frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 27 November 2023
DOI 10.3389/fsufs.2023.1266708

OPEN ACCESS

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RECEIVED 25 July 2023
ACCEPTED 21 September 2023
PUBLISHED 27 November 2023

CITATION
Lee S, Freer M, Wood R, Edelenbosch O, Sharmina M, Doelman J, van Vuuren D and Wilson C (2023) From future diets to dishes: communicating dietary shift associated with a 1.5°C scenario for Brazil, China, Sweden and the United Kingdom.
Front. Sustain. Food Syst. 7:1266708.
doi: 10.3389/fsufs.2023.1266708

From future diets to dishes: communicating dietary shift associated with a 1.5°C scenario for Brazil, China, Sweden and the United Kingdom

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Introduction: With the pressing need to mitigate greenhouse gas emissions, this study aims to simplify complex data from Integrated Assessment Models (IAMs). It focuses on identifying dietary shifts that align with the 1.5°C global warming limit as stipulated by the Paris Agreement.

Methods: The research utilises the IMAGE Integrated Assessment Model and applies the Diets, Dishes, Dish Ingredients (DDDI) communication framework. This methodology enables the visualisation of potential dietary and dish composition changes, thereby making the data more comprehensible to a broader audience.

Results: The study effectively translates traditional IAM outputs into accessible visualisations. These visual tools provide a nuanced understanding of a low greenhouse gas diet, extending its relevance beyond academia to include professionals in diet and nutrition.

Discussion: This research stands as a significant advancement in the field, lowering the barrier to understanding sustainable diets for the future. It enriches the existing dialogue on dietary change and climate goals and serves as a catalyst for further research and practical applications in diverse contexts.

KEYWORDS

communicating dietary change, plant-based diets, DDDI framework, visualisation techniques, sustainable diets, climate-compatible diets, future food changes, hybrid diets

1 Introduction

The increasing world population and associated increase in food consumption are putting pressure on natural resources worldwide, with the increased food production resulting in expanded agricultural land use and agriculture-related greenhouse gas (GHG) emissions. The global agricultural sector contributes approximately 23% of total greenhouse gas emissions (~12 $GtCO_2$ eq per year; Chen and Önal, 2016; IPCC, 2022), with much of these emissions arising from methane and nitrous oxides produced by human activities, primarily livestock rearing for meat production (Clark et al., 1979; Clune et al., 2017; IPCC, 2022). These emissions are projected to grow by 6% within the next decade, with livestock accounting for 90% of this increase (FAO, 2022a).

Dietary shifts towards healthier and more sustainable food systems could contribute to achieving all 17 United Nations Sustainable Development Goals (SDGs) by 2030 (FAO, 2022a). Furthermore, such dietary changes could aid countries in reducing greenhouse gas emissions, supporting the implementation of the Paris Agreement (UNFCCC, 2015). Numerous interventions have been proposed to promote these dietary changes, including reducing meat consumption and increasing plant-based protein intake (Macdiarmid et al., 2012; Tilman and Clark, 2014; Springmann et al., 2016). Their primary focus is on transitioning from meat-based to plant-based protein sources, reducing food waste, and consuming more locally. However, a holistic approach incorporating a decrease in caloric intake, a reduction in food losses and waste, and advancements in agricultural practices is essential for staying within planetary boundaries, alongside the shift from meat-based to plant-based diets (EAT, 2019). Achieving a reduction in meat consumption requires individual action (Laestadius et al., 2016; Jebb, 2018), information provision (Bailey and Harper, 2015), as well as institutional and national level involvement (UNFCCC, 2015; Jebb, 2018; FAO, 2022a). However, interpreting research findings on low-carbon diets can be challenging due to data being presented in various ways and units, such as percentage reductions in meat (De Boer and Aiking, 2022), grams/day (Scarborough et al., 2014; Micha et al., 2015; Godfray et al., 2018), kcal/capita/day (Tuninetti et al., 2022), and servings per day or per week (Hogbin and Hess, 1999; Micha et al., 2015). The relatively complex information provided often fails to capture the diverse range of individuals' diets within a country and can be too abstract for direct interpretation (Stehfest et al., 2009).

This study aims to interpret the implications of modelled changes in food demand for protein food items and individual diets in four countries (van Dooren et al., 2015; Bijl et al., 2017; Torstensson et al., 2021): Brazil, China (both rapidly developing), and Sweden and the United Kingdom (UK; developed countries) consistent with a 1.5°C emissions pathway to 2050. The selection of the four nations for analysis aligns with the different low-carbon development pathways outlined by the Centre for Climate Change and Socal Transformations, providing a diverse yet focused lens through which to examine the impact of dietary changes on climate goals (Howarth et al., 2019). To achieve this the study interprets the outputs from a 1.5°C emissions pathway generated using the IMAGE model (PBL Netherlands Environmental Assessment Agency, 2019); this model is frequently used to inform international global policy and contains a detailed food demand component. The detailed food demand component within the IMAGE climate Integrated Assessment Model (IAM) is a part of the model used to interpret the implications of changes in food demand, specifically focusing on protein food items and individual diets in various countries, in alignment with a 1.5°C emissions pathway to 2050. An IAM, such as the IMAGE IAM, simulates interactions between climate, economy, society and the biosphere to evaluate climate change impacts and develop mitigation policies.

De Boer and Aiking (2019) propose a hierarchical framework known as 'DDDI' (Diets, Dishes, and Dish Ingredients) to articulate a protein transition from animal to plant-based proteins. This framework aligns with the structure of food items used by the FAO and food groupings by various authors (Poore and Nemecek, 1979; Tilman and Clark, 2014; Springmann et al., 2016; Mazac et al., 2022; Tuninetti et al., 2022), as well as (Stehfest et al., 2009; Bijl et al., 2017; Van Vuuren et al., 2018), to represent dietary change within an IAM. Offering a more direct visualisation of dietary patterns, the DDDI framework can seamlessly connect to the results of IAM models, thanks to the novel linkages of both DDDI and IAM output to FAO information.

The Lifestyle Change (LiStCh) scenario, derived from the IMAGE IAM, plays a significant role in this context. This scenario represents a mitigation pathway that anticipates constrained technological advancement in the energy sector, leading to a more gradual reduction in greenhouse gas emissions. Within the framework of the IMAGE IAM model, four distinct mitigation scenarios are delineated (van Vuuren et al., 2011):

- Business-as-Usual (BAU): Presuming the absence of additional climate mitigation policies.
- Sustainable Development (ScD): Envisaging robust technological progress and a rapid transition to a low-carbon economy.
- Stabilisation (ScE): Projecting moderate technological advancement to stabilise greenhouse gas emissions at safe levels.
- Lifestyle Change (LiStCh): Anticipating barriers to technological progress in the energy sector, including innovation costs, political reluctance, and vested industrial interests, with limited public support for climate mitigation measures.

The LiStCh scenario within the IMAGE IAM assumes limited technological progress in the energy sector, leading to a slower decline in greenhouse gas emissions, and employs measures like bioenergy with carbon capture and storage to reduce emissions (Clery et al., 2021; Freer et al., 2021, 2022). While IAMs are valuable for assessing policy cost-effectiveness, evaluating impacts, and communicating risks, they also face challenges such as complexity and data requirements, leading to uncertainty. Despite these limitations, IAMs remain essential tools for understanding climate change and shaping mitigation strategies.

