Food Policy 117 (2023) 102444

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

From "good for people" to "good for people and planet" – Placing health and environment on equal footing when developing food-based dietary guidelines

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ARTICLE INFO

Keywords:
Dietary guidelines
Environmental sustainability
Food systems
Framework
Sweden

ABSTRACT

Dietary guidelines are a primary tool for promoting healthier and more sustainable diets. Despite several examples of dietary guidelines that consider - to various degrees - aspects of environmental sustainability, there is currently no framework that systematically incorporates environmental sustainability as a primary consideration. We present a five-step framework for developing environmentally sustainable dietary guidelines that would simultaneously meet nutritional requirements while staying within environmental boundaries. The steps comprise: 1) determining an average healthy diet for different population groups and criteria for healthy diets; 2) identifying relevant environmental aspects and establishing corresponding boundaries; 3) identifying systemic effects and crucial sustainability aspects; 4) altering the average diet to meet environmental goals and resolve trade-offs between environmental and nutritional goals; and 5) formulating sustainable food-based dietary guidelines. To exemplify the framework, we pilot it in the Swedish context, but it could be utilised for any other country.

1. Introduction

National food-based dietary guidelines (FBDG) are considered a primary tool to communicate healthy eating advice to populations and act as a basis for policy development (WHO, 1998; Zeraatkar et al., 2019). To date, the focus of these guidelines has largely been on meeting nutritional needs and promoting human health (Magni et al., 2017; Mazac et al., 2021). However, there is increasing awareness among policymakers that food not only plays a central role in promoting good health, but also that food systems are a major driver of several environmental pressures (Willett et al., 2019). Thus, interest is growing in dietary guidance that could simultaneously deliver on health and environmental sustainability goals (Lang and Mason, 2018; Tetens et al., 2020).

Relatively few guidelines provide explicit advice on environmentally sustainable eating (Gonzalez Fischer and Garnett, 2016), as reflected in the finding that eating patterns in line with most existing guidelines would fail to stay within global environmental boundaries for food systems (Springmann et al., 2020). Where environmental considerations are addressed, they are often included as a secondary consideration, *e.g.*, the Italian guidelines provide a high-level overview of various environmental aspects of food, including food waste, seasonality, organic food, food packaging, and the broad impacts of animal-sourced foods in the final chapter of the report (Intorre et al., 2021). Additionally, only a limited number of environmental concerns are typically considered, *e.g.*, the Danish dietary guidelines aim to reduce the climate impact of diets, but do not substantially incorporate other environmental indicators, such as land use, nutrient application or biodiversity loss (Ministeriet for Fødevarer Landbrug og Fiskeri, 2020). Further, environmental considerations, even when integrated throughout FBDG, rarely influence recommended intake levels of different food groups to the same extent as nutrient and health considerations. For example, the Swedish guidelines include a substantial discussion of environmental impacts of various food groups and the main message is to eat greener, meaning more

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https://doi.org/10.1016/j.foodpol.2023.102444
Received 15 July 2022; Received in revised form 15 March 2023; Accepted 19 March 2023
Available online 30 April 2023

plants and less meat, but environmental considerations do not substantially impact the intake values recommended (Livsmedelsverket, 2015; personal communication, Livsmedelsverket, 2022). For example, the limit for red meat consumption is justified by the recommendation from the World Cancer Research Fund (WCRF and AICR, 2007) based on reducing the risk of cancer (Bjerselius et al., 2014). These limitations should not overshadow the progress made by existing guidelines in incorporating sustainability concerns, but they indicate a need for a more systematic approach that assesses the impacts of diets on a range of environmental aspects and includes a range of additional systemic considerations (Mazac et al., 2021).

In this paper, we present a framework with concrete steps for developing environmentally sustainable food-based dietary guidelines (SFBDG), *i.e.,* guidelines that give equal consideration to nutritional targets and environmental boundaries. This equal prioritisation acknowledges that in order to provide healthy diets now and in the future, we must do so within the limits of our biosphere (Willett et al., 2019). Guidelines developed using this framework should result in diets that stay within absolute boundaries for environmental pressures while meeting criteria for healthy eating. The step-wise process can be modified based on available data and resources and the local context. Ideally, the process should be based on best available evidence, but every step includes inevitable normative decisions and should therefore involve relevant stakeholders in a democratic process to deliberate and resolve trade-offs. Relevant stakeholder will differ depending on the step of the process, but could include, for example, nutritionists, public health experts, environmental scientists, relevant authorities, and members of the public. We exemplify the use of the framework for the case of Sweden, highlighting the type of data, assessments and stakeholder negotiations needed along the way. However, it should be noted that this is a pilot study on use of the framework and not a complete development of Swedish SFBDG, which would require a thorough stakeholder process and should be led by relevant public agencies.

2. A step-wise framework for developing environmentally sustainable food-based dietary guidelines

The proposed framework includes five overarching steps (Fig. 1). Steps 1–3 involve defining boundary conditions, *i.e.,* goals for healthy eating and boundaries of environmental pressures that must not be transgressed for the diet to be considered environmentally sustainable, while Steps 4 and 5 involve development of SFBDG compatible with achieving these goals and staying within the boundaries. Below we describe the steps in the framework in general terms. Application of the framework to the Swedish context is illustrated in an infographic (Fig. 2) and described in more detail in Section 3.

2.1. Step 1: Determine an average healthy diet for a given population and criteria for healthy diets

The framework uses context-specific healthy diets as the starting point for creating SFBDG. This is a practical decision to provide a more accessible entry point, given that professionals in nutrition and public health are accustomed to working with healthy diets. It is widely acknowledged that there is no definitive healthy diet suitable for the entire population. However, for the purposes of applying this framework one (or a set of) context-specific diets that reflect average daily intakes for as many food groups as possible is needed.

The **first task** in this step is to determine an average healthy diet for a given population. As nutrient requirements vary across population groups (men, women, elderly, children, pregnant women, etc.) there can be a need to define a set of healthy diets or consider adjustments to the healthy diets based on such concerns. Determining an average healthy diet can be done using existing FBDG and/or archetype diets, or by

