumption-based indicator(s):

Body mass index (BMI)
Description: The indicator measures energy balance by the body mass index in the Swedish population.

Indicator:	Body mass index (BMI) (kg/m^2)
Indicator label:	C-1.1.3a
Type according to DPSIR:	S
Target:	BMI below 25
Data source:	BMI of adult men and women and some groups of adolescents and children is provided by the Public Health Agency of Sweden (2022c)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Excessive energy intake is a large behavioral risk factor for disease and premature death. In Sweden half of the adult population is overweight or obese. Share of population with overweight and obesity is increasing.	Well established indicator proposed in previous sustainability frameworks. National BMI data are self-reported which undermines the quality of data. National BMI data in adults are provided every second year. For children in some age groups data are provided every 4 years. BMI is partially determined by non-food related factors such as physical activity and genetics.	Quantitative indicator that is easy and intuitive to interpret. Clearly reflects trends in overweight and obesity of the population.	Straight-forward in evaluating the current status and in following trends based on available national data.

Background

Overweight and obesity are known risk factors for several non-communicable diseases, e.g., cardiovascular disease and type 2 diabetes. In Sweden, half of the adult population is overweight or obese and the prevalence is increasing (The Public Health Agency of Sweden, 2022e).Overweight and obesity are ranked among the primary causes of healthy years lost in the Swedish population (GBD, 2019).

In previous sustainability frameworks (Fanzo et al., 2021; Hebinck et al., 2021; Bené et al., 2019; Chaudhary et al., 2018), indicators proposed for energy balance, overweight and obesity are primarily based on body measures, such as the BMI (e.g., prevalence of overweight/obesity in adults/children/adolescents) or energy intake levels (e.g., share of population with a balanced energy intake). In this framework energy balance is proposed to be measured by the BMI in the population.

BMI is a body measure expressing the ratio of weight to height. Overweight means a BMI between 25-29.9 and obesity a BMI of 30 or higher. BMI is a commonly used indicator for overweight and obesity that is easy to monitor and interpret. BMI is one of the indicators currently used to measure public health in the Swedish population (The Public Health Agency, 2022d). Recently, the share of the adult population with a BMI above 25 in different population groups was also suggested as an indicator to monitor the sustainability of food consumption in Sweden by the Swedish Food Agency (2021a). However, using BMI as an indicator of energy balance also has some limitations, for example, that it only partly is determined by the energy intake and is affected by several factors (e.g., physical activity, genetics) which are outside the scope of this framework and its focus on the food system. In addition, self-reported body measures are known to suffer from underreporting (Swedish Food Agency, 2021b). Even so, BMI is suggested as the most suitable indicator to measure energy balance in the Swedish population based on the current availability of data.

The self-reported data on prevalence of overweight expressed as the BMI in the adult Swedish population are available and updated every second year (The Public Health Agency of Sweden, 2022c). These data are available for men and women, as well as for different education levels. For children and adolescents, the data for BMI are available from a survey performed every fourth year since 1985/86, targeting boys and girls in the ages 11, 13 and 15 years providing self-reported data on length and body weight (The Public Health Agency of Sweden, 2019). The available data on the BMI of the Swedish population are based on self-reported data, which negatively affects the reliability. In the future, it would be desirable to collect objectively measured data to monitor the body weight of the Swedish population (SFA, 2021a).To capture risk groups in the population, the indicator should preferably measure the BMI for different population groups by gender, age and socioeconomic characteristics (SFA, 2021a).

In addition to BMI, data to monitor the energy intake and supply of the Swedish population are available from the Swedish Food Agency via the national dietary surveys (performed every ten years) (SFA, 2012; SFA 2018) and from the Swedish Board of Agriculture (updated on yearly basis). Both data sources have some drawbacks, which limit their usefulness as indicators for energy balance. Self-reported energy intake data from dietary surveys are known to suffer greatly from underreporting, especially among adults, and are therefore not considered as a reliable source of data in this framework. The per capita supply data do not provide information on what is actually eaten, hide information on differences between population groups and are not applicable for benchmarking against the reference values for energy intake. Therefore, these data are not considered suitable to monitor the energy balance of individuals or population groups but may be useful to provide an indication of the national trend of per capita energy levels available.

The Nordic Nutrition Recommendations (NCM, 2014) provide reference values for the recommended energy intake (MJ/d) specified for men and women with a normal BMI and two levels of physical activity. The reference values for adults are provided for three specific age groups and are also available for children between 0-2 years of age, and in different age groups between 2-17 years old. Official targets useful to benchmark energy balance on a population level are not established. However, the mean energy requirement in the total Swedish population has been estimated to be 9.7 MJ per day (SFA, 2022c). The reference values for energy intake from the Nordic Nutrition Recommendations are useful to evaluate the energy intake based on actual intake levels and are therefore not applicable for benchmarking against the energy supply e.g., provided by the Swedish Board of Agriculture. A report from the Swedish Food Agency (SFA, 2021a) recently suggested national indicators and goals for overconsumption of energy and food. The proposed goal for 2030 was a per capita daily energy supply of 12 MJ (2870 kcal) based on direct consumption data from the Swedish Board of Agriculture. The proposed goal for the energy supply includes food that is wasted and has a margin to allow for a potential increase of energy demand due to unpredicted food security crisis and/or increase of physical activity in the Swedish population and therefore does not relate to the reference values for energy intake. The suggested indicator and goal are useful to monitor the energy supply in the population but are not suitable to use as a target for the energy balance in the population.

1.2 Theme: Food safety

Food safety, i.e., the handling, preparation and storage of food that prevent foodborne illnesses is crucial to human health. Food contamination may occur in any of the stages between production and consumption, and includes physical, chemical and biological contamination. Globally, bacterial contamination is the most common cause of foodborne illness. The overuse of antibiotics in livestock production is related to food safety since it leads to antimicrobial resistance, which lately has emerged as a global threat to human health.

1.2.1 Burden of foodborne illness

Territorial-based indicator(s):

NA

Consumption-based indicator(s):

National number of clinical reported cases of foodborne illnesses expressed per year and number of individuals

Description: The indicator captures the burden of foodborne illnesses expressed as number of clinical reported cases per year.

Indicator:	National number of clinical reported cases of foodborne illnesses expressed per year and number of individuals
Indicator label:	T-1.2.1a
Type according to DPSIR:	S
Target:	Swedish Food Agency has a general goal of keeping food safe (SFA, 2021a) No existing national quantitative target exist for foodborne illnesses. National targets exist to reduce foodborne illnesses and health effects from environmental pollution National targets also exist for specific foodborne illnesses e.g., National incidence of human cases of Salmonella should decrease compared to the current level (National Board of Health and Welfare, 2013) National incidence of infection with VTEC in humans should show a clear downward trend (National Board of Health and Welfare, 2014) SDG Target 3.9: Mortality from environmental pollution: Reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination SDG Target **3.3: By 2030 end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases.**
Data source:	The Swedish Food Agency estimates the national disease burden caused by the most common microorganisms spread via food based on clinically reported cases on yearly basis (SFA, 2019) National statistics of disease burden (The Public Health Agency of Sweden, 2022d)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Suggested as a relevant indicator in previous sustainability frameworks. Foodborne illness is a global problem affecting 1 in 10 people worldwide	Self-reported cases of foodborne illnesses are known to greatly underestimate the true number of cases. Clinical reported cases of foodborne illness is suggested as a more reliable source of data for quantitative	Quantitative indicator. Easy and intuitive to interpret.	Useful to evaluate the current status and follow trends based on available national data. No official target to evaluate current performance and development.

	measures and following trends. National data on clinical reported cases of foodborne illness are provided on a yearly basis. Cases of foodborne illness do not capture long-term health effects associated to e.g., dioxins and heavy metals.		

Background

The burden of foodborne illness is the indicator most commonly suggested to measure food safety in previous sustainability frameworks (Fanzo et al., 2021; Hebinck et al., 2021; Bené et al., 2019; Chaudhary, Gustafson and Mathys, 2018). Indicators for foodborne illness can also be related to the prevalence or numbers of specific pathogens or to human cases of foodborne illnesses. Other indicators proposed focus on countries' abilities to ensure the safety and health of food (e.g., Food Safety Score:Chaudhary, Gustafson and Mathys, 2018) by exploring structural elements of food safety (e.g., share of population with access to potable water).

Foodborne illness refers to the toxicity or infections caused by bacteria, viruses, parasites, molds or chemical substances entering the body through contaminated food or water (Hebinck et al., 2021) and include a wide range of diseases from diarrhea to cancers. Foodborne illnesses affect one in ten people worldwide every year and is a growing public health problem (WHO, 2022a). While foodborne illness is a global problem its burden primarily affects infants, children and elderly, especially in low- and middle-income countries (WHO, 2019, 2022a). In Europe, foodborne illnesses transmitted by animals (e.g., salmonellosis and campylobacteriosis) or animal parasites, antimicrobial resistance (see below) and various chemical hazards (e.g., persistent organic pollutants, acrylamide, pesticides and dioxin) are examples of public health risks (WHO, 2019).In Sweden, microbial hazards pose the greatest public health risk causing acute illness whereas chemical hazards are mainly related to long-term health effects (SFA, 2021d).

In Sweden the Swedish Food Agency handles data on foodborne illnesses. A report on the national reported suspected cases of foodborne illness has been published on yearly basis since 2003 (SFA, 2021b). The report provides information on the number of reported cases (suspected and confirmed) and the number of disease cases. Information is also available on the underlying cause, which food the case was associated to and which period of the year the case was reported. The quality of data based on self-reported cases of foodborne illness are known to be hampered by under-ascertainment and underreporting and are therefore not well suited for quantitative measures or to follow trends. For these purposes, cases of foodborne illness based on clinical records is a more reliable source of data. The Swedish Food Agency estimates the national disease burden caused by the most common microorganisms spread via food based on clinical reported cases (SFA, 2019). The reported cases are used to provide national statistics of the disease burden that are updated on a yearly basis (The Public Health Agency of Sweden, 2022d).In this framework, these data are suggested as the most suitable data to measure the foodborne illnesses in Sweden. To allow for comparisons with countries that differ in population size it is suggested that the number of cases is expressed per year and the number of individuals.

The cases on foodborne illness primarily capture illness caused directly from food intake (short-term effects). Other indicators may therefore be needed to capture the potential long-term health effects e.g., from chemical hazards, viruses and bacteria. However, linking long-term health effects to particular substances is difficult as the clinical effects often occur long after exposure and may depend on many different factors. The data to monitor intake from chemical hazards are available from the Swedish Food Agency through various surveys. The environmental toxins in the blood and mothers' milk and the share of the population using safe water are other indicators listed in the Swedish Agenda 2030 indicator list.

To strengthen countries' capacities to assess the burden of foodborne illness, the WHO proposed a method to quantify the foodborne disease incidence, mortality and disease burden in terms of disability-adjusted life years (DALYs) (WHO, 2015).This indicator includes the burden of foodborne disease based on over 30 hazards affecting more than 30 diseases. Within the WHO initiative, tools and protocols were developed to facilitate national studies of the burden of foodborne illness. According to Hebinck et al. (2021), a foodborne disease burden database is under development by the WHO which may be an additional source of data. The WHO indicator is not suggested for use in this framework as it includes several hazards that are important health risks mainly in low-income regions of the world but not as relevant for Swedish conditions. Several countries, e.g., Denmark and the Netherlands, produce data on the DALYs related to foodborne hazards on a yearly basis (Pires et al., 2021). The burden of disease expressed as the DALYs has also been calculated for the most common foodborne micro-organisms in outbreaks in Sweden for the period 2013-2017 by the Swedish Food Agency (2019). However, the DALYs are not used for the yearly reporting of foodborne illness in Sweden but could be explored as a possible future alternative indicator.

The Swedish Food Agency has an overall goal of keeping food safe with specific targets to ensure safe drinking water and reducing foodborne illness and health effects from environmental pollution e.g., chemical hazards (SFA, 2022d). In addition, national targets exist for specific foodborne illnesses. However, no quantitative national targets exist specifically for foodborne illness (SFA, 2021d). In previous sustainability frameworks, goals for food safety are most often set for prevalence of specific pathogenic micro-organisms or targets for the recorded cases of a specific foodborne disease (Hebinck et al., 2021). The official targets for health risks due to chemical hazards in food set on a population level are not available in Sweden (SFA, 2021d). However, per capita intake levels can be evaluated over time and compared against health-based guidance values (e.g., tolerable weekly intake) proposed by the European Food Safety Authority (EFSA). To minimize the health risk of specific chemicals, a safety margin should be kept between the levels of exposure in the population and the doses that could pose a health risk. At an international level, the SDG target 3.9 focusing on mortality from environmental pollution expresses an overall goal to reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination. Furthermore, the SDG target 3.3 expresses a goal to end **the epidemics of several food-borne illnesses by 2030**.

1.2.2 Antimicrobial resistance

Microbes include bacteria, fungi, viruses and parasites. Antimicrobials are a broad range of products that act on microbes, including antibiotics that are used to treat bacterial infections. Antimicrobial resistance (AMR) occurs naturally in microbes, but develops faster when antimicrobial pharmaceuticals are used. AMR makes such pharmaceuticals ineffective for the treatment of infections, thereby threatening public health as well as animal health, welfare and productivity. At large, the more antimicrobials we use, the worse does the emergence of AMR get. Thus, it is important to use these pharmaceuticals as restrictive as possible.

Territorial-based indicator(s):

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

Description: The indicator describes the sales of antibiotics in veterinary medicine.

Indicator	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.
Indicator label:	T-1.2.2a
Type according to DPSIR:	P
Target:	The national goal for the number of antibiotics treatments in humans, set by Strama - the Swedish strategic programme against antibiotic resistance, is less than 250 prescriptions/1000 inhabitants and year (www.strama.se). There is no national goal for the number of treatments in animals. In Sweden, sale of antibiotics to animals used for food production is a national indicator (indicator 2.4.4 and 12.1.3) for SDG2 (zero hunger) and SDG12 (responsible consumption and production), although the UN's SDGs do not specifically include AMR. WHO, FAO (Food and Agriculture Organization of the United Nations) and World Organisation for Animal Health (formerly OIE) all have global action plans or strategies against AMR, but no specific goals. The EU commission will "take action to reduce overall EU sales of antimicrobials for farmed animals and in aquaculture by 50% by 2030" (Farm to Fork Strategy, 2020). The need to reduce the use of antibiotics by choosing appropriate kinds of antibiotics and only for the treatment of sick animals is agreed on. The goal is a prudent, medically rational use of antibiotics.

Data source:	The Swedish Board of Agriculture: https://jordbruksverket.se/download/18.48cc999c17f29af389def6b/1651577852975/Forsaljning-av-djurlakemedel-2021-tga.pdf The National Veterinary Institute: https://www.sva.se/media/8da965da486b11e/swedres_svarm_2021.pdf

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Antimicrobial resistance is regarded as one of the largest threats to future human health, and to sustainable food systems.	There are scientific evidence for associations between the use of antibiotics in animal production and antimicrobial resistance.	Sold amounts of antibiotics is a proxy for the use of antibiotics that is a quantitative indicator easy and intuitive to interpret.	Amount of sold antibiotics is already used as a national indicator for SDG2 and SDG12.

Consumption-based indicator(s)

Antimicrobial resistance value for imported foods to supply Swedish diets

Description: The indicator is based on the sales of antibiotics in veterinary medicine for countries and species where such data are available and on a qualitative judgement based on the laws against misuse of antibiotics in animal production when data on the sales are not available. The indicator reflects the use of antibiotics for a species in a country and the amount of imported food products of that species from that country.

Indicator:	*If data on the sales of antibiotics are available for the country* Sales of antibiotics for different animal species used for food production, in mg/PCU, will be used for species and countries for the few countries where these data are available. The PCU (population corrected unit) is a measure of the use standardized for the total amount (biomass) of animals within each country. For countries where only the total sales for animals (not specified for species) are available, an expert opinion based on general knowledge about the use of antibiotics for different species will be used to estimate the distribution of the total amount over different species in each country. *If data on the sales of antibiotics are missing for the country* The existence of national laws regulating the use of antibiotics for animals will be used as an indicator for countries not reporting sales of antibiotics. Such laws can ban or regulate:

	• use of Critically Important Antimicrobials – or other antimicrobials – for human medicine (CIA) in veterinary medicine • use of antimicrobials as feed additives for growth promotion • regular use of antimicrobials for disease prevention The judgement will take law compliance into account, using the Rule of Law Index from the World Justice Project. The qualitative judgement of laws will be translated into judgement points for each species using the range of sales of antibiotics in reporting countries (see above) as a reference scale. Thus, the judgement points and sales of antibiotics can be used for the same purpose in this framework. *Estimation of AMR indicator value* The AMR (antimicrobial resistance) indicator value for animal-source food originating from a given species in a given country will be estimated based on the amount of imported animal-source products and sales of antibiotics in mg/PCU or the amount of imported animal-source products and qualitative judgment points.
Indicator label:	C – 1.2.2c
Type according to DPSIR:	P
Target:	WHO, FAO and OIE all have global action plans against antimicrobial resistance, but not specific goals. The EU commission will "take action to reduce overall EU sales of antimicrobials for farmed animals and in aquaculture by 50% by 2030" (European Commission, 2020b). The need to reduce the use of antibiotics by choosing the appropriate kinds of antibiotics and only for the treatment of sick animals is agreed on. The goal is a prudent, medically rational the use of antibiotics.
Data source:	ESVAC interactive database https://esvacbi.ema.europa.eu/analytics/saw.dll?PortalPages Sales of veterinary antimicrobial agents. ESVAC report 2021 https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-31-european-countries-2019-2020-trends-2010-2020-eleventh_en.pdf Hu and Cowling, (2020) Rabello *et al.*, (2020) Wallinga *et al.*, (2022) Tiseo *et al.*, (2020)

	Regulation and reporting: Maron et al. Globalization and Health 2013, 9:48. http://www.globalizationandhealth.com/content/9/1/48 OIE Annual report on antimicrobial agents intended for use in animals. https://www.woah.org/app/uploads/2021/03/annual-report-amr-3.pdf Law compliance: The World Justice Project (Rule of Law Index). https://worldjusticeproject.org/rule-of-law-index/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Antimicrobial resistance is regarded as one of the largest threats to future human health, and to sustainable food systems.	There are scientific proves for the associations between the use of antibiotics in animal production and antimicrobial resistance. The qualitative judgement points based on laws and law compliance can be questioned, and this estimation must therefore be reported with full transparence for each country and species.	Sold amounts of antibiotics is a proxy for the use of antibiotics that is a quantitative indicator easy and intuitive to interpret. Whether a country has a law regulating the use of antibiotics in veterinary medicine and as growth promotors or not is easy to interpret.	Data on the sold amounts of antibiotics aimed for different animal species are difficult to find for most countries. For several countries, even data on the total amount sold for animals are missing. Data on laws regulating the use of antibiotics are available for many countries (in theory). The usefulness of the indicators based on laws is restricted by variation in law compliance. Law compliance can be taken into account by adjusting the evaluation based on a law compliance index.

Background

All use of antimicrobials for humans and animals increase the risk of microbes developing resistance to antimicrobials. The fight between antimicrobials and microbes takes place in healthy and sick humans and animals and in the environment, e.g. in manure from treated animals. For example, when manure is used to fertilize the soil, bacteria in the manure that have achieved resistance due to mutations can transfer these resistance genes to other species of bacteria in the soil. One Health is a concept describing how the health of people, animals and our shared environment is closely connected. Antimicrobial resistance (AMR) is a core One Health issue. It should be handled with a One Health approach which means that joint efforts of different disciplines work together to provide solutions for human, animal and environmental health. Sick animals have a low welfare and they increase climate impact and other negative environmental effects of animal production by decreased yields and increased consumption of natural resources per amount of food product. The EU's Farm to Fork strategy (2020)(European Commission, 2020b) states that "Antimicrobial resistance (AMR) linked to the excessive and inappropriate use of antimicrobials in animal and human healthcare leads to an estimated 33,000 human deaths in the EU/EEA every year."

Antibiotics are needed in both human and veterinary medicine to cure infections, enable advanced surgery, transplants, cancer treatments etc. In total, 62.3 tons of antibiotics were sold in Sweden during 2021, of which 14 % was sold for animals (including sport and companion animals). Expressed as the active substance per estimated weight of body mass, 13 % were sold for animals (Swedres-Svarm, 2021). The animals that need antibiotics should be treated with the right substance in the right dose during the right treatment period. A completely antibiotic-free animal husbandry would be unacceptable from an animal welfare perspective. Thus, the goal is not a zero use of antibiotics, but a prudent, medically rational use of antibiotics. One example of a non-prudent use is when all piglets are treated with antibiotics at weaning, as a regular prevention. It is important to prevent infectious diseases by good management routines (e.g. cleaning of stables between animal batches) and breeding (e.g. selection for increased disease resistance), because healthy animals do not need antibiotics. In some production systems in some countries, antibiotics called 'growth promotors' are given to all animals during certain periods of their life. This is done in order to increase production levels. Sweden was the first country in the world that banned antibiotics as growth promotors (1986) and it has been forbidden in the EU since 2006. Since January 2022, use of antibiotics as regular disease prevention is also prohibited in the EU.

The indicators in this framework reflect the use of antibiotics as an indicator of healthy, adequate and safe diets although the food products from animals treated with antibiotics are not unhealthy in themselves. AMR is an *indirect* food safety aspect related to the use of antibiotics in the production of animal-source food. The amounts of antibiotics actually used for animals are not known, but the sales of antibiotics are reported. For many countries, the total amount of antibiotics sold for animals is available, and it can be used as an indicator describing animal production in different countries. The data on the amount (and type) of antibiotics sold for cattle, sheep, goats, pigs, poultry and fish are available for Sweden, but the distribution of antibiotics sold to different species or production systems in other countries are difficult to find. An alternative indicator for production could be the number of reported cases of failed treatments due to AMR from animal and or human health care data bases, or prevalence of AMR organisms from scientific studies of e.g. samples from farmers, animals, manure and soil. We have chosen the indicator based on the sales of antibiotics for this framework since AMR is not only an existing issue today but also (and even more) a future issue; the amounts of antibiotics used in animal production today influences the magnitude of the future AMR threat.

Since the sales of antibiotics are not reported in all countries (data are missing e.g. from several countries on the American continents), alternative indicators are needed for consumption. The fact that a country does not report its sales of antibiotics can be used as an indicator in itself; a country not reporting and sharing data on the sales of antibiotics indicates that the animal production in that country is less sustainable. The presence of laws restricting the use of antibiotics in veterinary medicine and banning the use of antibiotics for regular prevention and as growth promotors is an indicator that can be used for the imported animal-source food from different countries.