The LiStCh scenario offers insights into the modification of protein foods to align with a healthy diet, consistent with previous studies (Stehfest et al., 2009; Bijl et al., 2017). This scenario encompasses the role of food production and consumption within a 1.5°C pathway, integrating the broader context of GHG emissions. Data derived from the LiStCh scenario were instrumental in informing the creation of future diet and dish visualisations for this study, laying the groundwork for the potential re-application of the visualisation process to other distinct mitigation scenarios in future research. Such an approach could provide a more nuanced perspective on potential dietary shifts.

In the present study, the DDDI framework is synergistically combined with the LiStCh scenario outputs. This integration facilitates the calculation of the number of portions of key food groups consumed *per capita* within each country, illustrating the evolution of these quantities within the scenario from 2020 to 2050. The subsequent analysis explores the implications of such dietary changes on the ingredients of a popular dish selected for each of the four case-study countries. This examination vividly demonstrates the shifting patterns of meat and non-meat protein consumption, complemented by images of representative dishes from each nation.

These outputs serve a dual purpose: they translate traditional IAM outputs into a more accessible and salient set of information for audiences beyond the IAM academic sphere, and they offer insights into potential future food changes necessary to comply with the Paris Agreement. Furthermore, these findings contribute valuable comparative data for other studies focused on low-carbon food futures.

2 Methods

This section describes how the DDDI framework (De Boer and Aiking, 2019) is applied in order to communicate the outputs from the IMAGE LiStCh scenario of food demand measured in (tonnes/yr). The outputs from LiStCh provide annual *per capita* consumption for the food categories set out in Supplementary Table 2 for Brazil, China and Western Europe for 2010 (baseline year), 2020, 2030, 2040 and 2050 (scenario pathway). In order to communicate these through the DDDI framework, the numbers of portions of each food category consumed in 2020, 2030 and 2050 for Brazil, China, the UK and Sweden – the 'Diet' of DDDI are calculated. Secondly, typical dishes consumed in each country are identified (the 'Dish') and the recipes were illustrated according to the relative proportions of protein sources, staples and vegetables for the baseline year. Finally, the proportions and the type of protein (animal or plant-based) are used to illustrate how the Dish Ingredients would change over time to follow the LiStCh scenario.

As previously discussed, the LiStCh scenario is part of four scenarios demonstrating alternative pathways to 1.5°C by incorporating various lifestyle change measures. Alongside dietary change, the LiStCh scenario shows the possibility of achieving 1.5°C with significantly less reliance on Bioenergy with Carbon Capture and Storage (Van Vuuren et al., 2018). The DDDI framework is applied using the food demand data from the IMAGE IAM LiStCh (Lifestyle change) scenario (Van Vuuren et al., 2018). The LiStCh scenario includes dietary changes and delivers broader GHG emission reductions in line with 1.5°C (Van Vuuren et al., 2018; De Boer and Aiking, 2019).

The methodological structure of the analysis presented in this article, as illustrated in Figure 1, systematically examines the impact of modelled changes in food demand on regional diets and dish visualisations. The approach involves preparing and interpreting IAM scenario data, establishing food consumption baselines for Sweden, China, the UK, and Brazil, and applying the DDDI framework to analyse shifts in food consumption patterns and create visual representations of potential dishes for 2050.

The methodology first describes the LiStCh scenario outputs and how the base year was established. This is followed by a description of how the outputs were processed to develop the baseline and scenario trajectory. The methodology then describes how the portion sizes and dishes were selected and describes how the dish ingredients were adjusted to reflect the LiStCh scenario. The section concludes with the description of the dish visualisation process.

2.1 Preparation of integrated assessment model scenario datasets

2.1.1 Extracting and interpretation of IMAGE data

The analysis employs food demand outputs from the LiStCh scenario and the emissions reduction pathway from IMAGE (Scarborough et al., 2014), aligning with a pathway consistent with a 1.5°C increase. Within the IMAGE model, food demand propels food production, leading to GHG emissions from the agricultural sector and throughout the food supply chain (Van Vuuren et al., 2018).

The LiStCh scenario from 2020 to 2050 outlines a reduction in meat consumption, supplanted by pulses and oil crops (primarily soy). Concurrently, staples and luxuries are adjusted to preserve the total caloric intake, mirroring the default scenario SSP2. This SSP2 scenario is part of the Shared Socioeconomic Pathways (SSPs), a set of five future pathways describing global development in terms of population, economic growth, technological change, and environmental degradation. Specifically, SSP2 is a 'middle of the road' scenario, assuming moderate technological progress and steady global economic growth, and is widely used as a reference scenario, with 'middle-of-the-road' assumptions on various factors influencing emissions, ranging from economic growth to population growth and policy choices (Van Vuuren et al., 2018).

In the context of the LiStCh scenario, the changes in consumption are meticulously crafted to align with a healthy diet, contributing to emissions reduction through dietary transformation by 2050. The LiStCh 2050 healthy diet takes cues from the Willett diet (Willett, 2001), comprising 50% fruit and vegetables, 25% whole grains (including whole wheat bread, pasta, and brown rice), and protein foods such as meat, pulses, eggs, nuts, and seeds.

The scenario envisions a linear reduction in meat consumption between 2020 and 2050, counterbalanced by increased pulses, nuts, seeds, and soybeans. This substitution is predicated on protein content, assumed to be 20% for both meat and pulses based on fresh weight (Stehfest et al., 2009). Meanwhile, fruit, vegetables, and dairy items adhere to their reference scenario SSP2 (Bijl et al., 2017), exhibiting a modest increase in *per capita* consumption over the 30 years.

The IMAGE outputs provide food demand (FD) for 46 food categories (see Supplementary Table 2) and household waste for six food categories (*Animal*, *Fruit & Veg*, *Luxuries*, *Oils and Oil Crops*, *Pulses* and *Staples*) for three regions: Brazil, China and Western Europe (WEU). The outputs are for the baseline year of 2010 and scenario years of 2020, 2030, 2040 and 2050.

2.1.2 Applying the diets, dishes, and dish ingredients framework

De Boer and Aiking's DDDI framework defines diet as patterns of food items eaten by one or more individuals over a period of time and present it at the level of dishes and dish ingredients. Dish ingredients include protein food items such as meat, fish, eggs, dairy and pulses. The dishes themselves include a combination of food items on a plate.

To follow this framework and translate the LiStCh outputs into diet, the household waste figures were subtracted from food demand to give food consumed (g/cap/day), this was converted into the number of portions per year and month. The number of portions per week has been used by a number of other studies (van Dooren et al., 2018; BNF, 2021) that have worked with this frequency and used it in

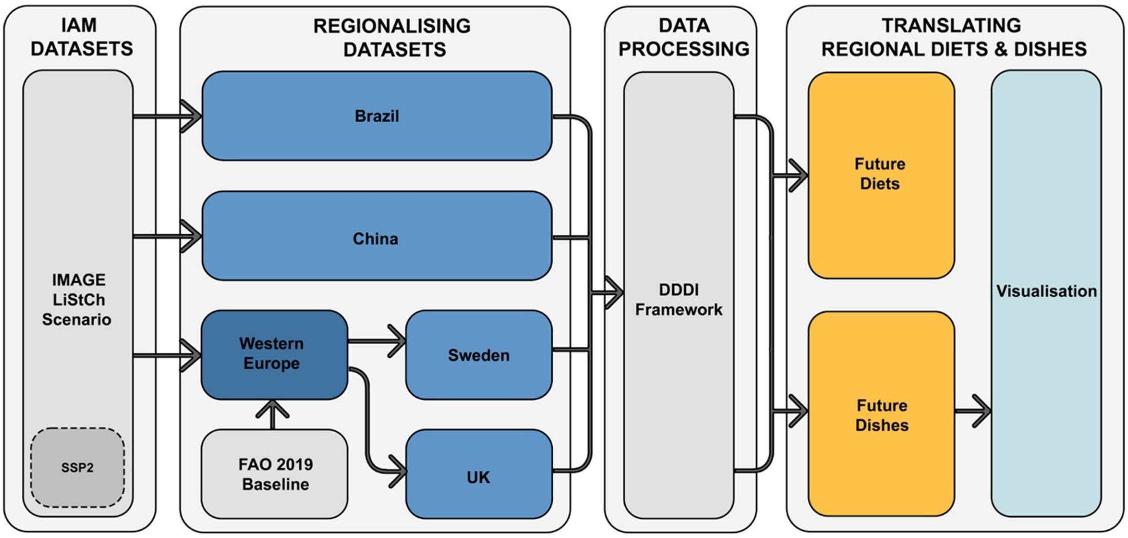

FIGURE 1
Methodology schematic representing the stages of Integrated Assessment Model (IAM) data processing and translating for the regional diets and dish visualisations.