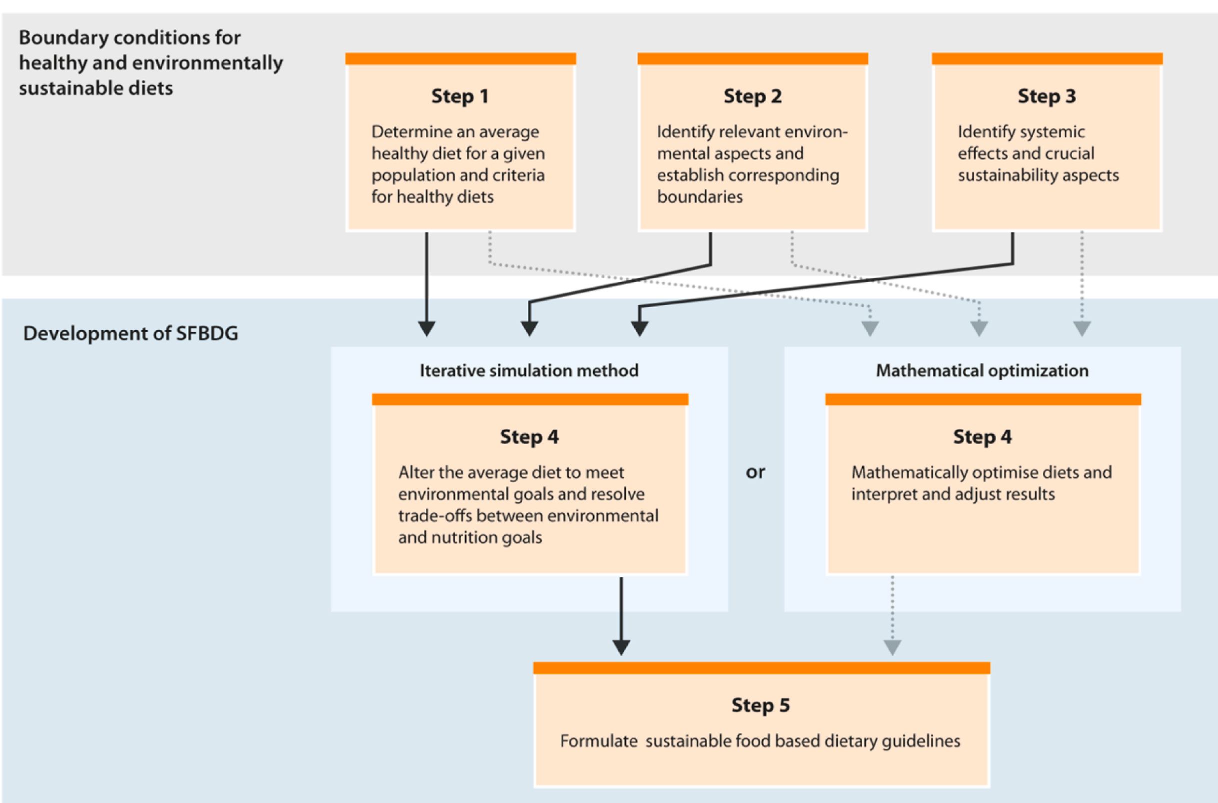

Fig. 1. Framework for developing sustainable food-based dietary guidelines (SFBDG). Solid arrows represent the approach described and illustrated in this paper, and dashed lines represent an alternative approach.

building upon nutrient recommendations. Many countries have issued FBDG, which typically account for eating habits and traditions in local contexts, in combination with evidence of healthy eating (Herforth et al., 2019). Archetype diets are dietary patterns that have proven to be associated with positive health outcomes (Guasch-Ferré and Willett, 2021) or diets that, when modelled, result in desirable health outcomes (Springmann et al., 2018). Archetype diets can be adapted to a given context, with knowledge of local consumption patterns being helpful in adaptation (Lassen et al., 2020). Where dietary guidelines or archetype diets are not available or appropriate, nutrient recommendations can be used. However, such recommendations do not provide direct guidance on consumption of foods and thus need to be translated into food-based advice to be used in this task of Step 1.

The average healthy diet identified in Step 1 and used as a starting point will likely be altered throughout the steps of this framework to ensure its environmental sustainability. To ensure that the final diet is both environmentally sustainable and healthy, the **second task** in Step 1 is to establish quantitative criteria for healthy diets against which the final diet can be benchmarked. This can be done in different ways, such as identifying crucial food group recommendations (*e.g.,* per capita consumption of 500 g of fruit and vegetables each day) that might already be available in FBDG, and/or using thresholds for critical nutrients that prevent deficiencies and are linked to prevention of *e.g.*, diet-related non-communicable diseases such as type 2 diabetes or cardiovascular disease (Lassen et al., 2020). Another approach is to determine a specific desired reduction (*e.g.,* percentage reduction) in premature mortality or disease burden that would result from following the new dietary recommendations produced using this framework (Springmann et al., 2018). Stakeholder and expert consultation can be used to identify such healthy eating targets or, as illustrated in our Swedish example (Fig. 2 and Methods), established nutrient recommendations can be used.

A **final task** in this step is to ensure that the Step 1 average healthy diet meets the healthy diet criteria when, for example, healthy eating targets are developed in a stakeholder process and differ from diets underlying the archetype or FBDG diets. This will require an expert moderator to first identify points of tension between newly developed guidelines and the quantitative criteria for healthy diets and then lead stakeholders through a process of reconciling the two.

2.2. Step 2: Identify relevant environmental aspects and establish corresponding boundaries

There are four core tasks in Step 2. The **first task** is to identify relevant environmental aspects to consider when designing the SFBDG. While some aspects are universal (*e.g.,* climate change) others can be context-specific (*e.g.,* water scarcity, deforestation, local impacts on biodiversity). The environmental aspects to be considered in development of the SFBDG can be identified through a combination of literature reviews, expert knowledge on local/regional environmental challenges and aspects covered by national environmental policy. For countries with significant food imports, it is important also to consider the outsourced impacts of national consumption patterns (Laroche et al., 2020). To assess outsourced impacts, trade data from national authorities or international databases and multi-regional input–output models can be used to identify which foods, in what amounts, are being imported to a country for consumption and the foods' corresponding environmental impacts (Schwarzmueller and Kastner, 2022; SEI and JNCC, 2022). It is crucial that quantitative boundaries can be established for environmental aspects to ensure that it is clear (as with nutrient requirements) when environmental considerations are being met or not. Step 3, described in section 2.3, addresses additional sustainability aspects that are difficult to quantify, yet could be included in the framework in other ways.

The **second task** is to determine an acceptable level of impact for each environmental aspect. Environmental targets can be relative (*e.g.,* a 50% reduction in greenhouse gas emissions from current levels associated with food consumption) or absolute (*e.g.,* reduce greenhouse gas emissions associated with food consumption to a certain amount of tCO_2eq per person per year). To date, most studies assessing the environmental sustainability of diets have compared impacts relative to other diets (Hallström et al., 2015), although absolute boundaries for food systems (Willett et al., 2019) and foods (Karlsson Potter and Röös, 2021) have been proposed. Policy targets from national or regional (*e.g.,* EU) levels can inform the boundaries, especially if the targets have legal status. Where policy targets are unclear, unambitious or absent, expert elicitation can be used to develop environmental targets for the SFBDG based on the best available science.

