Current Research in Environmental Sustainability 9 (2025) 100281

Contents lists available at ScienceDirect

Current Research in Environmental Sustainability

journal homepage: www.sciencedirect.com/journal/current-research-in-environmental-sustainability

Fostering unsustainability? An analysis of 4-year-olds' dietary impacts in Sweden

Maria Jacobsen [a,*], Lotta Moraeus [b], Emma Patterson [b,c], Anna Karin Lindroos [b,d], Mattias Eriksson [a], Elin Röös [a]

[a] Department of Energy and Technology, Swedish University of Agricultural Sciences, Box 7032, Uppsala 750 07, Sweden
[b] Division for Risk and Benefit Assessment, Swedish Food Agency, Uppsala 751 26, Sweden
[c] Department of Global Public Health, Karolinska Institutet, Stockholm, 171 77, Sweden
[d] Department of Food Studies, Nutrition and Dietetics, Uppsala University, Uppsala, Box 560, Uppsala 751 22, Sweden

ARTICLE INFO

Keywords:
Environmental impact
Dietary intake
RiksmatenFlex
Food system
Sustainability assessments of foods and diets

ABSTRACT

The dietary impacts of 746 young Swedish children were assessed across ten indicators: carbon footprint, cropland use, new nitrogen and phosphorus inputs, blue water use, ammonia emissions, pesticide use, biodiversity loss, antibiotic use, and animal welfare. This analysis utilized caretaker-reported food intake data from the Riksmaten Young Children study (2021–24). It employed the Sustainability Assessment of Foods And Diets tool to quantify these impacts against per capita 1000 kcal planetary boundaries and variations in dietary impacts based on factors such as gender, municipal area, parental education level, and consumption setting (home or preschool). We found that the mean dietary impacts fell within or exceeded the uncertainty zone per capita planetary boundaries for five out of six indicators, with only blue water use remaining within the 'safe space'; notably, zero children had eaten below the uncertainty levels for all indicators. Boys exhibited higher dietary impacts than girls in absolute terms and when adjusted for energy intake. Children from rural areas and those with lower parental education levels also demonstrated higher impacts than their peers. Carbon footprint analysis revealed no substantial differences between home and preschool settings, with lower meat consumption in preschools offset by higher dairy intake. The primary drivers of dietary impacts were red meat, dairy products, and fruit and vegetable consumption. These results highlight substantial challenges in achieving sustainable food production and diets in Sweden while providing essential insights for informing policy and governance frameworks to promote healthier dietary patterns among young children.

1. Introduction

The global food system is a major contributor to environmental pollution and resource depletion (Willett et al., 2019), accounting for approximately one-third of global greenhouse gas emissions (Crippa et al., 2021). Food production and consumption are the primary drivers of biodiversity loss, water stress, and eutrophication. Moreover, the food system accounts for 70 % of blue water use and 78 % of freshwater pollution (Poore and Nemecek, 2018; FAO, 2022). Additionally, agriculture uses approximately 75 % of ice-free land (IPCC, 2019), contributing to biodiversity loss through land occupation and land-use change (IPBES, 2019; Benton et al., 2021).

Recognizing these challenges, policy documents such as the EU Farm to Fork strategy (European Commission, 2020) and the new Nordic Nutrition Recommendations emphasize the importance of transitioning to healthy and sustainable diets (Blomhoff et al., 2023). To effectively reduce the food system's environmental footprint, a multi-faceted approach is necessary, including promoting dietary changes, advancing agricultural technology, improving crop yields, and minimizing food waste (Springmann et al., 2018; Willett et al., 2019). Research indicates that animal-based foods generally have a greater environmental impact than plant-based alternatives. In countries in which the consumption of animal products is high (commonly high-income countries), dietary transitions toward more plant-based diets are especially important (Steenson and Buttriss, 2021). Sweden, for example, has an average meat consumption of 79 kg (carcass weight) and dairy consumption of 358 kg milk-equivalents per person per year (Swedish Board of Agriculture, 2024), contributing to the transgression

* Corresponding author.
E-mail address: maria.jacobsen@slu.se (M. Jacobsen).

https://doi.org/10.1016/j.crsust.2025.100281
Received 28 November 2024; Received in revised form 20 December 2024; Accepted 30 January 2025
Available online 5 February 2025

of several planetary boundaries (Moberg et al., 2020).

While much is known about the global food system's impact on the environment, examining these effects at a national level and demography is crucial. In Sweden, several studies have analyzed the carbon footprint of adult Swedish diets (e.g., Röös et al., 2015; Bälter et al., 2017; Sjörs et al., 2017; Hallström et al., 2021) and adolescents (Lindroos et al., 2023). Hallström et al. (2022) recently conducted a comprehensive assessment of the Swedish diet's environmental impact against planetary boundaries, revealing that the average Swedish diet exceeds several boundaries. Despite these contributions, a substantial knowledge gap remains regarding the environmental impact of young children's diets in Sweden.

Studying children's dietary patterns is particularly important as eating habits are established at a young age and often persist into adolescence and adulthood (Nicklaus and Remy, 2013). Promoting healthy and sustainable dietary patterns among children is crucial for long-term environmental and health outcomes. Globally, organizations like the World Health Organization have identified Early Childhood Education and Care facilities as essential settings for promoting healthy eating (WHO, 2023).

In Sweden, the importance of focusing on children's diets is amplified by the country's comprehensive early education system. Approximately 86 % of all children aged one to five were enrolled in preschools in 2021 (Swedish National Agency for Education, 2022), consuming a large portion of their daily caloric intake there. Swedish preschools and schools provide meals to all pupils to reduce socioeconomic gaps, following recommendations, laws, and guidelines to ensure nutritious and free meals (Swedish Food Agency, 2021; Skolmat Sverige, 2023). Furthermore, 77 municipalities have set climate targets for public meals in these institutions (Swedish Food Agency, 2021a), highlighting a potentially impactful change in children's dietary habits in educational settings.

The Swedish Food Agency conducts regular national dietary surveys called 'Riksmaten' to collect information on food consumption, nutrient intake, and lifestyle factors among representative samples of the Swedish population (Swedish Food Agency, 2024b). These surveys provide valuable data for studying dietary habits, health relationships, and environmental impacts of diets. The Riksmaten Young Children 2021–24 survey (hereafter referred to as Riksmaten Young Children) offers a unique opportunity to study the environmental impact of Swedish children's diets. While Riksmaten Young Children provides valuable data on children's dietary habits, it also offers an opportunity to examine the environmental impacts of these diets in depth.

Utilizing the comprehensive data from Riksmaten Young Children, we can thoroughly evaluate the environmental and social impacts of children's diets. This assessment necessitates consideration of a wide range of indicators (Ran et al., 2024). While climate change impact, water use, and cropland use are commonly assessed (Harrison et al., 2022), a more holistic approach can reveal important trade-offs and provide a deeper understanding of diet-induced environmental impacts. We extend beyond the typical focus on climate impact by mapping eight environmental impact indicators, as well as animal welfare and antibiotic use, which represent social indicators connected to human health and ethical aspects of food consumption.

By studying this broader range of indicators, we aim to create a more comprehensive picture of which food groups constitute hotspots in children's diets and where efforts are needed to transform food consumption. This approach provides a basis for interventions to reduce the dietary impacts of children's diets while maintaining or increasing their nutrient intake. With this context in mind, our specific objectives are to 1) describe the environmental performance of children's diets and analyze potential differences by sex, socio-demographic characteristics, and place of consumption; 2) to evaluate the performance against the planetary boundaries; 3) to evaluate the contribution of different food groups to the environmental and social indicators and; 4) assess the correlation between indicators in the diet.

2. Material and methods

2.1. Study population

The study population includes participants in Riksmaten Young Children (746 children) aged four years whose parents or caretakers had filled in food diaries and food-frequency questionnaires (FFQ) in 2021–2022 (Bjermo et al., 2024; Moraeus et al., 2024). The cross-sectional study is population-based, and participants were invited by letter from a list of 7800 4-year-olds representative of the Swedish population in the age group provided by Statistics Sweden. Of the invited, 746 children had complete data on diet (10 %), covering 51 % boys and 49 % girls. Of the 573 children with available weight and height data, the average height was 104 cm (SD = 5.0), and the average weight was 17.2 kg (SD = 2.1) (Moraeus et al., 2024). Among these children, 79 % were classified as having normal weight, while 13 % were underweight, 6.5 % were overweight, and 1.4 % were obese. The sample of children was considered representative of Swedish 4-year-olds for sex, geographical spread, and family size; however, parental education level and geographical distribution represented a higher education level and more urban participants than the general Swedish population. A detailed description of the study design, methods and participation has been described elsewhere (Bjermo et al., 2024; Moraeus et al., 2024).

2.2. Indicators for sustainability

In this study, we use data on the impacts of food from the Sustainability Assessment of Food And Diets (SAFAD) tool (Röös et al. 2025), which includes eight environmental indicators and two social indicators (https://safad.se). The carbon footprint data employ a farm-to-fork perspective, expressed per kilogram or liter of food, including primary production, processing, packaging, transportation (excluding transport from retail to place of consumption), and food loss and waste in the food chain. Only emissions and resource use from primary production are included for the other indicators, as primary production is the main, or only, contributor.