conjunction with weekly meal planning. This analysis calculated a monthly figure as changes for some protein items were too small to appear in the weekly frequency. The data is available in the Supplementary Files 6–9. This way of communicating information can inform a varied dish pattern and enable different combinations for different consumers who may have different meat preferences or requirements (e.g. authenticity, convenience; De Boer and Aiking, 2019). A review of the case study countries was used to provide a context for meat consumption within that country and relative to other study countries is presented in the supplementary information (SI) for each of the four countries. Example mixed dishes for each country were identified to illustrate the 'Dish' and 'Dish Ingredient' elements of the Framework. Mixed dishes, defined by De Boer and Aiking (2019) as a mixture of both animal and plant protein, were chosen as they have the strategic potential to reduce meat. Section 'Regionalising diet and dish datasets' and 2.2 provides further detail on the application of the framework.

2.2 Regionalising diet and dish datasets

2.2.1 Food consumption year baselines for Sweden, China, United Kingdom and Brazil

Establishing consumption baselines in this study involved two interconnected steps: justifying the use of IMAGE 2020 scenario data as the baseline and downscaling WEU to the UK and Sweden. While the baseline year from IMAGE is 2010, the year 2020 was chosen for its greater relevance to the present day. To justify this choice, the 2020 LiStCh data, based on model outputs, were compared to the 2019 Food and Agricultural Organisation (FAO) data, selected for its initial use in calibrating the food demand model within IMAGE (see Supplementary File 1). The year 2019 was specifically chosen to avoid the impacts of the COVID-19 pandemic on the food supply.

The first step focused on determining the differences in the definitions of food supply between the FAO and IMAGE data related to household waste and supply chain losses. The total food supplied for each country closely matched the IMAGE food demand value in 2020, with variations of 2% for Brazil, 11% for China, and −5% for Western Europe (see Supplementary Table 1). This level of agreement was deemed acceptable given the unknowns in the actual data regarding wastage, with the main interest of this analysis being the distribution of main food groups and specific protein food items.

The second step focused on establishing the baseline involved with downscaling the 2020 LiStCh data for the UK and Sweden. Since the available data from IMAGE provides food demand for Western Europe, the baseline for the UK and Sweden was achieved using the ratios of UK and Swedish food supply to the total for Western Europe from the FAO 2019 Food Supply (see supplementary section on downscaling WEU to UK and Sweden). This calibration of 2020 model projections to 2019 observations and the minor differences observed validate the use of 2020 model projections in the analysis.

Once the baseline was established, the changes associated with the LiStCh scenario were applied to give g/cap/year for each food category. For Brazil and China, the LiStCh outputs were used directly. For the UK and Sweden, the scenario narrative states that by 2050, the composition of diets globally will homogenise, resulting in a linear trajectory of food demand changes from 2020 to converge on the 2050 Western Europe LiStCh food demand applied.

2.2.2 Selection of portion size

This analysis assumes consistent food portion sizes across the four study countries (Sweden, China, the UK, and Brazil) from 2020 to 2050 to enable a fair comparison of dietary changes. Portion sizes were determined using The British Nutrition Foundation's (BNF) guide (BNF, 2021), which aligns with the UK Government guidelines (PHE, 2016). Different countries present their recommended daily food consumption for specific food groups in slightly varying ways. For example, Sweden's guidelines (FAO, 2022b), produced by the Swedish National Food Agency (Livsmedelsverket, 2022), do not provide exact amounts but suggest a daily intake of at least 500 g of fruit and vegetables and no more than 500 g of cooked red and processed meat (Fischer and Garnett, 2016). Brazil's guidelines are less specific, recommending that citizens limit red meat consumption, eat seasonal and locally grown produce, and consume foods primarily of plant origin (FAO, 2001; Fischer and Garnett, 2016). China's guidelines (FAO, 2022c) specify amounts using a pagoda, with the base consisting of cereal, tubers, and legumes, followed by fruit and vegetables, meat protein, milk and dairy products with soybeans and nuts, and topped by a roof of salt and cooking oil. The modelled food consumption data are interpreted as servings based on standard portion sizes from the BNF amounts (UNFCCC, 2015) and are presented in the Supplementary Table 5. For all countries, Supplementary Figures 1A–H display the monthly frequency of consumption (number of servings a month) for a portion of protein food items (beef, pork, poultry, pulses, soybeans, nuts and seeds, fish and eggs) for 2020, 2030, and 2040.

2.2.3 Selection of dishes and dish ingredients for each country

This analysis used the main protein sources identified by IMAGE (meat categories, dairy, eggs, fish, pulses, nuts, and seeds) to examine national dishes with each ingredient as the primary protein source. It is important to note that the IMAGE model excludes protein in fruit and vegetables, staples, or luxuries (including tea and coffee) when calculating future food demand protein totals (De Boer and Aiking, 2019). Although protein levels in fruit and vegetables are generally low, staples exhibit higher levels [e.g. wheat: 12.2 g/100 g retail weight; see Supplementary Tables 1, 2 in FAO (2001)]. As these food items remain unchanged in the LiStCh scenario used here (Bijl et al., 2017), the focus is on meat, dairy, eggs, pulses, nuts and seeds, and soybeans. Following (Bijl et al., 2017), popular dishes from the study countries were identified through academic studies (Zhai et al., 2014; Lundberg-Hallén and Öhrvik, 2015; Zhou et al., 2015; Cobiac and Scarborough, 2019; Waltner, 2022; Yang and Ford, 2022), grey literature, newspapers (Bailey, 2018), travel websites (Condé Nast Traveler, 2022; Visit Sweden, 2022; Wind Horse Tour, 2022; China Travel, 2022a,b), and market research and consultancy surveys (Statista, 2020, 2021; Commisceo Global Consulting Ltd., 2022). Selected dishes represent a range of food groups consumed in each country, reflecting the current distribution of staples, fruit and vegetables, meat, eggs, and non-meat protein food items.

Similar to the method used in (Scarborough et al., 2014), a Google search was performed to find suitable recipes for the selected dishes. Criteria for selection included:

a) A mixed dish containing a meat protein that could potentially be substituted with a non-meat protein.
b) A meat dish containing chicken, pork, eggs, or beef to highlight the changing frequency of consumption between the present day, 2030, and 2050. Fish was excluded as the focus is on terrestrial meat (Bijl et al., 2017). Although consumed in the case study countries, Lamb was not included due to its small and declining consumption in the LiStCh scenario.
c) For visualisation, several recipes of the same dish were examined to determine a realistic portion size and suitable visual image to showcase the modelled changes.
d) The dish components had to be identifiable.
e) The dish needed to be visually appealing and colourful, as desirable diet changes must be translated into appetising dishes for consumers (De Boer and Aiking, 2019).