The **third task** in Step 2 is to establish a target year, *i.e.,* the point in time by which the chosen level of impact should be achieved, as reducing environmental impacts from the food system is a gradual process. Although the science is clear on the urgency of reducing environmental pressures (IPBES, 2019; IPCC, 2022), the speed of the transitioning to a sustainable food system is ultimately a political decision. For example, the EU aims at climate neutrality by 2050, with a target to reduce greenhouse gas (GHG) emissions to at least 55% below 1990 levels by 2030 (EU, 2021a).

While dietary change has major potential to reduce environmental pressures, reductions in food loss and waste and production improvements (*e.g.,* increased efficiency, fossil-free technologies) are also important mitigation options (IPCC, 2022; Willett et al., 2019). When benchmarking the impact from the diets to determine the dietary change needed to stay within boundaries, the **fourth task** in Step 2 is to factor in the mitigation potential from waste reductions and supply side improvements. These estimates can be based on, for example, existing estimates in the literature (see section 3.2.4) or expert elicitation.

Choosing environmental aspects to include, determining environmental boundaries for the food system, determining a target year and judging the potential to reduce waste and accomplish supply-side improvements are inherently normative tasks that should involve stakeholder consultation. That said, the power dynamics and interests of stakeholders needs to be taken into account by an expert facilitator in order to avoid omitting or downplaying environmental aspects identified as important in the scientific literature in an effort to promote business-as-usual operations (Nestle, 2018).

2.3. Step 3: Identify systemic effects and crucial sustainability aspects

While some environmental aspects can be assessed using quantitative indicators (Step 2), other aspects are more difficult to capture using currently available methods and data (van der Werf et al., 2020). One example is sourcing of seafood from sustainable stocks. In addition, there are several inherent couplings in food production that need consideration. In Step 3, such systemic effects and crucial sustainability aspects that are difficult to quantify can be introduced. However, we caution against the use of these additional sustainability aspects to trump the quantitative environmental boundaries developed in Step 2.

Some important couplings to consider include those between dairy and beef or meat and offal, *i.e.,* production of dairy and offal cannot be done in isolation from meat production. Thus, recommending, for example, only dairy and no/very low levels of red meat consumption is not resource-efficient. Another coupling is that of animal fat resulting from livestock production but not currently used fully as food, due to *e.g.,* advice to limit saturated fats in diets for health reasons. A consequence of this is that additional plant-based oils need to be produced to satisfy fat demand, which comes with a range of sustainability challenges (Bajželj et al., 2021). We recognise that national consumption levels of these foods do not have to match the production ratios at the national scale due to food trade, but the ratios can still serve as useful guides to ensure efficient use of resources globally.

Another aspect that is challenging to capture in indicator-based sustainability assessments is the ability of different livestock to utilise biomass streams that are indigestible or unwanted by humans, *e.g.,* by-products from the food industry or plant biomass from grasslands not suitable for cropping (van Selm et al., 2022). Producing food from such 'leftover' streams can reduce total cropland use (Van Zanten et al., 2018) and grazing biodiversity-rich pastures can also contribute to important ecosystem services (Karlsson Potter and Röös, 2021). Ruminant production, if based on perennial forage grown in rotation in mixed cropping systems, can also help preserve soil fertility. Hence, in certain contexts there might be reasons to include a certain number of animal products in diets based on such systemic effects. We stress that even if a country *can* sustainably produce a high number of grazed livestock, this does not justify changes to the Step 1 healthy diet (*i.e.,* higher red meat intake) or a relaxation of the environmental boundaries established in section 2.2 in order to match the recommended red meat intake to what is domestically produced. The final sustainable diet produced with this framework must still be within environmental limits settled in Step 2.

In addition, in some contexts it might be relevant to include concerns related to local food production, *e.g.,* when there are political goals to increase self-sufficiency, if local production provides social benefits and/or if local production systems prove to be less environmentally damaging. However, this should not be used as a justification to develop consumption guidelines based on current domestic production if domestic production is not in line with health and environmental targets. That is, even if livestock production is the major food producing sector in a country, this does not justify a recommendation to consume meat above healthy and environmentally sustainable limits. SFBDG could, however, recommend increased consumption of foods that contribute to meeting both health and sustainability goals and that can be sustainably produced in that country, such as variants of pulses, certain fruits/berries and vegetables, if a high-level of self-sufficiency is desirable.

The food system is unique in that it involves billions of sentient creatures in addition to the humans that benefit from outputs of the food system. The welfare of farm animals is increasingly being recognised as an important sustainability aspect that cannot be ignored in relation to sustainable diets and food systems (HLPE, 2016), especially considering the well-established trade-offs between animal welfare and *e.g.,* climate mitigation (Shields and Orme-Evans, 2015). Fig. 2 and Methods section 3.3 show examples of food system couplings and other crucial sustainability aspects such as animal welfare included in our Swedish example.

Identifying relevant systemic effects and crucial additional aspects needs to be done in an inclusive stakeholder process in which power structures are carefully considered (Juntti et al., 2009; Reed et al., 2018). Identification of these aspects can be guided by the use of frameworks such as those developed by Ahmed et al. (2019) and Mazac et al. (2021), where the latter examines sustainability aspects, including their interconnectedness, included in existing FBDG. However, we argue that this step should be limited to identifying aspects that are *directly related* to the *choice of food*, since FBDG are tools designed to influence food choices (*i.e.,* matching the policy tool with the desired change (Hassel and Wegrich, 2022)). Thus, aspects such as firms' economic profitability, job creation, labour conditions and so forth should not be introduced in this step. These sustainability aspects are important for overall societal sustainability and highly relevant for the more general issue of diet and food system sustainability, but are better addressed with separate (but coherent) policy instruments (*e.g.,* via agricultural or social security policy) as they are only weakly linked to consumption patterns. For example, concern for the livelihoods of migrant berry pickers is not best addressed in dietary guidelines by recommending lower berry intake, but rather through regulation of working conditions.

This step might be the most challenging to execute. On one hand, important aspects can get lost if a range of experts are not included in the stakeholder process. On the other hand, Step 3 can easily bring the overwhelming complexity of food systems to the fore, making it difficult to decide which considerations to include and how. A skilled and knowledgeable moderator could help the stakeholder group tease out relevant aspects to include and leave out. Most importantly, we caution against the risk of maintaining the status quo when faced with the argument that populations should eat a certain way since those diets match what is currently produced.

2.4. Step 4: Alter the average diet to meet environmental goals and resolve trade-offs between environmental and nutrition goals

In Step 4, diets are altered to remain within environmental boundaries. A range of multi-criteria techniques can be used to accomplish this. Diet optimisation using linear programming has been used extensively to identify diets that meet multiple nutritional and health goals (Schäfer et al., 2021) and has been used specifically to develop SFBDG for the Netherlands (Brink et al., 2019). In theory, mathematical optimisation of diets is an objective way of translating a set of requirements and constraints into a preferred diet. However, interpretation of optimisation results and translation of these into FBDG can still require expert judgement and an iterative process to address anomalies or undesirable dietary choices (*e.g.,* for cultural reasons) in the optimisation (Tetens et al., 2020).