Carbon footprint, measuring the impact on climate change, is a well-established indicator that measures the impact of global warming by aggregating emissions of carbon dioxide, methane, and nitrous oxide from a lifecycle perspective (ISO, 2018). Here, we use GWP100 and conversion factors from Forster et al. (2023), 27.0 for biogenic methane, 29.8 for fossil methane, and 273 for nitrous oxide. Cropland use, measured in m^2*years, captures the cropland area needed to produce the foods in the diet and is, hence, a measure of the diet's land intensity, which is important due to the limited availability of good cropland globally. Blue water use measures the surface and groundwater consumed primarily for irrigation in food production. New input of nitrogen (N) and phosphorus (P) serves as proxies for potential effects on biogeochemical flows caused by food production (Moberg et al., 2019; Willett et al., 2019). These inputs include synthetic fertilizers, nitrogen fixed by legumes, and mined phosphorus. The biodiversity impact from agricultural land use is estimated using the method proposed by Scherer et al. (2023), which assesses how different species are affected by land management practices associated with food production. Pesticide use provides insight into the diet's impact on chemical pollution. Ammonia emissions, an important driver for eutrophication, acidification, and particulate matter formation, are included as a separate indicator based on EEA Report (2019) guidelines. Animal welfare addresses various issues in animal production, including disease frequency, restricted living space, and mortality; a higher animal welfare index means more animal welfare issues. Antibiotic use reflects the use of antibiotics in livestock production, which contributes to the development of antibiotic-resistant bacteria, posing a substantial threat to human and animal health (Cassini et al., 2019), with a lower number indicating less antibiotic use. For more information on animal welfare and antibiotic use indicators, see Röös et al. 2025.

2.3. Dietary intake

Parents or caretakers filled in a web-based food diary (Riksmaten-FlexDiet) over two non-consecutive days, mapping all foods and drinks the child consumed. If the child attended preschool, the staff filled out a paper diary and later transferred it to the online diary. Riksmaten-FlexDiet has previously been validated in adolescents (Lindroos et al., 2019), and a pilot study in the current population indicated that the method was applicable to the target population (Bjermo et al., 2024; Moraeus et al., 2024). The participants searched for consumed foods or composite dishes and chose from the search results provided. They then indicated portion size from pictures or household measures. Time, meal type, and intake place were recorded for each meal. Each food is connected to the Swedish Food Agency's food database.

The Swedish Food Agency provided lists of foods and raw materials in processed and composite dishes. We linked the food items to the SAFAD tool (v. 1.230), further refining it to assess standardized Swedish compound foods and dishes. To do the sustainability assessment, we used the output from the tool for the Swedish Food Agency's recipes expressed per kg or liter of food and multiplied it by the amount of food items reported by each individual in Riksmaten Young Children.

2.3.1. Food groups

For descriptive purposes, we categorized the children's food and drink consumption into ten food groups, following the classification system used by the Swedish Food Agency. The food groups included are: Breads, grains, cereals, rice, and pasta; Dairy products; Fruits and nuts; Meat and meat dishes; Other; Pizza, hamburgers, sandwiches etc.; Poultry and eggs; Seafood and seafood dishes, Sweets and snacks; and Vegetables and vegetable dishes. See supplementary material, Table A1, for a detailed list of products in each food group.

2.3.2. Global boundaries

Our study employed a dietary benchmarking process based on the planetary boundaries defined for the food system in the EAT-Lancet Commission report (Willett et al., 2019), resulting in daily values for each boundary. To establish per capita estimates, we divided these global boundaries equally among the world's population (7.9 billion as of 2021). Given our focus on the dietary patterns of young children, we used a reference daily energy intake of 1828 kcal per person, which represents the global minimum daily dietary energy requirement per person considered adequate to ensure maintaining minimum weight for health (FAO (2023) – with major processing by Our World in Data). Environmental impact boundaries were calculated per 1000 kcal of dietary intake to standardize the analysis. This approach facilitates comparisons across different dietary patterns and energy intakes. Notably, boundaries for pesticide use and ammonia emissions were excluded due to a lack of established boundaries (Table 1).

2.4. Definition of socio-demographic characteristics

For analysis, the children were divided into different subgroups based on socio-demographic characteristics:

1. Gender (boys or girls) was based on information from Statistics Sweden.
2. Parental education level was dichotomized into high (at least one parent with >12 years of education) and low (has parents with ≤12 years of education) categories (Bjermo et al., 2024).
3. Three categories based on the municipal classification by the Swedish Association of Local Authorities and Regions (Sveriges Kommuner och Regioner, 2022) were used: i) small towns and rural municipalities, ii) larger cities and municipalities near larger cities, and iii) metropolitan areas and municipalities near metropolitan areas.
4. Food intake settings were defined as either home or preschool environments based on recorded places of intake to represent dietary patterns in each setting. All recorded food intake not explicitly identified as consumed at preschool was classified as part of the home environment.

2.5. Statistical analysis

We used the Multiple Source Method (MSM) to transform the dietary impacts and energy intake from short-term 2-day food intake data to long-term estimates. The transformation involves a three-step process: i) estimating the probability of consuming a particular food on a random day for each participant, ii) estimating the magnitude of dietary impact and amount of energy intake associated with consumption on a given day, and iii) multiplying the two components to derive the usual dietary impacts and energy intake for each individual. This method helps to reduce the effect of atypical intakes that may not be representative of habitual dietary patterns without influencing the mean values (Harttig et al., 2011; Haubrock et al., 2011). The MSM adjustment was performed separately for different socio-demographic characteristics to account for potential variations in dietary patterns across these subgroups. We then use the resulting 'usual intake' values to describe the overall diet's impacts and different food groups' contributions to the dietary indicators. Energy-adjusted indicators per 1000 kcal, equivalent to 4.19 MJ, were used when comparing differences between gender, parental education level, municipal classification, setting, and food group contribution.

We used the coefficient of variation to assess the variation, i.e., we divided the standard deviation with the mean, expressed as a percentage. Due to the non-normal distribution observed in the dataset, non-parametric statistical methods were employed. To examine differences in indicators between gender, parental education level, and preschool vs. home environments, we used Wilcoxon rank-sum tests (also known as Mann-Whitney *U* tests). To compare the impacts of dietary patterns among children living in the three different municipality classifications, we utilized Kruskal-Wallis tests followed by post-hoc analyses. Spearman's correlation coefficients were computed to assess the linear relationships between each indicator adjusted per 1000 kcal with the estimated impacts of each participant's diet derived from the food intake records. Statistical analyses were primarily conducted using RStudio version 2024.04.1 (RStudio Team, 2024), with a p-value <0.05 considered significant. For linear regression and mixed effect models, Minitab 21.4.3 (Minitab LLC, 2024) was used to investigate the observed

Table 1
Global food system boundaries defined by the EAT-Lancet Commission and downscaled to 1000 kcal food intake as defined per a minimum intake of 1828 kcal per day.

Earth system process:	Climate change	Blue water use	Land system change	Nitrogen cycling[a]	Phosphorus cycling[a]	Biodiversity loss
Control variable	*Carbon footprint*	*Blue water use*	*Cropland use*	*New nitrogen input*	*New phosphorus input*	*Extinction rate*
Global boundary, per year	5 Gton CO_2e (4.7–5.4)	2500 km^3 (1000–4000)	13 million km^2 (11–15)	90 Tg nitrogen (65–90)	8 Tg phosphorus (6–12)	10 E/MSY (1–80)
Per capita boundary, per year	594–683 kg CO_2e	123–506 m^3	1391–1897 m^2	8–11 kg nitrogen	0.8–1.5 kg phosphorus	1.3E-10–1.0E-8 E/MSY
Per 1000 kcal boundary	0.89–1.02 kg CO_2e	189–758 dm^3	2.1–2.8 m^2[a]year	12.3–17.1 g nitrogen	1.1–2.3 g phosphorus	1.9E-13–1.5E-11 E/MSY

Abbreviations: CO_2e, carbon dioxide equivalents: MSY, extinctions per million species-year.
Values presented as uncertainty range (lower – upper limit), except for global boundary per year which presents boundary (uncertainty range).
[a] Lower boundary assuming no adoption of improved production or redistribution strategies.

differences in indicators between groups while controlling for other socio-demographic predictors. In the mixed-effects model, individuals were included as a random factor to account for clustering in the data.

3. Results and discussion

3.1. Dietary environmental impacts in the study population

Our study revealed that children consume diets with a carbon footprint averaging 1.6 kg CO_2e per 1000 kcal or 2.3 kg CO_2e per person per day, along with cropland use of 2.3 m^2*year per 1000 kcal or 3.3 m^2*year per person per day (Table 2). Notably, we observed large standard deviations for all indicators, indicating considerable inter-individual variation. The children in Riksmaten Young Children have a mean energy-adjusted dietary carbon footprint comparable to that of children in grade 5 in Sweden, which is approximately 1.7 kg CO_2e per 1000 kcal (recalculated from 10 MJ to 1000 kcal, Lindroos et al., 2023). These values are lower than the adult Swedish population, reported at 2.4 kg CO_2e per 1000 kcal by Hallström et al. (2021). However, different climate data were used for the older children and adults.

The mean dietary impacts fell within or exceeded the uncertainty zone of per capita planetary boundaries for five out of six indicators, only blue water use falling within the 'safe space' (Fig. 1, Tables 1 and 2). The impacts on nitrogen cycling, carbon footprint, and phosphorus cycling were particularly critical, with the mean dietary impact exceeding the upper uncertainty limit by 1.7, 1.6, and 1.2 times, respectively. Cropland use and biodiversity loss surpassed the lower uncertainty limit by 1.1 and 2.7 times, respectively, but remained below the upper uncertainty level. However, the uncertainty range for biodiversity loss is wide (Table 1), indicating a high level of uncertainty in how far the dietary patterns are from the safe space for humanity.

Our results show that zero children in the Riksmaten Young Children study had dietary patterns within the safe operating space for humanity (i.e., below the lower uncertainty levels) for all indicators. Only four children had dietary patterns below the carbon impact limit; three followed vegetarian diets, while one consumed poultry. Additionally, we found that more than 700 children exceeded the upper uncertainty limits for nitrogen and phosphorus. However, dietary change is not the only mitigation option to stay within planetary boundaries; reductions in waste and improvements in production are also strategies that can reduce the impacts (UNEP, 2022). Precision agriculture, improved crop rotations, and better manure management, along with the development of new crop varieties that enhance nutrient use efficiently, are promising strategies for decreasing the need for virgin nitrogen and phosphorus (Sutton et al., 2022; Gu et al., 2023). Furthermore, increasing the recycling of nutrients from society can help maintain high crop yields while reducing fertilizer inputs. To our knowledge, no other studies have specifically compared young children's diets to planetary boundaries. However, a Finnish study examined dietary data from 3 to 6 year-olds against the EAT-Lancet reference diet (Bäck et al., 2022). Although environmental impacts were not analyzed in detail, the authors concluded that Finnish children need to make substantial dietary changes to eat within planetary limits.