For mixed dishes, the analysis selected dishes for each country containing protein, staples, and fruit and vegetables to demonstrate food item changes for 2030 and 2050. For single dishes, specific protein food items from a popular dish were chosen, so that the frequency of monthly consumption for 2020, 2030, and 2050 was calculated using the modelled changes for each item (see 'Translating IMAGE data into changes in dish ingredients').

In the process of selecting protein-focused dishes, primarily for lunch or dinner, recipes were extracted to identify diet ingredients within the four categories defined by Willett's Diet (and UK Dietary Guidelines): protein, staples (whole grains), and fruit and vegetables (combined). This categorisation included staples as used by FAO (2020) and Bijl et al. (2017), encompassing rice, pasta, bread, and potatoes. Since modelled trends for fruits and vegetables are similar, they were combined into one group. The Willett's Diet was chosen for this analysis because the LiStCh scenario employed its framework during creation. However, it is worth noting that relying on the Willett Diet may be a limitation for the analysis, as it could be considered outdated. Future research could explore the use of more contemporary diet frameworks such as the Mediterranean, DASH, MIND, or Planetary Health diets to determine if the LiStCh scenario data needs updating (Karanja et al., 2004; Guasch-Ferré and Willett, 2021; de Crom et al., 2022; Ojo et al., 2023).

Five main course dishes were selected for each country, including chicken, pork, and beef dishes, along with vegetarian and vegan dishes to provide information about alternative plant-based proteins as meat substitutes. Furthermore, the analysis for the UK and Sweden incorporated breakfasts that are traditionally high in meat-based foods, such as a full English breakfast, Fläskpannkaka, and Pyttipanna med korv. These breakfasts were evaluated with either meat or plant-based protein alongside a staple.

Each popular dish represents average consumption, so a small amount of meat will be retained, as reflected in the proportions displayed in the pie charts in the Supplementary Figures 2A–5C.

2.2.4 Translating IMAGE data into changes in dish ingredients

De Boer and Aiking (2019) propose promoting a varied dish pattern where some non-meat dishes can be selected as desired or a mixed dish whereby non-meat protein items can be included together with meat protein.

The analysis presented in this paper focuses on how the dish ingredients could change over the period 2020 to 2050. To keep the essential components of the dish, there are two options:

a) Substitute meat with non-meat protein (Mixed dishes)
b) Reduce the frequency of consumption of meat (Meat dishes)

The data from the previous steps was used to ascertain the amount (g) of protein based food for each selected dish for the present day (2020). The dish ingredients (food items) for each dish reflected the items consumed within that country and were allocated to one of three food groups: staples (rice, pasta, potatoes), protein [meat, eggs and non-meat (nuts and seeds, soybeans and pulses; beans, peas, lentils and chickpeas)], and fruit and vegetables on a plate. The amount or proportion of each dish ingredient was then altered according to the LiStCh scenario's changes in daily food consumption (g/cap/day) for 2020, 2030 and 2050. The frequency of servings per protein food item for each country is shown in Supplementary Tables 6A–D. Supplementary Figures 1A–H display the changes for meat food items (beef, fish poultry, and pork) and non-meat food items (pulses, soybeans, eggs, nuts, and seeds). Fish and seafood, dairy foods (milk, butter and cream) are included in this analysis (although they follow the SSP2 reference scenario in the IMAGE model) to ensure all food items in the diet are included. The luxuries category is also included. Using the LiStCh scenario, the meat is replaced by plant-based alternatives. This analysis is synthesised and presented in section 'Translating IMAGE outputs into regional dishes and their ingredients'.

2.2.5 Creation of future dish visualisations

Visualisations can take many forms, such as infographics, graphs, or interactive tools that allow users to explore different scenarios. For example, an infographic could compare the carbon footprint of different food groups, or an interactive tool could allow users to see the impact of their dietary choices on their carbon footprint and the environment. This analysis takes the potential future regional dishes and their ingredients extracted from the IMAGE model and creates proportional visual representations to better communicate the balance of plant and meat-based foods in potential future diets.

Pie charts of the relative proportions of the main protein groups, staples and fruit and vegetables were generated for the selected dish (see Supplementary Figures 5A–C for Brazilian Feijoada; Supplementary Figures 6A–C for Chinese Sweet and Sour Pork; Supplementary Figures 7A–C for Swedish meatballs; and Supplementary Figures 8A–C for UK chicken korma). These pie charts, together with existing images of the prepared dishes (e.g. Feijoada; Unknown, 2023a,b), were then used to discuss the changes with an illustrator to produce the final dishes, as shown in Supplementary Figures 3–6. It should be noted that the protein items (meat types, nuts and seeds, soybeans, pulses) are shown separately on the pie charts to show the changes for each dish but are mixed on the illustrated dish as they would be in reality.

For present-day mixed dishes with no pulses, nuts or seeds, these ingredients were increased in line with the modelled changes to replace the reduction in meat. The plant protein items used to substitute for meat were items selected from vegetarian versions of the dish. Within the model itself, the overall calorific consumption is retained as meat protein is replaced by non-meat protein, so it is assumed that the amounts of staples for each timeframe adjust to ensure this occurs. The total amount of the dish consumed by weight is the same for 2050 and 2020.

3 Results and discussion

3.1 Daily food consumption in future diet

Figure 2 shows the IMAGE scenario output of daily food consumption (converted to g/cap/day from t/yr. using IMAGE population data) for Sweden and the UK (for comparison with Brazil and China) for 2020 and 2050. The figure highlights the changes in the LiStCh scenario whereby the amount of meat decreases and the non-meat items increase over the 2020 to 2050 period for all four countries. The IMAGE LiStCh scenario ensures

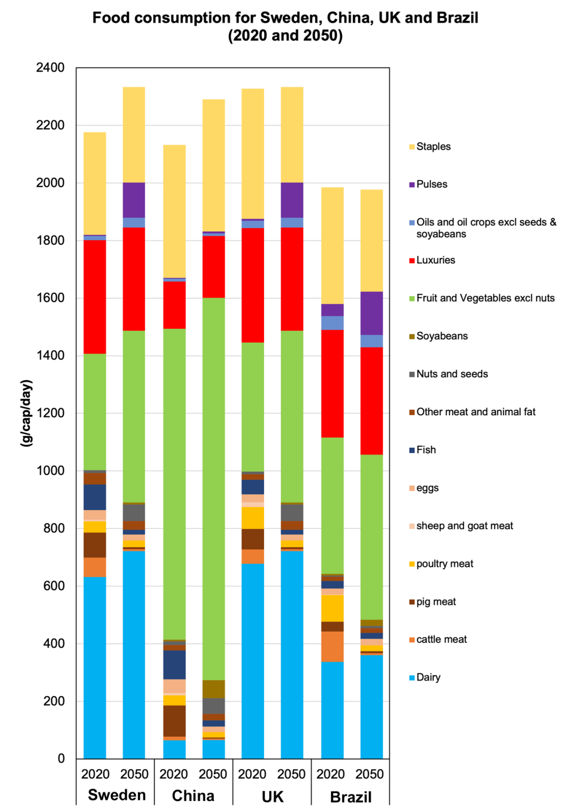

FIGURE 2
Changes in food consumption (g/cap/day) for Brazil, China, Sweden and the United Kingdom 2020 to 2050 for protein items and other food categories from the Lifestyle change (LiStCh) IMAGE Scenario.

a calorific balance within the model, as pulses, nuts and seeds or soybeans substitute meat. Figure 2 indicates that the total food consumption varies slightly between 2020 and 2050 as staples are adjusted within the model to keep total calorific consumption constant (Bijl et al., 2017). The individual countries vary between around 2000 g/cap/day for Brazil to 2,300 to 2040 for the other countries, but between 2020 and 2050, the total values are within 200 g/cap/day of each other.