An alternative approach used in our Swedish example (see Fig. 2 and Section 3) is to perform a step-wise simulation to iteratively tweak the average healthy diet identified in Step 1 in order to improve environmental outcomes. There are four core tasks when using the simulation approach. In the **first task**, the environmental performance of the average healthy diets developed in Step 1 is estimated (*e.g.,* by multiplying unit values of environmental impacts of a specific food group by the amount of this food group consumed, see section 3.4.1) and benchmarked against the environmental boundaries developed in Step 2. In the **second task**, the average healthy diet is adjusted to reduce environmental pressures in cases where boundaries are transgressed. This can be done by focusing on food groups/foods in the Step 1 diet that contribute most to environmental impacts and by first identifying substitutions within food groups or shifting the production origin of certain foods with large, known origin-specific impacts to areas where production could more sustainably expand. In this way, overall dietary composition is held constant and presumably closer to representing cultural preferences, since the dietary composition of the Step 1 diet should be culturally appropriate. If these changes are not sufficient to bring the impact below boundaries, the composition of the diet will need to be adjusted. This includes making substitutions across food groups (*e.g.,* switching from animal-source to plant-source proteins) and changing the intake amount of food groups (see Fig. 2 for an example in the case of Sweden). In the **third task**, once the diet falls within environmental boundaries, the healthy diet analysis should be repeated (see Section 2.1) to ensure that the changes made to improve the environmental sustainability of the diet still result in a healthy diet according to the criteria defined in Step 1. In the **fourth task**, it is likely that trade-offs between environmental and healthy eating/nutritional goals will need to be resolved. While some trade-offs might be resolved by choosing alternative adjustments, others will have no clear solution and will require a normative, context-based evaluation. Thus, stakeholder consultation is crucial to determine appropriate dietary shifts, assess trade-offs between health and environmental outcomes and acknowledge systemic effects when altering the diets.

2.5. Step 5: Formulate sustainable food-based dietary guidelines

By 'formulate SFBDG' we mean translating the criteria, boundaries and intake amounts developed in steps 1–4 into written, verbal or visual guides that ensure that individuals or groups can understand and use the SFBDG. Based on the healthy and sustainable diet(s) identified in Step 4, SFBDG can be formulated, communicated, promoted and disseminated in much the same way as FBDG without sustainability considerations, using implementation guidance such as that from EFSA (2010). This step should also be done in a multi-stakeholder process. In particular, members of the public and retailers can be involved to 'test' whether the guidelines are understandable, as was done in the development of the recent Danish dietary guidelines (Ministeriet for Fødevarer Landbrug og Fiskeri, 2020).

Finally, a note on interpretation of the guidelines produced in Step 5. Conventional FBDG are used both to provide advice to individuals about the composition of a health-promoting diet and to provide information to food system actors who supply advice on population level (Zeraatkar et al., 2019). The average diets identified in Step 4 are best interpreted at population level, *i.e.,* the average diet of individuals across a population determines the sustainability of national diets, whereas the food eaten by each individual will determine the impacts on that individual's health. Thus, the diets identified using our framework could have policy implications for governments, businesses and NGOs working to guide dietary shifts across the population. When adjusting an average dietary recommendation to specific groups (*e.g.,* those who are pregnant, have specific medical conditions, *etc.*), it is important that the aggregated environmental impacts estimated from these diets (weighted to the respective proportion of the population) remain within the chosen environmental boundaries.

3. Application of the framework to the Swedish context

We exemplify the framework by adapting it to the Swedish context. Fig. 2 summarises the steps as adapted to Sweden, and the following subsections describe the data sources, methods and assumptions used in more detail. We stress that this is a pilot study on the use of the framework and not a complete development of Swedish SFBDG, *i.e.,* we did not include a thorough stakeholder process and this was not led by relevant public agencies.

3.1. Step 1: Determine an average healthy diet for a given population and criteria for healthy diets

3.1.1. Task 1.1: Identify an average healthy diet

We based our average healthy diet for Sweden on the current Swedish FBDG (Livsmedelsverket, 2015). These guidelines are well-established, adapted to the Swedish population and based on the Nordic Nutrition Recommendations, a rigorous assessment of nutrient requirements for healthy diets (Nordic Council of Ministers, 2014). However, they do not provide guidelines for foods at the level of disaggregation chosen for this study. Various levels of aggregation of food groups can be used, but we aligned with the EAT-*Lancet* food groups (Willett et al., 2019): cereals, tubers/starchy vegetables, vegetables, fruits, dairy, red meat (beef/lamb/pork), poultry, eggs, fish, legumes, tree nuts, palm oil, unsaturated oils, lard or tallow and added sugars. To include the complete diet in the environmental assessment, we added several other food groups not included in the EAT-*Lancet* Commission reference diet (alcohol, coffee and tea, spices, miscellaneous foods). For some food groups, the Swedish FBDG provide qualitative rather than quantitative guidance (*e.g.,* "potatoes are part of a varied diet"), so we used a Nordic archetype diet to complement the Swedish FBDG where more specificity was needed, *i.e.,* for values on legumes, butter, cream, coffee and discretionary intake, and type of unsaturated oils prioritised (Mithril et al., 2013). The Nordic archetype