The global energy requirement of 1828 kcal per day used in this study is based on the minimum dietary energy needed for maintaining minimum weight for health (FAO (2023) – with major processing by Our World in Data). This figure represents the minimum requirement without any allowances for unequal food distribution, which poses a risk of hunger if not every individual receives their share. However, it is important to note that our calculation accounts for the entire global population, from infants to the elderly, justifying a lower average requirement than, for example, the 2500 kcal per day suggested for an average adult in the EAT-Lancet report (Willett et al., 2019). Additionally, if we were to calculate based on the 2500 kcal per day suggested for adults, the planetary boundaries would be further lowered when normalized per 1000 kcal. This would result in even fewer children falling within the safe operating space for the indicators.

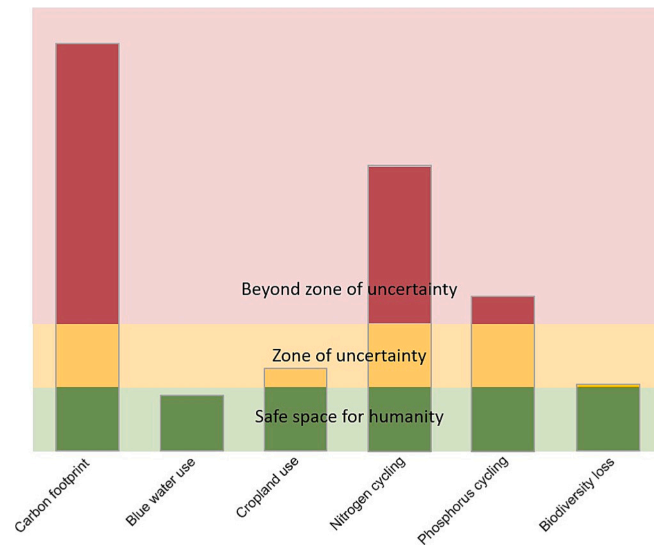

Fig. 1. Environmental impacts from the diets in Riksmaten Young Children benchmarked against EAT-Lancet global boundaries, normalized per 1000 kcal. Values are presented relative to the uncertainty zone, indicated in yellow. Note: the height of the bars does not directly represent the extent to which the limits have been exceeded; instead, it reflects how the values relate to the uncertainty zone. A larger uncertainty zone may result in shorter bars, even if the findings exceed the limits more than those with a narrower uncertainty zone. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Dietary impacts of 4-year-old children in Riksmaten Young Children ($n = 746$), including their daily caloric intake. Comparison to environmental targets.

	Mean (SD)	5-95th percentile
Impacts per total amount of food consumed (per person per day)		
Carbon footprint (kg CO_2e)	2.3 (0.5)	1.5–3.2
Cropland use (m^2*year)	3.3 (0.6)	2.4–4.4
Blue water use (dm^3)	125 (25)	88–167
New nitrogen (g N)	41 (10)	28–58
New phosphorus (g P)	4.0 (0.8)	2.9–5.5
Ammonia emission (g NH_3)	7.0 (2.7)	3.6–12.0
Pesticide use (g a.i.)	0.5 (0.1)	0.4–0.8
Biodiversity loss (E/MSY)	7.4E-13 (1.8E-13)	5.0E-13–1.1E-12
Antibiotic use (index)	4.3 (1.5)	2.1–7.2
Animal welfare (index)	2.1 (1.5)	0.7–5.3
Energy-adjusted impacts (per 1000 kcal)		
Carbon footprint (kg CO_2e)	1.6 (0.3)	1.2–2.1
Cropland use (m^2*year)	2.3 (0.3)	1.9–2.8
Blue water use (dm^3)	88 (16)	65–115
New nitrogen (g N)	29 (5)	21–38
New phosphorus (g P)	2.8 (0.4)	2.6–3.5
Ammonia emission (g NH_3)	4.9 (1.7)	2.5–8.1
Pesticide use (g a.i.)	0.4 (0.1)	0.3–0.5
Biodiversity loss (E/MSY)	5.2E-13 (1.1E-13)	3.7E-13–7.2E-13
Antibiotic use (index)	3.0 (1.0)	1.7–4.6
Animal welfare (index)	1.5 (1.0)	0.5–3.8
Energy intake (kcal per person per day)	1427 (197)[a]	1118–1767[b]

Abbreviations: CO_2e, carbon dioxide equivalents; E/MSY, extinctions per million species-year; a.i., active ingredient.

[a] 6.0 (0.8) MJ per person per day.

[b] 4.7–6.5 MJ per person per day

3.2. Food groups' contribution to dietary impacts

Our analysis reveals that animal-based products substantially contribute to impacts across indicators, accounting for 18 % to 87 % of the total impact, with meat and dairy products being the primary drivers (Fig. 2, Table A2). In contrast, plant-based foods showed varying impacts across indicators, with notable contributions to pesticide use, biodiversity loss, and blue water use. These findings align with previous research on adult diets in affluent countries, where animal products have been found to contribute disproportionately to environmental impacts relative to their caloric inputs (e.g., Willett et al., 2019; Hallström et al., 2022).

Sweets and snacks, including sugar-sweetened beverages, contributed substantially to the children's energy intake (15 %) and had notable impacts on blue water use and pesticide use despite their low nutritional value. For instance, fruit juices and sweets were major contributors to blue water and pesticide use due to the high level of irrigation and pesticides applied to fruits and cacao. These mirror those in the adult Swedish population, where discretionary foods – energy-dense, nutrient-poor foods – contributed to 18 % of the total energy intake and 12 % of climate impact (Hallström et al., 2022).

In contrast, seafood had low impacts except for antibiotic use and animal welfare, where the impacts were substantial. Antibiotics are commonly used in aquaculture to treat or prevent diseases, leading to the development of antibiotic-resistant- bacteria, posing risks for both animals and humans. Notably, poultry, egg, and shrimp production contributed substantially to the total animal welfare impact index despite their relatively small contribution to energy intake (Table A2). This is mainly due to the high number of animals required to produce 1 kg of edible product, coupled with welfare issues related to housing conditions, disease, and mortality rates (Rydhmer and Röös, 2025). Furthermore, while contributing modestly to energy intake, the food group consisting of pizza, hamburgers, sandwiches and similar items represented a disproportionate share of the diet's total impacts – particularly blue water use and ammonia emissions.

3.3. Difference in impacts within the study population

3.3.1. Gender differences

Our analysis of impacts per total amount of food consumed revealed that boys consistently showed higher impacts across all indicators except animal welfare (Table 3). For ammonia emissions, new nitrogen input, carbon footprint, and cropland use, boys showed impacts that were between 10 % and 13 % higher. However, the most pronounced disparity was found for the animal welfare index, where girls had impacts 17 % higher than boys.

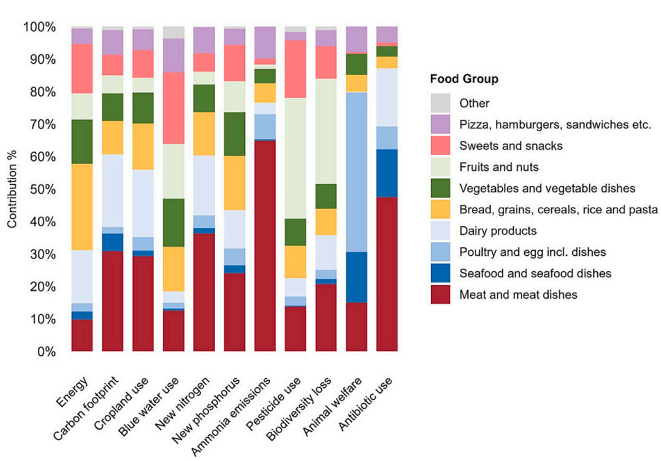

Fig. 2. Relative contributions of food groups to dietary impacts in Riksmaten Young Children.

Table 3
Dietary impacts of 4-year-old girls and boys in Riksmaten Young Children.

	Girls (n = 364) Mean (SD)	Boys (n = 382) Mean (SD)	Significance level
Impacts per total amount of food consumed (per person per day)			
Carbon footprint (kg CO_2e)	2.1 (0.5)	2.4 (0.5)	***
Cropland use (m^2*year)	3.1 (0.6)	3.5 (0.6)	***
Blue water use (dm^3)	119 (28)	131 (21)	***
New nitrogen (g N)	38 (10)	44 (9)	***
New phosphorus (g P)	3.9 (0.7)	4.2 (0.9)	***
Ammonia emission (g NH_3)	6.6 (2.6)	7.5 (2.6)	***
Pesticide use (g a.i.)	0.5 (0.1)	0.6 (0.1)	***
Biodiversity loss (E/MSY)	7.1E-13 (1.8E-13)	7.6E-13 (1.9E-13)	**
Antibiotic use (index)	4.2 (1.5)	4.5 (1.6)	*
Animal welfare (index)	2.4 (1.7)	2.0 (1.2)	**
Energy-adjusted impacts (per 1000 kcal)			
Carbon footprint (kg CO_2e)	1.6 (0.3)	1.6 (0.3)	***
Cropland use (m^2*year)	2.3 (0.3)	2.4 (0.3)	***
Blue water use (dm^3)	87 (18)	89 (14)	*
New nitrogen (g N)	28 (6)	29 (5)	***
New phosphorus (g P)	2.8 (0.3)	2.8 (0.4)	ns
Ammonia emission (g NH_3)	4.8 (1.7)	5.1 (1.6)	**
Pesticide use (g a.i.)	0.4 (0.1)	0.4 (0.1)	ns
Biodiversity loss (E/MSY)	5.2E-13 (1.1E-13)	5.1E-13 (1.0E-13)	ns
Antibiotic use (index)	3.0 (1.0)	3.0 (1.0)	ns
Animal welfare (index)	1.8 (1.2)	1.4 (0.8)	***
Energy intake (kcal per person per day)	1371 (165)[a]	1481 (214)[b]	***

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns = not significant. Abbreviations: a.i., active ingredient; CO_2e, carbon dioxide equivalents; E/MSY, extinctions per million species-year.
[a] 5.7 (0.7) MJ per person per day.
[b] 6.2 (0.9) MJ per person per day.