1.2 Theme: Ensure food availability

The theme focuses on ensuring that sufficient food and a variety of nutrients are available for the Swedish population, as well as the extent to which Swedish agriculture contribute to global food supply. This is measured by what is produced in Sweden in terms of i) total kcal produced, protein, fat, and fruit and vegetables available, both of the fields and what reaches the final consumer, and ii) trade channels which relates to how Sweden can either support other countries if facing food shortages, or import food if there is risk of food insecurity within the country, and last iii) stable commodity prices for consumers such that households can plan and afford nutritious food. In relation to Hebinck et al. (2021) these themes cover increased food security and nutrition, and the right to food.1.3.1. Production of food

1.3.1. Food available from Swedish production

Territorial-based indicator(s):

Domestically produced nutrients of the fields, and domestically produced fruit & vegetables in relation to the population need

Description: Indicators measuring the amount of energy, protein, fat, and fruits and vegetables produced in Sweden. Domestically produced volumes of these indicates the extent to which the current production is sufficient to ensure the domestic needs of nutrients.

Indicator	Domestically produced nutrients of the fields, and domestically produced fruit & vegetables in relation to the population need.
Indicator label:	T-1.3.1a
Type according to DPSIR:	S
Target:	Increased food production (Regeringskansliet, 2015)
Data source:	The Swedish Board of Agriculture: https://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets%20statistikdatabas/?rxid=5adf4929-f548-4f27-9bc9-78e127837625 The Swedish Food Agency: https://www.livsmedelsverket.se/livsmedel-och-innehall/naringsamne/livsmedelsdatabasen

Indicator justification:

Relevant:	High-quality:	Interpretable:	Useful:
The total amount of nutrients and fruit and vegetables produced of the fields' show how many people can be fed from the fields, if what is produced in the primary sector is used for food, and not e.g. for feed. The indicator is likely relevant mostly to highlight vulnerability in relation to a crisis, if Sweden would need to feed its own population entirely by itself.	What is produced in Sweden in terms of kcal, protein, fats, and fruit and vegetables is easily calculated during times of normality. Production information is accessible from the Swedish Board of Agriculture, and nutritional content from the Swedish Food Agency.	Easily interpreted. The indicator highlights if there is enough available nutrients produced in Sweden to feed the population.	A large share of the total amount of produced nutrients is used for feed (and biofuel). As such, a share of produced nutrients is lost. The indicator shows how many people can potentially be fed if all that is produced from the fields is used for human consumption.

Domestically produced nutrients and fruit and vegetables that reach the consumer, in relation to population need

Description: Indicators measuring the amount of energy, protein, fat, and fruits and vegetables produced in Sweden, and which finally reach the consumers through consumption goods of Swedish origin. Domestically produced volumes of these indicates the extent to which the current production is sufficient to ensure the domestic needs of nutrients, at current diets.

Indicator	Domestically produced nutrients and fruit and vegetables that reach the consumer, in relation to the population need.
Indicator label:	T-1.3.1b
Type according to DPSIR:	S
Target:	Increased food production (Regeringskansliet, 2015)
Data source:	The Swedish Board of Agriculture: https://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets%20statistikdatabas/?rxid=5adf4929-f548-4f27-9bc9-78e127837625 The Swedish Food Agency: https://www.livsmedelsverket.se/livsmedel-och-innehall/naringsamne/livsmedelsdatabasen

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The total amount of nutrients and fruits and vegetables delivered from Swedish production to the final consumer, highlights how many can be fed when primary products are transformed to final products. The indicator thus includes losses when e.g. grain is used for feed.	What is produced in Sweden in terms of kcal, protein, total fat, and fruit and vegetables is easily calculated during times of normality. Production information is accessible from the Swedish Board of Agriculture, and nutritional content from the Swedish Food Agency. Final supply available for consumption is	In essence, the indicator shows how many people can be fed from the agricultural land that is used in Sweden, given value added.	It is useful to know how many people can be fed from what is produced, after value added.

	available from the Statistical database provided by the Board of Agriculture.		

Background

We suggest that total amount of kcal, protein, fat, and fruit and vegetables is measured from the two indicators. The nutrients are included in the indicator framework as the available amount per ton food, and fruit and vegetables as tons of food. The first indicator measures the potential number of people fed by what is primarily produced in Sweden, and the second how many can be fed today given dietary patterns that include value added and processing. In both cases taking dietary recommendation into consideration as a basis for the calculations. The indicators can also be down scaled to number of people fed per hectare as suggested by e.g. (Cassidy *et al.*, 2013)

The included nutrients, and fruit & vegetables are suggested by e.g. Kummu *et al.*, (2020) as a measure of food supply diversity, which is an additional aspect for sustainable production and supply. Our two indicators thus also highlight how dependent Sweden is on trade to supply diverse food to the population. Sweden is a country with large import levels of food. As an example, only around 20% of the fruit and vegetables consumed are domestically produced, and 55-60% of the beef (Swedish Board of Agriculture, 2021). In addition, Sweden is a country with high consumption levels of meat and dairy, and much of what comes from the agricultural fields is used as feed, reducing available nutrients reaching the final consumer (Swedish Board of Agriculture, 2014, (Swedish Board of Agriculture, 2022). Combining the two included measures show how many additional people could be sustained by domestically produced food if e.g. grain and grain legumes was not used for feed (and bioenergy).

The four indicators can be calculated from information about production and consumption of different types of food commodities which is available from the Swedish Board of Agriculture and the nutritional content found at the Swedish Food Agency.

Consumption-based indicator(s):

NA

1.3.2. Trade possibilities of food products

Territorial indicator:

NA

Consumption indicator:

Diversity of trading connections – Shannon diversity index

Description: The indicator assesses the interconnection between the Swedish food system and food systems abroad through trading.

Indicator	Diversity of trading connections – Shannon diversity index.
Indicator label:	C-1.3.2a
Type according to DPSIR:	S
Target:	Several equally large connections is preferable to a few dominating partners, se e.g Kummu *et al.*, 2020
Data source:	Trade partners for food products can be accessed via FAOSTAT : https://www.fao.org/faostat/en/#data

Relevant:	High-quality:	Interpretable:	Useful:
Trade is important for upholding food security such that food can be transported to where it is needed. The risk of food shortages increases if a country is highly depending on only domestic production, and on food from only a few major trade partners. If a country instead has many equally large partners, the possibility of imports in case of internal shocks, increases. In addition, a country with excess production can	Trading partners and the value of trade are available from the Swedish Board of Agriculture and FAOSTAT	A low value on the Shannon index indicates a lower spread of trading partners such that a country is more at risk, and a high value indicates a larger spread of partners such that a country has a lower risk of facing trading difficulties.	Yes, trade is important for food availability and the risk of trade channels closing increases the risk of food shortages in the event of crisis.

support others where shortages might appear if trade channels are already established.			

Background

Open trade channels are central for stability in food availability, at least if there are not sufficient storage possibilities which can cover food losses in case of domestic production shocks. The number and size of trading partners are also important. If trade is dominated by imports from one large source, the risk of food insecurity increases in case of shocks to that country (see e.g. Kummu et al., 2020). A good example is the war in Ukraine and the reduced exports from Ukraine to east Africa, where the risk of food shortages increased due to the domination of Ukraine as a food supplier in that region. If a country has several trading partners, of similar size, the food security risk decreases. The indicator is constructed such that few or several small trading partners give low scores, and that several large partners give a higher score.

1.3.3 Stable commodity prices

Territorial-based indicator(s):

Not applicable

Consumption-based indicator(s):

KPI-J/wage increases, where KPI-J is the consumer price index for agricultural products.

Description: The indicator is a consumption food price index which considers the increases in food prices in relation to the increases in wages.

Indicator:	KPI-J / wage increases (index), where KPI-J is the consumer price index for agricultural products.
Indicator label:	C – 1.3.3a
Type according to DPSIR:	S
Official target:	Sweden has an overall inflation target of 2%/year, though no target on real purchasing possibilities. Should be less than or close to 1 for reduced insecurity

Data source:	Swedish Board of Agriculture – official statistics : https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2022-05-16-prisindex-och-priser-pa-livsmedelsomradet--ars--och-manadsstatistik---202203 and the Swedish National Mediation Office: https://www.mi.se/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Consumer price index for agricultural products (KPI-J) in relation to wage increase clearly show how food prices fluctuate in relation to income levels.	KPI-J is measured by the Swedish Board of Agriculture and presented once per year. Wage increases are presented each year after all salary negotiations between employers and unions are finished.	Easily interpretable. The indicator highlights if food prices are increasing more rapidly than income level. If they are, household expenditure possibilities decrease and cause insecurity.	Useful to evaluate uncertainty in household purchasing possibilities, unrelated to external factors such as energy prices and interest rates which also impacts purchasing possibilities.

Background

The KPI-J is an adaptation of KPI, the main overall consumer price index, where the Swedish Board of Agriculture measures price changes of only agricultural products (gardening products excluded) available on the Swedish market.

Relating the KPI-J to wage increases shows the changes in expenditure possibilities for Swedish households when food prices fluctuate. If the ratio is close to one there is little fluctuation and insecurity for households. Households in general spend a small share of their income on food (Statistics Sweden, 2023) and one could argue there is room for fluctuation and an increase in food prices. However, a small share of income on food does not necessarily mean that consumers can spend more on food – at least not in the short-term. Food consumers participate on other markets, such as markets for housing and energy, which means that their total expenditure – at least in the short-term – may not be easily re-distributed. For example, the expenditure on housing (and now energy) has increased rapidly over the past few years leaving little room for increases in other types of consumption. Many households could thus be negatively affected by instability in food prices.

Commonly, stable commodity prices are measured by the share of disposable income used on food. However, we argue that it is more accurate to measure the real price changes (price changes/ wage increase) as the share spent on food is affected by for example housing (via interest rates) and electricity prices. For households with small marginal, what is spent on food might be reduced in favor of housing, and families are forced to turn to charity. By measuring the real price changes, sectors outside of the food system are omitted to the extent possible from the analysis.

2. CEILING: Just, ethical and equitable food systems

Just, ethical and equitable food systems are central to a sustainable system, refer to *how* activities within the food system are organized and can be said to generally be about the fairness of the food system. Previous food system frameworks include various dimensions and themes which can be said to be related to the fairness of the food system. These include poverty and income distribution, employment, social protection, rights, gender equality, affordability, working conditions and community rights and access to knowledge and technology (e.g. Fanzo *et al.,* 2021; Béné *et al.,* 2019;). We use the overall label *Just, ethical and equitable food systems* from Hebinck et al. (2021) for this part of the Food System Sustainability House. We use four dimensions in devising indicators for the Swedish food system:

- *Market power* refers to the extent to which actors in the food value chain can exercise market power on each other and use their positions to affect prices throughout the system.
- *Good jobs* refers to the overall working conditions for food system workers.
- *Recreational values* to refer to the cultural and aesthetical values from the food system.
- *Rights of indigenous people* which refers to rights of having access to traditional foods.
- *Animal welfare* refers to the overall-welfare of the animals used to produce food.

2.1. Theme: Market power

2.1.1 Extent of market concentration

Territorial-based indicator(s):

Learner index

Description: Market concentration assesses the degree to which actors in the food system can exercise market power on other actors in the system. Here we propose to measure it through the Learner Index.

Indicator:	Learner index
Indicator label:	T-2.1.1a
Type according to DPSIR:	S

Target:	0 – indicating perfect competition (Unless functioning cooperatives)
Data source:	An index can be estimated based on data from Statistics Sweden's business registrar: https://www.scb.se/vara-tjanster/bestall-data-och-statistik/foretagsregistret/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Monopoly and monopsony structures that arise from cooperation between firms rather than from "natural causes" such as high start-up or fixed costs, can decrease overall welfare. Monopoly and monopsony structures in the food value chain imply uneven distribution of the overall welfare produced by the economic activities that takes place in the value chain.	Calculating the Learner Index is straightforward given access to appropriate data. The Swedish competition authority evaluates the market concentration and competition possibilities in the food system.	A high share of market power can imply inefficient pricing on the market.	Considering the market power exercised in the food value chain is highly relevant for understanding if and to what extent market concentration becomes a problem for producers and consumers.

Background

Efficient market structures would be where actors can only exercise little or, preferably, no market power over each other. In a situation where firms in the food value chain exercise market power, two outcomes can happen. First, if the buyers of agricultural and/or food produce function as monopsonies, they can negotiate prices that are below their marginal benefit of the produce. In this situation, the producers will suffer from prices that are lower than they could obtain in a situation with less or no market power, where buyers would pay prices that are closer to or equal to their marginal benefit of the products. Second, if the sellers of products exercise market power they can charge prices of their products that are above their marginal price of production. This means that the buyers will suffer from prices that are higher than what would be charged in a situation with less or no market power.

Market concentration can also have other impacts, such as impact of type of innovations that are pushed forward. See Clapp, (2021).

The food value chain can typically be described as having an “hour-glass” shape, with several agricultural producers at one end, a few firms in the processing and retail part of the chain and several consumers at the other end of the chain. In such a structure, a situation with only one major buyer of agricultural produce, it is possible that the buyer can exercise market power to decrease the payments to agricultural producers. Similarly, a situation with only one major seller of products, for example one dominant retailer, contributes to increasing the consumer prices by increased margins and by controlling the availability.

The Swedish food system includes major actors with large market shares, affecting both consumption and production. In a sustainability assessment of the food system, the indicator capturing market power thus needs to be measured at several stages of the system. The market situation of the Swedish food value chain was recently assessed by the Swedish Competition Authority, which concluded that the competition is well-functioning (Swedish Competition Authority, 2018). Still, the method applied - round-table discussions that were used to analyze the situation - may have affected the outcome.

Cooperative firms, formed by producers or consumers can have the potential to reduce the negative impact of the market power in the food value chain. However, this will only be the case if the cooperatives do not exercise their market power by acting on their monopoly and monopsony power.

Market power exercised on consumers

To assess the market power that is exercised on consumers, one can assess the market power of the retailers by assessing their Learner Index, which measures the difference between the price levels faced by consumers and the marginal costs faced by the sellers to the consumers, in relation to the price levels faced by consumers. A value close to 1 indicates high market power, while a value close to 0 indicates little or negligible market power.

Market power exercised on producers

To assess the market power that is exercised on producers, especially the agricultural producers, one can assess the market power of the buyers of agricultural produce by assessing their Learner Index. In this case, the Learner Index takes into consideration the difference between the marginal benefits of buyers and the marginal cost of producers. Again, a value close to 1 indicates high market power, whereas a value close to 0 indicates little or negligible market power.

2.2 Theme: Safe jobs

Territorial-based indicator(s):

2.2.1 Working conditions in the food system

Sick leave due to occupational accident or disease, number of days during a specified time period.

Description: Working conditions by workers in the food system.

Indicator:	Sick leave due to occupational accident or disease, number of days during a specified time period
Indicator label:	T-2.2.1a
Type according to DPSIR:	S
Target:	Not available
Data source:	Statistics Sweden: https://www.scb.se/hitta-statistik/temaomraden/jamstalldhet/ekonomisk-jamstalldhet/sjukdom-och-sjukfranvaro/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Safe and secure working environments are one of the essential parts of the Sustainable development Goal 8: Decent Work and Economic Growth (Eurostat, 2022	Sick leave longer than one week can only occur after ordination of a medical doctor. Reasons for sick leave are reported.	Easy to interpret (number of days during a specific time period that workers are on sick leave due to occupational accidence or disease). Increasing or decreasing has a clear meaning, where less is better than more. Can be followed over time.	Heavily influenced by the actions taken by the food sector to reduce the risk of workers being in occupational accident and/or developing work related disease.

Incidence of unreported salaries in the food system, divided by the total number of workers.

Description: The indicator measure the incidence of unreported salaries in the food system, in relation to total number of workers.

Indicator:	Incidence of unreported salaries in the food system, divided by the total number of workers.
Indicator label:	T-2.2.1b
Type according to DPSIR:	S
Target:	Not available
Data source:	The Swedish Tax Authority: https://www.skatteverket.se/privat.4.76a43be412206334b89800052864.html

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Reported salaries imply that the companies pay tax and social fees related to salaries. These also imply that the workers can enjoy the social benefits that are connected to salaries in Sweden. Properly reported salaries also safeguard against unreasonably low salaries.	The Swedish Tax Authority investigates the occurrence of unreported salaries using random controls in high-risk industries.	Easy to interpret. Number of reported incidences in relation to the total number of workers has a clear meaning. Furthermore, increasing or decreasing has a clear meaning, where less is better than more. Can be followed over time.	Strongly related to the workers possibilities to enjoy social benefits connected to being employed.

Description: The indicator measures reports of serious personal injuries, incidents and deaths.

Indicator:	Report of serious personal injuries, serious incidents and deaths
Indicator label:	T-2.2.1b
Type according to DPSIR:	
Target:	Not available
Data source:	The Swedish Work Environment Authority, outcome of random controls: https://www.av.se/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Safe and secure working environments are one of the essential parts of the Sustainable development Goal 8: Decent Work and Economic Growth.	Employers are requested to report incidence at work which means personal injuries, serious incidents or deaths according to the Swedish Work Environment Authority.	Easy to interpret. Number of reported incidences has a clear meaning. Furthermore, increasing or decreasing has a clear meaning, where less is better than more. Can be followed over time.	Heavily influenced by the actions taken by the food sector to reduce the risk of workers being in occupational accident or suffer from occupational injury.

Consumption-based indicator(s):

Share of sales of food products with fair trade certification, from fair trade eligible countries.

Description: The indicator measures the share of sales of food products that are certified according to fair trade, in relation to total sales of food products with origin from fair trade eligible countries.

Indicator:	Share of sales of food products with fair trade certification, from fair trade eligible countries.
Indicator label:	C-2.2.1c
Type according to DPSIR:	
Target:	Not available
Data source:	Fair trade: https://fairtrade.net

Indicator justification:

Relevant:	High-quality:	Interpretable:	Useful:
Safe and secure working environments are one of the essential parts of the Sustainable development Goal 8: Decent Work and Economic Growth.	Fair trade certified producers with employees are required to comply to Fair trade standards regarding social rights and worker security.	Easy to interpret. Share of sales of food products with fair trade certification has a clear meaning. Furthermore, increasing or decreasing has a clear meaning, where more is better than less. Can be followed over time.	The certification might be time demanding and producers might chose not to certify. There may be decent working conditions also in situations where there is no certification.

Extent of child labour.

Description: The indicator measures the extent of child labour in countries from where Sweden imports food products

Indicator:	Extent of child labour
Indicator label:	C-2.2.1d
Type according to DPSIR:	
Target:	Not available
Data source:	International Labour Organisation (2021)

Relevant:	High-quality:	Interpretable:	Useful:
A sustainable food system cannot use child labour. No use of child labour is essential to achieve both SDG 8 and 16 (International Labour Organization, 2017)	The Internatinal Labour Organization provides estimates on child labour in different countries based on country services.	Easy to interpret. Can be followed over time.	There might be countries without surveys on child labour where imputation methods need to be used.

Background

A *just, ethical and equitable food system* would be a system with fair working conditions (e.g. Hebinck et al. 2021). The working conditions in Sweden are regulated by the work environment legislations which are not unique to the food system. Wages are determined in negotiations between the worker and employer trade unions. Compliance with those general legislations and agreements between labour market partners is expected as a hygiene factor.

To assess working conditions, we focus here on the risk of being in an occupational accident or of developing disease due to conditions at work. These aspects cover many underlying work environment aspects such as safety in managing machinery and equipment and animals, exposure to harmful chemicals and exposure to negative stress, which are all possible to affect by individual employers. To capture more severe incidence of the neglect of work environment conditions, we also focus on the reporting of serious injuries and incidences, which should all be reported to the Swedish work environment authority.

We also focus on the incidence of unreported salaries in relation to the total number of workers. This indicator captures the extent to which there are workers who are not able to enjoy the social benefits of employment and at least to some extent that the wages are reasonable in relation to the qualifications.

Looking at the consumption side, we suggest to use the share of sales from fair trade certificated producers, from sales of countries eligible for fair trade. The producers under fair trade certification who have employees have to guarantee certain standards regarding social rights and worker security. We also suggest to use extent of child labour in imported food products as an indicator of working conditions. Child labour is unacceptable in a sustainable food system. No child labour is essential for both SDG 8 and 16 (International Labour Organization, 2017).

2.3 Theme: Contribution to cultural values

Food patterns and behaviours are heavily influenced by social traditions, cultures, religious beliefs and social norms. Foods are also central to personal identity. The food systems in themselves also form, uphold or deteriorate cultural values and traditions that we find valuable (HLPE, 2017). Hence, cultural values are also an outcome of food systems that we can monitor. There is an extensive literature related to the study of cultural ecosystem services (Cheng et al., 2019; Milcu et al., 2013)). However, cultural values are multifaceted, complex and subjective and do not easily lend themselves to being captured in a limited set of indicators. Here we include a set of indicators related to aesthetic values, cultural heritage and recreational values. These indicators are only relevant on the territorial level. It could potentially be relevant to include consumption side indicators related to the dietary patterns in Sweden. However, it is difficult to establish such values as dietary patterns and behaviours are constantly evolving and highly varying across populations groups. Therefore, in this first version of the framework, we only include territorial-based indicators for this theme.

2.3.1 Attractive landscapes

Territorial-based indicator(s):

Area of pasture (thousands of ha)

Description: An indicator that captures the aesthetics of agricultural landscapes. Area of pasture is used as a proxy for this although it is only a subset of attractive agricultural landscape types and not all pastures have high aesthetic values.

Indicator:	Area of pasture (thousands of ha)
Indicator label:	T-2.3.1a
Type according to DPSIR:	S
Target:	Not available
Data source:	The Swedish Board of Agriculture: https://jordbruksverket.se/e-tjanster-databaser-och-appar/ovriga-e-tjanster-och-databaser/statistikdatabasen

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Landscape aesthetics contribute to human well-being. It is well established that semi-natural grasslands are highly valued nature types for its beauty. How agriculture is performed will affect how landscapes develop and thereby the attractiveness of landscapes.	The area of pasture (betesmark) is measured yearly by the Swedish Board of Agriculture. A large part of this (although not all) can be classified as semi-natural grasslands with high biodiversity values.	Easy to interpret (area of a valuable nature type). Increasing or decreasing area has a clear meaning (more is better). Measured yearly and can be followed over time.	Heavily influenced by policy decisions regarding support for preserving such areas, and by decisions taken by farmers.