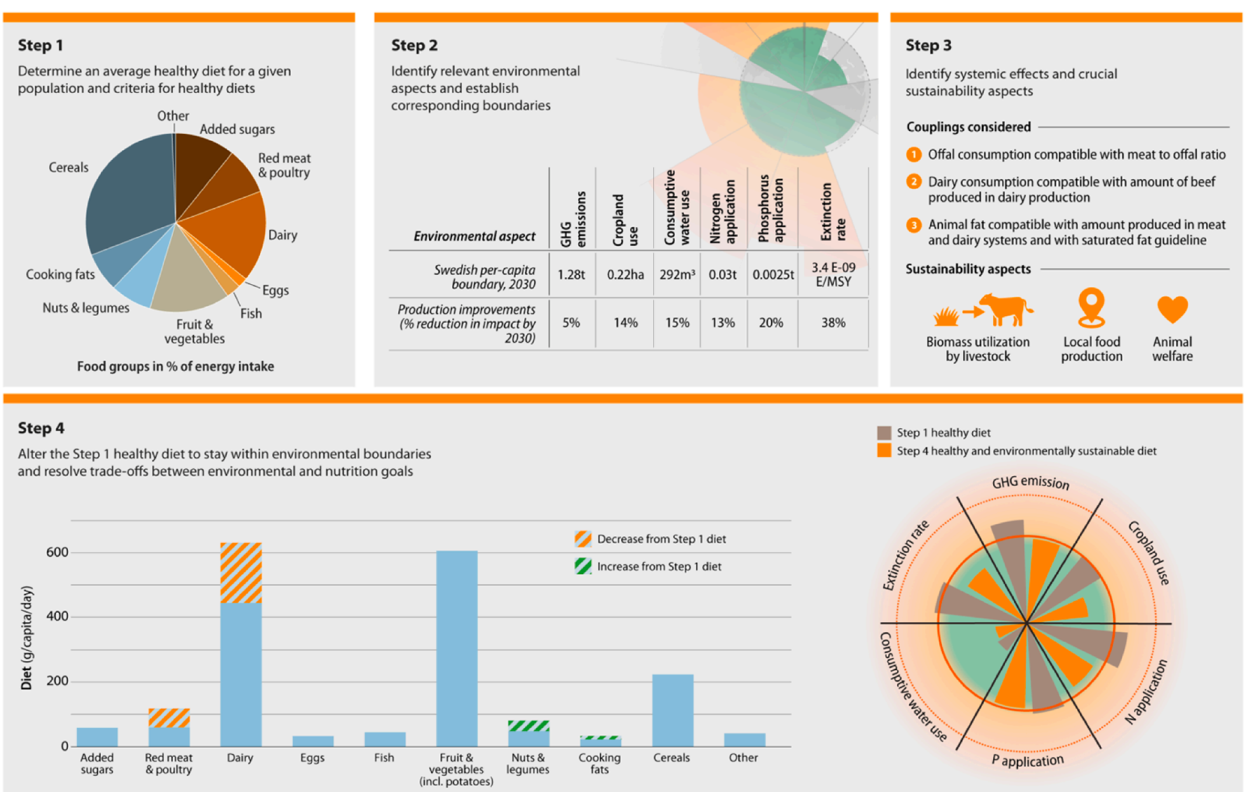

Fig. 2. Overview of application of the framework to develop Sustainable Food-Based Dietary Guidelines for Sweden. In Step 1, the current Swedish food-based dietary guidelines in combination with a Nordic archetype diet are used to develop an average context-specific healthy diet (pie chart in Step 1) for use as a starting point. In Step 2, the environmental control variables suggested by the EAT-Lancet Commission (Willett et al., 2019) are taken as relevant environmental aspects to include and the corresponding boundaries downscaled per capita are applied (table in Step 2). The target year is 2030, and we assumed that 50% of the estimated potential to reduce impacts through technical production improvements by 2050 could be achieved by the target year of 2030. In Step 3, food system couplings and additional sustainability aspects relevant to consider for this context are identified. In Step 4, the healthy diet identified in Step 1 is iteratively tweaked to bring it within the environmental boundaries by adjusting intake of food groups (bar diagram in Step 4) and country of origin of some foods, considering simultaneously the systemic effects and additional sustainability aspects identified in Step 3 (for details, see corresponding subsections in Section 3).

diet takes aspects such as health and Nordic food culture, palatability and availability into account (Mithril et al., 2013). The average healthy diet for Sweden used as a starting point is shown in Table 1 of the Appendix.

3.1.2. Task 1.2: Establish criteria for healthy diets

In addition to food group-based recommendations in the Swedish FBDG, for which quantities are specified (upper limits for red meat, sugar and alcohol, lower limits for fruits and vegetables, ranges for fish and dairy products), we used critical nutrient recommendations as quantitative criteria for healthy diets.[2] We used established criteria from the Nordic Nutrition Recommendations (NNR) (Nordic Council of Ministers, 2014) to assess the nutrient adequacy of diets, in this example only for the adult population. We considered the adequacy of energy, protein, carbohydrates, fats, saturated, monounsaturated and polyunsaturated fatty acids, fibre, vitamin C, vitamin A, vitamin D, thiamin, riboflavin, niacin, vitamin B6, vitamin B12, folate, calcium, iron, zinc, potassium, phosphorus and magnesium. Here, the energy intake recommendation considered the average value for women and men calculated in the NNR, using a reference weight corresponding to body mass index of 23 kg/m^2 and 'active' physical activity level, but as mentioned above, it is important for the nutrient analysis to consider variation in requirements across population groups.

3.1.3. Task 1.3: Ensure the average healthy diet meets criteria for healthy diets

In addition to the FBDG criteria, we performed a nutrient analysis to ensure that the average healthy diet developed in Task 1.1 actually met the criteria for healthy diets established in Task 1.2 (Appendix Table 2). We linked each food item with its nutrient composition. To do this, we disaggregated food groups (*i.e.,* obtained the proportion of each food within a food group, such as fruit types within the 250 g recommendation) using data from the FAO Supply Utilization Accounts (SUA) except for fish (not reported in SUA data), hence reflecting current consumption patterns. For fish, we derived the proportion of different kinds of fish based on Borthwick et al. (2019), from which we considered five fish species (salmon, shrimp, herring, cod and whitefish), which constitute approximately 70% of Swedish seafood consumption. We linked each food to its nutrient composition using data from the Swedish Food Agency database version 2021–05-03 (Livsmedelsverket, 2015). Where the SUA data were still too generic, *e.g.,* fresh fruit, prepared food, processed cheese, prepared groundnuts, we calculated the average nutrient composition of similar food items. For food groups where the Swedish FBDG offer quantitative upper or lower limits, we ensured that the quantities in the average healthy diet were within these limits.

The nutrient analysis revealed that the diet was just over the threshold for saturated fat. Butter contributed the most to saturated fat in the diet, so we lowered butter intake slightly (from 12 to 10 g/cap/day). With this change, the Step 1 diet fulfilled our healthy diet criteria (see Appendix Table 2).

3.2. Step 2: Identify relevant environmental aspects and establish corresponding boundaries

3.2.1. Task 2.1: Identify environmental aspects to include

For our Swedish example, we used the same environmental aspects and control variables as the EAT-*Lancet* Commission (Willett et al., 2019), namely GHG emissions, nitrogen and phosphorus application, consumptive water use, biodiversity loss and cropland use. These indicators work as proxies for the main impacts caused by food production (Willett et al., 2019). However, there are additional important aspects to consider, *e.g.,* use of novel entities, including use of pesticides (Persson et al., 2022; van der Werf et al., 2020).

3.2.2. Task 2.2: Establish environmental boundaries

For our Swedish example, we used the boundaries suggested by the EAT-*Lancet* Commission (Willett et al., 2019) corresponding to the environmental aspects identified in Task 2.1 (Fig. 2). The EAT-*Lancet* boundaries apply to the global food system as a whole. To establish a boundary for the average Swede, we downscaled the boundaries by dividing the emissions space or resource use evenly across the global population. This approach assigns the global citizen an equal 'allowance' of emissions and resource use, regardless of where impacts are caused or resources are used. However, there may be reasons to use other sharing principles, which should be done in a deliberate process, *e.g.*, using the framework suggested by Ryberg et al. (2020).