These findings on gender differences in environmental impacts align with previous studies on adult populations in Sweden. Sjörs et al. (2017) reported higher unadjusted median annual carbon footprints for men compared to women. Similarly, Hallström et al. (2021, 2022) found consistently higher average annual carbon footprints for Swedish men than women. Expanding on these carbon footprint findings, Hallström et al. (2022) also reported higher annual impacts per capita for men than women across several other indicators, including cropland use, nitrogen and phosphorus application, and blue water use. However, they found higher annual biodiversity loss from men's diets per capita, contrasting our results.

The variability within indicators was substantial across all metrics. Animal welfare exhibited the highest variability at 69 % and 60 % for girls and boys, respectively. This variability mainly stems from dietary differences among the children, ranging from high consumption of poultry, shrimp, and fish to vegan or lacto-ovo vegetarian diets.

Gender differences persisted for several indicators even after energy adjustment, suggesting variations in dietary composition. Carbon footprint, cropland and blue water use, new nitrogen input, and ammonia emissions remained higher for boys (Table 3). Conversely, animal welfare impacts showed a marked increase in disparity, with girls' diets associated with 24 % higher impacts per 1000 kcal food consumed. This disparity is primarily driven by proportionally higher poultry, eggs, and seafood intakes among girls – food groups contributing to animal welfare loss. These findings are similar to those of the adult Swedish population. Hallström et al. (2021) found little difference in climate impact between men's and women's diets when adjusted for energy, with women's diets having a slightly higher impact, suggesting dietary changes may occur when young girls grow up.

Interestingly, phosphorus input, pesticide use, biodiversity loss, and antibiotic use showed no statistical difference between boys and girls when adjusted for energy intake. This suggests that the observed differences in total impacts per food consumed for these indicators were primarily due to the quantity of food consumed rather than dietary composition, as supported by the distribution of energy intake (Fig. 3). However, it is important to note that differences in specific food choices within the same food group could also contribute to these results.

Analysis of how food groups contributed to the energy-adjusted diet for boys and girls revealed minor gender differences (Fig. 3, Table A3). One difference was the consumption of vegetables, fruits and nuts, where girls reported a larger proportion of their intake. Conversely, girls show higher impacts for indicators associated with vegetable and fruit production, such as blue water and pesticide use. A recent environmental analysis of Riksmaten Adolescents (Lindroos et al., 2023) corroborates our findings, noting higher climate impacts for males.

Apparent gender differences in dietary patterns are already visible among 4-year-olds. The Riksmaten Young Children study (Moraeus et al., 2024) found that boys consume more red meat while girls eat more fruits and vegetables. This pattern is reflected in environmental impact indicators: those more strongly associated with animal-sourced foods, such as carbon footprint, cropland use, and nitrogen inputs, are higher among boys than girls. Interestingly, girls' dietary patterns are associated with greater animal welfare issues. It is important to note that while energy needs vary between individuals based on factors like height, weight, and physical movement, the general energy requirements for 4-year-olds are similar across genders (Swedish Food Agency, 2024a). Therefore, the observed differences in food choices – or food offered to the children – are likely influenced by structural and cultural factors.

3.3.2. Differences between home and preschool setting

All indicators showed significant differences, except for new nitrogen input when comparing dietary impacts at home and preschool (Table 4). Only a few of these differences were of substantial magnitude to warrant practical consideration, including blue water use and new phosphorus input, with home settings exhibiting 21 % and 11 % higher impacts than preschool settings. Conversely, the animal welfare index of consumed food was 28 % higher in preschools.

The variability within indicators was higher in the preschool setting for all metrics, with animal welfare and blue water use exhibiting the greatest variability at 210 % and 124 %, respectively. The differences and high variability for animal welfare can be explained by differences in reported food intake in the preschool setting; some children have only consumed small amounts of food consisting of fruits and rice or pasta, reported with few or no animal welfare issues associated with them. On the other hand, other children consume several meals at preschool (i.e., larger amounts of food) consisting of poultry or seafood dishes. The differences in blue water use can be attributed to some children consuming mainly bread, pasta, and fruits such as apples and pears. Conversely, others consumed more water resource-demanding foods such as dried dates, stir-fried vegetables, and rice. For new phosphorus inputs, dietary patterns in home environments mainly contribute to the high inputs of red meat, poultry, and citrus fruits. On the other hand, children with low phosphorus inputs mainly consume crispbread, apples, and water in preschool settings. Additionally, dietary misreporting may have contributed to the differences and variability. For example, some children reported high amounts of fish sauce, contributing substantially to high blue water use. Alternatively, others reported sandwiches as their only food intake in preschools, which does not contribute substantially to phosphorus inputs.

Meat and meat dishes comprise a lower energy proportion in

Table 4
Energy-adjusted dietary impacts (per 1000 kcal) of 4-year-old children consuming food in both home and preschool settings in Riksmaten Young Children.

	Home (n = 450) Mean (SD)	Preschool (n = 450) Mean (SD)	Significance level
Carbon footprint (kg CO_2e)	1.6 (0.03)	1.6 (0.8)	***
Cropland use (m^2*year)	2.3 (0.04)	2.2 (0.9)	***
Blue water use (dm^3)	91 (3)	72 (89)	***
New nitrogen (g N)	29 (1)	30 (16)	ns
New phosphorus (g P)	2.9 (0.05)	2.6 (0.9)	***
Ammonia emission (g NH_3)	4.9 (0.2)	4.5 (3.7)	***
Pesticide use (g a.i.)	0.4 (0.01)	0.4 (0.2)	***
Biodiversity loss (E/MSY)	5.4E-13 (1.5E-14)	5.3E-13 (4.7E-13)	***
Antibiotic use (index)	3.1 (0.1)	3.0 (3.1)	***
Animal welfare (index)	1.4 (0.6)	2.0 (3.9)	***

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns = not significant ($p \geq 0.05$). Abbreviations: a.i., active ingredient; CO_2e, carbon dioxide equivalents; E/MSY, extinctions per million species-year. Average energy intake was 1086 and 721 kcal per person per day in home and preschool settings, respectively.

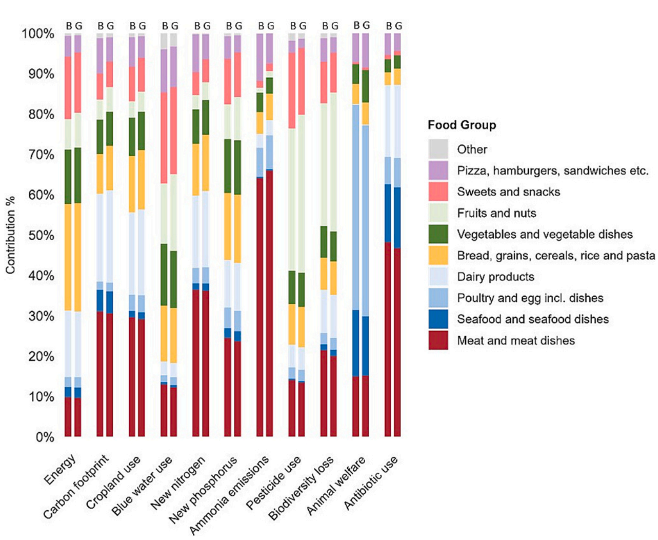

Fig. 3. Relative contributions of food groups to dietary impacts from 1000 kcal dietary patterns among boys (B) (n = 382) and girls (G) (n = 364) in Riksmaten Young Children.

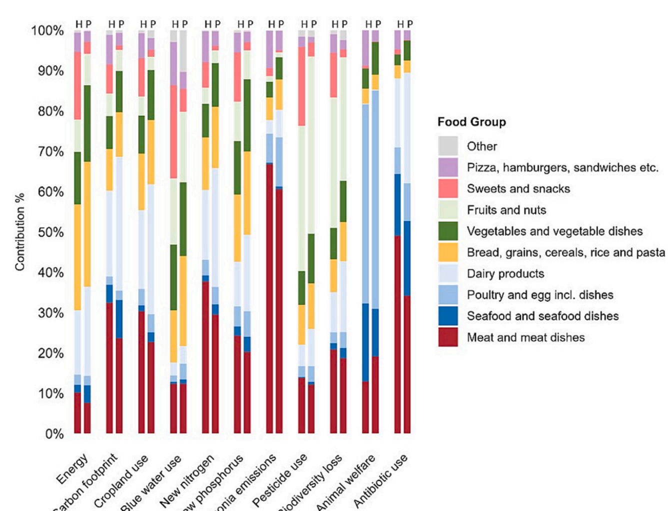

Fig. 4. Relative contributions of food groups to impacts from dietary patterns in home and preschool settings. The home setting (H) is presented to the left, and the preschool setting (P) is presented to the right. Includes the 450 young children who consumed food in both settings in Riksmaten Young Children.

preschools than in homes, whereas dairy consumption was higher in preschools (Fig. 4, Table A4). Interestingly, despite these compositional differences, the overall carbon footprint of diets in preschools and homes exhibited only a small, albeit statistically significant difference. The increased seafood and dairy consumption in preschools appeared to offset the impact reductions from the decreased meat intake in terms of carbon footprint. This finding suggests that while preschools are making efforts to adhere to the Swedish Food Agency's dietary recommendations for environmentally friendly foods by reducing meat consumption (Swedish Food Agency, 2021), the effect of these efforts may be canceled by the high consumption of dairy.

Overall, we found some compositional differences in dietary patterns in preschools and homes. In preschools, a larger share of the energy intake came from specific food groups including seafood, dairy products, vegetables, and bread and grains. In contrast, at home, a large share of energy intake was derived from other food groups, such as sweets and snacks, pizza, hamburgers and sandwiches etc., as well as other foods. The difference is probably due to the recommendations that educational institutions for early childhood should refrain from serving sugary-rich foods and beverages such as sugary drinks, sweets, and pastries in preschools (Swedish Food Agency, 2021).