Consumption-based indicator(s):

NA

Background

Attractiveness is highly subjective and varies between individuals and cultures. Studies from Sweden however show that people in general appreciate certain types of landscapes; mosaic landscapes, open landscapes, natural pastures, landscape elements such as stone walls and animals in the landscape (Hasund, Kataria and Lagerkvist, 2011; Kumm, 2017). Attractiveness of landscapes is not currently monitored or measured in Sweden. A range of indicators or a composite index would be needed to capture the multiple aspects of attractive aesthetics including for example indicators such as (Karlsson, Tidåker and Röös, 2022):

- 'Landscape variation' defined as the length of edges between different land cover patches represented in the GSD Property Map (block-database from the Swedish Board of Agriculture) divided by the farm's total study area (Karlsson, Tidåker and Röös, 2022). Although the results have been variable and non-linear, the density of the edges between contrasting landscape patches (e.g. field margins and forest edges) is generally also seen as beneficial for aesthetic landscape qualities and related ecosystem services (Dronova, 2017).

- ‘Roadside variation’ defined as the number of land cover patches intersected by or adjacent (within 25 m) to roads and paths (excluding motorways and railways), divided by the total length of roads within the study area (Karlsson, Tidåker and Röös, 2022). Although results have been variable, measures of landscape diversity generally show positive impacts on the perceived landscape beauty and visual quality (Dramstad et al., 2006; Dronova, 2017) and roads and paths are the primary means by which people move through a landscape.
- ‘Accessibility’ defined as the fraction of a landscape within 100 m from roads as an indicator for accessibility (also considering population density).
- ‘No of visitors’ - can be captured by tracking e.g. photos on social media or mobility, using tracking of mobile phones, visits to farm stores etc.

Another possible indicator that would be straight-forward to use is the ‘Area of semi-natural pastures’. The semi-natural pastures are well-known for their aesthetic values and this is already an indicator that is used for the Swedish Environmental Objective “Ett rikt odlingslandskap”[1]. Here in this first version of the framework we use this indicator for simplicity[2]. This indicator could be improved by also considering where these areas are located. They would provide a greater value if they are located so that many people can easily appreciate their beauty, e.g. if they are located in more densely populated areas.

The limitation with this indicator is naturally that it only considers semi-natural pastures. However, there are other landscape types and landscape elements that are important for attractive landscapes (Hasund, Kataria and Lagerkvist, 2011; Kumm, 2017). In addition, elements like stone walls, tree alleys and traditional buildings are considered important parts of landscape heritage. Previously (2007-2013) there were payments within the Rural Development Programme for preserving such elements, a sign that these are valuable to society (Frisk and Stadin, 2016). Therefore, an indicator related to such landscape elements monitored based on schemes used in the previous payment system could be an option. However, it can be discussed whether the causal link between food systems and the preservation of these landscape elements is too weak as many of these elements could be preserved independently of how cropping and livestock systems are managed. The payments from society directly to preserving these landscape elements (like in the previous Rural Development Programme) might be more influential in determining how many of them that are preserved, and such payments are (largely) disconnected from food systems. However, some of these elements are indeed influenced by management practices. For example, in more specialized and intensified production systems, elements like e.g. stone walls are removed in such fields to make the fields more efficient to cultivate.

[1] https://www.sverigesmiljomal.se/miljomalen/ett-rikt-odlingslandskap/betesmarker-och-slatterangar/

[2] In the statistics from the Board of Agriculture the land use type is pasture (betesmark) which includes different types of pastures, varying from those with those with very high biological values to those with low values.

2.3.2. Preservation of food related traditions

Territorial-based indicator(s):

People educate per year in artisan food preparation (no per year)

Description: An indicator capturing how the knowledge in artisan food preparation is upheld. It is measured by the number of people educated per year in such practices.

Indicator:	People educated per year in artisan food preparation (no per year)
Indicator label:	T-2.3.2a
Type according to DPSIR:	S
Target:	Not available
Data source:	Eldrimner: https://www.eldrimner.com/om-eldrimner/31997.hitta_mathantverkare.html

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The extent to which traditional food preparation methods are preserved can be seen as one important outcome of how food systems function. As this knowledge is not acquired neither in homes nor in public schools, it is measured here as the number of people within tertiary levels of education	Should be straight-forward to gather this information as it should be available in (needs to be investigated exactly how)	Number of people educated is a quantitative concept that is easily interpreted.	Outcomes of this indicator can be influenced based on the investment and promotion of these food preparation practices. Also through the extent these foods are used in public meals. Challenging to set a target.

Livestock from threatened breeds kept (no of animal units per year)

Description*:* An indicator to capture the extent to which threatened old livestock breeds are preserved. Measured here by aggregating all animals of these breeds into livestock units.

Indicator:	Livestock from threatened breeds kept (no of animal units per year)
Indicator label:	T-2.3.2b
Type according to DPSIR:	D
Target:	Not available
Data source:	Swedish Board of Agriculture: https://jordbruksverket.se/djur/lantbruksdjur-och-hastar/husdjursraser-och-avelsorganisationer/husdjursraser

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The traditional livestock breeds are part of our cultural heritage.	High-quality statistics on number of animals are kept by the Swedish Board of Agriculture.	Animal units are commonly used to aggregate smaller and larger animals.	Difficult to set target.

Consumption-based indicator(s):

NA

Background

Our cultural heritage is connected to food in relation to food preparation, eating habits and food production including agricultural systems. These cultural values, an output from food systems just like food, are seldom included in food system sustainability assessments. There are a wide range of possible indicators to include. Here, however, we suggest just two examples of possible indicators to be used as a starting point when discussing this theme more going forward.

The first one relates to artisanal food production which includes food such as breads, cheeses, fruit preserves, cured meats and beverages produced mainly by hand using traditional methods by skilled craftsmen (artisans). These skills were wide-spread in traditional households but have to a large extent been lost due to the modernization of the food system. The preservation of such skills can therefore be seen as an important cultural value. We suggest here an indicator that measures the number of people that are educated in these practices yearly. Such education is offered in various types of tertiary education (e.g. Eldrimner, https://www.eldrimner.com/).

The current livestock production involves just a few breeds per species that have been bred for high productivity. The second indicator we suggest here relates to the preservation of threatened traditional livestock breeds, as landrace livestock breeds are also part of our cultural heritage. Currently, there are payment schemes in place to support the preservation of a range of different breeds of cattle, sheep, pigs and goats (Jordbruksverket, 2022). Here we suggest that the indicator tracks the total number of these animals kept per year (aggregated into livestock units). The statistics on this is kept by the Swedish Board of Agriculture. This could later be extended to also include e.g. crop landraces (Last et al., 2014).

2.3.3 Recreational values

Territorial-based indicator(s):

Number of farms that provide recreational values

Description: An indicator with the aim to capture the extent to which the food system offers recreational values in terms of farm visits and similar. Measured as the number of farms that provide such services.

Indicator:	Number of farms that provide recreational activities
Indicator label:	T-2.3.3a
Type according to DPSIR:	P
Target:	Not available
Data source:	The Swedish Board of Agriculture, Farm Economics Survey (JEU): https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2022-02-25-jordbruksekonomiska-undersokningen-2020

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Recreational values can be an important value delivered by food systems depending on how these are organized.	The Farm Economics Survey provides high-quality data on farms' economic activities.	Easy to interpret.	Difficult to set a target.

Description: The food system supplies recreational values that go beyond the pleasure of eating foods, which can reconnect people with nature with positive effects on societal well-being (Hermes *et al.,* 2018). A part from providing attracting landscapes for nature experiences, some farms provide farm shops, restaurants and cafés and the possibility to stay for longer periods in farmstays. We here suggest the number of farms that provide such services as an indicator of the food system's recreational values. The Farm Economics Survey from the Swedish Board of Agriculture (Swedish Board of Agriculture, 2022) provides data on the economic income from 'Other Gainful Activity' (OGA), which includes incomes from activities such as snow ploughing and tourism. This data can be used to estimate the number of farms that provide recreational values in terms of farm visits etc. Exactly how this indicator will be defined and calculated is still to be decided.

2.3 Theme: Rights of indigenous people

2.3.1 Protect the rights of the Sami people

Territorial-based indicator(s):

Number of reindeer owners in Sweden

Description: An indicator with the aim to capture the extent to which the Sami population can practice traditional reindeer herding. Measured here as the number of reindeer owners.

Indicator:	Number of reindeer owners in Sweden
Indicator label:	T-2.3.1a
Type according to DPSIR:	S
Official target:	Too be discussed with the Sami Parliament
"Science-based target":	Not available
Data source:	Sami Parliament https://www.sametinget.se/english

Ratio of public institutions (schools, elderly care etc.) that offer meals reflecting the rights of indigenous people

Description: An indicator with the aim to capture the extent to which extent the Sami population can consume a culturally appropriate diet.

Indicator:	Ratio of public institutions (schools, elderly care etc.) that offer meals reflecting the rights of indigenous people
Indicator label:	T-2.3.1b
Type according to DPSIR:	S
Target:	Not available
Data source:	Unclear, needs investigation

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The rights of the Sami people to practice traditional keeping of reindeer and eat culturally appropriate meals in public institutions are captured.	The Sami Parliament keeps high quality statistics on the number of reindeer owners (needs to be double-checked). For T-2.3.4b data availability needs to be investigated.	Easy to interpret.	To be discussed with the Sami Parliament to which extent these indicators are useful or if other indicators would be more useful.

Background

This theme involves the recognition and protection of the intellectual property rights of indigenous people according to the United Nations declaration (United Nations, 2008). The indigenous rights include the right to uphold and practice cultural knowledge, including rituals, arts and customs in general. In terms of food systems, indigenous rights include knowledge related to the farming and catching methods, the use of specific seeds/breeds and medicinal plants and their uses. In Sweden, the most important food related practice related to the indigenous Sami population is the keeping of reindeer in the north of Sweden. Reindeer herding is a Sami occupation that is reserved for the Sami. The right to herd reindeer is based on the claim from time immemorial as reindeer management existed before Sweden was formed. There are 4600 owners of reindeers, approximately 1000 reindeer companies that keep and manage the herds, and between 225 000 and 280 000 reindeers in Sweden (Sametinget, 2022).

Here we suggest two indicators to reflect the indigenous rights of the Sami people; one related to the keeping of reindeer and one to the possibility of eating food reflecting the cultures and traditions of the Sami population in public institutions (schools, elderly homes etc.). For the first one, we suggest the number of reindeer owners as an indicator as this shows the number of indigenous people involved in this tradition. This more broadly captures the involvement then e.g. the number of reindeer companies or number of reindeer. Regarding the possibility to consume food reflecting Sami culture and traditions, we include an indicator of the ratio of the public institutions that offer such possibilities. This indicator has to be further defined to be useful. These two indicators are tentative suggestions to be discussed and confirmed with the Sami parliament. If possible and relevant, they should also be aligned with indicators related to the rights of indigenous people being developed within the (Naturvårdsverket, www).

2.4 Theme: High animal welfare

The World Organisation for Animal Health (formely OIE) has defined animal welfare as "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (World Organisation for Animal Health, www). Although animal welfare is not explicitly mentioned in the SDGs, working to achieve the SDGs is compatible with working to improve animal welfare (Keeling *et al.*, 2019). Our goal for High animal welfare in Mistra Food Futures is in accordance with the goal of Hebinck et al (2021): "Increase share of animal products with high animal welfare quality standards".

2.4.1. Total welfare index

Territorial-based indicator(s):

Total welfare index for animals in production

Description: Total welfare index for animals in production is an index summarizing the animal welfare of all animals used for the production of animal-sourced food in Sweden. The index includes the number of animals and the severity of the animal welfare issues these animals are exposed to.

Indicator	Total welfare index for animals in, based on • Number of involved animals of different species and animal types (e.g. chickens for slaughter or hens for egg production) • These animals' (species') abilities to perceive negative effects • Animal welfare assessment value for different production systems, based on - Mortality, number of animals dead on farm / total number of animals - Diseases, number of animals affected by diseases or injuries / total number of animals

	- Barren environment, number of animals in a barren environment / total number of animals - Duration of slaughter process (including time for catching animals, transport of live animals, waiting at slaughter plant and actual slaughter) The calculation of the index is described below the table.
Indicator label:	T-2.4.1a
Type according to DPSIR:	S
Target:	There is no specified Swedish or global official targets for animal welfare. The Swedish board of Agriculture includes three goals in its strategy for 2020-2025 and they cover animal welfare legislation law compliance, development of animal production so that animal welfare, production and competitiveness are increased, and stronger clarity and security in the work for animal protection. Animal welfare is not mentioned in the SDG, but a resolution adopted by the UN Environment Assembly (2022) acknowledges that “animal welfare can contribute to addressing environmental challenges, promoting the One Health approach and achieving the SDG” and notes that “health and welfare of animals, sustainable development and the environment are connected to human health and well-being”. The goal is a low index value, which reflects better welfare for animals used for food production in Sweden. The goal is calculated based on the current production volumes from different production systems. Lowest possible index value means mortality on farm is zero, all animals are healthy, no animals live in a barren environment and the duration of slaughter process is no more than 10 minutes.
Data source:	The Swedish Board of Agriculture (animal numbers), questionnaire to university staff (animals’ ability to perceive negative effects; see below), web pages and reports from the Swedish dairy, beef, pork, chicken, egg, fish and aquaculture industry (mortality, disease, management; see below).

Justification for indicator choice

Relevant:	High-quality:	Interpretable:	Useful:
Ideally, the welfare value in the index is calculated according to The Welfare Quality® Assessment Protocols which emphasize animal-based measures. This would be complicated,	A judgement of species’ ability to perceive negative or positive effects of production systems collected with a questionnaire is possible to report according to standards for	The indicator reflects the animal welfare of all animals involved in Swedish food production. Larger number of animals with higher ability to perceive negative effects in production systems with weaker	The SDGs do not include animal welfare, but the UN Environment Assembly of the United Nations Environment Programme (UNEP, 2022) has recently

expensive and time consuming since the assessment is based on records from visits at a representative sample of farms of each production system. Furthermore, there are only protocols for cattle, pigs, chickens and laying hens. High index values (i.e. low animal welfare) due to bad management are a non-efficient use of natural resources and reduced waste generation is part of SDG 12 (but the number of affected animals is mainly related to the size of the animals)	survey studies (average, rank, response ratio etc). Although the four organic principles of International Federation of Organic Agriculture Movements (IFOAM) do not highlight animal welfare, several studies show that many aspects of animal welfare are better in organic than conventional systems (but not all).	animal welfare result in a higher index value. The goal (a lower value = less negative impact on the animals) is easy to communicate. The index for production is built in the same way as the index for consumption. Mean and standard deviation of the indices can be standardised so that they are easy to compare.	acknowledged its importance. The index value is possible to influence through the choice of species and animal type (i.e. food product).

Description of index calculation:

The *number of involved animals* is calculated based on the production of animal-sourced food from different species and an average assumed number of animals needed to produce these amounts of food. These numbers also include animals not producing food themselves, e.g. discarded male chickens in egg production and animals dying on farms. We identify standard numbers of animals per amount of food product based on statistics from the Swedish Board of Agriculture.

Animals’ cognitive ability is related to the ability to feel pain, fear and discomfort and these abilities are very complicated to study. Species differ in their cognitive ability, but there is a lack of knowledge, especially for arthropods like crayfish and crickets. Scherer et al (2018) used a so called moral value to account for self-awareness in the sustainability assessments of animal products. The aim of this value was to describe “expected intelligence relative to a human being” and it was based on either brain mass, total number of neurons or number of cortical neurons, depending on data availability. For example, the moral value for cattle and pigs was 0.3 as compared to 1 x 10-6 for shrimp. This idea was presented and criticized at the Animal Welfare Science Symposium in Uppsala in June 2022. The estimate of cognitive ability (Scherer et al, 2018) was regarded as too large of a simplification. There are not enough scientific studies on cognitive ability or ability to feel pain, fear and discomfort in all species used for food production. The lack of proof of e.g. blue mussels’ ability to feel fear simply means that it has not been studied; it does not mean that it has been proved that blue mussels do not feel fear.

Animals’ (species’) *ability to perceive negative or positive effects* will be used in the index calculation. Most people would say that for example getting injured or suffocating has larger negative effects for a bull than for a blue mussel. We will use this intuitive knowledge as a base for the ability value. The relative ability of animals of different species to perceive negative (or positive) effects, i.e. effects of handling, feeding, housing etc, in a production system will be assessed using a questionnaire to staff at the Faculty of Veterinary Medicine and Animal Science at SLU. This 'ability value' is an acceptable simplification as long as the method to achieve it is reported. In the future, when more knowledge on animals' ability to perceive negative effects is available, it can be replaced by a scientifically based value of this ability.

The impact of the Swedish production systems with regard to *animal welfare* is classified into a welfare class, based on data from various open access data bases and so called grey literature presented by the industry. The *animal welfare class* is a combination of

- Mortality, number of animals dead on farm / total number of animals
- Diseases, number of animals affected by diseases or injuries / total number of animals
- Barren environment, number of animals *not* provided with an enriched environment / total number of animals
- Duration of slaughter process (including time for catching animals, transport of live animals, waiting at slaughter plant and actual slaughter)

Mortality and diseases are assumed to be zero for wild animals used for animal-sourced food, such as shrimps and game. The availability of data on diseases varies between production systems, but some key diseases for each species will be used as an alternative to all diseased and injured animals. Examples of key diseases are mastitis and leg problems for cattle, leg problems and lung diseases for pigs and bone injuries for poultry.

We will use a simple classification of the environment into barren or enriched. An environment is enriched if at least one of these conditions is fulfilled:

- Organic production system
- On pasture at least 40% of total life time
- Wild animal

and otherwise barren. At least 40% of pasture is based on the Swedish climate where being outdoors during winter is not always associated with high welfare.

A simple classification of duration of slaughter process is used, based on average duration. The range of duration of slaughter given by Scherer et al (2018) was used as a starting point when setting the *slaughter duration classes* given below:

- More than 12 hours = 2
- Between 1 and 12 hours = 1
- Between 10 minutes and 1 hour = 0.5
- No longer than 10 minutes = 0.1

The *welfare class* summarises the three ratios for mortality, diseases and barren environment, and the slaughter duration class.

The index is calculated based on the raw, edible food product, e.g. 1 kg beef (without bones) calculated with the average carcass weight and percent of meat in the carcass, or 1 kg pealed shrimps. A sub-index value is calculated for each animal product (e.g. 1 kg of eggs): *sub-index*$_{eggs}$ *= number of individuals x ability to perceive negative effects x welfare-class*

The total welfare index for production describing our total production of animal-sourced food in Sweden is calculated as the sum of all sub-index values:

Total welfare index for production = sub-index$_{eggs}$ + sub-index$_{beef}$ + sub-index$_{shrimps}$ + ...

Consumption-based indicator(s):

Total welfare index for all animals used for consumption

Description: Total welfare index for consumption is an index summarising animal welfare of all animals used for the production of animal-sourced food consumed in Sweden. The index includes proxies for the number of animals and the severity of the animal welfare issues these animals are exposed to.

Indicator	Total welfare index for consumption, based on • Number of involved animals of different species and type (e.g. chickens for slaughter or hens for egg production) • These animals' (species') ability to perceive negative effects • Animal welfare legislation in the countries where these animals are used for food production • Law compliance in these countries
Indicator label:	C-2.4.1b
Type according to DPSIR:	S
Target:	The goal is a low index value, which reflects less animals involved in food production, and better welfare for these animals. The goal is calculated based on the number of animals of different species required to achieve a consumption in line with the Swedish Food Agency recommendations, where all animals come from countries with the best World Animal Protection Index (API).
Data source:	The Swedish Board of Agriculture (animal numbers), questionnaire to university staff (ability to perceive negative effects; see above), World Animal Protection (World Animal Protection Index) and The World Justice Project (Rule of Law Index).

Justification for indicator choice

Relevant:	High-quality:	Interpretable:	Useful:
It would be more relevant to use measurements of animal welfare performed on farms and slaughter plants, but there are no data bases covering all welfare issues of all animals used for producing animal-	World Animal Protection is a 55-year-old NGO with offices in 14 countries, including Sweden. Their World Animal Protection Index (API) is well documented and clearly explained. The 2nd edition is most recent (2020).	The indicator reflects the animal welfare of all animals involved in our consumption. Larger number of animals with higher ability to perceive negative effects, from countries with a weaker animal welfare legislation and lower law compliance result in a higher index value. The goal (a lower	The SDGs do not include animal welfare. Possible to influence through choice of species (i.e. food product) and import country for food of animal origin.

sourced food consumed in Sweden. Adjusting the World Animal Protection Index (API) for law compliance increases the relevance, since countries with the same law can differ a lot in management practice. High numbers of involved animals due to bad management is a non-efficient use of natural resources and reduced waste generation is part of SDG 12 (but the number of affected animals is mainly related to the size of the animals).	The World Justice Project is an independent, multidisciplinary, non-profit organization. The 'ability to perceive-value' is not based on scientific studies of animals, but on a scientific study of humans' opinions. Calculating yield (amount of food product/animal), assuming Swedish average numbers for all countries is a simplification, but by assuming the same yield for all countries we avoid favouring countries with very high average yields at the cost of lower animal welfare.	value = less negative impact on the animals) is easy to communicate. The index for consumption is built in the same way as the index for production. Mean and standard deviation of the indices can be standardised so that they are easy to compare.	

Description of index calculation

The *number of involved animals* are calculated based on the consumption of food from different species and an average assumed number of animals needed to produce these amounts of food. These numbers also include animals not producing food themselves, e.g. discarded male chickens in egg production. The standard number of animals per amount of food product based on Swedish animal production will be identified and these numbers will be applied to all countries that we import animal-sourced food from. Thus, we assume that the production in countries exporting animal-sourced food to Sweden is similar to the Swedish production when it comes to average production levels, weight at slaughter etc.

The *ability to perceive negative effects* is related to the ability to feel pain, fear and discomfort (see background to Production indicator above).

The *animal welfare legislation* of different countries is classified by an international NGO called World Animal Protection, in a World Animal Protection Index (API). The API measures the recognition of animal sentience and prohibition of animal suffering, support for international animal welfare standards, presence of animal welfare legislation, establishment of supportive government bodies and support for international animal welfare standards. The 50 countries included are large producers of beef, poultry, pork, sheep, milk and eggs. We assume that the animal welfare legislation as classified in the API is a good enough indicator for all species in the country. The API values range from A (best) to G (worst). For example, Sweden is classified as B and Thailand as D.

The API does not describe *law compliance*. The API will be adjusted based on an index describing the general law compliance in different countries, and we use the World Justice Project Rule of Law Index (WJPLI) for this. The factors of the WJPLI include constraints on government powers, absence of corruption, open government, fundamental rights, order and security, regulatory enforcement, civil justice and criminal justice. The WJPLI can range from 0 to 1. For example, Sweden has a WJPLI value of 0.86 as compared to 0.90

for Finland and 0.50 for Thailand. The API scale is transformed to a scale from 1 (A, best) to 7 (G, worst). Thereafter the API value is adjusted for law compliance so that a lower compliance gives a higher API-adjusted value.