The data reveals distinct trends in food consumption across Sweden, China, the UK, and Brazil from 2020 to 2050, including a universal decline in meat and fish, varied dairy trends, and a general increase in pulses and fruits/vegetables.

In Sweden, dairy consumption is projected to increase by 1.16 times, while meat and fish are expected to decrease, showing a 4.00 and 5.26 times decrease, respectively. Pulses and fruits/vegetables are on the rise, with pulses showing a dramatic 30.81 times increase and fruits/vegetables increasing by 1.48 times.

China's trends are similar, with a modest increase in dairy at 1.01 times and in meat and fish showing a 4.55 and 4.76 times decrease, respectively. Pulses are expected to increase by 2.25 times, and fruits/vegetables by 1.18 times.

In the UK, dairy and meat are both expected to decrease significantly, showing only a 4.00 and 4.35 times decrease, respectively. Fish is also projected to show a 5.00 times decrease. However, pulses are set to increase by 4.08 times, and despite a decrease in fruits/vegetables at 0.43 times, nuts and seeds are expected to surge by 5.19 times.

10.3389/fsufs.2023.1266708

TABLE 1 Frequency of consumption of different protein food items for Sweden, China, United Kingdom and Brazil (number of servings a month of a portion of food item) following the LiStCh Scenario.

Food Category	Sweden			China			United Kingdom			Brazil		
	Frequency of servings per month			Frequency of servings per month			Frequency of servings per month			Frequency of servings per month		
	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
Dairy including milk and cheese	151	161	175	16	16	16	167	172	175	82	85	88
Beef (cattle meat) – 100 g; 2 slices roast beef; serving of beef mince	20	15	2	4	3	1	15	11	2	32	23	2
Eggs	17	15	10	24	19	10	14	13	10	10	11	12
Fish and seafood	23	17	4	26	21	5	13	10	4	7	6	5
Other meat – 100 g; 2 sausages	12	11	9	5	6	7	6	7	9	5	5	5
Pork – 100 g; 2 slices; 1 chop	26	19	2	33	22	1	21	15	2	10	8	2
Chicken – 100 g; 2 slices	12	11	7	11	9	6	23	18	7	28	22	6
Lamb – 100 g; 2 slices; 1 chop	2	1	0	2	2	0	5	3	0	1	0	0
Nuts and seeds	12	37	88	20	39	85	11	36	88	6	8	11
Soybeans	0	1	2	2	8	24	0	1	2	2	4	8
Fruit and vegetables (excl nuts)	154	180	227	443	484	525	170	191	227	180	195	218
Luxuries	599	585	545	252	286	328	604	588	545	569	571	567
Oils and oil crops (excl seeds and soybeans)	32	44	68	22	21	19	52	58	68	97	94	87
Pulses	2	26	74	2	4	4	4	27	74	25	46	92
Staples	144	145	134	203	195	190	183	173	133	165	159	143
Meat based	95	74	24	81	63	20	83	64	24	83	64	20
Plant based	200	288	459	489	556	657	237	313	459	310	347	416
All foods	*1,207*	*1,268*	*1,350*	*1,065*	*1,134*	*1,221*	*1,289*	*1,324*	*1,349*	*1,218*	*1,236*	*1,246*

Brazil shows a 1.07 times increase in dairy and meat is expected to decrease by 4.55 times. Fish consumption is expected to decrease by 1.28 times. Pulses and fruits/vegetables are also increasing, with pulses at 3.65 times and fruits/vegetables at 1.21 times.

The substantial reductions in beef consumption across the UK, Sweden, and Brazil to 7 g/cap/day by 2050, down from initial levels of 50 g, 67 g, and 106 g/cap/day in 2020, respectively, underscore the shifts in consumption patterns. China follows suit with a reduction to 5 g/cap/day by 2050 from 13 g/cap/day in 2020. These changes are not merely statistical observations but pivotal in shaping dietary choices and dish ingredients and aligning with a broader transition towards sustainability and health consciousness.

The core objective of this research is to make the complex IAMs from the already published IMAGE model more accessible rather than to validate its results. In this process, the study highlights certain model and scenario artefacts, such as unexpected quantities of luxuries and pulses in dietary projections (Van Vuuren et al., 2018; SBT, 2021; Aboumahboub et al., 2022). These artefacts are noteworthy for future applications, serving as focal points for subsequent research to align the IMAGE model more closely with existing dietary guidelines.

3.2 Frequency of consumption of different food groups in future diet

The frequency of consumption of a serving of meat or non-meat per person per month of different food items or dish ingredients (the number of times a portion of food can be consumed per month) will change drastically from 2020 to 2050 under the LiStCh scenario (Table 1). This analysis focused on the years 2030 (the near future) and 2050 (the longer term). The frequency of consumption of the analysed food groups for 2020, 2030 and 2050 is presented in Table 1.

Across all 4 nations, the number of servings of meat-based food groups will decrease and plant-based food groups will increase towards 2050. The number of meat-based foods will decrease from 81–95 servings per month in 2020 to 20–24 servings per month in 2050, while the number of plant-based foods will increase from 200–489 servings per month in 2020 to 416–657 servings per month in 2050.

There is a greater change in LiStCh scenario diets for the four nations from the present-day to the long-term than the present-day to the short-term. Currently, meat-based foods constitute 8, 8, 6 and 7% of diet in Sweden, China, the UK and Brazil, respectively, and plant-based foods constitute 17, 46, 18 and 25%. In 2030, the proportion of meat-based foods decrease in diets to 6, 6, 5 and 5% for Sweden, China, the UK and Brazil, respectively, and the proportion of plant-based foods increase in diets to 23, 49, 24 and 28%. In the 2050 lifestyle change scenario, the proportion of meat-based foods on a weight basis decreases in diets to 2% for all four nations, and the proportion of plant-based foods increases in diets to 34, 54, 34 and 33%. In other words, meat consumption converges between the four nations by 2050 by the percentage share of consumption. However, plant-based consumption does not converge by 2050 and will vary in percentage depending on the proportion of food staples in diets.

The proportion of meat-based foods within individuals' diets decreases over time in the LiStCh scenario for all nations, resulting in smaller proportions of diets containing meat-based food by 2050. However, a complete elimination of meat is not included in the scenario. Both national interpretations and individual preferences will influence the remaining proportion of meat-based foods in diets, allowing for variations among individuals and households while maintaining consistency with national averages or aggregates. This concept is akin to a 'meat-budget'. The introduction of national meat-budgets could reduce greenhouse gas emissions and align consumption patterns with lifestyle changes consistent with a 1.5°C scenario, as suggested by the IMAGE modelling (Van Vuuren et al., 2018). It is important to note that while the IMAGE model provides national averages or aggregates, the dish-level analysis allows for individual variations. Further research is necessary to examine the socio-environmental and lifestyle implications of implementing national meat-budgets and evaluate the social acceptability of top-down government dietary interventions.