3.3.3. Differences between rural, larger city, and metropolitan areas

Animal welfare impacts varied substantially across residential areas: children's diets in large cities scored 53 % higher on the index than those in rural areas. In comparison, metropolitan diets were 37 % higher than rural diets. The comparison between large cities and metropolitan areas revealed a minor yet notable difference, with diets in large cities scoring 26 % higher on the animal welfare index than those in metropolitan areas (Table 5). These differences can be explained by children living in rural areas consuming the least poultry and seafood, followed by children in metropolitan areas, and those living in larger cities consuming the most (Fig. 5, Table A5). Large inter-personal variation in poultry and seafood consumption in metropolitan and larger city areas results in greater coefficients of variation in animal welfare (77 % and 65 %, respectively) compared to rural areas (16 %). Other indicators showed similar patterns across regions.

Dietary patterns in rural areas led to higher impacts for ammonia emissions (17 %) and new nitrogen input (10 %) compared to large city and metropolitan areas. The higher consumption of meat and meat dishes, including those found in pizza, hamburgers and sandwiches and similar items in rural areas, typically results in higher ammonia emissions and increased use of new nitrogen, as shown in Fig. 5. Analysis of food group contributions confirms a higher intake of meat and meat dishes in rural areas (12 %) compared to metropolitan areas (9 %).

Table 5
Energy-adjusted dietary impacts (per 1000 kcal) of 4-year-old children by municipal typologies in Riksmaten Young Children.

	Type 1 (n = 109)	Type 2 (n = 277)	Type 3 (n = 360)	Significance level
	Mean (SD)	Mean (SD)	Mean (SD)	
Carbon footprint (kg CO_2e)	1.7 (0.2)	1.6 (0.3)	1.6 (0.3)	1–2***, 1–3***
Cropland use (m^2*year)	2.5 (0.3)	2.3 (0.3)	2.3 (0.3)	1–2***, 1–3***
Blue water use (dm^3)	84 (19)	93 (12)	85 (19)	1–2***, 2–3***
New nitrogen (g N)	31 (4)	28 (6)	28 (6)	1–2***, 1–3***
New phosphorus (g P)	2.9 (0.3)	2.9 (0.4)	2.8 (0.3)	1–3**, 2–3***
Ammonia emission (g NH_3)	5.9 (0.9)	4.9 (1.7)	4.8 (1.8)	1–2***, 1–3***
Pesticide use (g a.i.)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)	1–2**, 2–3**
Biodiversity loss (E/MSY)	5.2E-13 (1.2E-13)	5.3E-13 (1.2E-13)	5.1E-13 (9.6E-14)	2–3*
Antibiotic use (index)	3.3 (0.9)	3.1 (1.1)	3.0 (0.9)	1–2*, 1–3**
Animal welfare (index)	0.9 (0.1)	2.0 (1.3)	1.5 (1.1)	1–2***, 1–3***, 2–3***
Energy intake (kcal per person per day)	1400 (217)	1416 (201)	1442 (187)	

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns = not significant ($p \geq 0.05$). Abbreviations: a.i., active ingredient; CO_2e, carbon dioxide equivalents; E/MSY, extinctions per million species-year. Type 1: Small towns areas and rural municipalities. Type 2: Larger cities and municipalities near larger cities. Type 3: Metropolitan areas and municipalities near metropolitan areas.

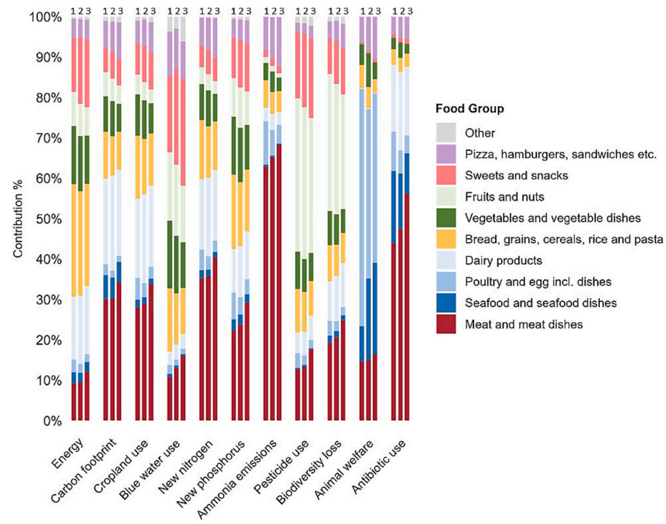

Fig. 5. Relative contributions of food groups by municipal typologies in Riksmaten Young Children. Small towns areas and rural municipalities (1) are presented to the left ($n = 109$), larger cities and municipalities near larger cities (2) are presented in the middle ($n = 277$), and metropolitan areas and municipalities near metropolitan areas (3) are presented to the right ($n = 360$).

We found that children in rural areas had dietary patterns associated with higher carbon footprints, mainly from meat dishes, including pizza, hamburgers and sandwiches, and dairy products. These findings contrast those of Strid et al. (2019), who showed that living in an urban environment was associated with higher dietary climate impact among adults in Västerbotten county, Sweden. The difference may be attributed to several factors: the differing age groups (children vs. adults), Riksmaten Young Children being a nationwide study rather than regional or potential socioeconomic and cultural differences between rural and urban areas that influence dietary choices.

3.3.4. Differences between parental education level

Dietary patterns among children in the low parental education group show higher environmental impacts for several indicators (Table 6). The most pronounced disparity was observed in animal welfare impact, with a 28 % higher score in the low parental education group, primarily due to slightly higher consumption of poultry and shrimps. Ammonia emissions also showed a substantial difference, being 14 % higher in the low parental education group, attributed to higher consumption of meat in meat dishes and items like pizza, hamburgers and sandwiches.

Analysis of food group contributions to energy intake and dietary impacts across parental education levels revealed subtle differences (Fig. 6, Table A6). Children of highly educated parents consumed more bread, grains, cereals, rice, and pasta, while those from less educated households consumed more sweets and snacks. Both these food groups contribute particularly to blue water use and pesticide use. Although differences in consumption of meat and meat dishes were less pronounced, households with lower parental education levels showed slightly higher impacts in this category, particularly in carbon footprint and new nitrogen.

While previous research in Sweden has shown that families with higher parental education levels tend to have healthier dietary patterns (Mattisson, 2016), it is not necessarily true that healthier foods have

Table 6
Energy-adjusted dietary impacts (per 1000 kcal) of 4-year-old children by parental education level in Riksmaten Young Children.

	High parental education level (*n* = 644) Mean (SD)	Low parental education level (n = 102) Mean (SD)	Significance level
Carbon footprint (kg CO_2e)	1.6 (0.3)	1.7 (0.3)	***
Cropland use (m^2*year)	2.3 (0.3)	2.4 (0.4)	***
Blue water use (dm^3)	88 (14)	87 (24)	ns
New nitrogen (g N)	28 (5)	31 (6)	***
New phosphorus (g P)	2.8 (0.4)	2.9 (0.4)	ns
Ammonia emission (g NH_3)	4.9 (1.7)	5.7 (1.8)	***
Pesticide use (g a. i.)	0.4 (0.1)	0.4 (0.1)	*
Biodiversity loss (E/MSY)	5.1E-13 (1.0E-13)	5.5E-13 (1.5E-13)	*
Antibiotic use (index)	3.0 (1.0)	3.2 (0.9)	*
Animal welfare (index)	1.5 (1.0)	2.1 (1.0)	***

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns = not significant ($p \geq 0.05$). Abbreviations: a.i., active ingredient; CO_2e, carbon dioxide equivalents; E/MSY, extinctions per million species-year.

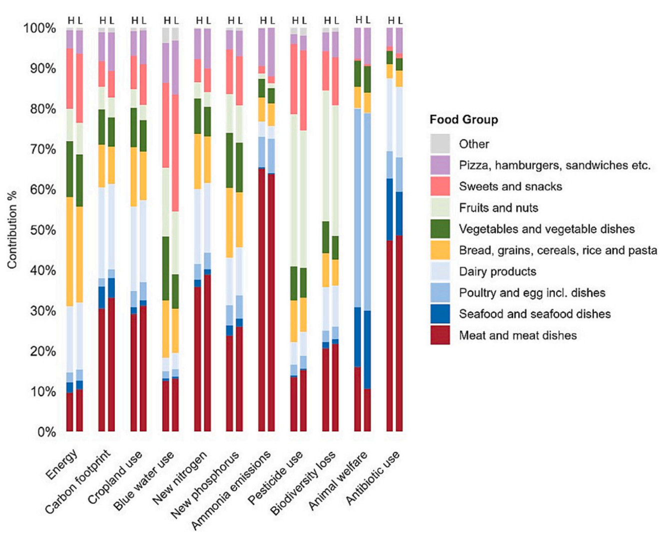

Fig. 6. Relative contributions of food groups to dietary impacts by parental education level in Riksmaten Young Children. High parental education level (H) is presented to the left (*n* = 644), and low parental education level (L) is presented to the right (*n* = 102).

lower environmental impacts. However, the findings indicate substantial variability in the dietary impacts of children's diets across different parental education levels in Sweden.

3.4. Correlation between indicators in the diet

Analysis of dietary intake data revealed strong positive correlations between multiple indicators (Table 7). Carbon footprint strongly correlates with nitrogen input, cropland use, and ammonia emissions. Blue water use and animal welfare exhibited weaker correlations with most other indicators. The strongest relationships observed between blue water use and pesticide use, as well as between animal welfare and antibiotic use.