API-adjusted = API x 1/WJPLI

The index is calculated based on the raw, edible food product, e.g. 1 kg beef (without bones) calculated with the average carcass weight and percent of meat in carcass or 1 kg pealed shrimps.

A sub-index value is calculated for each animal product from each country (e.g. 1 kg of eggs from Finland):

$\textit{sub-index}_{\textit{finnish-eggs}}$ = *number of individuals x ability to perceive negative effects x API-adjusted*

The welfare index value for the consumption of each product is calculated based on the consumed sum of this product from different origins:

$\textit{product-index}_{\textit{eggs}}$ = *amount of Swedish eggs x sub-index for Swedish eggs + amount of Finnish eggs x sub-index for Finnish eggs + …*

The total welfare index for consumption describing our total consumption of animal products is calculated as the sum of all product index values:

Total welfare index for consumption = $\textit{product-index}_{\textit{eggs}}$ + $\textit{product-index}_{\textit{beef}}$ + $\textit{product-index}_{\textit{shrimps}}$ + *…*

General background

A large part of the Swedish food consumption consists of food from animals in agriculture and aquaculture and a minor part consists of food from wild animals. The welfare of all these animals should not be ignored. Animal welfare is important for many humans. In the Eurobarometer survey (2021), 82% of the respondents agree to the statement "in general, the welfare of farmed animals should be better protected than it is now". In the Rural Development Programmes of the EU's Common Agricultural Policy, animal welfare is a specific measure. According to the EU's Farm to Fork Strategy (2020) "Better animal welfare improves animal health and food quality, reduces the need for medication and can help preserve biodiversity. This illustrates that animal welfare (as AMR, see 1.2.2) is a One Health issue.

In this framework, animal welfare includes animal health and other welfare aspects and other ethical aspects (i.e. the number of involved animal lives). Global data on animal health are, however, not possible to find and therefore this assessment of consumption is based on national animal welfare legislation.

The animal welfare assessments should include not only the production site but also the transport and slaughter, i.e. the complete life cycle. Many animals move between farms during their lifetime. Young surplus calves from dairy farms are e.g. often transported to specialised beef production farms where they are raised until slaughter. The production on a farm can also be dependent on animals outside the farm, e.g. bulls producing semen for artificial insemination. Ideally, the number of affected animals, the duration of the distress and the severity (intensity) of the distress should be taken into account in an animal welfare assessment expressed per functional unit. Keeping in mind that consumption may change to a larger proportion of protein from insects, the animals' cognitive capacity (sentience) is also relevant to include in the assessment. Based on neurons and brain mass, Scherer et al (2018) give a higher so called 'moral value' to, for example, a pig than a mealworm. There is, however, a lack of data on cognitive ability of all species used for food production. Furthermore, the scientific proofs for the association between the number of neurons or weight of brain mass and the cognitive ability are also scarce.

The Farm Animal Welfare Council (1993) defined five freedoms that need to be provided to achieve high animal welfare: (1) freedom from thirst, hunger and malnutrition; (2) freedom from discomfort; (3) freedom from pain, injury and disease; (4) freedom to express normal behaviour; and (5) freedom from fear and distress. Animal health is related to several of these freedoms. Disease is an opposite of health, health problems can also cause pain, fear, distress and inability to express normal behaviour and malnutrition can decrease health. It should be noted that health problems include both diseases (infectious or not) and injuries. Even though health is included in the animal welfare concept, the terms "animal health and welfare" and "animal welfare and health" are very common in the literature. There are animal welfare issues that go beyond health, for example the freedom to express normal behaviour.

The World Organisation for Animal Health (OIE) has in their Terrestrial Code defined animal welfare as "the physical and mental state of an animal in relation to the conditions in which it lives and dies." This definition is relevant also for aquatic animals. From OIE global animal welfare strategy (2017): "Animal welfare is closely linked to animal health, the health and wellbeing of people, and the sustainability of socio-economic and ecological systems. Animal welfare is a complex, multifaceted, international and domestic public policy issue with scientific, ethical, economic, legal, religious and cultural dimensions plus important trade policy implications. It is a responsibility that must be shared between governments, communities, the people who own, care for and use animals, civil society, educational institutions, veterinarians and scientists." Animal welfare refers to *the state* of the animal. The treatment that an animal receives, i.e. animal care, animal husbandry, and humane slaughter or killing, influences this state and causes low or high animal welfare.

The animal welfare law is more or less strong in different countries and some countries have no legislation dedicated to animal welfare. All the EU member states must fulfill the EU's animal welfare law, but countries can have more stringent national rules. The EU's 'Treaty on the Functioning of the European Union' recognizes that animals are sentient beings. Article 13 of Title II states that "In formulating and implementing the Union's agriculture, fisheries, transport, internal market, research and technological development and space policies, the Union and the Member States shall, since animals are sentient beings, pay full regard to the welfare requirements of animals, while respecting the legislative or administrative provisions and customs of the EU countries relating in particular to religious rites, cultural traditions and regional heritage."

Neither Béné et al (2019), nor Fanzo et al (2021) mention animals used for food production in their articles about food system sustainability and animals are not regarded as stakeholders in the UNEP's (UNEP 2020) guidelines for social LCA. Animals used for food production are almost absent in the UN's SDGs, in spite of their positive and negative impacts on the fulfillment of many of the goals. Hebinck et al (2021) and Chaudhary, Gustafson and Mathys, 2018 (2018) both include animal welfare in the sustainability assessments of food systems. In Hebinck's Sustainability Compass (2021), the sustainability dimension is "Increase share of animal products with high animal welfare quality standards" and suggested progress indicators are "share of certified organic products sold" and share of animal welfare certified animal products. Chaudhary et al (2018) use the animal protection index from the World Animal Protection Organisation as an indicator of the indicator Animal health and welfare within the metric Sociocultural wellbeing.

High animal welfare is important for an ethically justified animal production but there are ethical questions that go beyond welfare. An ethical aspect that goes beyond animal welfare is the number of animal lives (i.e. the number of affected individuals) behind the food consumption. A hundred chickens have to be slaughtered to produce the same amount of meat as one young bull. This ethical aspect is included in our work. The right to use animals at all – for any purpose – is an ethical question that we have not included in our work; we assume that humans have the right to use animals for food production.

3. FLOOR: Clean and healthy planet

A clean and healthy planet is fundamental for life and thus a prerequisite for sustainable food systems. At the same time, current food systems cause resource depletion, biodiversity loss, pollution of air and water as well as climate change (Willett et al., 2019). Environmental indicators are, in general, well represented in the existing food system sustainability frameworks (e.g. Hebinck et al., 2021). Here we used the same four themes (areas of concerns) as Hebinck et al. (2021): Climate stabilisation, biodiversity conservation, preservation of natural resources and clean air and water. Our point of departure was the performance indicators included in the framework by Hebinck et al (2021) but we made some adjustments to the indicators to increase the indicators relevance in a Swedish context and the data available. We also added the theme 'Manage soils and water'. 3.1 Theme: Climate stabilization.

3.1 Theme: Climate stabilization

A stable climate is crucial for safeguarding human welfare and the conservation of natural ecosystems. Already, with global mean temperatures having risen by just over one degree Celsius over pre-industrial level, we see "*widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure*" due to more frequent and intense weather and climate extremes, such as droughts, heavy precipitation events, wildfires, coral reef bleaching and heatwaves (Pörtner et al., 2022b). To limit future negative impacts of climate change, and reduce the risk of catastrophic impacts, the global community has pledged to limit global warming to below 2 degrees, aiming to keep temperature rise close to a maximum of 1.5 degrees (UNFCCC, 2015). Doing so will require rapid and deep cuts in greenhouse gas emissions across countries and sectors, including from food systems that currently account for roughly a third of all the greenhouse gas emissions.

3.1.1 Greenhouse gas emissions

Territorial-based indicator(s):

Greenhouse gas emissions, separately per gas (in Mt) and in total (in $MtCO_2$-equivalents ($MtCO_2e$), weighted using the GWP100-metric)

Description: Total territorial greenhouse gas emissions from the Swedish food production (primary production and domestically produced agricultural inputs, land use and land-use change and downstream emissions in transport and processing). This means that this indicator includes all territorial emissions from the Swedish food production (primary production, processing and transport), regardless of where the food produced is ultimately consumed.

Indicator:	Greenhouse gas emissions, separately per gas (in Mt) and in total (in $MtCO_2$-equivalents ($MtCO_2e$), weighted using the GWP100-metric).
Indicator label:	T - 3.1.1a
Type according to DPSIR:	Pressure (individual emissions), Impact (aggregated using GWP)
Target:	Not available, but should be below 10.7 $MtCO_2e$ 2045 (15% of emissions in 1990), which is the target for total territorial greenhouse gas emissions, but there is no official target for the share of this emission budget available for the food system (or agricultural sector).
Data source:	Statistics Sweden (for agricultural production and land-use change); data on downstream emissions are currently not available from official statistics, but can be estimated using the PRINCE methodology (see Cederberg et al. 2019 for details).

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Climate change is one of the major environmental challenges facing humanity.	The methods for calculating territorial emissions in primary production are well-established and follow international guidelines (IPCC/UNFCCC). For the additional emission sources suggested to be included here, there are also well-established methodologies (multi-regional input-output models).	Greenhouse gas emissions in carbon dioxide equivalents are a well-established indicator of contributions to climate change.	Although there is no current breakdown of the Swedish territorial emissions target for 2045, such a decision will ultimately have to be made politically, and this indicator can also help inform that discussion.

Consumption-based indicator(s):

Greenhouse gas emissions, separately per gas (in Mt) and in total (in $MtCO_2$-equivalents, weighted using the GWP100-metric)

Description: Total greenhouse gas emissions from Swedish food consumption. This includes all of the emissions due to Swedish food consumption (in primary production, processing and transport), regardless of where in the world these emissions occur.

Indicator:	Greenhouse gas emissions, separately per gas (in Mt) and in total (in $MtCO_2$-equivalents, weighted using the GWP100-metric).
Indicator label:	C - 3.1.1b
Type according to DPSIR:	Pressure (individual emissions), Impact (aggregated using GWP)
Target:	Around 5 $MtCO_2e$, based on a total emission budget for agriculture of 5 $GtCO_2e$ from EAT-*Lancet* and equal per-capita emissions globally (Swedish population 10 million, global 10 billion, by mid-century), following Moberg et al. (2020)
Data source:	SCB / EXIOBASE (Stadler et al., 2018) (for fossil CO_2, CH_4 & N_2O), plus (Pendrill *et al.*, 2022)(for CO_2 from land-use change)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Climate change is one of the major environmental challenges facing humanity.	The methods for estimating total consumption-based greenhouse gas emissions (multi-regional input-output modelling) are well-established. There are challenges in extracting food-related emissions from these models (due to the sectoral composition) as well as in	Greenhouse gas emissions in carbon dioxide equivalents are a well-established indicator of contributions to climate change.	A consumption-based greenhouse gas target for Sweden is currently being discussed in a parliamentary committee, and having an indicator of food-related emissions can help inform a target-setting process.

	underlying data (e.g., land-use change emissions), but the results are still expected to be robust and can be cross-checked with alternative estimation methods (based on life-cycle assessment data).		

Background

Our food systems are key drivers of climate change, with a total of greenhouse gas emissions estimated to be around 14-18 $GtCO_2e$ per year (billion tons of carbon dioxide-equivalents per year; Crippa et al., 2021; Poore and Nemecek, 2018; Vermeulen, Campbell and Ingram, 2012). This constitutes around a third of the total global anthropogenic greenhouse gas emissions, which implies that unless we reduce food system emissions, we will not be able to meet the climate targets agreed upon in the Paris Agreement (Clark *et al.*, 2020).

The Swedish territorial emissions from agriculture amounted to just under 7 $MtCO_2$-eq in 2020, constituting 15% of the total territorial greenhouse gas emissions (Naturvårdsverket, 2022). However, in accordance with the UNFCCC accounting and reporting framework, this estimate includes only parts of the emissions from agricultural production, namely methane (CH_4) from ruminants (42%) and manure (4%), and nitrous oxide (N_2O) emissions from manure (5%), nitrous oxide from agricultural soils (47%), and carbon dioxide from lime application (2%). It thus omits wider food production emissions, from the production of inputs such as mineral fertilizers (though most of these emissions occur outside Swedish borders), from energy use in production (i.e., agricultural machinery), transport, processing etc., as well as emissions from land-use and land-use change.

While whole food system emissions are not easily estimated from official statistics (e.g., as reported to the UNFCCC), because they fall under other sectors (e.g., energy and transport), they can be estimated using economic input-output models. This is done by Cederberg et al. (2019), based on data from the multi-regional input-output model EXIOBASE (Stadler et al. 2018). They estimate that in 2011, territorial fossil CO_2 emissions linked to the Swedish food consumption amounted to 1.6 $MtCO_2$. This estimate includes all territorial emissions across Swedish supply-chains, from primary production, transport and processing, but excludes emissions for food products being exported (though these emissions can also be estimated from the model used), and is thus an underestimate of the actual territorial emissions from fossil fuel use in Swedish food supply-chains. Similarly, the Swedish Board of Agriculture estimates that the territorial CO_2 emissions from agricultural machinery and premises amounted to 0.7 $MtCO_2$ in 2016 (Markensten et al., 2018). This estimate, however, includes also premises for the forestry sector, but excludes downstream processing and transport emissions. In addition to these fossil CO_2 emissions, the land-use change emissions due to the drainage of organic (peat) soils for agricultural production (croplands and peatlands) are estimated to be around 3 $MtCO_2e$ per year (Statistics Sweden, 2022b).

This implies that although at the moment there is no comprehensive measurement or monitoring of emissions from Swedish production and supply chains, by compiling data from different sources, they can be estimated to amount to at least 12 $MtCO_2e$ per year (i.e., the sum of estimates from agricultural production, land-use change, and wider food system processes given above). This estimate can be related to Sweden's overall target of reducing territorial greenhouse gas emissions by at least 85% in the period 1990-2045 (emissions should be net-zero by 2045, but 15% of 1990 emissions can be compensated by "complementary measures", such as carbon sequestration or offsetting), which translates to an emission budget of 10.7 $MtCO_2e$ in 2045. While there are no indications of the share of this budget that can be claimed by the food system, it is still smaller than the current total emissions from the Swedish food production, processing, transport and retailing, estimated to >12 $MtCO_2e$ per year here, implying a need for emission reductions.

This estimate of the total territorial emissions from the Swedish food system is still substantially lower than estimates of the total emissions from Swedish food consumption (i.e., total food system emissions, inside and outside Swedish borders linked to Swedish consumption), at around 20 $MtCO_2e$ (Cederberg et al., 2019; Moberg et al. 2020), which is due the large share of imports in Swedish food consumption. Note, also, that these estimates do not include emissions from drained peatlands in Sweden (though the land-use change emissions, from deforestation and peatland-drainage in the tropics are included). Adding the estimates of these emissions would thus raise the consumption-based emissions somewhat (though not by the full 3 $MtCO_2e$ per year given above, as some of these emissions are linked to the agricultural production that is exported).

While there have been recent steps to formulate consumption-based emission targets for Sweden (Miljömålsberedningen 2022), no concrete targets for food consumption have been proposed. However, the EAT-*Lancet* commission (Willett et al., 2019) proposes an emission boundary for the global food systems of 5 $GtCO_2e$, which—if distributed equally per capita—would translate to a Swedish target of around 6 $MtCO_2e$ (assuming that Sweden's population constitute 10 million out of a global population of 10 billion in 2050), indicating a need to drastically reduce the emissions associated with Swedish food consumption.

Finally, it is worth noting that a large share of the food system's greenhouse gas emissions (nationally and globally) is in the form of CH_4 and N_2O. Contrary to CO_2 emissions, which need to be reduced to zero if the climate is to be stabilised, CH_4 and N_2O emissions are eventually completely broken down and removed from the atmosphere, implying that some emissions of these gases can be compatible with climate stabilisation (more so for CH_4, which has a much shorter lifetime than N_2O) (Pires *et al.*, 2021). This has led to calls for formulating targets for short-lived (e.g., CH_4) and long-lived (e.g., CO_2) greenhouse gas emissions separately, rather than using the Global Warming Potential (GWP) metric to aggregate all gases into CO_2e, which is the current practice in climate policy (Allen et al. 2022).

It is thus reasonable to have a target for decarbonising the Swedish food system (i.e., reducing CO_2 emissions to zero), as that is necessary for climate stabilisation. Aiming for net-zero emissions measured in CO_2e, however, would imply that emissions of CH_4 and N_2O (which are difficult to completely mitigate, especially N_2O) would need to be compensated with carbon removal (or complementary measures if allowed). This would lead to decreasing temperatures in the long term.

However, one should also consider the fact that all CH_4 and N_2O emissions (even when stabilised) add additional warming compared to if they would not have been emitted. In terms of reaching global temperature targets, methane emitted around the time when global temperatures are stabilising (at 1.5 or 2 degrees), are highly influential on the final temperatures. The IPCC scenarios for pathways to stay below these climate targets therefore all include large reductions (50-60%) in methane emissions (Masson-Delmotte et al., 2021) . As the current global average temperature increase (approx. 1.1) is already close to the climate target of 1.5 degrees, reductions in methane emissions are becoming increasingly important.

Based on this we suggest monitoring greenhouse gas emissions both separately, and aggregated into CO_2e using GWP100 for comparison with current policy. This argument holds both for territorial and consumption-based targets, as it does not matter where in the world the CO_2, CH_4 or N_2O is emitted.

3.2 Theme: Biodiversity conservation

Conserving Earths biodiversity and ecosystems is fundamental to human survival. Without the ecological processes that organisms maintain in both terrestrial and aquatic ecosystems, there will be no utilisation of resources from these. Without the services that biodiversity offers (provisioning, regulating and supporting) agriculture or aquaculture cannot persist (IPBES, 2019). Wild diversity is also the base from which domestic diversity, the animals we rear and the plants we grow, are coming and being developed from (Dempewolf et al., 2017). The impacts of agri- and aquaculture on natural habitats are extreme and includes habitat loss and destruction (e.g., from converting old grassland fragments into crop fields and damaging sea floors from trawling), overharvesting of resources (e.g., fishing) and the following reduction of species (Tilman et al., 2017; IPBES 2019).

Domesticated plants and animals form the foundation of agriculture, and present in themselves the ultimate limits of the nutritional and energetic values that can be derived from agricultural production. The past decades have seen a rapid decrease of genetic diversity in domestic species which has been combined with a low interest and understanding of the value of this diversity (Johns et al. 2013; Leroy et al. 2018). With large environmental changes now affecting agriculture the capacity of domestic species to dela with these changes are becoming more and more important.

3.2.1 Terrestrial biodiversity

Territorial-based indicator(s):

Pollinator abundance and diversity

Description: Presence and abundance of pollinator species in surveyed locations in Sweden.

Indicator:	Pollinator abundance and diversity
Indicator label:	T - 3.2.1.a
Type according to DPSIR:	S
Target:	'The decline of pollinators is reversed' using year 2000 as a reference year, from the EU biodiversity strategy (European Commission, 2020a)
Data source:	National data exist from the NILS (Nationella Inventeringar av Landskapet i Sverige) program https://www.slu.se/centrumbildningar-och-projekt/nils/. Nevertheless, this data is restricted to a set of habitats, which limits its overall usefulness. A new national pollinator survey program focused on agricultural landscapes is planned to start https://www.slu.se/centrumbildningar-och-projekt/nils/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Pollinators are heavily affected by agriculture. The reasons are several and include a reduction of the	For the territorial part there is high quality data for some pollinators from the NILS	Easy to interpret where data is available. Indexes are calculated using good quality data.	Very useful where data exists. Pollinators (and their services) are known by many (farmers as well as

amount and diversity of flowering plants which are used as a food resource, as well as places to reproduce. The use of pesticides also affects species negatively.	(Nationella Inventeringar av Landskapet i Sverige) program, but this does not cover the whole agricultural landscape. A survey program focused on pollinators in the agricultural landscape is on its way and will likely be very useful.		the public) and their importance have been highlighted the last few years.

Farmland birds index

Description: Index of farmland birds. This indicator is a composite index that measures the rate of the change in the relative abundance of common bird species at selected sites.

Indicator:	Farmland birds index
Indicator label:	T – 3.2.1.b
Type according to DPSIR:	S
Target:	'Species show no deterioration in conservation trend and status' using year 2000 as reference year, from the EU biodiversity strategy (European Commission, 2020a)
Data source:	Lund University, fågeltaxeringen https://www.fageltaxering.lu.se

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Farmland birds are decreasing in numbers due to the intensification of agricultural land. There are different reasons for this: land cover types	Farmland bird population trends are available for the territorial area via 'Fågeltaxeringen' Lund University.	Easy to interpret and well used index.	Farmlands birds are considered good indicators for the overall state of biodiversity, known to many, farmers care about

that they need for food, shelter etc. are removed and thereby different resources are strongly reduced or gone. Pesticide use, which reduce insect abundance, means less food for insect eating birds.			them and they are well correlated to how the landscape is used.

Area of semi-natural grassland (ha)

Description*:* Area of semi-natural grasslands.

Indicator:	Area of semi-natural grasslands (ha).
Indicator label:	T - 3.2.1.c
Type according to DPSIR:	S
Target:	Not available
Data source:	Digital maps, e.g., National land cover database (NMD), https://jordbruksverket.se/e-tjanster-databaser-och-appar/e-tjanster-och-databaser-stod/kartor-och-gis, TUVA https://jordbruksverket.se/e-tjanster-databaser-och-appar/e-tjanster-och-databaser-stod/tuva, https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2021-02-03-jordbruksmarkens-anvandning-2020.-slutlig-statistik#h-Spannmal20002020, https://www.lantmateriet.se/sv/Kartor-och-geografisk-information/geodataprodukter/produktlista/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
These are habitats in agricultural landscapes that harbour native flora	There are very good data in Sweden from digital maps. These data have to be	Data on land cover of semi-natural grasslands or similar	The extent of natural habitats gives very useful information on the

and fauna and have withstood agricultural expansion. Often they are very species rich and some have developed historically with low-intensity traditional use. In these habitats species live and can move out into the more intensively used areas that surrounds them.	collected from maps and adapted.	habitats are very easy to interpret.	base for biodiversity in the landscape and species potential to remain in viable populations. Index would be very useful.

Area of small biotopes (ha)

Description: Area of small biotopes. The heterogeneity of landscapes can be measured by calculating the area of small biotopes in the landscape using data from Swedish land cover databases.