The primary objective of this research is to render the complex IAMs of the previously published IMAGE model into more tangible forms. As previously discussed, several model and scenario artefacts have been identified, such as the high servings per month of luxuries and the large number of fruit and vegetable servings projected for China by 2050. These artefacts serve as indicators for future research to align the IMAGE model more closely with current dietary guidelines, such as the Mediterranean or Planetary Health diets (Van Vuuren et al., 2018; Guasch-Ferré and Willett, 2021; Ojo et al., 2023).

3.3 Current and future diet protein content in regional diets

The future protein content in diets is subject to many influences, such as shifts in global dietary patterns, technological advancements in food production, and changes in agricultural practices (Bijl et al., 2017; Torstensson et al., 2021). These factors create a complex landscape that makes it challenging to predict specific changes in protein content. In the LiStCh scenario, the protein sources for the diets of Sweden, China, the UK, and Brazil are categorised into dairy, meat, eggs, fish and plant-based origins, as illustrated in Figure 3. While the LiStCh scenario standardises the calorific content in its projections, it does not extend this standardisation to other nutrients like protein, which is a major criticism of the scenario (SBT, 2019; Toth, 2022; Cordova-Pozo and Rouwette, 2023).

The data on projected changes in protein content from 2020 to 2050 for the UK, Sweden, China, and Brazil reveals significant shifts in dietary patterns. In the UK, dairy-derived protein is expected to increase by 5%, while protein from meat and fish is projected to decline by 75 and 69%, respectively. Protein from eggs will also decrease at a more moderate rate of 29%. Notably, plant-based protein is anticipated to increase dramatically by 481%.

Sweden shows a similar pattern, with a 16% increase in dairy-derived protein and steep declines in protein from meat and fish, at 75 and 83%, respectively. Egg-derived protein is also expected to decrease by 41%, while plant-based protein is projected to increase by 489%.

In China, dairy-derived protein levels are expected to remain stable, with no change projected. However, meat and fish-derived protein are expected to decline by 75 and 81%, respectively. Protein from eggs will decrease by 58%, and plant-based protein will increase by 189%.

Brazil's projections indicate a 7% increase in dairy-derived protein and an 83% decline in meat-derived protein, the most significant decline among the four countries. Fish-derived protein is expected to decrease by 29%, while egg-derived protein is projected to increase by 20%. Plant-based protein is expected to rise by 121%.

These projections highlight a universal decline in meat-derived protein and a substantial increase in plant-based protein across all four countries. However, the extent of these changes varies by country. Dairy and egg-derived proteins show mixed trends. These findings emphasise the complex factors that will influence future diets, especially in the context of protein sources.

The LiStCh scenario, while insightful, has a notable limitation in that it standardises future diet projections to maintain calorific content but does not do the same for protein content. This could result in inadequate nutritional intake by 2050, particularly concerning protein (Neufingerl and Eilander, 2022). The scenario assumes that people will continue their current dietary habits, an assumption that may not hold due to several factors that could influence future protein content.

One key factor is the potential change in the availability of protein sources. For instance, declining fish stocks could limit access to marine-based protein. Another consideration is the shift in dietary habits, such as increasing adoption of vegetarian or vegan diets, which would necessitate alternative protein sources. Technological advancements, like the development of lab-grown meat, could also introduce new protein options, thereby altering future dietary compositions.

The transition to plant-based or mixed diets, as projected by the LiStCh scenario, poses significant health risks due to potential nutrient inadequacies. For instance, the less efficient absorption of iron from plant foods could lead to anaemia, a condition that is already prevalent in certain populations. Similarly, the lower bioavailability of zinc in plant foods could compromise immune health, making populations more susceptible to infections. The absence of Vitamin B12 in plant foods is particularly concerning, as its deficiency can result in neurological issues.

Moreover, the risks are not uniformly distributed among nations. For example, countries with existing lower intake levels of certain nutrients may find these deficiencies exacerbated in a plant-based transition. The decline in meat-derived protein by 83% in Brazil, as per the LiStCh data, could make the population more vulnerable to protein-energy malnutrition. On the other hand, the 489% increase in plant-based protein in Sweden might not offset the risks associated with other nutrient deficiencies.

These health risks highlight the need for caution in implementing broad dietary transitions, as they could inadvertently exacerbate existing public health issues (Neufingerl and Eilander, 2022). The LiStCh scenario serves as a valuable tool for understanding these complexities, but it also underscores the need for more nuanced strategies to ensure nutritional adequacy during such transitions.

While the LiStCh scenario provides a useful framework for understanding the potential impacts of climate change on future diets, it is but one of many possible scenarios. The actual future will be influenced by a range of factors not currently accounted for in the model.

Future studies could benefit from exploring alternative IMAGE modelling scenarios that aim to stabilise protein content across diet projections. This could be extended to other essential nutrients like carbohydrates, vitamins, fibre, amino-acids and water, offering a more comprehensive view of future diets (Tessari et al., 2016). Such an approach would address the current limitations of the LiStCh scenario and contribute to a more robust understanding of the complex interplay between climate change and global diets.