The environmental impact of animal production is substantial across multiple indicators, as evidenced by the SAFAD tool's comprehensive assessment (Röös et al. 2025). Animal-based foods consistently impact cropland use, greenhouse gas emissions, new nitrogen input, and ammonia emissions more than plant-based alternatives. This aligns with the findings of Willett et al. (2019) and Ran et al. (2024), who emphasize the multi-faceted environmental pressures exerted by animal agriculture. The interconnected nature of these impacts is particularly noteworthy and stems primarily from the substantial feed requirements of livestock. A high demand for animal feed necessitates extensive utilization of cropland and substantial nitrogen inputs as fertilizers. Ammonia emissions, a notable contributor to air pollution, predominantly originate from manure management practices in animal husbandry. The intensive use of cropland and high nitrogen inputs further exacerbate environmental impacts through increased nitrous oxide emissions. Additionally, the energy-intensive nature of these agricultural practices, encompassing both the operation of machinery and the production of fertilizers, contributes substantially to the overall carbon footprint of animal-based food production.

Conversely, the environmental footprint of fruits and vegetables is generally lower across most indicators. However, it is crucial to note that certain aspects of fruit and vegetable production warrant careful consideration. The blue water footprint, for instance, can be substantial for some crops, particularly in irrigated cropping systems, in water-stressed regions (Mekonnen and Hoekstra, 2010). This underscores the importance of considering local environmental conditions when assessing different food items' sustainability, as Ran et al. (2024) suggested. Additionally, the pesticide use indicator in the SAFAD tool provides valuable insights into the potential ecological impacts of intensive horticultural practices. However, estimates come with major uncertainties due to the lack of reliable statistics on pesticide use, especially for crops from outside Europe (Röös et al. 2025).

When working on diet-related impacts in recommendations, governance, and policy for young children, we propose focusing on five key indicators: carbon footprint, animal welfare, blue water use, pesticide use, and biodiversity loss. The strong correlations observed between carbon footprint, cropland use, new nitrogen input, and ammonia emissions suggest that governance and policies to reduce carbon footprints may concurrently mitigate impacts in these related areas. Conversely, the other proposed indicators exhibit lower correlations and thus warrant specific attention. This approach balances practicality and comprehensive environmental and social considerations, offering a more nuanced understanding of the broader implications of dietary choices and highlighting potential trade-offs between impacts.

3.5. Regression analysis of demographic factors influencing dietary impacts

Both linear regression and mixed effect models were employed to examine the relationships between dietary impact indicators and demographic factors. Despite the inclusion of gender, parental educational level, municipality type, and setting (in mixed effect models) as predictors, both types of models consistently showed low R-square values across all indicators. The highest R-squared value in the linear regression models was merely 2.29 % for carbon footprint and ammonia emissions. In contrast, the mixed effect models showed slightly higher but still low R-squared values, with a maximum of 8.89 % for new phosphorus input.

Notwithstanding the limited explanatory power of these models, several individual predictors demonstrated statistical significance across dietary impact indicators. This paradoxical finding suggests that while socio-demographic factors influence dietary impacts somewhat, they account for only a small fraction of the overall variation observed. The low explanatory power could be attributed to unmeasured variables or the possibility that the existing variables are too broadly categorized.

Table 7
Spearman's Correlation Coefficients between dietary indicators in Riksmaten Young Children (adjusted to 1000 kcal).

Indicator	Carbon footprint	Cropland use	Blue water use	Nitrogen input	Phosphorus input	Ammonia emission	Pesticide use	Biodiversity loss	Antibiotic use	Animal welfare
Carbon footprint	1	0.85	0.10	0.90	0.57	0.75	0.19	0.43	0.51	0.08
Cropland use		1	0.20	0.93	0.67	0.86	0.23	0.43	0.64	0.15
Blue water use			1	0.11	0.39	0.16	0.48	0.33	-0.02	0.10
Nitrogen input				1	0.66	0.89	0.18	0.45	0.55	0.09
Phosphorus input					1	0.66	0.40	0.51	0.57	0.28
Ammonia emission						1	0.25	0.45	0.60	0.20
Pesticide use							1	0.54	0.10	0.10
Biodiversity loss								1	0.23	0.08
Antibiotic use									1	0.47
Animal welfare										1

The table presents correlations between ten indicators: carbon footprint, cropland use, blue water use, nitrogen and phosphorus inputs, ammonia emission, pesticide use, biodiversity loss, antibiotic use, and animal welfare. Color scale: Dark blue = strong positive correlation $r \geq 0.7$, Medium blue = moderately strong positive correlations $0.5 \leq r < 0.7$, Light blue = weak positive correlations $0.3 \leq r < 0.5$, White = correlations close to $-0.3 < r < 0.3$; n = 746, data adjusted to 1000 kcal intake

While no finer categorization is possible for gender, a more nuanced stratification of education level and municipal classification could yield a better model fit.

Dietary choices are deeply rooted in cultural norms, personal preferences, and family traditions, making them challenging to predict or influence (Fernqvist et al., 2024), especially for young children. Our findings suggest that interventions targeting these specific socio-demographic factors alone are unlikely to yield substantial improvements in the dietary impacts of 4-year-olds. Instead, our results underscore the need for a more comprehensive approach to address the impacts observed.

3.6. Methodological considerations for the dietary assessment of diets

The assessment of dietary impacts among Swedish young children is subject to methodological limitations and uncertainties. The two-day dietary intake data collection period may not accurately capture habitual consumption patterns. From a sustainability standpoint, long-term food intake and its associated dietary impacts are most pertinent. To address this limitation and estimate habitual dietary consumption more reliably, we applied the Multiple Source Method (Harttig et al., 2011). The overrepresentation of weekend days in Riksmaten Young Children may have led to an overestimation of energy-dense and nutrient-poor food consumption, particularly sweets and snacks. Conversely, dietary surveys often underrepresent these foods (Moraeus et al., 2024). It is important to note that while these foods typically do not contribute substantially to indicators such as carbon footprint or land use, they may have noteworthy impacts on other indicators. For instance, the production of nuts and cacao could involve higher pesticide or blue water use. Additionally, the overrepresentation of parents with higher education levels in Riksmaten Young Children (Moraeus et al., 2024) may have influenced the results, as higher education is often associated with higher fruit and vegetable consumption (Mattisson, 2016; Moraeus et al., 2018). Consequently, the minor differences in this study between parental education levels, particularly in blue water and pesticide use associated with fruit and vegetable production, may be underestimated and reduce generalizability. Future research should prioritize strategies to increase participation from households with lower socioeconomic positions to ensure more representative dietary assessments across all education levels.

The indicators utilized in this study provide valuable insights despite inherent limitations. For instance, blue water use does not account for local water stress, and biodiversity loss is associated with major uncertainties (Ran et al., 2024). Assessing the environmental performance of a diet is challenging due to model and data uncertainties in calculating environmental impacts, as highlighted by Röös et al. (2025). Carbon footprint, for example, arises from several processes and depends on factors such as climate conditions and soil characteristics. Additionally, methodological choices in accounting for emissions can affect the results (Moberg et al., 2020). Diets include foods with various origins, and food diaries and FFQs provide limited information about the origin, production systems, and conditions at the production sites. The limited information prevents the use of indicators that rely on site-specific information. Consequently, we have used more general indicators that do not depend on site-specific data (Ran et al., 2024). Despite these limitations, we consider the chosen indicators good proxies for environmental impacts caused by food production and valuable tools for identifying trade-offs in dietary sustainability. Lastly, defining absolute global boundaries for the food system is challenging due to the complexity and interconnection between drivers of Earth system processes (Willett et al., 2019). To account for some of the uncertainties in these boundaries, we have compared our results to the lower uncertainty limit.3.8 Challenges of dietary sustainability and international implications.

Dietary patterns among young Swedish children are currently environmentally unsustainable, with none of the children meeting all the planetary boundaries (see section 3.2). The high consumption of animal-sourced foods is the main contributor to this (see section 3.3). Children themselves are not responsible for their dietary habits. Rather, these patterns mirror the broader social and cultural contexts in which they are raised. Consequently, the findings from this study are relevant not only in Sweden but also to other countries, particularly those with similar dietary patterns or institutional frameworks. Challenges identified in Sweden, such as the elevated carbon footprint due to persistent dairy consumption, provide valuable insights for other countries aiming for more sustainable eating patterns.

Research indicates that early dietary habits have a lasting impact on long-term eating patterns and, therefore, on sustainability outcomes (e.g., Dubois et al. ., 2022). By addressing barriers and promoting sustainable practices, countries can encourage healthier eating habits among children and contribute to the development of more sustainable food systems globally. Sweden's emphasis on integrating sustainability in early education – through programs that promote healthy eating and environmental awareness (Swedish National Agency for Education, 2019) serves as a useful model. The Nordic countries, including Sweden, can be seen as forerunners in sustainable food policy. Nordic Council of Ministers (2018) has suggested 24 innovative approaches to nutrition, food culture, public meals, food waste reduction, and sustainable diets, covering, e.g., Nordic Nutrition Recommendations, Keyhole Label, building regional food identities, universal school meal programs, public meal models, and encouraging collaboration to reduce food waste. However, practical challenges such as cultural preferences and existing policies may hinder dietary changes. Fernqvist et al. (2024) emphasize that the food environment has a critical influence on food choices. This influence is particularly evident since access to healthy food is often limited in socioeconomically disadvantaged areas, a finding supported in a Swedish context by Mattisson (2016). Additionally, cultural norms, lifestyles, and societal influences further shape food choices, including among children (Graça et al., 2019; Govzman et al., 2021).

There is a unique opportunity to control the food environment in the context of public meals. This extensive reach across socioeconomic groups allows for substantial influence over food choices and eating habits. By carefully designing menus, implementing nutritional guidelines, and creating positive dining experiences, public meal service can shape healthier and more sustainable food environments. Public policies, such as implementing vegetarian days in preschools or setting sustainable procurement standards, can contribute to shifting behaviors toward more sustainable consumption patterns (Spendrup et al., 2024). Furthermore, the role of family members and social networks in shaping food preferences and individual choices should not be overlooked.