Indicator:	Area of small biotopes (ha).
Indicator label:	T - 3.2.1.d
Type according to DPSIR:	S
Target:	At least 10% of agricultural area is under high-diversity landscape features' from the EU biodiversity strategy (EC, 2020a)
Data source:	Digital maps, e.g . National land cover database (NMD), https://jordbruksverket.se/e-tjanster-databaser-och-appar/e-tjanster-och-databaser-stod/kartor-och-gis, TUVA https://jordbruksverket.se/e-tjanster-databaser-och-appar/e-tjanster-och-databaser-stod/tuva, https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2021-02-03-jordbruksmarkens-anvandning-2020.-slutlig-statistik#h-Spannmal20002020, https://www.lantmateriet.se/sv/Kartor-och-geografisk-information/geodataprodukter/produktlista/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
These are habitats in agricultural landscapes that harbour native flora and fauna and have withstood agricultural expansion and intensification in terms of removal. They can still be very affected by pesticides and by being isolated from other natural habitats. In these habitats and patches species can live and move out into the more intensively used areas that surrounds them.	There are very good data in Sweden from digital maps. These data have to be collected from maps.	Data on land cover of small biotopes habitats are very easy to interpret.	The extent of small natural biotopes gives very useful information on the base for biodiversity in the landscape and species potential to remain in viable populations. This data would be very useful.

Consumption-based indicator(s):

Total area of agricultural and used per year (Mha)

Description: The total amount of agricultural land (cropland and pasture) that is needed to produce the food consumed yearly in Sweden.

Indicator:	Area of total agricultural land used per year (Mha)
Indicator label:	C – 3.2.1.e
Type according to DPSIR:	P
Target:	For cropland, cropland use boundary according to EAT-*Lancet:* 1.3 Mha $year^{-1}$ For pastures, according to definition in Resare Sahlin, *et al.*, (2023)
Data source:	Can be calculated based on data on the yearly food consumption from Statistics Sweden and the yield levels from the Swedish Board of Agriculture for Swedish produce and FAO for imported foods, see Moberg et al. (2020). Or from physical-based trade models (Kastner et al., 2012) or from multi-regional input-output (MRIO) models (Stadler et al., 2018).

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The expansion of agricultural land is a major driver of biodiversity loss. The use of agricultural land is directly related to food consumption. Land use tightly follows the types of food commodities in diets so observing change in this indicator when diets change is clear. The indicator is coarse in the sense that it does not capture how land is used, which heavily affects biodiversity outcomes. However, the total use of agricultural land is a clear indicator of the pressure that a certain food consumption pattern involves.	For cropland rather straightforward to calculate based on the commodities needed to produce the food in the diet based on the yield data which is available with reasonable accuracy for crops. For pasture there are considerable uncertainties, however. Land use is a well-established indicator used in many studies (Jones et al., 2016).	Easy and intuitive to interpret. Quantitative.	Lacks official policy goals. Possible to influence through changes in diet, reduced waste and higher yields. Threshold available through the EAT-*Lancet* for cropland and through the definition of sustainable pasture use in (Resare Sahlin, *et al.*, 2023)

Extinctions per million species per year (E/MSY)

Description: Estimation of the extinction rate from Swedish food consumption.

Indicator:	Extinctions per million species year (E/MSY)
Indicator label:	C – 3.2.1.f
Type according to DPSIR:	Impact
Target:	Extinction rate boundary according to EAT-*Lancet:* 1.4 × 10^{-9} E/MSY per capita
Data source:	Calculated based on the total use of agricultural land (C – 3.2.1.a) and factors in Chaudhary & Brooks (2018), see Moberg et al. (2020)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
This indicator gives a coarse estimation of the number of species affected by the land use as defined in C – 3.2.1.a by weighting in how the richness of five taxa are affected by the use of land. The method e.g. captures if consumption is high of products from tropical regions with high endemic biodiversity.	The method by Chaudhary & Brooks (2018) used to assess the impact on biodiversity from land use and relating it to different food products, is the method recommended by the UNEP/SETAC (Koellner *et al.*, 2013).	This method is coarse but provides a way to compare biodiversity impacts across space and time. Quantitative. Results change depending on diet composition (e.g. amount of meat which reflects total use of land, and amount of products from regions with high biodiversity).	Adds an additional layer of information than just using the total agricultural land.

Background

The expansion and intensification of agriculture cause major declines in biodiversity and the ecosystem services that it provides, and these negative effects are estimated to increase with a growing global population (Laurance, Sayer and Cassman, 2014; IPBES 2019). The reasons for the declines are multifold and include habitat destruction (e.g., from changing natural habitats to pastures), habitat degradation (e.g., from use of pesticides and other chemicals), and fragmentation of natural habitats. At the same time as agriculture is a major cause of biodiversity decline and extinctions globally, it is dependent on the ecosystem services that this diversity provides, such as soil nutrient cycling and pollination (Vanbergen et al., 2020).

The importance of and dependence on pollinators for agricultural production cannot be overstated (Aizen et al., 2019). At the same time, agricultural practises negatively affect pollinators and in this group many species are declining, and some are threatened (Powney et al., 2019; Raven and Wagner, 2021). Data to estimate abundance and diversity of pollinators exists for limited habitats in Sweden (e.g., Fjärils & humleinventeringen, NILS, https://www.slu.se/institutioner/skoglig-resurshushallning/miljoanalys/fhin/). For some other countries (e.g., the UK) data on pollinators are very good, but for others information is limited. There is currently a new survey program focused on pollinators starting in Sweden (Aguilera Nuñez et al. 2022) that likely will be very useful for monitoring how agriculture affects the biodiversity of pollinators. An index on the diversity and abundance of pollinators (indicator 3.2.1a) would be very useful and is important, but it is still unclear how the current available information on pollinators can be used. There is potential to use data and knowledge collected in different research projects, but this data is not compiled in a way that is useful for assessing food production's impact on biodiversity.

Farmland birds are an important part of the biodiversity in agricultural landscapes. They are dependent on the resources in these systems and therefore respond with changes in diversity and abundance depending on what is grown and how it is grown. Surveys of bird species have been carried out in Sweden and other countries for a very long time (Moussy et al., 2022).For many countries, there are annual follow-ups on the state of birds in different types of systems, where the agricultural system is one (Green, Haas and Lindström, 2022; Harris et al., 2021). The Farmland Birds Index (Indicator 3.2.1b) has been widely used in several countries.

There are no precise national targets for the preservation of pollinators and farmland birds. The Swedish environmental objectives 'A varied agricultural landscape' includes the general targets: 1) habitats and species associated with the agricultural landscape have a favourable conservation status and sufficient genetic variation within and between populations, 2) threatened species and natural environments have recovered. Therefore, the targets from the EU biodiversity strategy 'The decline of pollinators is reversed' and 'Species show no deterioration in conservation trend and status', using year 2000 as a reference year, are used (European Commission, 2020a).

Biodiversity can also be estimated indirectly by measuring the remaining extent of habitats that species need to survive. For this, data on different types of land cover (natural habitats remaining) and data that capture the heterogeneity of the landscape can be used. The latter is important as agricultural activities not only remove natural habitats, but it also fragments the landscape so that the remaining habitats become isolated and the organisms living there (both plants and animals) are more likely to go extinct. This is due to that both their place to live gets physically smaller, but also because they have trouble to move between and colonize the remaining fragments. By maintaining heterogeneity in landscapes, there is an increased likelihood that the organisms inhabiting these can survive, currently no goal or index is developed for this.

Semi-natural grasslands is a habitat important for many species in the agricultural landscape and besides having a high conservation value, grasslands are also important contributors to ecosystem services (Bengtsson et al., 2019). The total area of semi-natural grasslands (all sub-types combined and here we use the Swedish terms ‘ängs- och betesmark’) needed in Sweden for a favourable conservation status can be estimated to be approximately 1.22 Mha. This number is estimated using the data from Eide et al., (2014) and Wallander et al., (2019). The area of semi-natural grasslands can be gathered from statistics and digital maps for Sweden.

As for assessing the impacts on biodiversity from the Swedish food consumption, indicators are needed that can capture impacts consistently across products and countries. By coupling the per kg of product impacts with the yearly consumed quantities of food, the biodiversity impact from Swedish consumption can be assessed in terms of potential species extinctions, although uncertainties are considerable (Moberg, Karlsson Potter, Wood, Hansson, and Röös (2020). Methods for including impacts of food production on biodiversity in LCA are less consolidated in comparison to, e.g., the impact category of climate change. The United Nations Environment Program - Society of Environmental Toxicology and Chemistry (UNEP-SETAC) guidelines suggest a method for including land use impacts on biodiversity in LCA that includes impacts due to occupation and transformation of land (Koellner *et al.*, 2013).

Land transformation—e.g., clearing natural forests or grassland to grow annual crops—often causes a decrease in biodiversity. In addition, land occupation—i.e., continuous use of land for cropping or grazing of domestic livestock—prevents re-growth of natural vegetation. Hence, land occupation also leads to impacts on biodiversity. So-called ‘characterization factors’ (CFs) are determined by comparing the relative difference in biodiversity (e.g., using species richness or another indicator) of a certain land use with that of a (natural) reference situation. At a UNEP-SETAC consensus workshop and in a review by (Curran *et al.*, 2016), the methodology suggested by Chaudhary et al. (2015) was recommended as a basis for further method advancement (Westhoek et al., 2016) The most updated variant of this method provides CFs for projecting potential species losses of five taxa resulting from five broad land use types (managed forests, plantations, pasture, cropland, urban) under three intensity levels (minimal, light, and intense use) in each of the 804 terrestrial ecoregions (Chaudhary and Brooks, 2018). It should be noted, however, that this indicator is sensitive to the choice of reference state and is a based on a relatively narrow measure of biodiversity (species count) that disregards other relevant aspects (e.g., endemism), which can have important policy implications (Vrasdonk, Palme and Lennartsson, 2019).

3.2.2 Aquatic biodiversity

Territorial-based indicator(s):

The index Maximum Sustainable Yield (MSY)

Description: Threshold is highest possible yield for the fisheries without risking the reproduction of the fish population.

Indicator:	The index Maximum Sustainable Yield (MSY)
Indicator label:	T-3.2.2a
Type according to DPSIR:	S
Target:	Maximum sustainable yield values are set for the focus species. Thresholds published by HaV.
Data source:	Artdatabanken: https://www.artdatabanken.se/globalassets/ew/subw/artd/2.-var-verksamhet/publikationer/32.-tillstand-och-trender-2020/tillstand-trender.pdf http://stateofthebalticsea.helcom.fi/biodiversity-and-its-status/, Havs och vattenmyndigheten (HAV) and (SLU), https://www.slu.se/globalassets/ew/org/inst/aqua/externwebb/sidan-publikationer/resursoversikten/resursoversikt-2021-220307-mindre.pdf https://www.slu.se/globalassets/ew/org/inst/aqua/externwebb/sidan-publikationer/resursoversikten/resursoversikt-2021-220307-mindre.pdf

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Fishing can be a severe pressure on aquatic species and high harvest pressure can result in populations going extinct. Different fishing practices that negatively impact water environments (such as trawling) also affects many	National data is of high quality and the data is recalculated annually. One negative aspect is that MSY is not calculated for all species and mainly focus on fish.	The indicator is easy and straightforward to interpret.	It is constructed to be used in policy decisions and likely useful for other analyses as well.

species that are not target species. The MSY index is widely used and couples harvesting with the status of fish populations.			

Area of marine protected areas (Mha)

Description: This indicator describes the area of protected marine habitats within the country.

Indicator:	Area of marine protected areas (Mha)
Indicator label:	T-3.2.2b
Type according to DPSIR:	P
Target:	Suggested target is the EU biodiversity strategy ‘legally protect minimum of 30% of the Swedish marine areas’ while research suggests that 37% of marine areas are protected (O’Leary et al., 2016)
Data source:	SCB: https://www.scb.se/hitta-statistik/statistik-efter-amne/miljo/markanvandning/skyddad-natur/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Protecting some marine areas from fishing and other resource use will make it possible for different species of fish and other marine organisms to sustain viable populations in these areas. The areas will still be affected by climate change and pollution, but will be protected from fishing.	National data is of high quality.	Data is easy to interpret.	As protected areas are one of the foremost ways to save marine organism from over harvesting, they are a tool to conserve marine biodiversity and knowledge how much of these is present is very important.

Consumption-based indicator(s):

Share of fish in diets that are certified or rated as green in WWFs Fish guide

Description*:* The indicator assess the share of fish in diets that are certified or rated as green in WWFs Fish guide.

Indicator:	Share of fish in diets that are certified or rated as green in WWFs Fish guide.
Indicator label:	C-3.2.2c
Type according to DPSIR:	P
Target:	Not available.
Data source:	Data are not available.

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
It would be highly relevant to measure the share of fish in diets that are certified or rated as green in WWFs Fish guide. Current consumption patterns are difficult to sort as the same species can originate from different locations and harvesting methods.	Certification of fish or that they are rated as green in WWFs Fish guide implies that there is a standardised approach to assessing the sustainability aspects of the practices regarding fish that are used in diets. How final consumption patterns relate to the certifications or to the fish guide is however still unclear and difficult to assess.	The indictor (when data exists) would be easy to interpret and to follow over time, given transparent import data on origin and harvesting method.	The indicator would be a useful to assess the sustainability of practices regarding fish that are included in diets.

Background

The Swedish seafood consumption measures to around 12.5 kilos cleaned fish and shellfish per person and year (25 kilos before cleaning). Only 26-28% of the total volume is caught in Swedish waters or from Swedish fish farms, and the rest is imported mainly from Norway followed by Denmark and China (Borthwick, Bergman and Ziegler, 2019; Hornborg, Bergman and Ziegler, 2021) . The most commonly consumed fish is salmon, and almost all comes from fish farms in Norway which receives a "be careful" mark in the WWF fish guide (WWF, 2023; Ziegler *et al.*, no date).

The threats that aquatic diversity are under are diverse and not only from fishing. One if these are agricultural practises that negatively affect biodiversity by, e.g., nutrient and pesticide run-offs. Other negative affects come from using aquatic environments to harvest wild species from and areas to rear organisms in for consumption. There is pollution of different kinds, as well as changes in the temperature and water composition due to climate change. For aquatic systems, there are less data than for the terrestrial systems and biodiversity assessments are not done similarly and as often as in terrestrial environments. This is due to aquatic systems being both harder to work in and to monitor. There are yearly national estimations of the number of commercially interesting fish and shellfish species in major lakes and both the east- and west coast (Sundelöf et al., 2022). The data show the status and trends of the species using data from different populations and areas.

There are no precise national targets for preserving biodiversity in aquatic systems. The Swedish environmental objectives 'Flourishing lakes and streams' includes the general targets: important ecosystem services of lakes and watercourses are preserved, lakes and watercourses have structures and water flows that facilitate habitats and dispersal pathways for wild plant and animal species as a part of a green infrastructure, habitats and naturally occurring species associated with lakes and watercourses have a favourable conservation status and sufficient genetic variation within and between populations, threatened species have recovered and habitats have been restored in valuable lakes and watercourses. 'A non-toxic environment' includes the targets: total exposure to chemical substances via all sources of exposure is not harmful to people or biodiversity, total exposure to chemical substances via all sources of exposure is not harmful to people or biodiversity. 'A balanced marine environment, flourishing coastal areas and archipelagos' include the targets: important ecosystem services of coasts and seas are preserved, shallow coastal areas are characterised by a rich biodiversity and natural recruitment of fish, and offer habitats and dispersal pathways for plant and animal species as a part of a green infrastructure, habitats and naturally occurring species associated with coasts and seas have a favourable conservation status and sufficient genetic variation within and between populations, and populations of naturally occurring fish species and other marine species remain viable, threatened species have recovered and habitats have been restored in valuable coastal and sea waters.

The index most widely used for aquatic species that are managed (i.e. fished) is variation of the threshold Maximum Sustainable Yield (MSY). The goal of this threshold is highest possible yield for the fisheries without risking the reproduction of the fish population. There are also varieties of MSY called F_{MSY} and MSY $B_{trigger}$. They are suitable when the fish species are long-lived and where good data is available. 'F' in F_{MSY} is a measure how much mortality from fishing a population can withstand, where fishing under this value is regarded a sustainable. For MSY $B_{trigger}$ the reproductive part of the population has to be over this value for sustainable harvesting, if not the population has to be managed so that it increases (Sundlöf et al. 2022).

3.2.3 Diversity of domesticated plants and animals

Territorial-based indicator(s):

Shannon index for the number of species and breeds farmed and for crop species and varieties grown

Description: Diversity of domestic animals and plants used in production.

Indicator:	For animals: using Shannon index with the number of species and breeds farmed; for crops using Shannon index for species and varieties grown.
Indicator label:	T-3.2.3a
Type according to DPSIR:	S
Target:	Suggested target is a modification of the EU biodiversity strategy ''The diversity of species, breeds and varieties show no decrease' using year 2000 as reference year.
Data source:	Swedish Board of Agriculture: https://jordbruksverket.se/djur/lantbruksdjur-och-hastar/husdjursraser-och-avelsorganisationer/husdjursraser Swedish Board of Agriculture: https://jordbruksverket.se/jordbruket-miljon-och-klimatet/forskning-om-ekologisk-produktion/arkiv/2022-01-17-svenska-genbanker

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The number of domestic animals and plants used in food production has been declining for a	Likely good data on some breeds and varieties used in Sweden in general. Not easy to access	Easy to interpret.	Would be very useful as a measure of how this resource is used from a resource and diversity point of view. It would

long time. There is a problem with that as diversity of species, breeds and varieties means an inherent increase resistance for disturbances on production.	from a database presently.		also be very valuable from a human health point of view in terms of both nutrients and cultural values (see other section).

Consumption-based indicator(s):

Sum of species of animals (including breeds) and plants (including sorts) in the diet / yr

Description: Diversity of domestic animals and plants consumed

Indicator:	Sum of species of animals (including breeds) and plants (including sorts) in the diet / yr
Indicator label:	C-3.2.3a
Type according to DPSIR:	P
Target:	None available. Suggested target: > 48 species consumed per year.
Data source:	Dietary surveys by the Swedish Food Agency are irregular (SFA, 2012; 2018), but these give the best information on consumption in Sweden.

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The number of species, breeds and varieties of domestic plants and animals consumed has declined over time. A low variation of the available food likely affects the diversity of the produced food and vice versa. Except	Sum of species consumed per year has successfully been used in very scale-scale pan-national studies (e.g., Hanley-Cook et al. 2021). This is a taxonomic level that can be used, though it will not cover all of the diversity (number of breeds and varieties)	Easy to interpret but will likely not show the entire diversity aspect which is under the species level. This is due to that the index likely will be based on data that are coarser than ideal.	This is a very useful information as there are clear links between resilience of food systems – domestic biodiversity – diverse diets – health. The major hindrance using this indicator is that national surveys are irregular.

from that a species rich diet is healthier, a highly varied consumption may positively influence food production to be more diverse and resilient. Suggested target >48 species consumed per year are based that diet-related mortality in consumers is highly reduced beyond this level (Hanley-Cook et al. 2021). This solely a 'human health' part of the motivation for the index	interesting. Dietary surveys by the Swedish Food Agency are irregular (SFA, 2012; 2018), but these give the best information on consumption in Sweden.		

Background

The diversity of domesticated species (both animals and plants) is derived from wild biodiversity. This diversity is what forms the biological base of our food (and feed to domesticated animals). Their capacities are the limits that set what nutritional and energetic values that we can derive from agricultural production. A rapid decrease of genetic diversity in domestic species used in agriculture in combination with a low interest in this diversity has been present for decades (Johns et al., 2013; Leroy et al., 2018) The large environmental changes resulting from climate change will threaten food production in many parts of the world. To be able to deal with these threats a new approach is needed that also takes the capacity of domestic species and this existing diversity into account (Bullock et al., 2017). New pathogens are likely to emerge and be more common from the interaction between climate change and habitat degradation (Schmeller, Courchamp and Killeen, 2020). To be able to better withstand the diverse impacts of changes, domestic species need to have a genetic capacity and adaptive ability for them to be resilient (Sejian et al., 2019). With a diversity of domestic animals and plants in the production system, there is a greater ability to maintain a secure food production when facing future threats (Chrenek, Kubovičová and Alexander Makarevich, 2021). Domestic (and geographically suitable species) are also interesting from a Swedish civil contingency perspective (MSB).

An indicator that would measure the diversity of species, varieties and breeds that are used in production and diversity of species consumed would be very good and useful from many different perspectives.

There are no precise national targets at the moment. The Swedish environmental objectives ’A varied agricultural landscape’ includes the general target: biological and cultural heritage values of the agricultural landscape that have emerged through long-term, traditional management are preserved or improved, local breeds of domestic animals and the genetic resources of cultivated crops are sustainably preserved. The suggested target is a modification of the EU biodiversity strategy ‘‘The diversity of species, breeds and varieties show no decrease’ using year 2000 as reference year would work towards keeping a level of biodiversity that future development of suitable species, breeds and varieties could utilise. The Swedish Board of Agriculture has conservation and developmental plans for animal breeds, but not specific numeric targets set(Gustafsson and Nord, 2010).

A diet that is diverse in terms of the plant and animal species that are consumed and the different varieties and breeds therein, may stimulate a food production that is more diverse. Diversity in what is produced will increase the resilience of a food system. By producing more diverse food that the consumers encounter and can choose from, there will likely be a change in the consumers’ preferences towards a more varied diet. Diets based on a higher diversity of domesticated plant and animal species, breeds and varieties will then loop back and support a more varied and resilient food production (Chrenek, Kubovičová and Alexander Makarevich, 2021).

3.3 Theme: Preservation of natural resources

Food production is heavily dependent on a range of natural resources including land, water, energy and minerals and also a major user of these resources (UNEP, 2016). The use of natural resources are often inefficient, e.g. only 15-20% of nitrogen and phosphorus added to soils are actually embedded in the food produced (UNEP, 2016). This theme contains indicators to measure the use of crucial natural resources: land, water, energy and mineral fertilisers, both from a territorial and consumption based perspective. The theme is present in the Hebinck et al. (2020) framework, however the sub-themes we included here differ in the following regards: we include the caring of soils ('Stop soil erosion' in Hebinck et al. 2020) in the new theme "Manage soils and water" and the maximum yield for fisheries we treat as a biodiversity conservation theme instead (section 3.2.2). We expand this theme by also considering land, energy and mineral fertilisers, in addition to water which was considered by (Hebinck *et al.*, 2021).

3.3.1 Land use

Territorial-based indicator(s):

Amount of cropland used per year (Mha)

Description: The amount of cropland used for agricultural production in Sweden.