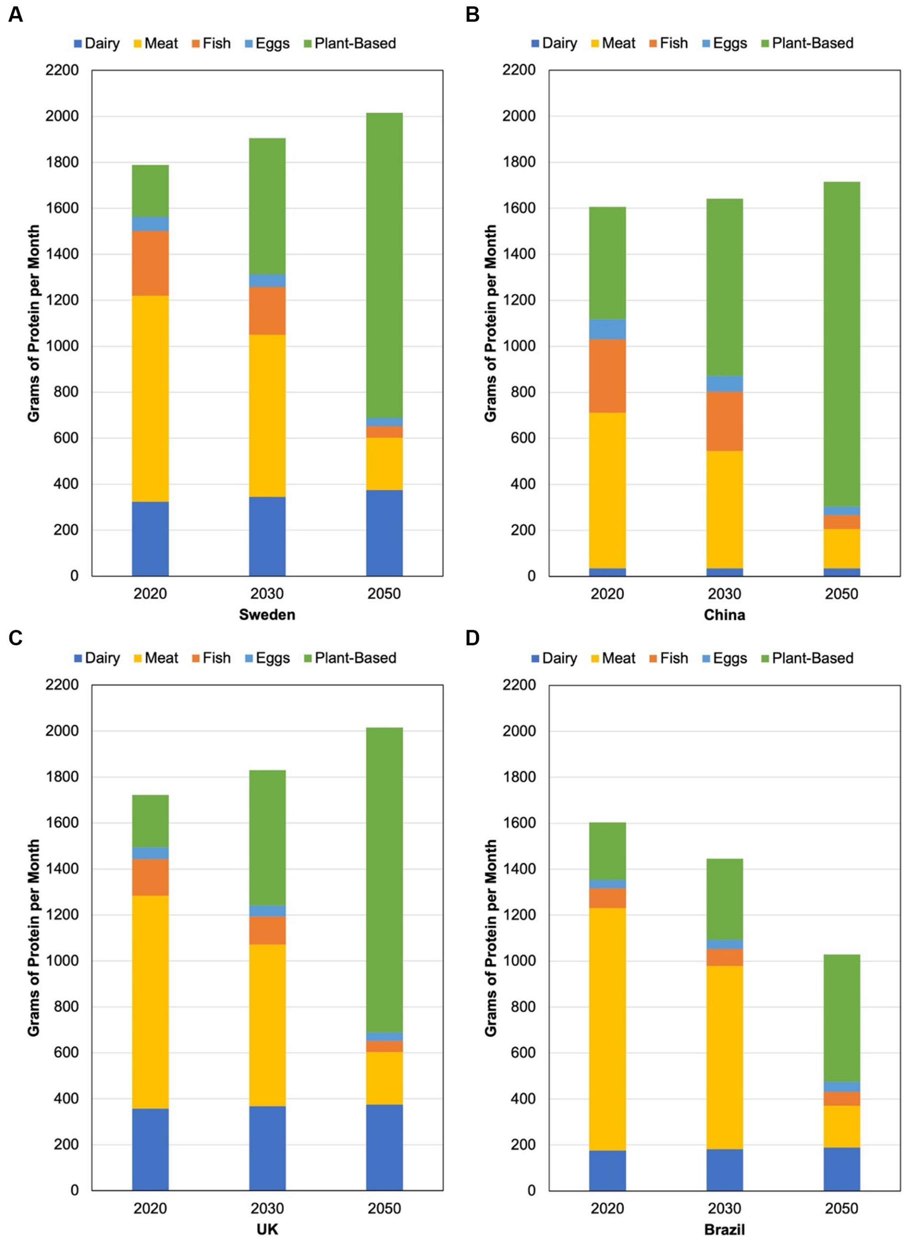

FIGURE 3
Sources of dairy, meat (beef, pork, chicken and lamb), eggs, fish and plant-based (nuts, seeds, soybeans, fruits, vegetables and pulses) protein in grams per month projected to 2020, 2030 and 2050 diets for **(A)** Sweden, **(B)** China, **(C)** United Kingdom and **(D)** Brazil.

3.4 Translating IMAGE outputs into regional dishes and their ingredients

The ingredients of the four regional dishes projected for 2020, 2030 and 2050 were extracted from the IMAGE modelling and are presented in Table 2. Ingredients from other regional dishes from Sweden, China, UK and Brazil extracted from the IMAGE modelling are presented in Supplementary Files 4–7.

Across all of the dishes and similar to the overall projected diets of the four nations, the percentage of meat-based food in the traditional dishes will converge at 1–2% by 2050, and the percentage of plant-based food in the dishes will vary against the proportion of staples in the dish from nation to nation. Presenting the proportional percentages of plant-based and meat-based ingredients in future dishes will aid the communication of how the dishes that people eat will change in the future. These meat-based vs. plant-based can be replicated for a range of future dishes across any nation to improve the communication of how people's dishes may change in achieving 1.5°C.

In the research presented, the shift to alternative diets is modelled to occur between 2010 and 2030, without accounting for implementation or other associated costs. Proteins from meat, eggs, and dairy products, including milk, butter, and cheese, are replaced by proteins from pulses and soybeans across all scenarios. This substitution is based solely on protein content, estimated at 20% for

TABLE 2 Composition of projected traditional dishes for Sweden, China, the United Kingdom and Brazil for 2020, 2030, 2050 in percentage of the dish for each food groups.

	Percentage of Dish Composition (%)											
	Sweden: meatballs			China: sweet and sour pork			United Kingdom: chicken korma			Brazil: feijoada		
	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
Dairy	–	–	–	–	–	–	–	–	–	–	–	–
Cattle meat	7	5	1	–	–	–	–	–	–	10	7	1
Eggs	–	–	–	–	–	–	–	–	–	–	–	–
Fish and seafood	–	–	–	–	–	–	–	–	–	–	–	–
Other meat and animal fat	–	–	–	–	–	–	–	–	–	–	–	–
Pig meat	9	6	1	6	4	1	–	–	–	3	2	1
Poultry meat	–	–	–	–	–	–	8	6	2	–	–	–
Sheep and goat meat	–	–	–	–	–	–	–	–	–	–	–	–
Nuts and seeds	1	2	5	1	1	3	1	2	5	0	0	1
Soybeans	0	0	1	0	1	3	0	0	1	1	1	2
Fruit and vegetables (excl nuts)	44	47	54	65	68	69	45	48	53	44	47	51
Luxuries	–	–	–	–	–	–	–	–	–	–	–	–
Oils and oil crops (excl seeds and soybeans)	–	–	–	–	–	–	–	–	–	–	–	–
Pulses	0	4	11	0	0	0	1	4	11	4	7	13
Staples	38	35	29	28	25	24	46	40	29	38	36	31
Meat based	*17*	*11*	*1*	*6*	*4*	*1*	*8*	*6*	*2*	*13*	*9*	*1*
Plant based	*45*	*54*	*70*	*66*	*71*	*75*	*47*	*55*	*69*	*49*	*55*	*67*

both meat and pulses, and 4% for milk, calculated based on fresh weight. Soybeans are projected to constitute 60% of the additional food-pulse production, aligning with the current fraction as of the year 2000. All other aspects of food crop consumption and livestock production systems, such as feed composition and conversion efficiencies, are assumed to align with the reference case, detailed in Table 2. For further information on the reference case, the authors can be contacted (Lee et al., 2022).

While the current analysis has the potential to utilise visualisation as a useful tool for communicating dietary change in alignment with national guidelines, it does not encompass the nutritional adequacy of the proposed dietary shifts. This omission could be an area for future research, bridging the connection between visual representation and 'nutritional reality'. Such an approach would ensure that the visualised future dishes align with environmental goals and nutritional soundness, providing a more comprehensive heuristic for future diet and dish guideline planning. For instance, the quality of proteins is known to vary, and certain nutrients such as calcium, iron, and vitamin D may be less readily accessible from plant-based sourced foods. This could lead to inadequate intake of these key nutrients, an aspect that would further enrich the understanding of the proposed dietary shifts.

3.5 Visualisation of projected future regional dishes for Sweden, China, United Kingdom and Brazil

Visualisations of future diets and highlighting the potential proportions of plant and meat-based ingredients in future dishes will play an important role in improving communication about the impact of diets on climate change and empowering people to make informed decisions about their food choices. Presenting information in a visual format can make it easier for people to understand and remember the key points and see the potential benefits and trade-offs of different dietary patterns. The visualisations of the four future regional dishes from Sweden, China, UK and Brazil are presented in Figure 4. For visualisation purposes, the dietary changes are illustrated in the form of a plate for a popular dish from each country and presented in Supplementary Table 7.

This study's methodology builds upon and enhances existing dietary research by illustrating how visualising dishes has the potential to aid the communication of future dietary shifts. The representation of diets as dietary plates align with national guidelines, which many countries adopt to communicate such changes. Visual charts, including plates of food exemplifying a healthy diet, often supplement these guidelines.

The dish visualisations more intuitively illustrate how the ingredients in each meat-based dish from Sweden, China, the UK, and Brazil evolve from present-day to future dishes in line with the LiStCh scenario. These future dishes incorporate alternative protein sources such as lentils, chickpeas, nuts and seeds, tofu, and fruit and vegetables. However, these visualisations should be used in conjunction with the data in Table 2 to act as a more rounded heuristic for future diet and dish guideline planning.

Between 2020 and 2050, the dish components change according to the LiStCh scenario, including meat decreases, pulses increase, fruits and vegetables remaining relatively and staples experiencing a slight decline. See Supplementary Figures 2A-5C for the changing proportions for 2020, 2030, and 2050. This study's methodology effectively complements existing dietary research by demonstrating how visualising dishes can be a useful tool for communicating dietary change in alignment with national guidelines.