4. Conclusion and future directions

This comprehensive study of dietary impacts among young Swedish children reveals that their current dietary patterns are unsustainable, with only blue water use falling within the safe operating space for humanity. The most critical areas exceeding planetary boundaries are nitrogen and phosphorus cycling, carbon footprint, and biodiversity loss, highlighting priorities for future policy development. We found that boys generally show higher dietary impacts than girls, both in absolute and energy-adjusted impacts, indicating a social structure where young boys are fostered to consume more environmentally resource-demanding foods, suggesting that gender-specific dietary patterns are established early. Additionally, children living in rural areas generally have higher dietary impacts than those in larger cities and metropolitan regions. Despite existing policies aimed at reducing carbon footprints, we found no substantial difference in the carbon footprint of preschool diets compared to those consumed at home, indicating insufficient efforts to mitigate environmental impact. Moreover, strong correlations exist between carbon footprint, cropland use, nitrogen input, and ammonia emissions, suggesting that policies targeting carbon footprint reduction will yield broader environmental benefits. Notably, sociodemographic variables alone do not strongly predict dietary impacts, underscoring the need for interventions and strategies that address the target group rather than focusing on individual sub-groups. To secure human health and planetary well-being for future generations, we recommend researching and developing multi-faceted interventions that simultaneously address various aspects of the food system, including sustainable food production practices, consumer education, policy reforms, and food industry engagement. Additionally, we suggest intervention strategies to foster children and increase food system sustainability should focus on carbon footprint, animal welfare, blue water use, pesticide use and biodiversity loss. By fostering environments that promote sustainable and healthy dietary behaviors from an early age, we can potentially influence lifelong dietary choices and their associated environmental impacts. Future research should also assess how aligning diets with current Swedish dietary recommendations could reduce environmental impacts without compromising nutritional adequacy. This approach recognizes the far-reaching consequences of childhood dietary patterns and emphasizes the importance of early intervention in shaping a sustainable food future.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Perplexity in order to improve linguistics. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Funding

The study was funded by the project “*Food systems transformation towards healthy and sustainable dietary behaviour - PLAN’EAT*” granted by the European Union’s Horizon Europe Research and Innovation Programme under the Grant Agreement n° 101061023. The views reflected in this article represent the professional views of the authors and do not necessarily reflect the views of the European Commission or other PLAN’EAT partners.

CRediT authorship contribution statement

Maria Jacobsen: Conceptualization, Data curation, Methodology, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Lotta Moraeus:** Conceptualization, Data curation, Writing – review & editing. **Emma Patterson:** Conceptualization, Data curation, Writing – review & editing. **Anna Karin Lindroos:** Conceptualization, Data curation, Writing – review & editing. **Mattias Eriksson:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Elin Röös:** Conceptualization, Methodology, Supervision, Funding acquisition, Writing – review & editing.

Declaration of competing interest

The authors have no competing interests to declare.

Acknowledgements

We would like to thank all participants and everyone who worked with all parts of data collection in Riksmaten Young Children. Thanks to Claudia von Brömsen for consultations regarding statistical analysis. A special thanks to Wilhelm Wanecek and Ludvig Karlsson for all their work updating the SAFAD tool.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crsust.2025.100281.

Data availability

The data that has been used is confidential.

References

Bäck, S., Skaffari, E., Vepsäläinen, H., Lehto, R., Lehto, E., Nissinen, K., Ray, C., Nevalainen, J., Roos, E., Erkkola, M., Korkalo, L., 2022. Sustainability analysis of Finnish pre-schoolers’ diet based on targets of the EAT-lancet reference diet. Eur. J. Nutr. 61 (2), 717–728. https://doi.org/10.1007/s00394-021-02672-3.

Bälter, K., Sjörs, C., Sjölander, A., Gardner, C., Hedenus, F., Tillander, A., 2017. Is a diet low in greenhouse gas emissions a nutritious diet? – analyses of self-selected diets in the LifeGene study. Arch. Public Health 75 (1), 17. https://doi.org/10.1186/s13690-017-0185-9.

Benton, T.G., Bieg, C., Harwatt, H., Pudasaini, R., Wellesley, L., 2021. Food System Impacts on Biodiversity Loss. https://www.chathamhouse.org/2021/02/food-system-impacts-biodiversity-loss.

Bjermo, H., Patterson, E., Petrelius Sipinen, J., Lignell, S., Stenberg, K., Larsson, E., Lindroos, A.K., Ottoson, J., Warensjö Lemming, E., Moraeus, L., 2024. Design, methods, and participation in Riksmaten young children—a Swedish National Dietary Survey. Curr. Develop. Nutr. 8 (5), 102150. https://doi.org/10.1016/j.cdnut.2024.102150.

Blomhoff, R., Andersen, R., Arnesen, E.K., Christensen, J.J., Eneroth, H., Erkkola, M., Gudanaviciene, I., Halldórsson, Þ.I., Höyer-Lund, A., Lemming, E.W., 2023. Nordic Nutrition Recommendations 2023: Integrating Environmental Aspects. Nordic Council of Ministers.

Cassini, A., Högberg, L.D., Plachouras, D., Quattrocchi, A., Hoxha, A., Simonsen, G.S., Colomb-Cotinat, M., Kretzschmar, M.E., Devleesschauwer, B., Cecchini, M., Ouakrim, D.A., Oliveira, T.C., Struelens, M.J., Suetens, C., Monnet, D.L., Strauss, R., Mertens, K., Struyf, T., Catry, B., Latour, K., Ivanov, I.N., Dobreva, E.G., Tambic Andraševic, A., Soprek, S., Budimir, A., Paphitou, N., Žemlicková, H., Schytte

Olsen, S., Wolff Sönksen, U., Märtin, P., Ivanova, M., Lyytikäinen, O., Jalava, J., Coignard, B., Eckmanns, T., Abu Sin, M., Haller, S., Daikos, G.L., Gikas, A., Tsiodras, S., Kontopidou, F., Tóth, Á., Hajdu, Á., Guólaugsson, Ó., Kristinsson, K.G., Murchan, S., Burns, K., Pezzotti, P., Gagliotti, C., Dumpis, U., Liuimiene, A., Perrin, M., Borg, M.A., De Greeff, S.C., Monen, J.C., Koek, M.B., Elstrøm, P., Zabicka, D., Deptula, A., Hryniewicz, W., Caniça, M., Nogueira, P.J., Fernandes, P.A., Manageiro, V., Popescu, G.A., Serban, R.I., Schréterová, E., Litvová, S., Štefkovicová, M., Kolman, J., Klavs, I., Korošec, A., Aracil, B., Asensio, A., Pérez-Vázquez, M., Billström, H., Larsson, S., Reilly, J.S., Johnson, A., Hopkins, S., 2019. Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European economic area in 2015: a population-level modelling analysis. Lancet Infect. Dis. 19 (1), 56–66. https://doi.org/10.1016/S1473-3099(18)30605-4.

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N., Leip, A., 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food 2 (3), 198–209. https://doi.org/10.1038/s43016-021-00225-9.

EEA Report, 2019. EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019, 3B Manure Management (No 13/2019). European Environment Agency.

European Commission, 2020. Farm to Fork Strategy - for a Fair, Healthy and Environmentally-Friendly Food System. European Commission. https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf.

FAO, 2022. The State of the World's Land and Water Resources for Food and Agriculture 2021 – Systems at Breaking Point. FAO. https://doi.org/10.4060/cb9910en.

FAO, 2023. *Minimum Daily Requirement of Calories* - FAO [dataset]. Food and Agriculture Organization of the United Nations, "Food Security and Nutrition: Suite of Food Security Indicators" [Original Data]. With Major Processing by Our World in Data (n. d.). https://ourworldindata.org/grapher/minimum-requirement-calories (2024-06-24).

Fernqvist, F., Spendrup, S., Tellström, R., 2024. Understanding food choice: a systematic review of reviews. Heliyon 10 (12), e32492. https://doi.org/10.1016/j.heliyon.2024.e32492.

Forster, P., Storelvmo, T., Armour, W., Collins, W., Dufresne, J.L., Frame, D., Lunt, D.J., Mauritsen, T., Palmer, M.D., Watanabe, M., Wild, M., Zhang, H., 2023. In: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., Zhou, B. (Eds.), Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 1. ed. Cambridge University Press. https://doi.org/10.1017/9781009157896.

Govzman, S., Looby, S., Wang, X., Butler, F., Gibney, E.R., Timon, C.M., 2021. A systematic review of the determinants of seafood consumption. Br. J. Nutr. 126 (1), 66–80. https://doi.org/10.1017/S0007114520003773.

Graça, J., Godinho, C.A., Truninger, M., 2019. Reducing meat consumption and following plant-based diets: Current evidence and future directions to inform integrated transitions. Trends Food Sci. Technol. 91, 380–390. https://doi.org/10.1016/j.tifs.2019.07.046.

Gu, B., Zhang, X., Lam, S.K., Yu, Y., Van Grinsven, H.J.M., Zhang, S., Wang, X., Bodirsky, B.L., Wang, S., Duan, J., Ren, C., Bouwman, L., De Vries, W., Xu, J., Sutton, M.A., Chen, D., 2023. Cost-effective mitigation of nitrogen pollution from global croplands. Nature 613 (7942), 77–84. https://doi.org/10.1038/s41586-022-05481-8.

Hallström, E., Bajzelj, B., Håkansson, N., Sjons, J., Åkesson, A., Wolk, A., Sonesson, U., 2021. Dietary climate impact: contribution of foods and dietary patterns by gender and age in a Swedish population. J. Clean. Prod. 306, 127189. https://doi.org/10.1016/j.jclepro.2021.127189.

Hallström, E., Davis, J., Håkansson, N., Ahlgren, S., Åkesson, A., Wolk, A., Sonesson, U., 2022. Dietary environmental impacts relative to planetary boundaries for six environmental indicators – a population-based study. J. Clean. Prod. 373, 133949. https://doi.org/10.1016/j.jclepro.2022.133949.

Harrison, M.R., Palma, G., Buendia, T., Bueno-Tarodo, M., Quell, D., Hachem, F., 2022. A scoping review of indicators for sustainable healthy diets. Front. Sustain. Food Syst. 5, 822263. https://doi.org/10.3389/fsufs.2021.822263.