Indicator:	Amount of cropland used per year (Mha)
Indicator label:	T – 3.3.1.a
Type according to DPSIR:	Driver (of resource use)
Official target:	Not available
Data source:	Swedish Board of Agriculture: https://jordbruksverket.se/e-tjanster-databaser-och-appar/ovriga-e-tjanster-och-databaser/statistikdatabasen

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Agricultural land is generally a limited resource (see below). However, in Sweden the goal	Good data available at the Swedish Board of Agriculture.	Easy and intuitive to interpret. Quantitative.	The indicator is useful to assess the amount agricultural land that is used for per year.

might not be to minimise this land use but rather to keep it at a certain level to ensure production capacity.			

Consumption-based indicator(s):

Amount of cropland used per year (Mha)

Description: The amount of cropland needed per year to produce food (and feed for animals) for the Swedish population.

Indicator:	Amount of cropland used per year (Mha)
Indicator label:	C – 3.3.1.b
Type according to DPSIR:	P
Target:	Cropland use boundary according to EAT-*Lancet:* 1.3 Mha $year^{-1}$
Data source:	FAOSTAT calculated according to methodology in Moberg et al. (2020)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Cropland is a limited resource that is crucial for food production. It is directly related to food consumption. Land use tightly follows the types of food commodities in diets so observing change in this indicator when diets change is clear. Here we decided to use the amount of	Straightforward to calculate based on commodities needed to produce the food in the diet based on the yield data which is available with good accuracy. Land use is a well-established indicator used in many studies (Jones et al., 2016).	Easy and intuitive to interpret. Quantitative. Clearly reflects the use of this important resource based on the amount and type of commodities consumed. The cropland use in different geographical areas can be aggregated. However, as productivity varies across land it could be relevant to bring	Lacks official policy goals but is highly relevant for assessing resource use from food. Possible to influence through changes in diet, reduced waste and higher yields. Threshold available through the EAT-*Lancet*.

cropland per year and capita needed to produce the food consumed. We chose cropland as opposed to total agricultural land since cropland is more limited and a boundary for cropland use has been suggested in the literature.		that into the aggregation of different land type. However, since productivity is highly influenced by management and inputs we chose in this initial version to stay with aggregation without considering productivity variation.	

Background

Land suitable for agriculture is a limited resource. Agriculture currently occupies half of the habitable land (FAOSTAT, 2022). Land use is a commonly used indicator in the assessment of foods and diets (Jones et al., 2016). It is calculated from the crop yield (kg per ha), giving the area needed to produce 1 kg of the given food product (Temme *et al.*, 2013). For animal products, the type and the amount of feed are used to calculate the land requirement.

Land use can be divided into different land types reflecting their suitability for different types of production e.g. land suited for annual or permanent crops, or pasture, although studies also commonly show results of land use on an aggregated level only. As some pasture is unfit for cropping (Mottet et al., 2017), it is important to differentiate between different types of land (Eshel et al., 2014; Meier et al., 2014) . Global croplands are the major producers of food. Productivity differs considerably between different croplands but is also highly influenced by management and inputs.

The consumption based indicator tracks the cropland use needed for producing the Swedish diet yearly. This land is located both within and outside Sweden. We use cropland here, as opposed to total agricultural land, as cropland is the most scarce resource in terms of land. In terms of targets for land use, the EAT-*Lancet* commission (Willett et al., 2019) suggests a food system land boundary for the global food system of 13 million km^2 (uncertainty range 11-15 million km^2) which equates to a Swedish target of around 13,000 km^2 or 1.3 Mha (if Swedes constitute 10 million out of a global population of 10 billion) if distributed equally per capita.

In terms of the territorial based indicator, we measure the amount of land used for cropping in Sweden. A low use of land for cropping is preferable from a resource perspective but it is also usually preferable for environmental reasons, as land use for agriculture is a major driver of biodiversity loss (Laurance, Sayer and Cassman, 2014). In

Sweden however, in stark contrast to most other countries, forestry, rather than agriculture, is the dominant user of land. The agricultural land (mainly cropland) occupies only about 7% of the total land area (Statistics Sweden, 2022a).

3.3.2 Water use

Territorial-based indicator(s):

Total blue water used in food production (m^3 $year^{-1}$)

Description*:* The total amount of water used in food production in Sweden (agriculture - irrigation and animal rearing and food processing).

Indicator:	Total blue water used in food production (m^3 $year^{-1}$)
Indicator label:	T – 3.3.2a
Type according to DPSIR:	P
Target:	Increase water-use efficiency (SDG target 6.4[3]) (Statistics Sweden, 2016)
Data source:	Statistics Sweden has use in agriculture and the food sector (Statistics Sweden, 2021a)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Although water availability is generally good in Sweden, it is still relevant to follow how water use develops over time.	Statistics Sweden has data on aggregated level – should be enough to follow this on the aggregated territorial level.	Easy to interpret the indicator as such but for the amount of water is not easily relatable. Rather it is the trend in total water use that can be easily interpretable.	Possible to influence through changes in management. The official policy goals are formulated as increased water use efficiency which does not match the indicator directly.

[3] Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity. https://unstats.un.org/sdgs/metadata/?Text=&Goal=&Target=6.4

- Indicator 6.4.1: Change in water-use efficiency over time (CWUE).
- Indicator 6.4.2: Level of water stress: freshwater withdrawal as a proportion of available freshwater resources

Level of water stress - freshwater withdrawal as a proportion of available freshwater

Description: Level of water stress. Measures freshwater withdrawal as a proportion of available freshwater.

Indicator:	Level of water stress - freshwater withdrawal as a proportion of available freshwater
Indicator label:	T – 3.3.2b
Type according to DPSIR:	I
Official target:	Increase water-use efficiency (SDG target 6.4)
Target:	Not available
Data source:	https://sdg6data.org/indicator/6.4.2

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
This indicator complements the indicator of total water use by accounting for also the availability of freshwater.	An SDG indicator so well established.	Relatively interpretable.	Water stress can be reduced by management, but this indicator also reflects water availability which is determined by many factors external from the food system (e.g. climate).

Consumption-based indicator(s):

Total blue water used for food consumption (m^{3} year^{-1} per year)

Description: The amount of water needed to produce food for the Swedish population.

Indicator:	Total blue water used for food consumption (m^{3} year^{-1} per year)
Indicator label:	C – 3.3.2c
Type according to DPSIR:	P
Target:	Land use boundary according to the EAT-*Lancet:* 339 m^{3} capita^{-1} year^{-1}
Data source:	Moberg et al. 2020

Scarcity adjusted blue water use

Description: Indicator of scarcity adjusted blue water use.

Indicator:	Scarcity adjusted blue water use, https://wulca-waterlca.org/aware/what-is-aware/
Indicator label:	C – 3.3.2d
Type according to DPSIR:	I
Target:	Not available
Data source:	https://wulca-waterlca.org/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Water is a limited resource that is crucial for food production. It is directly related to food consumption. Both indicators follows the types of food commodities in diets and for scarcity it reflects where crops are grown. Observing change in this indicator when diets change is clear.	Straight-forward to calculate based on available water use data and scarcity factors available in literature. However, water use data is old and associated with large uncertainty. Precise water scarcity factors require knowledge of watershed in which food is grown which is seldom available. Water use is a well-established indicator used in many studies (Jones et al., 2016).	Rather easy and intuitive to interpret, especially blue water use although the number says little to people. Quantitative. Clearly reflects the use of this important resource based on the amount, type and origin of commodities consumed. Blue water use in different geographical areas can be aggregated.	Lacks official policy goals but is highly relevant for assessing resource use from food. Possible to influence through changes in diet, reduced waste and change in origin. Threshold available through the EAT-*Lancet* for blue water use.

Background

Water is another important resource for food production. It has been estimated that the global food system accounts for 70% of the global freshwater use (Steffen et al., 2015). In a global perspective, water availability in Sweden is usually good, although with great inter-annual and geographical variation. There are no official policy targets related to water use in Sweden except the SDG target 6.4, which states that the water-use efficiency should be increased and that the sustainable water withdrawals should be ensured. Measuring water use is complex and dependent on multiple data sources. In Sweden, the total water use in different sectors is assessed regularly (Statistics Sweden, 2021a) . Here we include both the total water use to be consistent with the other indicators in this theme, and an indicator also reflecting the water stress caused by the use of water.

On the consumption side, a commonly used indicator for water use is the water footprint (WF) as set out by the Water Footprint Network (Aldaya *et al.*, 2012)). The WF is the demand for freshwater resources required in all life cycle steps to produce goods and services. It represents a measure of human appropriation of freshwater, which is measured as the volume of water used. Water use can be direct or indirect, where direct use is the individual's direct consumption of water, such as water for cooking, whereas indirect use, sometimes called 'virtual water', is the water needed for all goods and services earlier in the supply chain. In addition, water is divided into green, blue and grey water. Blue water is surface or groundwater, green water is rain water or moisture stored in the topsoil layer and grey water is the volume of freshwater needed to 'assimilate a load of pollutants' caused by the activity in question. The grey water volume is affected by the natural background concentration of pollutions and existing water quality standards. As blue water in some respect represents water as a finite resource, it is common to let blue water represent the overall WF (Eshel et al., 2014), which is also our choice here as one of the consumption indicators. This can also be used to compare against the EAT-Lancet boundary for freshwater use.

Methodologies to account for the differences in the actual impact of water use given regional differences in water scarcity have also been developed (Ridoutt and Pfister, 2010). (Hess *et al.*, 2015) suggest an indicator called the Water Stress Index (WSI) which reflects blue water availability. The WSI is expressed as a number between 0.01 and 1, where a value of <0.01 indicates no water stress, values between 0.1 and <0.2 indicate a low water stress, values between 0.2 and <0.4 indicate a moderate water stress, values between 0.4 and <0.8 indicate a high water stress and values of >0.8 indicate a very high water stress. Hess et al. (2015) used the WSI to calculate a blue water scarcity footprint (WSF) (m3 H20 equivalents) which reflects the equivalent amount of water withdrawn from a water body at the global average level of water stress.

There is some controversy as to whether water use quantification or including water stress is most appropriate.(Hoekstra, 2016) lists the potential pitfalls and dangers of weighting the water footprint with water stress or scarcity and argues that the WSI obscures the debate of water resources, neglects the importance of green water scarcity, is inconsistent with how other environmental footprints are designed and lacks ‘meaningful physical interpretation’. A recent consensus building process within the UNEP-SETAC Life Cycle Initiative recommends the use of the AWARE method which is based on “the quantification of the relative available water remaining per area once the demand of humans and aquatic ecosystems has been met” (Boulay *et al.*, 2018). Here we decided to use both the blue water use that can be compared against the EAT-*Lancet* boundaries (Willett et al., 2019) which is easy to interpret and the water scarcity adjusted blue water use to account for the scarcity of water resources.

3.3.3 Energy use

Territorial-based indicator(s):

The use of primary energy per year for food production in Sweden (agriculture, food industry)

Description*:* The total amount of energy used in food production in Sweden (agriculture and food industry).

Indicator:	The use of primary energy per year for food production in Sweden (agriculture, food industry). This indicator includes on-farm energy use, indirect energy i.e. energy to produce inputs are not included.
Indicator label:	T – 3.3.3a
Type according to DPSIR:	Driver (of resource use)
Official target:	Not available
“Science-based target”:	Not available
Data source:	For energy use in Swedish agriculture:(Swedish Energy Agency, 2019) For energy use in Swedish Food industry: (Swedish Energy Agency, 2022) Swedish Energy Agency (2022)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Energy in different forms (e.g. electricity and liquid/solid fuels)	Energy use, converted to primary energy	Rather easy and intuitive to interpret. Clearly reflects the use of energy.	The indicator is highly relevant for assessing resource use from food.

are limited resources and crucial for the entire food production value chain. By following energy use, an indication of the energy efficiency of the food production can be obtained.	with conversion factors. Energy use in agriculture is reported per disaggregated energy source and can be converted to primary energy. Energy use in the food industry is reported as total energy and divided by fossil electricity and biomass. So in order to recalculate to primary energy, a few assumptions have to be made e.g. on electricity mix.		Targets for the agrifood sector specifically is lacking, however part of the SDGs and national targets for energy use in society can be applied. Possible to influence through changes in diet, reduced waste and energy efficiency throughout the value chain.

Consumption-based indicator(s):

The use of primary energy per year for food consumption

Description: The amount of energy needed to produce food for the Swedish population (agriculture and food industry within and outside the country, production of inputs, transports, domestic energy use by retail and consumer).

Indicator:	The use of (primary) energy per year for food consumption
Indicator label:	T – 3.3.3b
Type according to DPSIR:	Driver (of resource use)
Official target:	Not available
"Science-based target":	Not available
Data source:	For energy use in Swedish agriculture: (Swedish Energy Agency, 2019). For energy use to produce inputs: Import/use of agricultural inputs from e.g.

	Statistic Sweden and coupled energy use factors from literature. For energy use in Swedish Food industry: Swedish Energy Agency (2022). For transports, retail, consumer: No readily available data. For energy use of imported food: Research projects, I/O databases e.g. Exiobase

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Energy in different forms (e.g. electricity and liquid/solid fuels) are limited resources, but crucial for the entire food production value chain. By following energy use, you can get an indication of the energy efficiency of the food production.	Direct energy use in agriculture and food industry available, see energy territorial-based indicator. Indirect energy use by agriculture (imported to farms in form of products e.g. mineral fertilisers based on fossil energy) can be calculated based on literature. Data for energy use for food transport, retail and consumer is not readily available, neither energy use data of imported food. Conversion to primary energy will require assumptions on e.g. energy sources in electricity mix.	Rather easy and intuitive to interpret. Clearly reflects the use of energy.	Is highly relevant for assessing the resource use from food. Targets for the agrifood sector specifically is lacking, however part of the SDGs and national targets for energy use in society can be applied. Possible to influence through changes in diet, reduced waste and energy efficiency throughout the value chain.

Background

Energy is an important input in agriculture, both as a direct energy use at farms (e.g. diesel for farm machinery, crop crying, heating and cooling) but agriculture is also indirectly dependent on energy (e.g. for production of nitrogen mineral fertilisers). Further along the food chain, energy is also important for the transportation of ingredients and food, the food industry and retail. As many energy sources are limited resources (oil, gas, coal, uranium) this is an important sustainability issue for the food chain. Many energy sources are also obtained from politically instable regions, which pose a threat to Sweden's ability to produce food. During the war in Ukraine, we have for example seen very sharp increases in the nitrogen fertiliser prices (Russia is a large producer of nitrogen fertilisers based on natural gas, as well as a large supplier of gas used for fertiliser production in European countries).

The data for direct energy use in agriculture is available at the (Swedish Energy Agency, 2019). There are however no statistics on indirect energy use, i.e. energy used for e.g. the production of inputs, this must be calculated based on the import statistics of agricultural inputs and coupled energy use factors from the literature. (Landquist *et al.*, 2019) estimated the total energy use in Swedish agriculture to 6 and 3.5 TWh for the direct and indirect energy respectively. The data for the direct energy use in the food industry (estimated to 5 TWh in 2020) is available at the Swedish Energy Agency (2022), a yearly publication of energy use in Sweden. As a comparison, the total energy use in Sweden was 369 TWh in 2019.

There are no official statistical data available on the energy use of the food consumption level that also includes energy for imported foods. However, in a project funded by the Swedish Environmental Protection Agency the impact of Swedish consumption both inside and outside Sweden's borders was mapped. For the year 2014, it was estimated that agricultural products, food, beverages and tobacco used 27 TWh of fossil and biobased energy (PRINCE project, 2022).

The political parties in Sweden have agreed on a goal of 50% improvement in energy efficiency by 2030, compared to 2004. In December 2021, the Swedish Energy Agency put forward five strategies for how to reach this goal in different sectors, including production, trade and consumption (Swedish Energy Agency, 2021). Food and agriculture is however not mentioned in any of these documents.

A governmental investigation on fossil independent agriculture was commissioned in 2021. The purpose was to explore how less fossil fuels can be used to reduce climate impact, decrease dependency on import of agricultural input products, and to strengthen Swedish agriculture´s competitiveness. The investigation put forward a number of suggestions on policy measures to fulfil this goal (SOU, 2021).

There is an SDG goal for energy efficiency: SDG target 7.3: "*By 2030, double the global rate of improvement in energy efficiency".* The indicator for this target is "Energy intensity measured in terms of primary energy and GDP". Likewise, the European Union has committed itself to a 20% improvement in the energy efficiency target for 2020 and at least 32.5% target for 2030, compared to 2007. Targets for the agrifood sector specifically are lacking.

An optional indicator could be to track fossil fuel, nuclear and renewable energy separately. This way, a clearer picture of the depletion of finite resources can be captured. This can be done for the territorial-based energy indicator were disaggregated data is available. Finding disaggregated energy data for the consumption-based indictor will on the other hand be a challenge.

The lack of disaggregated energy data for imported foods will also make it difficult calculate the primary energy use, as each energy source (fossil, nuclear, wind etc) has its own primary energy conversion factor. Rough assumptions can be made e.g. electricity mix in countries from where we import food for the calculations. If it is not possible to calculate the primary energy use, the total energy use can however give a sufficient overview.

3.3.4 Mineral fertiliser use

Territorial-based indicator(s):

Use of virgin P per year (Mt)

Description: The amount of virgin mineral fertilisers used in food production in Sweden (agriculture, food industry, retail, consumer).

Indicator:	Use of virgin P per year (Mt)
Indicator label:	T – 3.3.4a
Type according to DPSIR:	P
Target:	50 percent of the phosphorus recycled to food production by 2030 and/or an obligatory share of the recycled phosphorus in all sold products (as suggested by The delegation on circular economy, 2022).
Data source:	Statistic Sweden, import statistics

Consumption-based indicator(s):

Use of virgin P per year (Mt)

Description*:* The amount of virgin mineral fertilisers to produce food for the Swedish population.

Indicator:	Use of virgin P per year (Mt)
Indicator label:	T – 3.3.4b
Type according to DPSIR:	P
Target:	1.1 kg P per capita per year (Willett et al., 2019)
Data source:	Moberg et al. (2020).

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Minerals in different forms (e.g. phosphorus, potassium, sulphur) are limited resources, but crucial for food production. By tracking use of virgin mineral fertilisers, you can get an indication of the efficiency and recirculation level in the food system.	For phosphorus, indicators have so far been mainly directed toward environmental impact and not so much as a limited resource. For phosphorus, Moberg et al. (2020) provide data for Swedish food consumption. Data is not readily available for the other minerals.	Clearly reflects the use of minerals, comparable over time and different diets and countries, easy to communicate.	Is highly relevant for assessing the resource use from food. Targets for agrifood sector specifically is lacking, however part of the SDGs and national targets for energy use in society can be applied. Possible to influence through changes in diet, reduced waste and by changing food system towards more circular flows.

Background

Minerals are indispensable building blocks in plants and must be added to soil to replace the minerals in crops removed from the land and lost to surrounding ecosystems. At the same time, minerals are limited resources. To secure future food production, the use of virgin mineral fertilisers must decrease and the recycling rate of nutrients within agriculture and from urban to agriculture must increase. The global economic reserves for production of mineral phosphorus fertiliser were in 2021 estimated correspond to 323 years of production (USGS, 2022), while the reserves for the production of potassium and sulphur fertilisers in 2017 were estimated to 93 and 60 years of production, respectively (Jönsson, 2019). Nitrogen fertilisers are produced in a chemical process (Haber-Bosch) which requires nitrogen from normal air and hydrogen. The hydrogen is often obtained from fossil fuels, thus nitrogen fertilisers are covered in the energy indicator.

In this work we focus on phosphorus. It could be of interest to also include more indictors e.g. for potassium, sulphur and micronutrients (e.g. boron, copper, manganese, zinc) which are limited natural resources. However, fertilisers are often spread as compounds so by focusing on phosphorus we can get an indication of the overall mineral fertiliser use. Further, since phosphorus has been of societal interest due to its eutrophication issues and the limitations of the resource, there is much more data for phosphorus than for the other macro- och micronutrients.

Global phosphate fertiliser consumption amounted to some 45.6 million metric tons in 2018 (Statista, 2022), equivalent to about 6 kg P per capita. However, the use is very unevenly distributed with shortages in low-income countries (Langhans et al., 2022)For phosphorus, the per capita boundary downscaled from the global boundaries given by the EAT-Lancet Commission is 1.1 kg P per year (Moberg et al., 2020). This includes the application of phosphorus as mineral fertiliser, for which the EAT-*Lancet* Commission set a boundary based on the maximum inputs that do not lead to eutrophication of terrestrial and marine systems (Willett et al., 2019). In other words, the boundary is not set with regards to phosphorus being a limited resource.

The Swedish government has investigated the recirculation of phosphorus for several decades. In the latest investigation 2019, it was suggested that at least 60 percent of the phosphorus contained in produced sewage sludge must be recycled on an annual basis for wastewater treatment plants with more than 20 000 person equivalent connected (Swedish Government Official Reports, 2020). A Swedish delegation on the circular economy has also come forward with several suggestions, for example a goal of at least 50 percent of phosphorus recycled to food production by 2030, and to introduce an obligatory share of recycled phosphorus in all sold products (The delegation on circular economy, 2022).

3.4 Theme: Clean air and water

Clean air and water are fundamental for the health of humans and ecosystems but are currently seriously threatened by agriculture and other human activities. Eutrophication, caused by nutrient enrichment of aquatic ecosystems due to losses, overuse or misuse of nitrogen and phosphorus, is one severe environmental problem leading to algae blooms, degradation of water quality and oxygen depletion. The water quality can also be negatively affected by pesticide leaching.

The food system also contributes to air pollution. Ammonia is a substance of particular interest since the contribution from agriculture to the total national emissions amount to 88% (Statistics Sweden, 2022). Also other air pollutants are associated with food production but not at such a large proportion as ammonia, why only ammonia emissions were included as an indicator in this report.

Under this theme, progress indicators similar to the ones included in Hebinck et al. (2021) are proposed, i.e. reduction of phosphorus and nitrogen surplus presented under the heading ‘Eutrophication’, reduction of ammonia and reduced use of toxic substances.

3.4.1 Eutrophication

Territorial-based indicator(s):

N and P surpluses on Swedish agricultural land expressed in total and per ha

Description: Nitrogen and phosphorus surplus

Indicators:	N and P surpluses on Swedish agricultural land expressed in total and per ha.
Indicator label:	T – 3.4.1a-b
Type according to DPSIR:	P
Target:	Not available
Data source:	Statistics Sweden (2021) presents nutrient budgets for Swedish agricultural land on regular, but not yearly, basis. Yearly estimates can be compiled using other statistical data.