3.2.3. Task 2.3: Establish a target year

While the EAT-*Lancet* Commission adopted a target year of 2050, we deemed this to be too distant to be policy-relevant, so we chose 2030 as our target year. We assumed that by then the impact from the Swedish diets should be halfway towards remaining within the EAT-*Lancet* 2050 boundaries. However, Sweden is already below the 2050 EAT-*Lancet* boundary for water use, so we used this original boundary for 2030.

3.2.4. Task 2.4: Determining the mitigation potential from waste reductions and supply-side improvements

The Swedish political goal to reduce food losses and waste has a milestone target for 2025, but not for 2030. However, the Swedish goal is set based on the Sustainable Develop Goals to reduce food losses and waste by 50% by 2030 (Miljömål, 2022). Thus, we adopted the goal of 50% reduction in food losses and waste across the entire food chain (from production to consumer waste). We used average estimates of production improvement potential (by 2050) relating to each environmental indicator from Willett et al. (2019) and assumed that 50% of these production improvements could be achieved by 2030. For example, where the evidence suggested a possible 10% reduction in GHG emissions by 2050 due to production improvements, we assumed a 5% reduction by 2030.

The aspects and boundaries described here were developed only to illustrate the use of the framework, and thus we did not include stakeholders in this process, which is crucial for real-world application of the framework. Ongoing processes not initiated to develop SFBDG yet that bring the relevant expertise and stakeholders together could provide a forum for stakeholder discussions. For example, in Sweden, the National Food Agency and Public Health Agency have been tasked with developing goals for healthy and sustainable food consumption (Ministry of Enterprise and Innovation, 2017). Alternatively, a large transdisciplinary (*i.e.,* research, business and public sector representatives) research programme has been established (https://mistrafoodfutures.se/), in part to develop indicators and targets for sustainable food consumption.

3.3. Step 3: Identify systemic effects and crucial sustainability aspects

The following food production couplings were considered in our Swedish example:

Meat-offal: Edible blood and organs make up approximately 12–14% of animal live weight (Ockerman and Hansen, 1999), while approximately 50% is meat (Clune et al., 2017). We therefore ensured that the offal (including lard and tallow) to meat ratio was below $14/50 \approx 0.3$. The Step 1 healthy diet in our example had an offal to meat ratio of 0.06. For environmental sustainability, a ratio close to 14/50 is preferable, but considering the current preference for meat over offal in the Swedish context we judged such high consumption of offal to be unrealistic.

[2] We acknowledge that a nutrient analysis does not provide a comprehensive picture of the healthiness of a diet. However, this analysis might be the most feasible option where e.g. existing infrastructure for this analysis exists or additional resources are lacking. We used this as one measure of healthy diets to illustrate the use of the framework.

Dairy-beef meat: In dairy production, beef meat is also produced. In Western intensive dairy systems, for every 1000 g of milk produced approximately 25–30 g of beef meat is obtained from culled cows and dairy offspring raised for meat (calculated using data in Cederberg et al. (2009)). To ensure that all beef produced in dairy systems is used, the beef to dairy (including drinking milk, cheese, butter *etc*. in milk equivalents) ratio should be above 30/1000 ≈ 0.03. In our Step 1 healthy diet, the beef to dairy ratio was 0.05.

Dairy product-dairy fat: Existing FBDG commonly recommend use of low-fat dairy products (Herforth et al., 2019). However, as producing sufficient fat sustainably for the current and future population is a challenge (Bajželj et al., 2021), it would be advisable to consume all dairy fat inherent in dairy production as long as this is acceptable from a health perspective. Doing so would reduce the need for vegetable oils, which are associated with certain environmental challenges (Bajželj et al., 2021). Therefore, advice on different dairy products should be aligned so that total fat in these matches the total fat in cow's milk (approximately 4%).

In addition, we gave preference to ruminant meat over pork considering the benefits of ruminant systems in terms of enabling grass-clover leys in cropping systems. Grazing animals are also indispensable in preserving biodiversity in semi-natural pastures in Sweden (Eriksson, 2021).

Regarding local production, one objective in Swedish Food Policy (Ministry of Enterprise and Innovation, 2017) is to increase food production and self-sufficiency in Sweden. We acknowledged this by prioritising Swedish production. This also made sense from an environmental sustainability point of view, since Sweden is not a biodiversity hotspot (Myers et al., 2000), agriculture is not the main land user (only 8% of the total land area is agricultural land (Statistics Sweden, 2019)) and environmental, animal welfare and labour rights regulations are among the strictest in the world. Hence, increasing food production in Sweden and avoiding displacement of production to more sensitive areas can also reduce some environmental pressures. Again, we stress that the prioritisation of increased self-sufficiency should not be used to justify greater *intake amounts* of domestically produced foods above healthy or sustainable levels. Further, there can be legal concerns related to EU trade regulations in recommending Swedish produce that were not considered here. Finally, to illustrate how animal welfare considerations could be included in the framework, we limited poultry in the diet considering the substantial animal welfare concerns associated with intensive broiler production (Dawson et al., 2021; De Jong and Guémené, 2011).

3.4. Step 4: Alter the average diet to meet environmental goals and resolve trade-offs between environmental and nutrition goals

3.4.1. Task 4.1: Assess the environmental performance of the diet

To assess the environmental performance related to the aspects chosen for the Swedish case in Step 2, we used control variables suggested by Springmann et al. (2018) and the EAT-*Lancet* Commission (Willett et al., 2019). Our environmental analysis built on Moberg et al. (2020), who assessed the environmental sustainability of the current average Swedish diet based on the same variables and data representing foods on the Swedish market. We multiplied per-kg values of GHG emissions, cropland use, nitrogen and phosphorus application, consumptive water use and terrestrial extinction rate associated with production of a specific food group in the diet by the amount of this food group consumed (Appendix Table 3). We combined these to estimate the environmental pressure of the whole average diet and benchmarked this pressure against the downscaled per-capita EAT-*Lancet* boundaries (identified in Section 3.2.2), assuming that a 50% reduction in current impact should be achieved by 2030 (as defined in Section 3.2.3).

Below, we give a brief description of key inventory data used for assessing the environmental performance of the diet. For a more thorough description of the methods used for the environmental assessment, see Moberg et al. (2020). The simplified version of the tool containing all data is available at (10.5281/zenodo.7723242). The results of the environmental analysis of the Step 1 healthy diet, including considerations from Steps 2 and 3, can be found in Appendix Table 3 (column: Step 4.1).

Data on domestic production and import countries: The environmental pressure of each food item assessed was a weighted average reflecting the pressure from domestic production and production in other countries (for imported products). To calculate the market share of domestic production for a food item, we calculated the self-sufficiency of this item as the relationship between domestic production and food supply based on data from FAO (FAO, 2021a, b). We then used import statistics from Statistics Sweden, 2021 to identify the largest import countries.