Harttig, U., Haubrock, J., Knüppel, S., Boeing, H., on behalf of the EFCOVAL Consortium, 2011. The MSM program: web-based statistics package for estimating usual dietary intake using the multiple source method. Eur. J. Clin. Nutr. 65 (S1), S87–S91. https://doi.org/10.1038/ejcn.2011.92.

Haubrock, J., Nöthlings, U., Volatier, J.-L., Dekkers, A., Ocké, M., Harttig, U., Illner, A.-K., Knüppel, S., Andersen, L.F., Boeing, H., 2011. Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam calibration Study1–3. J. Nutr. 141 (5), 914–920. https://doi.org/10.3945/jn.109.120394.

IPBES, 2019. *Summary for policymakers of the global assessment report on biodiversity and ecosystem services* (summary for policy makers). Zenodo. https://doi.org/10.5281/ZENODO.3553579.

IPCC, 2019. IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems.

ISO, 2018. ISO 14067:2018 Greenhouse Gases — Carbon Footprint of Products — Requirements and Guidelines for Quantification.

Lindroos, A.K., Petrelius Sipinen, J., Axelsson, C., Nyberg, G., Landberg, R., Leanderson, P., Arnemo, M., Warensjö Lemming, E., 2019. Use of a web-based dietary assessment tool (RiksmatenFlex) in Swedish adolescents: comparison and validation study. J. Med. Internet Res. 21 (10), e12572. https://doi.org/10.2196/12572.

Lindroos, A.K., Hallström, E., Moraeus, L., Strid, A., Winkvist, A., 2023. Dietary greenhouse gas emissions and diet quality in a cross-sectional study of Swedish adolescents. Am. J. Clin. Nutr. https://doi.org/10.1016/j.ajcnut.2023.09.001. S0002916523661246.

Mattisson, I., 2016. *Socioekonomiska skillnader i matvanor i Sverige*. (Rapport 9-2016). https://www.livsmedelsverket.se/globalassets/publikationsdatabas/rapporter/2016/rapport-nr-9-2016-socioekonomiska-skillnader-i-matvanor-i-sverige.pdf.

Mekonnen, M.M., Hoekstra, A.Y., 2010. The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products, Value of Water Research Report Series No. 47.

Minitab LLC, 2024. (Minitab (Version 21.4.3)) [Computer Software]. www.minitab.com.

Moberg, E., Walker Andersson, M., Säll, S., Hansson, P.-A., Röös, E., 2019. Determining the climate impact of food for use in a climate tax—design of a consistent and transparent model. Int. J. Life Cycle Assess. 24 (9), 1715–1728. https://doi.org/10.1007/s11367-019-01597-8.

Moberg, E., Karlsson Potter, H., Wood, A., Hansson, P.-A., Röös, E., 2020. Benchmarking the Swedish diet relative to global and National Environmental Targets—Identification of Indicator limitations and data gaps. Sustainability 12 (4), 1407. https://doi.org/10.3390/su12041407.

Moraeus, L., Bjermo, H., Petrelius Sipinen, J., Patterson, E., Larsson, E., Stenberg, K., Lindroos, A.K., 2024. *L 2024 nr 12: Riksmaten småbarn 2021–24 – Så äter småbarn i Sverige*. (Livsmedelsverket rapportserie). https://www.livsmedelsverket.se/om-oss/publikationer/artiklar/2024/l-2024-nr-12-riksmaten-smabarn-2021-24.

Moraeus, L., Lemming, E.W., Hursti, U.-K.K., Arnemo, M., Sipinen, J.P., Lindroos, A.-K., 2018. Riksmaten Adolescents 2016–17: A national dietary survey in Sweden – design, methods, and participation. Food Nutr. Res. 62 (0). https://doi.org/10.29219/fnr.v62.1381.

Nicklaus, S., Remy, E., 2013. Early origins of overeating: tracking between early food habits and later eating patterns. Curr. Obes. Rep. 2 (2), 179–184. https://doi.org/10.1007/s13679-013-0055-x.

Poore, J., Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. Science 360 (6392), 987–992. https://doi.org/10.1126/science.aaq0216.

Ran, Y., Cederberg, C., Jonell, M., Bergman, K., De Boer, I.J.M., Einarsson, R., Karlsson, J., Potter, H.K., Martin, M., Metson, G.S., Nemecek, T., Nicholas, K.A., Strand, Å., Tidåker, P., Van Der Werf, H., Vanham, D., Van Zanten, H.H.E., Verones, F., Röös, E., 2024. Environmental assessment of diets: overview and guidance on indicator choice. Lancet Planet. Health 8 (3), e172–e187. https://doi.org/10.1016/S2542-5196(24)00006-8.

Röös, E., Karlsson, H., Witthöft, C., Sundberg, C., 2015. Evaluating the sustainability of diets–combining environmental and nutritional aspects. Environ. Sci. Pol. 47, 157–166. https://doi.org/10.1016/j.envsci.2014.12.001.

Röös, E., Jacobsen, M., Karlsson, L., Wanecek, W., Spångberg, J., Mazec, R., Rydhmer, L., 2025. Introducing a Comprehensive and Configurable Tool for Calculating Environmental and Social Footprints for use in Dietary Assessments. Forthcoming. (In review in Journal of Cleaner Production).

RStudio Team, 2024 (2024.04.01). RStudio, PBC. www.rstudio.com.

Rydhmer, L., Röös, E., 2025. Including Animal Welfare and Use of Antibiotics in Diet Assessments to Highlight Trade-offs with Environmental Impact. In review in Sustainable Production and Consumption. Forthcoming.

Scherer, L., Rosa, F., Sun, Z., Michelsen, O., De Laurentiis, V., Marques, A., Pfister, S., Verones, F., Kuipers, K.J.J., 2023. Biodiversity impact assessment considering land use intensities and fragmentation. Environ. Sci. Technol. 57 (48), 19612–19623. https://doi.org/10.1021/acs.est.3c04191.

Sjörs, C., Hedenus, F., Sjölander, A., Tillander, A., Bälter, K., 2017. Adherence to dietary recommendations for Swedish adults across categories of greenhouse gas emissions from food. Public Health Nutr. 20 (18), 3381–3393. https://doi.org/10.1017/S1368980017002300.

Skolmat Sverige, 2023. Skolmatens historia. https://www.skolmatsverige.se/om-oss/skolmatens-historia/.

Spendrup, S., Tellström, R., Fernqvist, F., 2024. *Därför äter vi som vi gör: en kunskapsöversikt om matval*. SLU Framtidens mat. Sveriges lantbruksuniversitet.. https://doi.org/10.54612/a.1vtb3t672h.

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L., de Vries, W., Vermeulen, S.J., Herrero, M., Carlson, K.M., Jonell, M., Troell, M., DeClerck, F., Gordon, L.J., Zurayk, R., Scarborough, P., Rayner, M., Loken, B., Fanzo, J., Godfray, H.C.J., Tilman, D., Rockström, J., Willett, W., 2018. Options for keeping the food system within environmental limits. Nature 562 (7728), 519–525. https://doi.org/10.1038/s41586-018-0594-0.

Steenson, S., Buttriss, J.L., 2021. Healthier and more sustainable diets: what changes are needed in high-income countries? Nutr. Bull. 46 (3), 279–309. https://doi.org/10.1111/nbu.12518.

Strid, A., Hallström, E., Hjorth, T., Johansson, I., Lindahl, B., Sonesson, U., Winkvist, A., Huseinovic, E., 2019. Climate impact from diet in relation to background and sociodemographic characteristics in the Västerbotten Intervention Programme. Public Health Nutr. 22 (17), 3288–3297. https://doi.org/10.1017/S1368980019002131.

Sutton, M., Howard, C.M., Manson, K.E., Brownlie, W., Cordovil, C., 2022. Nitrogen Opportunities for Agriculture, Food & Environment: UNECE Guidance Document on Integrated Sustainable Nitrogen Management. UK Centre for Ecology & Hydrology, Edinburgh.

Sveriges Kommuner och Regioner, 2022. Municipal Group Division. https://skr.se/download/18.ef4ba7d1849a2f55db2898a/1669978414789/Kommungruppsindelning-2023.pdf.

Swedish Board of Agriculture, 2024. Konsumtion-animalieprodukter-tga.xlsx. https://jordbruksverket.se/download/18.382598821783902f1ef924e/1710749412302/Konsumtion-animalieprodukter-tga.xlsx.

Swedish Food Agency, 2021. Riktlinjer för måltider i förskolan. https://www.livsmedelsverket.se/globalassets/publikationsdatabas/broschyrer-foldrar/riktlinjer-for-maltider-i-forskolan.pdf.

Swedish Food Agency, 2021a. maltider-i-forskolan-resultat-redovisade-per-kommun.2021. https://www.livsmedelsverket.se/matvanor-halsa–miljo/maltider-i-vard-skola-och-omsorg/fakta-om-offentliga-maltider/fakta-kommunovergripande (2024-11-05).

Swedish Food Agency, 2024a. Energi, kalorier. https://www.livsmedelsverket.se/livsmedel-och-innehall/naringsamne/energi-kalorier.

Swedish Food Agency, 2024b. Matvanor - undersökningar. https://www.livsmedelsverket.se/matvanor-halsa–miljo/matvanor—undersokningar.

Swedish National Agency for Education. Curriculum for the preschool: Lpfö 10. Skolverket.

Swedish National Agency for Education, 2022. *Statistik över barn och personal i förskola 2021*. [text]. https://www.skolverket.se/skolutveckling/statistik/fler-statistiknyheter/statistik/2022-04-28-statistik-over-barn-och-personal-i-forskola-2021 (2022-11-28).

UNEP (Ed.), 2022. The Closing Window: Climate Crisis Calls for Rapid Transformation of Societies. United Nations Environment Programme. (The emissions gap report; 2022).

WHO, 2023. Health Promoting Schools. https://www.who.int/health-topics/health-promoting-schools.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L.J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J.A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S.E., Srinath Reddy, K., Narain, S., Nishtar, S., Murray, C.J.L., 2019. Summary Report of the EAT-Lancet Commission. https://eatforum.org/eat-lancet-commission/eat-lancet-commission-summary-report/.