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Gives a clear indication of the risk of losses (but proximity to sensitive watercourses and regional variations also need to be considered)	High-quality data based on compiled information from Statistics Sweden. The two recent publications with N and P budgets consider the years 2016 and 2019.	Easy to interpret in particular if expressed per hectare.	Lacks official policy goals but is used in extension service on farm and field level, in legislation on field level and in different certification schemes (e.g. KRAV and Sigill).

Consumption-based indicator(s):

P fertiliser to arable land per year (thousands of tons)

Description: Amount of phosphorus fertiliser from mined origin that is used to produce the food in the Swedish diet.

Indicator:	P fertiliser to arable land per year (thousands of tons)
Indicator label:	T – 3.4.1c
Type according to DPSIR:	P
Target:	Based on EAT-Lancet (Willet et al., 2019) and current global population: 1.1 kg P capita^{-1} year^{-1}
Data source:	Moberg et al. 2020 (and references herein)

Total new reactive kg N (synthetic fertiliser+N-fixation) to arable land per year (thousand tons)

Description: New reactive nitrogen to arable land.

Indicator:	Total new reactive kg N (synthetic fertiliser+N-fixation) to arable land per year (thousand tons)
Indicator label:	C – 3.4.1d
Type according to DPSIR:	P
"Science-based target":	According to EAT-*Lancet:* 12 kg N capita^{-1} year^{-1}
Data source:	Moberg et al. 2020 (and references herein)

Justification for indicator choice:

Relevant:	Quality:	Interpretable:	Useful:
High P application over time increases the risk for eutrophication in freshwater systems but also in parts of the Baltic Sea. Excess N application (above crop's need) increases the risk for eutrophication in the sea and increases the risk for nitrate contamination of groundwater.	High-quality data available for consumption of food produced in Sweden which can be based on sale statistics and fertiliser use from SCB's questionnaires. Higher uncertainty for imported products but good estimates available (e.g. in Moberg)	Easy to understand. However, only indirectly reflecting the actual impact due to varying retention, soil status, soil types and management. E.g. high P application implies higher risk in areas close to watercourses and in soils with P-saturation/ high P status. Do not consider removal through crops and thus surplus.	Can be used on different levels and data from farm level can be compiled into indicators for products as well.

Background

The biochemical flows of phosphorus and nitrogen have been identified as beyond a "safe operating space" for human societies with transgressed boundaries for both nitrogen and phosphorus according to Steffen et al (2015). The boundary for phosphorus is defined both on a global level, including phosphorus from freshwater systems into the ocean, and on a regional level emphasising freshwater eutrophication, based on application of phosphorus mineral fertilisers.

Phosphorus is usually considered the limiting nutrient in freshwater systems while nitrogen is the limiting nutrient in coastal and oceanic waters. However, in the Baltic Sea, phosphorus is also a limiting factor in parts of the sea. According to Bergström et al., (2018), more than 97% of the Baltic Sea suffers from eutrophication and despite many measures taken, urgent actions are still needed to improve the status. "Zero eutrophication" is thus one of Sweden's environmental objectives formulated as: "nutrient levels in soil and water must not be such that they adversely affect human health, the conditions for biological diversity or the possibility of varied use of land and water." Due to the severe situation, nitrogen and phosphorus application rates are also strictly regulated in the Swedish legislation since long.

The combination of the severity eutrophication poses and the role of food system as a driver (according to Poore and Nemecek, food production causes 78% of eutrophication), means that indicators which can be used for identifying the overuse and tracking changes in the risk for losses are of utmost importance.

Although the link between nitrogen and phosphorus application and leaching is not straightforward due to inherent spatial and temporal variability, we still suggest an indicator for consumption based on the application of new reactive nitrogen (including synthetic nitrogen fertilisers and symbiotic nitrogen fixation) and synthetic phosphorus fertiliser since it is relatively easy to collect and compile data for these. This is also in line with the proposed global indicator from the EAT-*Lancet* commission built on a refinement of the variables proposed in the Planetary boundary framework. Moberg et al. (2020) downscaled the EAT-*Lancet* boundary to a figure expressed per capita for assessment of the Swedish diets, which can be used for Swedish food consumption when multiplied with the number of inhabitants in Sweden.

The same indicator for consumption could potentially be used also for territorial impact (domestic agricultural production), i.e. the total amount of P as synthetic fertiliser and new reactive nitrogen applied to arable land. However, since more detailed information is available for the Swedish agriculture through Statistics Sweden, we suggest more fine-tuned indicators based on budgets for agricultural land, which consider also other inflow of nitrogen and phosphorus as well as outflow (as harvest). These indicators can also be expressed in percentage indicating the efficiency. The proposed indicators can also be populated with farm data of high resolution from extension service through the project “Greppa Näringen” which can be used for benchmarking. We further suggest that the territorial indicators are expressed both in total for Sweden and per hectare. Presenting the territorial indicators as surplus *per hectare* (instead of total surplus for Sweden) makes it possible to compare regions and farm types, and is easier to intuitively understand.

In addition, the overuse and misuse of nitrogen does not only increase losses to water but also increases the risk for nitrous oxide emissions, which also stresses the importance of efficient use of nitrogen.

3.4.3 Use of toxic substances

Territorial-based indicator(s):

Pesticide risk index for health and environment

Description: Pesticide risk

Indicator:	Pesticide risk index for health and environment
Indicator label:	T – 3.4.3a-b

Type according to DPSIR:	I
Official target:	Not available
Data source:	The Swedish Chemical Agency (2004)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The indicator includes both amount and risk and is presented yearly	High-quality data based on actual use and a risk assessment in use for many years	Easy to compare over years, and possible to interpret what is behind the variation between the years	Already in use for national evaluation but could also be used on other levels (regional and farm level)

Consumption-based indicator(s):

Organic products' share of total market value

Description: Pesticide use

Indicator:	Organic products' share of total market value
Indicator label:	T – 3.4.2c
Type according to DPSIR:	D
Target:	There is an official target currently that says that 60% of food in public procurement should be organic.
Data source:	Joint publications from Ekologiska Lantbrukarna, Ekomatcentrum and Organic Sweden (Ekologiska lantbrukarna, Ekomatcentrum and Organic Sweden, 2022)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Not using pesticides is a core principle of organic farming and an increasing market share of organic products	Data for sale and purchase is collected and reported yearly in a joint publication by three organisations Ekologiska	Easy to interpret	Useful since it is reported yearly and can be related to targets set by different actors in the food system.

reduces the total pesticide use and thus the associated risks.	Lantbrukarna, Ekomatcentrum and Organic Sweden		

Background

Pesticides are efficient in boosting crop yields but are also harmful to the environment and human health if not managed properly. Pesticides and other toxic substances are included in the Swedish Environmental Quality Objective 'A Non-Toxic Environment' with several indicators, e.g. a toxicity index for the level of pesticide residues in surface water. Due to the risks associated with pesticides, the European Commission calls for a reduced dependency on pesticides in their Farm to Fork Strategy (European Commission, 2020b). The European Commission has also established 'Harmonised Risk Indicators' to track progress towards a reduction of the risks related to pesticides. One indicator is based on the quantities of active substances on the market, using weighting factors based on the classification of the active substance. The Swedish Board of Agriculture and the Swedish Chemicals Agency have 22 different indicators in use for evaluation of the risk with pesticides. Two of these indicators are a national risk index for health and environment based on the calculation model 'PRI-Nation' and the proportion of organically cultivated agricultural land. The model 'PRI-Nation' was developed by the Swedish Chemicals Agency (2004) for tracking trends in the impact of pesticides over time. Based on the same approach, the Swedish Chemicals Agency has also developed the indicator model, 'PRI-Farm', which is used to evaluate pesticide risk trends on individual farms and between production systems.

The indicator based on 'PRI-Nation' considers both environment and health aspects for about 300 substances and is compiled and presented yearly together with hectare doses. This indicator is also considered a suitable indicator for the territorial evaluation of Swedish food production in our framework and can potentially also be complemented with the area cultivated according to the principles of organic farming.

Toxic substances affecting food systems are both unintentionally spread and intentionally used in agriculture. An example of the first is e.g. heavy metals applied to cropland through manure and sewage sludge or via precipitation. Under this heading we focus on the second type of toxic substances, i.e. the use of agricultural pesticides. Cadmium is a highly toxic heavy metal causing deep concern. The inflows and accumulation of cadmium on field level is therefore included in the regulation as well as in the standards (e.g. Svenskt Sigill). However, detailed data is not available for populating indicators on a food system level why we exclude cadmium and other heavy metals from this compilation of indicators.

A large proportion of pesticide use related to food consumption is associated with imported food. Due to a lack of reliable data on pesticide use in specified imported food, there is a need for a more general approach. In our framework we propose the organic products' share of total market value as the consumption-based indicator for pesticide use since this information is already collected and presented yearly. A drawback is that it only roughly indicates hazardous use of pesticide since it gives no information of the pesticide intensity and associated risk in the remaining production of conventional food consumed.

As an alternative, we also suggest the use of an indicator for agrochemicals developed in the PRINCE-project and based on a combination of statistics and a global multi-regional input output database called EXIOBASE3 (Cederberg et al., 2019). This indicator better reflects hazardous use of pesticides but is not yet as easily available as information of market value. The Swedish Food Agency (2021) is monitoring pesticide residues through extensive analyses and specific pesticide residues have also previously been suggested as an indicator (The Swedish Food Agency, 2012). A possible indicator on consumption level could potentially therefore be the proportion of food that exceeds the maximum residue level (MRL). However, since the selection in the analyses is directed towards food products considered to have a higher risk of exceeding limit values and foods for more vulnerable target groups such as young children are selected in larger extent, we believe that the indicator has too many limitations for our purpose.

3.4.5 Air pollution

Territorial-based indicator(s):

Ammonia emissions per year (thousand tons)

Description: Ammonia emissions

Indicator:	Ammonia emissions per year (thousand tons)
Indicator label:	T – 3.4.5a
Type according to DPSIR:	P
Target:	17% decrease until 2030 compared to 2005 according to National Emissions Ceilings (NEC) Directive (2016/2284/EU).
Data source:	Statistics Sweden (2022b) based on e.g. SMED.

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
High relevance since reduction of NH3 is a prioritized area of concern.	High-quality data available based on statistics, inquiries and national estimates yearly updated by SMED using their emission calculation model.	Straightforward, can be used on different levels.	Already in use and important for following-up emissions reduction targets.

Consumption-based indicator(s):

Ammonia emissions per year from Swedish consumption (thousand tons)

Description: Ammonia emissions

Indicator:	Ammonia emissions per year from Swedish consumption (thousand tons)
Indicator label:	T – 3.4.5b
Type according to DPSIR:	P
Target:	Not available.
Data source:	Moberg et al. (2020)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
High relevance since reduction of NH3 is a prioritized area of concern.	Available data for 52 food products in Moberg et al (2020) but more fine-tuned data taking into account the variability is desirable in the future	A direct measure of the burden.	The EU directive in place targeting the territorial level. Also a consumption-based indicator could be a complement to also address imported food.

Background

Ammonia emissions are of environmental concern for several different reasons. They are contributing to soil acidification and terrestrial and aquatic eutrophication. Indirectly, ammonia emissions lead to nitrous oxide formation, a potent greenhouse gas and ammonia may also cause health problems through the formation of secondary inorganic aerosols (Hellsten, 2017). The single most dominant source of ammonia volatilisation in Sweden is from storage and spreading of manure, which means that ammonia emissions are of particular concern for the food system. Regulations with regards to regards storage facilities, and timing and techniques for spreading are in place and have been sharpened over time and through the national advisory programme ‘Greppa Näringen’ (Focus on Nutrients) together with environmental investments through the Rural Development Programme other policy instruments are available (Hellsten, 2017). However, after a slight decrease in yearly emissions between 1990 and 2010, there has been no clear sign of further decrease in Sweden (Swedish Environmental Protection Agency, 2021) and further actions are needed to reduce the emissions. In the EU directive 2016/2284/EU (the National Emission Reduction Commitments Directive or the NEC-directive) and the Gothenburg Protocol, national ceilings are defined for ammonia emissions, and a target for reduction (17%) is set for the year 2030 in relation to the base year 2005. In Sweden, the consortium SMED (Swedish Environmental Emissions Data) is responsible for estimating the emissions using an ammonia calculation model (www.smed.se).

An indicator for terrestrial emission of ammonia can be based on yearly updated high-quality data provided by SMED through their emission calculation model which is based on statistics, inquiries and national estimates. This indicator is important to include for territorial emissions related to food production since there is a strong focus on territorial reduction measures through legislation, advisory service, investments etc. As a consumption-based indicator we suggest data from the supplementary material in Moberg al (2021) to be used. This data is provided for 52 different food groups and can be used for summarising the entire consumption including diet changes over time. However, since no variability within each food product is considered, the consumption-based indicators should be considered rather coarse.

3.5. Theme: Manage soils and water

Access to good quality soils and the management of water resources are indispensable for food production. This is a new theme in comparison with Hebinck et al. (2020) we added to reflect the importance of these resources separately. While the theme 3.3, 'Preservation of natural resources' deals with the preservation of these resources per se, i.e. as a sustainability issue in itself, here we deal with the management of soils and water for their use as production resources in agriculture. That is, limiting land use to avoid agriculture's expansion into pristine ecosystems is a sustainability aspect dealt with under 3.3, while here we are concerned about the soil fertility of agricultural soils for agricultural production. A major distinction between the two sections is thus that individual producers have a large impact on managing natural resources at the farm and noticing improvements, which are included in this section. The topics covered in 3.3 concern the common goods on a larger scale, where the individual farmer cannot directly see improvements created by their own actions.

3.5.1. Soil fertility

Territorial-based indicator(s):

Changes in soil organic carbon (SOC) in mineral topsoils on cropland (thousand tonnes per year)

Description: Changes in soil organic carbon

Indicator:	Changes in soil organic carbon (SOC) in mineral topsoils on cropland (thousand tonnes per year)
Indicator label:	T – 3.5.1a
Type according to DPSIR:	S
Target:	Not available.
Data source:	The National Inventory Report (NIR) (United Nations, 2021) based on modelling using ICBM.

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
SOC is often proposed for and	Changes in SOC are often modelled	Easy to understand and	Already in use and can be used for

commonly used as an indicator for soil fertility since C content is positively associated with many soil-related ecosystem services.	using the soil C model ICBM, which is continuously refined using data from long-term field experiments. Can be complemented with other modelling tools, soil monitoring and/or field trials.	interpret. Could easily also be recalculated and presented as soil organic matter which is easier for e.g. farmers to interpret.	multiple purposes besides being an indicator for soil fertility, e.g. a measure for carbon sequestration as a climate mitigation option.

Background

According to the FAO, soil fertility is "*the ability of a soil to sustain plant growth by providing essential plant nutrients and favorable chemical, physical, and biological characteristics*" (FAO, 2022) . Soil fertility is thus a key component in sustainable food systems. However, constructing an indicator for food consumption based considering the variety of products from many countries and regions does not seem possible since soil fertility shows great variation across regions at the same time as information on soil status often is lacking. One of Sweden's environmental quality objective ('A varied agricultural landscape') considers the maintenance of "*the physical, chemical, hydrological, and biological qualities and processes of arable land.*" However, despite the importance of soil fertility, Sweden has no indicators in use specifically for this environmental quality objective.

Many different indicators have been proposed in the literature with the most common being organic matter, pH, available P and water storage (Bünemann *et al.*, 2018). Soil organic matter (of which slightly more than half consists of soil organic carbon (SOC)) is positively associated with water-holding capacity, nutrient delivery and erosion resistance and has been suggested as a robust indicator for soil fertility or soil quality (see e.g (Milà i Canals, Romanyà and Cowell, 2007) and production capacity of agricultural soils (Fanzo et al., 2021). Other possible indicators are e.g. bulk density or earthworm diversity but they are not commonly assessed since data is not available with required coverage.

The changes in SOC in Swedish arable topsoil are quantified both in the Swedish soil and crop monitoring programme and in the National Inventory Report (NIR). The soil and crop monitoring programme includes approximately 2000 sites all over Sweden on different farm types with repeated sampling every ten years (Henryson et al., 2022). The monitoring programme thus gives information about retrospective changes in the SOC but is only suitable for trend evaluation over past decades, not yearly updates.

In the NIR, the soil C balance model ICBM, developed at SLU is used to calculate SOC changes in mineral soils while estimated SOC changes in grasslands are based on soil sampling (NIR, 2022). As an indicator to be used for soil fertility, we suggest the SOC changes in cropland on mineral soils as reported in the NIR. From 2020, the annual change is reported as a three-year moving average. As a complement, updated data from the crop and soil monitoring could be used when available, see e.g. Henryson et al. (2022).

However, it is important to bear in mind that changes in soil organic carbon only capture partly what constitutes as soil fertility. Other aspects important to consider are e.g. soil compaction and phosphorus status.

3.5.2. Water management

Territorial-based indicator(s):

Area of Swedish cropland that is irrigated (thousands of ha)

Description: The amount of cropland that is equipped for being irrigated continuously or in case of drought. Here measured by the currently irrigated area.

Indicator:	Area of Swedish cropland that is irrigated (thousands of ha)
Indicator label:	T – 3.5.2a
Type according to DPSIR:	S
Target:	Should correspond to the estimated water need (Mattsson, Andersson, et al., 2018)
Data source:	Jordbrukets strukturundersökning: https://data.europa.eu/data/datasets/arinrajid0ph6h0uozi8w?locale=sv

Area of cropland with access to sufficient water stored in the landscape (thousands of ha)

Description: The amount of cropland that has access to management of water resources to ensure sufficient water for the cultivation of crops (e.g. irrigation) and the management of excess water from e.g. heavy rainfall.

Indicator:	Area of cropland with access to sufficient water stored in the landscape (thousands of ha)
Indicator label:	T – 3.5.2b
Type according to DPSIR:	S
Target:	Not available
Data source:	Not available

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The ability to irrigate land, through having land equipped for irrigation and enough water resources in the landscape is important for coping with droughts.	Irrigated land is measured regularly by the Board of agriculture and data is publicly available. For T – 3.5.2b a data collection methodology has to be developed.	Easy to understand and interpret. Quantitative and easy to communicate.	Aligned with policy. Policy can stimulate action to improve on this indicator through different interventions, e.g. support in the CAP. Exact targets are a bit unclear but the direction is clear.

Percentage of cropland with acceptable drainage

Description: The management of excess water from e.g. heavy rainfall.

Indicator:	Percentage of cropland with acceptable drainage
Indicator label	T-3.5.2c
Type according to DPSIR:	S
Target:	Not available
Data source:	Measured by the Board of Agriculture through surveys, has been done 2013 and 2017 (Mattsson, Johansson, *et al.*, 2018)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
The percentage of cropland with acceptable drainage is measured regularly	Percentage of cropland with acceptable drainage is measured by collecting data	Easy to understand and interpret. Quantitative and	Aligned with policy. Policy can stimulate action to improve on these indicators through

by the Board of Agriculture and data is publically available.	directly from farmers. For especially "acceptable" there is a measure of subjectivity involved, however, farmers are the ones who can best judge if the drainage works.	easy to communicate.	different interventions, e.g. support in the CAP. Exact targets are a bit unclear but the direction is clear.

Background

This theme deals with the management of water resources to ensure enough water for the cultivation of crops (e.g. irrigation) and the management of excess water from e.g. heavy rainfall. The management of water resources in terms of sustainable removals is covered by indicator 3.3.2 Water use.

Water management is very relevant for maintaining the production capacity under climate change. In a changing climate droughts and floods will be become more frequent and severe (Pörtner *et al.*, 2022a). Most Swedish agricultural land is rain fed, but fruits, vegetables and roots are commonly irrigated. Out of total cropland however, only a small area of the total Swedish agricultural land is irrigated. Greater preparedness to be able to irrigate crops when needed has been brought forward as an important climate adaptation strategy (e.g. in the Strategic Plan for the CAP (GOS, 2022)). The Board of Agriculture monitors the area of irrigated land and makes data available for using the irrigated area as an indicator of how well water resources are managed.

Preparedness to irrigate involves having the necessary infrastructure in place (e.g. irrigation equipment) and maybe more importantly having access to water in the landscapes including lakes, streams, ponds, wetlands etc. (Jennie Barron, prof SLU, personal communication). In terms of infrastructure we used the currently irrigated land as an indicator. This does not fully capture the preparedness as there could be equipment available that is currently in use. As for water availability in the landscape this is not monitored currently and no methodology has been developed. However, we include this indicator here to highlight the importance of developing such an indicator.

Drainage of the Swedish agricultural land is in need of serious improvement. Climate change will place additional demands on drainage systems. Climate change affects the need for drainage through increased precipitation, less frost, longer growing season and longer dry periods. It is estimated that one fifth of the agricultural land is in need of drainage (Mattsson, Johansson, *et al.*, 2018). The drainage status is measured by the Board of Agriculture through surveys to farmers.

4. WALLS: The economy as a tool for sustainable food systems

A well-functioning economic system is central in a market-based and sustainable food system for several reasons. Firms need to be profitable over time to ensure continued production. To achieve this, firms need to simultaneously work to be calibrated with consumer demand and to ensure efficiency in their production processes. A well-functioning governance system needs to be in place to ensure that externalities of production are internalized into both firms' and consumers' rational decision-making. Many food system sustainability frameworks include themes and indicators of economic nature, but are typically not clear on the underlying rational for choosing those specific themes and indicators. For instance, the framework by Hebinck et al (2021) includes 'economically thriving, robust food value chains' to account for economic sustainability and introduces themes and indicators to assess this. While we used the suggestions from Hebinck et al. as an initial point for our selection of themes and indicators to consider economic sustainability, we went further and developed our framework based on central aspects that we claim must be in place for the economy in a sustainable food system. In particular, we argue that in a sustainable food system, the economic system should take the role of an enabler, or tool to achieve sustainability. This means that the role of the economic system in a sustainable food system, is articulated. Furthermore, this view on the economic system means that we can distinguish its role in relation to the other dimensions of a sustainable food system. For the economic system to function as a tool, or enabler of a sustainable food system, we argue that two central aspects need to be in place:

(1) A functioning governance system which ensures that the system is kept within the environmental foundations (this is the floor in our case), while delivering on the social goal of the system (this is the ceiling in our case). This means that the governance system is capable of fully handling the externalities of food production and consumption so that they are integrated into producers' and consumers' rational decision-making.

(2) That the operations by the food system firms can be ensured over time. This means that the firms need to run with a positive return over time and that they are resilient to disturbances regarding access to production inputs. Furthermore, to ensure that operations can be ensured over time, diversity in production is likely needed. Diversity in production implies that if one type of production fails due to poor production conditions, then other types of production may still continue. The stability of prices would be central to ensure

this over time. Price instability cannot totally be controlled by actors in the food system. However by taking precautions, strategies such as keeping a stock of essential production inputs or using strategies where inputs can be substituted with others in times of price instability, the overall inflation in the food system can at least to some extent be managed.