Data used to calculate the GHG emissions: We used data on GHG emissions from different food groups taken from Moberg et al. (2019), who developed a method to assess the climate impact of foods on the Swedish market. Included GHGs were carbon dioxide, methane, nitrous oxide and the hydrochlorofluorocarbon R22. The different GHGs were weighted into CO_2-equivalents according to their impact on the climate, using the GWP_{100} metric with factors from the latest IPCC report (Forster et al., 2021). Emission sources included production of inputs (including emissions from deforestation for soy and palm oil), primary production (including changes to soil carbon stocks) and processing, packaging and transport up to retail, including losses and waste along the chain. We updated some input data in Moberg et al. (2019) where new data were available, *e.g.*, on energy use in Swedish greenhouses and land use change emission factors.

As input data to the GHG emissions calculations, where possible Moberg et al. (2019) used primary site-specific data retrieved from official statistics in statistical databases (Swedish Board of Agriculture, 2021; EU, 2021b; FAO, 2021a, b), National Inventory Reporting by the producing countries under the United Nations Framework Convention on Climate Change (UNFCCC, 2021) or national guidelines and reports from advisory services. For some foods included in this study, data were lacking in Moberg et al. (2019). For these, we collected country-specific data in the following order of priority based on availability: data from the World Food LCA Database (available through the Ecoinvent database (Wernet et al., 2016)), peer-reviewed studies and reports. We adjusted all data to match the methodology in Moberg et al. (2019), *i.e.,* to include the same emission factors for packaging and transportation, emissions/sequestration to and from soils due to land use, and emissions from land use change. Following Moberg et al. (2019), we adjusted the data to account for waste and losses along the production chain and for allocation between by-products in multi-output production systems.

A limitation is that we used the quantities of food reported in FAO Food Balance Sheets (FAO, 2021b) (*e.g.,* cereals, raw vegetables, raw meat, *etc*.), rather than the form in which the food is consumed, to assess the GHG emissions, so we missed some emissions associated with food processing. Although the majority of GHG emissions arise in agriculture, substantial emissions can also arise in post-farm processes and more attention should be paid to these emissions, especially as the level of processing has increased over time (Crippa et al., 2021; Seferidi et al., 2020). This would require determination of the average healthy diet (Step 1) to include specifications on the level of processing. As the level and type of processing are also highly relevant for human health (Fardet, 2018), highlighted *e.g.*, in the Brazilian FBDG (Ministry of Health of Brazil, 2015), there are good reasons to include such considerations in Step 1.

Inventory data for other environmental aspects: We calculated the cropland area needed to sustain the diet by using country-specific yield levels for plant-based products and feed. Data on yield were primarily taken from official statistical databases (Swedish Board of Agriculture, 2021; EU, 2021b; FAO, 2021a, b) or, when lacking in these sources, from peer-reviewed life cycle assessment studies and reports.

Data on nitrogen and phosphorus application rates were collected in the following order of prioritisation based on availability: national official statistics (Statistics Sweden, 2021); official guidelines (IFA et al., 2002); national guidelines and reports from advisory services; the World Food LCA database (Nemecek et al., 2014); peer-reviewed studies and reports. Data on biological nitrogen fixation rates by legumes were taken from the literature (Cederberg and Nilsson, 2004; Lassaletta et al., 2014) and data on consumptive water use from the WaterStat database (Mekonnen and Hoekstra, 2011; Mekonnen and Hoekstra, 2012).

To assess the extinction rate associated with the diet, we used characterisation factors on potential species loss from occupation of land taken from Chaudhary and Brooks (2018). These factors are differentiated by country and for occupation of cropland and pasture. Pasture use was calculated as time spent on pasture, using data primarily obtained from the National Inventory Reporting by country (UNFCCC, 2021), and pasture use per animal, using data taken from advisory services and reports.

3.4.2. Task 4.2. Alter diets to stay within environmental boundaries

Red meat, dairy and fruits were consistently the largest contributors to environmental pressures from the Step 1 healthy diet. We also considered the following systemic aspects from Step 3: coupling ratios, utilisation of ruminants grazing semi-natural pastures and desirability of increased self-sufficiency. We first kept the diet composition constant and shifted the market share of products within food groups in order to minimise changes to the overall diet.

To address high biodiversity impacts, we shifted apple and mutton consumption away from imports, with high biodiversity impact, to lower-impact apples and mutton from Sweden, also reflecting the political goal of increased self-sufficiency. We shifted from tropical fruits to temperate fruits (*e.g.,* a reduction in bananas and citrus fruits and an increase in apples) to further reduce biodiversity impacts. Within the red meat category, the amount of beef in the Step 1 diet was above the maximum that could be produced by animals grazing currently available semi-natural pastures in Sweden. We focused on the carrying capacity of Swedish semi-natural pastures due to the political goal of self-sufficiency. Swedish production conditions only influenced the *amount* of beef consumed here because current consumption is *higher* than what can be sustainably produced in Sweden (and must be changed if environmental boundaries are transgressed). Thus, we decreased the proportion of bovine meat in the diet to align with the number of animals needed to graze semi-natural pastures, an important ecosystem service in Sweden. We then increased the proportion of offal in order to keep the absolute intake of red meat constant, and to come more in line with the meat-offal coupling ratio.

These changes did not produce a diet that was within environmental boundaries. While the boundary for biodiversity was now met, the boundaries for GHG emissions and nitrogen and phosphorus application were still exceeded. The foods contributing the most to the transgression of these environmental boundaries were, again, red meat and dairy.

Thus, we now shifted the composition of the diet by changing the intake values of foods and food groups. First, we halved poultry consumption to reflect our consideration of animal welfare. We reduced the total amount of red meat to limit GHG emissions and nitrogen application. Reducing the overall amount of red meat in turn decreased the total amount of beef. To maintain a consumption level that supported grazing of semi-natural pastures, we increased the proportion of beef, which then also allowed us to decrease the proportion of pork, in line with our systemic consideration to favour ruminants. We also reduced dairy products, which as noted were large contributors to nitrogen application and greenhouse gas emissions. At this point, the diet met all of our environmental criteria (see Appendix Table 3, Step 4.2).

3.4.3. Task 4.3: Repeat healthy diet analysis

The diet still aligned with the FBDG food group criteria, but the nutritional analysis revealed that the adjusted environmentally sustainable diet was low in calories (Appendix Table 2 Step 4.2). To identify the foods that should be increased in the diet, we identified that the task 4.2 diet was at the lower threshold for total fats, monounsaturated fatty acids and polyunsaturated fatty acids.