4.1. Economic wall 1: Governance

To assess the governance structure, we focus on the efficiency of policy and on actors' trust in policy. Efficiency in policy refers to how well policy succeeds in covering the aspects it should cover to internalize externalities. We focus on GHGs and biodiversity, and how well policy covers environmental pressures from the food system. For governance to work, actors must trust policy. We therefore also suggest to include measures in actors' trust in policy in our framework.

4.1.1 Efficient policy

Territorial-based indicator(s):

Share of greenhouse gas emissions from the Swedish food production system that are included in price based policies

Description: Priced GHG emissions from food production/ all GHG emissions from food production.

Indicator:	Share of greenhouse gas emissions from the Swedish food production system that are included in price based policies
Indicator label:	T – 4.1.1a
Type according to DPSIR:	R
Target:	All emissions should be priced
Data source:	Swedish Environmental Protection Agency for emission data and Statistic Sweden Environmental accounting for environmental taxes https://www.naturvardsverket.se/data-och-statistik/klimat/vaxthusgaser-utslapp-fran-arbetsmaskiner/ https://www.naturvardsverket.se/data-och-statistik/klimat/vaxthusgaser-utslapp-fran-egen-uppvarmning-av-bostader-och-lokaler/ https://www.naturvardsverket.se/data-och-statistik/klimat/vaxthusgaser-nettoutslapp-och-nettoupptag-fran-markanvandning/ https://www.naturvardsverket.se/data-och-statistik/klimat/vaxthusgaser-utslapp-fran-jordbruk/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
A large share of GHG that is emitted when producing food, is not yet included in any type of price based policy scheme, such as emission taxes or trading system. Including all emissions from both fossil fuels and biological processes in price based policy schemes would include relevant external effects in economic decision making.	A share of GHG emissions from the food system that are included in price based policies, is easy enough to calculate from current and policy coverage and emissions connected to the food system. Potential errors can regard the measurement of biological gases. Sector divided emission levels are presented yearly by the Swedish Environmental Protection Agency, official statistics, climate.	Easily interpretable, are all production related external effects from GHG emissions included in policies, or not?	It is useful to measure all GHGs included in price based schemes. By including biological gases such as methane and nitrous oxides in price schemes, which are currently excluded, not only are all relevant climate impacts included but there are also potential synergies with other environmental pressures.

Policies aiming at improving biodiversity

Description: Policies supporting an increase in biodiversity in the agricultural landscape.

Indicator:	Policies covering threatened species or ecosystems in agricultural systems
Indicator label:	T – 4.1.1b
Type according to DPSIR:	
Target:	100%
Data source:	Data not available. Own assessment is needed.

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
All external effects should be covered by policy to ensure a functioning market for e.g. ecosystem services.	Potentially difficult to measure. In (Wenche *et al.*, 2020) 20% of 7400 species connected to the agricultural landscape, are found to be threatened. Many are due to loss of open spaces and grasslands, and others are due to eutrophication, climate change, invasive species and ditches. To cover how many of these threatened species are covered by policy, is difficult and time consuming.	Easily interpretable.	It is useful to measure how well policies cover threatened species or ecosystems that are used in the agricultural systems, as it provides an understanding about the extent to which external effects related to biodiversity are actually covered by policy.

Policy objective achievement (%)

Description: Efficiency of policy in achieving its objectives.

Indicator:	Policy objective achievement (%)
Indicator label:	T – 4.1.1c
Type according to DPSIR:	R
Target:	As close to 100% as possible
Data source:	Data not available. Assessments can be based on literature review of policy objective achievement evaluations and on own assessment.

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
It is highly relevant to evaluate the effect of policy. If money is spent on measures that do not give the targeted result, money that could have been used more efficiently is wasted	This indicator is potentially difficult to calculate and estimate even though evaluation of policy after implementation is crucial.	Evaluation studies often measures the percentage of success, which can be easily interpretable, even though different studies might define success differently.	It is necessary to evaluate the achievement of policy such that money is used as efficiently as possible

Consumption-based indicator(s):

Share of greenhouse gas emissions from Swedish food consumption that is included in price based policy

Description: Priced GHG emissions from food consumption/ all GHG emissions from food consumption

Indicator:	Share of greenhouse gas emissions from Swedish food consumption that is included in price based policy
Indicator label:	C – 4.1.1.d
Type according to DPSIR:	R
Target:	All emissions should be included
Data source:	Total emissions from food consumption can be obtained from the Swedish Environmental Protection Agency: https://www.naturvardsverket.se/data-och-statistik/konsumtion/vaxthusgaser-konsumtionsbaserade-utslapp-per-person Taxed domestic emissions – see territorial based indicator, taxed imported emissions which can be combined with trade channels that can be obtained from the Swedish board of Agriculture https://webbutiken.jordbruksverket.se/sv/artiklar/ra2211.html and from FAOSTAT: https://www.fao.org/faostat/en/#data/TCL Taxed agricultural emissions which can be found for OECD countries in (OECD, 2020)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
GHG emitted from imported food products are not included in price based policy, unless parts of emissions from the use of energy and fossil fuels are covered in exporting countries regulation systems. The priced shares of emissions are however in general low, as biological emissions from food are not covered anywhere globally (methane taxes for agriculture might be relevant in New Zeeland within a few years). Emissions connected to domestically produced food might be included in the domestic or EU policies, though as of today they only cover fossil fuels and energy related emissions.	This indicator has the potential to be difficult to monitor as food emission measurements in other countries can be difficult to assess, and accounting for already priced emission sources can cause high transaction costs.	Easily interpretable, are all consumption related external effects from GHG emissions included in policies, or not?	As a high share of the food consumed in Sweden is imported, it is useful to monitor how climate impact caused by Swedish consumption is priced. In addition, when all GHGs are priced, there are synergies to other environmental pressures, both within and outside of Sweden.

Share of sugar consumption included in price based policy

OECD, (2020) Description: Health related price policies

Indicator:	Share of sugar consumption included in price based policy
Indicator label:	C – 4.1.1d
Type according to DPSIR:	R
Target:	All negative externalities should be included
Data source:	Not available as there is no tax on sugar in place

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
A high sugar intake can increase the risk of decreased health and as such cause costs both for individuals and for society. By pricing these negative externa effects, the costs can decrease.	Such policies are not in place, though if implemented it should be straight forward to estimate the share of sugar intake that is priced.	Easy to interpret.	Useful to measure the internalization of external effects in the economy.

Background

Governance and policy should theoretically aim to handle market failures. Negative external effects, mainly from production of food and the related effects on common goods, are some of the most prominent market failures that need to be addressed for food system sustainability.

Economic policies such as taxes or emission trading systems are economically efficient given that emission reduction is achieved at minimum cost, and participation is not voluntary. Taxation could be at consumption level such that imports are covered, or on the production level leading to increasing producer incentives to increase reduction efficiency (see any environmental economic textbook, such as Baumol and Oates (1988). Given large import levels, it is likely more efficient on the consumption side of the market such that competition possibilities for domestic producers are not reduced (see e.g. (Säll and Gren, 2015)Other regulatory frameworks can also be considered, such that policy makers enforce abatement levels for producers and as such in principle forces emitters to pay for emission mitigation.

To date, the GHG emissions connected to agriculture are not priced in Sweden (or in any country) as emissions from machinery and energy use are accounted for under e.g. working machinery, and for heating premises. In the national accounting at The Swedish Environmental Protection Agency, close to 7 million tons of GHG emissions are emitted from agriculture, which only covers methane and nitrous dioxide (and a small part of CO2 from chalk appliances). Emissions from machinery and heating emit around 1 million tons additionally, and 3-4 million tons more are leaking from land use and land use change (LULUC) (How emissions are divided between the sectors are collected and presented by the Swedish Environmental Protection Agency climate reporting).

Current policies in Sweden thus only cover the 1 million tons from machinery and e.g. heating via carbon and energy taxes and the ETS when relevant. The additional 10-11 million tons of emissions arising from biological processes are not covered in any price policy (Statistics Sweden, www).

We include indicators for both production and consumption given that a large share of Swedish household diets and environmental pressure is based on imported food products (Swedish Board of Agriculture, 2021; Prince project, www). Territorial based price schemes cannot capture emissions created in other countries, and with only territorial based policy the competitiveness on the Swedish market would be disrupted. One way to capture emissions created in other countries can be to include Carbon Border Adjustment measures on imported products, there are however evidence that such measures cannot fully compensate for emission leakages (Arvanitopoulos, Garsous and Agnolucci, 2021; OECD, www).

Even though different price based policies such as taxes or trading systems in theory should reach more or less the same reduction levels, given the same price of e.g. emissions, they have different implications for the included actors. The INFORMAS framework (INFORMAS, 2023) highlights taxes as one of the most efficient policy regarding health issues, which is likely true. Though one should not discard trading systems if leakage effects can be dealt with, as this method is usually less costly for affected actors (Baumol and Oates, 1988)

All external effects could or should theoretically be priced separately (Baumol and Oates, 1988). However, given the difficulties of valuing and measuring for example loss of biodiversity, together with synergies between GHG emissions and other environmental pressures, taxing all GHGs could be a pragmatic way to move forward as the most GHG emitting output is also highly nutrient and land demanding (e.g. Moberg et al., 2020). A tax scheme/ emission trading system that includes biological GHGs thus capture the most emission intense productions and have potential to reduce nutrient and land usage, as well as the negative impact on biodiversity (Willett *et al.*, 2019; Einarsson *et al.*, 2022; Moberg *et al.*, 2020). We do however include policy for preserved biodiversity as an indicator as some of the most climate impacting food products are positive for biodiversity (grazing animals on semi-natural pasture land) and to highlight the importance of addressing the rapidly decreasing loss of species. Climate change and biodiversity are also highly interlinked, and focusing on both simultaneously is important to ensure future food security (Pörtner *et al.*, 2021).

Good policy instruments are ideally cost efficient and fulfill targets. Dead weight losses (effects would have happened regardless of support, and losses due to e.g. environmental damage costs), substitution effects (both at the expense of other individuals or organizations, and in other regions) should be minimized. Additionally, transactional costs for implementation should be low and distributional effects considered. If these conditions are not met, there are likely better ways of governing change.

For example, Scown et al. (2020) show how CAP has been used and the extent to which objectives were achieved during the time period investigated. The authors find that spent CAP money increases income inequality and does little to promote production in a more climate and biodiverse manner. The results are supported by (FAO, 2021)) who show that even though EU-agriculture receives half of EU climate spending's via CAP, emissions from agriculture are not decreasing.

A common way to measure the effect of policy is the number of participants in programs, which might exclude the assessment on environmental improvements as the result of policy implementation.

Turning to health related price policies, negative external effects should be captured by policy. There are several components that could be included in a health related policy: saturated fats, salt or sugar for example. Saturated fats are however mainly from animal origin, and as such covered to some extent by the GHG pricing included above. Animal products have the highest environmental impact and thus the highest GHG price. Even though the GHG pricing would not target the health impacts of saturated fats, the policy should decrease intake. Salt is also difficult to price. Intake of salt is necessary, but becomes problematic when intake is too high. Sugar content on the other hand is taxed in around 85 countries, and as such a tested path of dealing with the external effects of intake of unhealthy foods (see overview in (WHO, 2022b)). In addition global sugar cane production account for 21% of total crop production globally, used for mainly discretionary foods (FAO, 2021) By taxing sugar, it is possible to capture both health related costs and decrease the acreages of land used for largely unnecessary consumption.

4.1.2 Trust in institutions

Territorial-based and consumption-based indicator(s):

Description: Trust in institutions

Indicator:	Actor’s trust in public institutions
Indicator label:	C-T – 4.1.2a
Type according to DPSIR:	R
Target:	Not available.
Data source:	Gothenburg University, (2023)

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Actors’ trust in validated research guides their willingness to participate in sustainability measures.	Trust is generally considered a latent construct, meaning that it is not directly observable but has to be measured through indicators. There are advanced methods to do this as well as to assess the reliability of the measures.	The indicator is easy and intuitive to interpret.	The indicator is highly relevant in considering the needed transition of food systems.

Background

Efficient transition in food systems requires actors who are willing to participate in changing practices. Actors’ trust in institutions would be instrumental for their willingness to participate in changing behavior aimed at the areas covered under the heading ‘Clean and healthy planet’. In present times when “fake news” has become a well-known term, it is increasingly important for politicians and scientists to work to improve trust in scientific results and in institutions. Distrust in science makes it more difficult to improve sustainability in the food system as acceptance for policy and change might decrease. Also, actors’ trust in governance would be instrumental for their willingness to participate in policy measures aimed at the areas covered under the heading ‘Clean and healthy planet’.

Previous literature focused on the farmers' participation in agri-envronmental schemes has confirmed the role of trust in participation in policy measures (Polman and Slangen, 2008; Christensen *et al.*, 2011; Gatto, Mozzato and Defrancesco, 2019).

It would have been preferable to include food system actor's trust in food system policy, and food related institutions and science. However, as measures of trust in e.g. food related research and policy is limited to single research studies, it is difficult to access data that can be followed over time. We thus include the more commonly used indicator *Trust in institutions* (see e.g. OECD, 2022;(as a measure for the possibilities of coherence in the needed transformation process of the food system. Trust in public institutions in Sweden is continuously followed by the SOM-institute, allowing for time series data (see e.g. the SOM-Institute (Gothenburg University, 2023).

4.2 Economic wall 2: Economic enablers

An economically viable food system requires firms that can continue to produce over time. Their internal processes they need to generate economic value to the extent that the capital invested in the firms can grow. This means that firms need to make positive profits, at least over time. Moreover, the firms need to be autonomous to the extent that they can continue to produce even under circumstances where they might be cut off from the input supply market.

Indicators of economic viability are not well-consolidated in the food system sustainability literature. We therefore suggest to measure the economic viability of food system firms with the following three indicators: Returns to total (economic) capital, which assesses the ability of firms to generate returns to economic capital invested in them, through the processes on-firm which generates economic value. Autonomy, which assesses the extent to which firms are independent from external suppliers of production inputs. Finally, we suggest to consider diversity in production which is related to the resilience of the food system as such.

5.2.1. Returns to total economic capital

Territorial-based indicator(s):

Returns to total economic capital (%), average for food system firms in Sweden

Description: Returns to capital invested in firms assesses the profitability of firms in relation to the capital invested in them.

Indicator:	Returns to total economic capital (%), average for food system firms in Sweden
Indicator label:	T – 4.2.1a
Type according to DPSIR:	R
Target:	Returns to capital should be larger than the opportunity cost of the capital investment.
Data source:	Statistics Sweden's business registrar: https://www.scb.se/vara-tjanster/bestall-data-och-statistik/foretagsregistret/ The Swedish Board of Agriculture, farm economic survey: https://www.scb.se/en/finding-statistics/statistics-by-subject-area/agriculture-forestry-and-fishery/agricultural-economy/agricultural-economics-survey/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Economic capital invested in food system firms needs a return that is equal to or exceeds the opportunity cost of the capital investment. Any return below this threshold implies that economic capital is reduced over time.	It is straightforward to calculate the return of economic capital invested in the food system firms. This is a well-established measure which is presented even in most text-books at undergraduate level.	Easy and intuitive to interpret. Quantitative. Reflects clearly how stocks of economic capital develops over time.	Highly relevant for assessing how the economy functions as tool to achieve the goals of the food system.

Consumption-based indicator(s):

Returns to total economic capital (%), average for food system firms which export food products to Sweden

Description: Returns to capital invested in firms assesses the profitability of firms in relation to the capital invested in them.

Indicator:	Returns to total economic capital (%), average for food system firms which export food products to Sweden
Indicator label:	T – 4.2.1b
Target:	Returns to capital should be larger than the opportunity cost of the capital investment.
Data source:	It is possible to use the farm accountancy data network for European agriculture: https://agriculture.ec.europa.eu/data-and-analysis/farm-structures-and-economics/fadn_en For other firms, data availability is more problematic.

Indicator justification:

Relevant:	High-quality:	Interpretable:	Useful:
Economic capital invested in food system firms needs a return that is equal to or exceeds the opportunity cost of the capital investment. Any return below this threshold implies that economic capital is reduced over time.	It is straightforward to calculate the return of economic capital invested in the food system firms. This is a well-established measure which is presented even in most text-books at undergraduate level.	Easy and intuitive to interpret. Quantitative. Reflects clearly how stocks of economic capital develops over time.	Highly relevant for assessing how the economy functions as tool to achieve the goals of the food system.

Background

Returns to capital relates firm profit to the economic capital (total capital, including external loans or equity focusing only on the capital the owner(s) has invested in the firm, depending on which capital basis is considered). As such, the indicator returns to economic capital measures the percentage return of capital provided by the firm's investors. Any non-negative returns to capital indicate that the capital invested in the firm is at least not subject to de-growth, whereas negative returns to capital signals de-growth. Based on investment theory, the lower limit for return to capital should be set at a level that covers the opportunity cost of capital and a risk premium corresponding to the riskiness of the investment (Ross, Westerfield and Jaffe, 2005).

In considering the capital basis, one can also extend the reasoning by including the natural capital. In this respect the literature talks about weak and strong sustainability (Ayres, van den Bergh and Gowdy, 2001; van den Bergh, 2010), and relates to whether there is a separation between the two types of capital in considering the returns to capital. In particular, weak sustainability considers the sum of the two types of capital whereas strong sustainability keeps each type of capital separate. Strong sustainability thus speaks in favor for separating between economic and natural capital in considering them. In this indicator framework, we opted not to use return of the natural capital as an indicator. The reason is that this would imply duplicating the type of sustainability concern that we measure with indicators to cover the theme 'A clean and healthy planet'.

Consumption based indicator: In principle we can assess the same type of indicator for firms that are involved in production of food products which are exported to Sweden when data are available for food system firms abroad.

4.2.2. Autonomy

Territorial-based indicator(s):

Value Added (VA) divided by Gross value of production (GVP), where (GVP = VA + C where C=intermediate inputs + depreciation)

Description*:* The degree of dependence on externally obtained production factors.

Indicator:	Value Added (VA) divided by Gross value of production (GVP), where (*GVP* = *VA* + *C* where *C*=intermediate inputs + depreciation). Governmental income supports are excluded from gross value of production.
Indicator label:	T – 4.2.2a
Type according to DPSIR:	S
Target:	Not available
Data source:	Statistics Sweden's business registrar: https://www.scb.se/vara-tjanster/bestall-data-och-statistik/foretagsregistret/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
Autonomy refers to the independence of firms, in terms of access to production factors needed to produce. In terms of fluctuations in access to externally obtained production factors, firms with higher autonomy would be in better positions to continue to produce.	Straightforward to calculate based available data.	Easy and intuitive to interpret, Quantitative.	Highly relevant for assessing how the economy functions as tool to achieve the goals of the food system.

Value of production factors sourced from import market/total value of production factors

Description: The indicator assesses the extent to which firms are dependent on production factors sourced from import markets.

Indicator:	Value of production factors sourced from import market/total value of production factors
Indicator label:	T-4.2.2b
Type according to DPSIR:	S
Target:	Not available
Data source:	Available for agriculture through the Farm Accounting Data Network: https://agriculture.ec.europa.eu/data-and-analysis/farm-structures-and-economics/fadn_en based on assumptions about from where inputs are sourced.

Indicator justification:

Relevant:	High-quality:	Interpretable:	Useful:
Externally sourced production factors implies a risk that averse environmental effects are 'outsourced' to other countries and thus not being accounted for based on territorial measures. This indicator gives an overview of the risk of 'outsourcing' adverse environmental effects to other countries.	Straightforward to calculate based available data.	Easy and intuitive to interpret, Quantitative. Indicates the risk of contributing to adverse environmental impact abroad.	Relevant for assessing the risk that adverse environmental effects are 'outsourced' to other countries. Nevertheless it should of course be noted that imported production factors may come from clean production conditions and this indicator should be interpreted only as a *risk* of outsources environmental impacts.

Consumption based indicator(s)

NA.

Background

Dependence on externally obtained production factors (e.g. fertilizers, fuels and pesticides) is inevitable in most firms and in cases of stable and certain inflow of such production factors it can also be desirable. Indeed, the business strategies to outsource production of production factors has allowed firms to focus on their core specializations and concepts such as just-in-time has been developed to reduce the amount of capital tied to the storage of production factors. Still, such strategies can put firms at risk in times of crises where steady supply may no longer be guaranteed. They can also imply significant price risks to firms in times where prices are fluctuating. Hence, we argue that a heavy dependence on externally obtained production factors can put firms' abilities to continue to produce at risk and that it is reasonable to consider firms' autonomy in evaluating their ability to continue to produce. The suggested indicator considers the value added by firms divided by the gross value of production. The difference between the two measures are the intermediate inputs and depreciation. If firms purchase a large share of intermediate inputs, the ratio will be lower and vice versa.

Dependence on production factors sourced from import markets implies a risk that adverse environmental effects are ‘outsourced’ to other markets. The suggested indicator should be used as a measure of risk and carefully evaluated to follow up on whether there is a real transfer of negative environmental impacts to other territories.

5.2.3 Diversity in production

Territorial-based indicator(s):

Entropy index

Description: The indicator measures unrelated variety in food system firms

Indicator:	Entropy index
Indicator label:	T – 4.2.3a
Type according to DPSIR:	S
Target:	Not available.
Data source:	The indicator can be calculated based on data from the Swedish Business Register by Statistics Sweden: https://www.scb.se/en/services/ordering-data-and-statistics/statistics-swedens-business-register/

Justification for indicator choice:

Relevant:	High-quality:	Interpretable:	Useful:
An entropy index for unrelated variety in agricultural firms highlights diversity in agricultural production	The entropy index can be used through information about farms’ type of specialization. These data are collected by the Swedish Board of Agriculture and exit at a yearly basis.	The entropy index is easy to calculate and to interpret.	The entropy index of unrelated variety is highly relevant to measure and evaluate the diversity among agricultural firms, by taking the focus from between the farms.

Background

From a resilience perspective, diversity among firms can be considered as an insurance against the loss of food products under unfavorable conditions. Consider for instance a growing season with unfavorable weather conditions for one type of crop. In a diversified agricultural sector there are other types of production, specialized in other types of produce that may still be able to produce under those conditions. Research has also shown that variety among firms can function as a counterforce against the unemployment in the area (Frenken, Van Oort and Verburg, 2007) and that agricultural production can improve its efficiency by diversification (Hansson, 2007; Nilsson *et al.*, 2022). Looking at the agricultural sector, there are also agronomic and ecological benefits from diversified agricultural production.

Consumption based indicator:

NA

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