3.4.4. Task 4.4: Resolve trade-offs between environmental and nutritional goals

We chose to increase unsaturated fats (*e.g.* plant-based oils) in order to increase total fats and monounsaturated fats, and to increase legumes in order to increase calories with little additional environmental impact. When we made this adjustment, the diet slightly transgressed the climate boundary. While beef and milk were the highest contributors to greenhouse gas emissions in the diet, we chose to first explore other options for reducing climate impact, given the prioritisation of supporting grazing of semi-natural pastures. Instead, we looked at the third most climate intensive food, crustaceans. We shifted the composition of the fish food group, decreasing the proportion of crustaceans and increasing the proportion of pelagic fish in the diet. At this point, the diet (Appendix Table 1) satisfied nutrition goals (Appendix Table 2), was below environmental boundaries (Appendix Table 3) and the food groups were also within the limits of the Swedish FBDG where quantitative ranges existed. In addition, the ratios of offal to meat (0.12) and beef to dairy (0.05) in the Step 4.4 diet were more aligned with desired coupling ratios presented in section 3.3 (offal to meat approximately 0.3, beef to dairy approximately 0.03). In our example, there were no additional trade-offs to consider, but more significant shifts to the diet (*e.g.,* stricter environmental boundaries) would likely lead to more trade-offs between environmental and nutrition goals. The average healthy and environmentally sustainable diet resulting from Step 4 that could be used as the basis for developing SFBDG in Step 5 is shown in Appendix Table 1. We again stress that the iterative tweaks to the diet performed here is provided solely as an example, and other alterations could be justified for other reasons.

3.5. Step 5: Formulate sustainable food-based dietary guidelines

We did not undertake Step 5 for the Swedish example. Again, stakeholder consultation would be needed to determine how the average diet in Step 4 should be communicated, promoted and disseminated to the Swedish population. Care would be needed to clearly communicate the different implications for individuals (*i.e.,* an individual's diet directly affects their health) and for the population as a whole (*i.e.,* the average diet of individuals across a population determines the sustainability of national diets).

4. Discussion

4.1. Policy implications

To our knowledge, this paper presents the first detailed, step-wise framework for systematic development of SFBDG policy. The framework extends the approach currently used to create sustainability-focused FBDG by placing healthy eating considerations on an equal footing with environmental sustainability considerations. Thus, SFBDG can be a policy tool to help simultaneously deliver on (or identify contradictions among) national health and environmental policy objectives.

SFBDG are not only an important policy tool in themselves for public education (Mozaffarian et al., 2018), but they also have the potential to affect a broad range of public policies. Although translation of the guidelines into policy and regulation has been somewhat limited (Gonzalez Fischer and Garnett, 2016), several links between FBDG and policy can be found. Traditionally, health-and nutrition-focused FBDG have been used to guide policies related to nutrition (*e.g.,* school, hospital or elder care facility meals), food assistance (*e.g.,* SNAP program in the US), food labeling and health (*e.g.,* health promotion or disease prevention programmes) (ODPHP, 2022; Slavin, 2015; Zeraatkar et al., 2019). We argue, in line with Parsons and Hawkes (2018), that SFBDG could be used to inform policies across the entire food system, including agricultural, distribution, trade, processing, marketing and retail and taxation policies. In other words, SFBDG could provide a clear picture of the healthy and sustainable foods that should be in focus from farm to fork. This alignment could help create coherence among policy domains that have long been siloed, such as agricultural and nutrition policies (Hoddinott, 2012).

Development of SFBDG is as much a political as a scientific process and has been shown to be a highly sensitive policy matter (Lang and Mason, 2018). Explicitly prioritising both aspects of sustainability, as in our framework, decreases the risk of stakeholder influence when determining the extent to which environmental aspects should be incorporated into SFBDG policies. Limiting stakeholder influence over the representation of environmental considerations should not be confused with limiting stakeholder engagement in the policy development process. Our framework is science-based and transparent in its explicit goal to create healthy and environmentally sustainable dietary guidelines, and inclusion of environmental variables and quantitative measures of environmental sustainability is central and non-negotiable. However, as highlighted throughout this paper, stakeholder engagement in the policy development process is essential, particularly so that the framework can best be adapted to the local context and to resolve trade-offs between aspects of healthy eating/nutrition and environmental sustainability. We stress that the stakeholder engagement process needs to be inclusive and transparent, so that trust in the recommendations is created (Mielke et al., 2017).

That said, the involvement of private sector actors in the formulation of dietary guidelines is contentious (Freidberg, 2016). Industry involvement and power should not be used to enforce a business-as-usual food system or set nutritional and environmental criteria that are not in line with the best available science (Nestle, 2018). However, examples of industry involvement could include sharing environmental data relating to their production operations (where data collection and analysis is transparent), or the involvement of retailers in Step 5 of the process. In addition, industry actors could feedback through an open and transparent public consultation process (Helsedirektoratet, 2022).

5. Strengths and limitations

A benefit of our framework is the systemic, yet targeted, approach to environmental assessment that it espouses. The framework is systemic in that it permits inclusion of considerations which are inherent to food systems, *i.e.,* animal welfare considerations. At the same time, we argue that only considerations directly related to dietary patterns should be included, as indirectly related sustainability aspects (*e.g.,* working conditions) are handled more efficiently in other policy processes. A major strength of our framework is that it can be adapted to any context, based on available resources and data.

That said, there are several challenges related to use of the framework. For example, while indicators such as climate impact or land use are well-established and data availability is (relatively) good, other indicators are associated with many uncertainties in the existing methods and data. There are also uncertainties with regard to recommendations and boundaries related to environmental aspects (Moberg et al., 2020), which makes it challenging to include these in the framework in a meaningful way. However, these limitations reflect the quality and extent of existing data, rather than the quality of the framework outputs. As with the approach used when developing existing FBDG-based purely on health and nutrition considerations, the lack of absolute certainty in data on environmental impacts should not be used as an excuse for inaction. However, as with current FBDG, it is crucial that the SFBDG are updated continuously in light of new evidence.

6. Concluding remarks

Given the urgent need to shift diets, on a global scale, to less environmentally-intensive ways of eating, advice on environmentally sustainable diets is needed. Despite this, current SFBDG prioritise health above environmental considerations. Our framework fills a gap in research and practice by proposing five steps that put health and environmental sustainability goals on equal footing in SFBDG. Our framework provides enough structure to guide stakeholders through the development of SFBDG while leaving flexibility to adapt the steps based on the local context and data and resource availability. SFBDG is the basis on which many additional policy tools can be developed to help shift diets in a healthier and more environmentally sustainable direction.

CRediT authorship contribution statement

A. Wood: Conceptualization, Methodology, Investigation, Supervision, Project administration, Writing – original draft, Writing – review & editing. **E. Moberg:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **K. Curi-Quinto:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **P. Van Rysselberge:** Formal analysis, Writing – review & editing. **E. Röös:** Conceptualization, Methodology, Investigation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Jerker Lokrantz of Azote for producing the figures. AW was supported by funding from the Swedish Research Council Formas (grant number 2019-01579). The figures were developed with support from the IKEA Foundation grant 31002610. The funders had no involvement in the conduct of the research or preparation of the article. Other authors did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodpol.2023.102444.

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