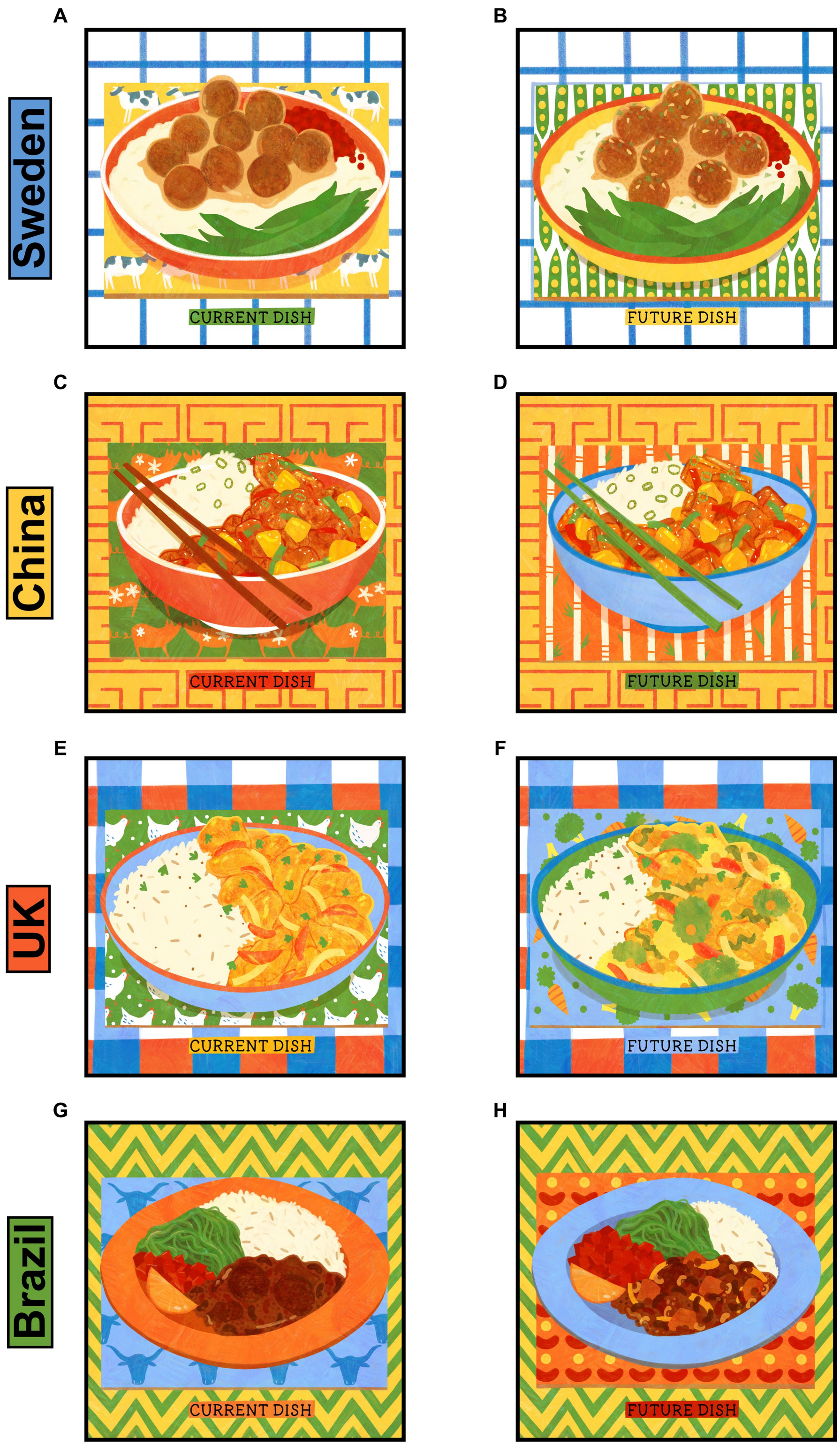

FIGURE 4
Visualisations of potential current and 2050 dish compositions. **(A)** Current Swedish meatballs, **(B)** future Swedish meatballs, **(C)** current sweet and sour pork, **(D)** future sweet and sour pork, **(E)** current chicken korma, **(F)** future chicken korma, **(G)** current feijoada, **(H)** future feijoada.

3.5.1 Potential future Swedish dish – meatballs

The meatballs comprise beef and pork and are served with gravy, mashed potatoes, lingonberries, and green beans (Figure 4A). Gradually, meat (beef and pork) is replaced by lentils, nuts, and seeds, while the proportion of vegetables expands to occupy half the dish. By 2050, the quantity of meat in the future dish (Figure 4B) will correspond to the UK's levels and reflects a healthy diet. See Supplementary Figures 4A–C for the changing proportions for 2020, 2030, and 2050.

3.5.2 Potential future Chinese dish – sweet and sour pork

The current dish (Figure 4C) features pork with pineapple, red and green peppers, and onions. Chinese diets already comprise significant amounts of fruit and vegetables (almost two-thirds of the diet), which is apparent in the dish composition. Meat (pork) accounts for roughly 6% of the dish. By 2050 (Figure 4D), the meat will diminish to a sixth of its present amount, replaced by soy curd and tofu. Rice decreases marginally by around 4%, while vegetable proportions remain fairly constant. See Supplementary Figures 3A–C for the changing proportions for 2020, 2030, and 2050.

3.5.3 Potential future British dish – chicken korma

The current visualised dish (Figure 4E) consists of chicken, vegetables (onion, tomatoes, and a sprinkling of coriander), and rice, with proportions based on the existing UK diet and ingredients from a recipe. By 2050 (Figure 4F), chicken will constitute a reduced 2% of the dish (down from 8%) rice will decrease from just under half to around a third, and pulses (chickpeas and lentils) will make up 10% of the dish. Broccoli is introduced, shifting from 46% to 56% of the meal, shifting from around a third to 50% of the meal. See Supplementary Figures 5A–C for the changing proportions for 2020, 2030, and 2050.

3.5.4 Potential future Brazilian dish – feijoada

The present-day feijoada (Figure 4G) is protein-dense, featuring pork, beef, and beans, and is accompanied by a slice of orange, salsa, pan-fried collard beans with garlic, and rice (Amigo Foods, 2023). Collard beans are a leafy vegetable common in Brazil and belong to the cruciferous family, which includes kale and broccoli. In the future dish (Figure 4H), beans will increase to 12% of the dish, joined by sweet potato (considered a staple similar to rice) and black-eyed peas (pulses). The salsa and collard beans also increase by approximately 15%, together comprising around half the dish. The meat content is dramatically reduced to 1% of the dish composition.

3.6 Better communicating shifts in future diet and dish

People's reactions to proposed future diet change to help tackle climate change can vary greatly depending on several factors, such as cultural and personal beliefs, socioeconomic status, and the perceived impact of dietary changes on their daily lives. Some people may embrace the idea of dietary change as a way to take action on climate change and may be motivated by the potential environmental and health benefits. Others may resist change, particularly if they are attached to traditional diets or feel that dietary changes would significantly impact their way of life or food choices.

It is essential for researchers to effectively communicate their work regarding climate change and carbon targets to a wide audience, helping people make informed decisions (Sparks et al., 1996; Laestadius et al., 2016) about possible lifestyle adjustments. These changes can promote healthier living and contribute to reducing overall global emissions from agriculture by decreasing *per capita* meat consumption. The quality of information and the expertise of those providing it are significant factors influencing such decisions (Sparks et al., 1996; CCC, 2020, 2023). Often, the public may not be fully aware of academic work, especially in the area of modelling. Integrated assessment models offer a distinctive analytical approach, as they compute long-term cumulative carbon budgets for all emitting sectors of the economy, encompassing land use and food. These models are the sole tools capable of connecting comprehensive lifestyle-related changes to warming outcomes, such as a 1.5°C climate stabilisation target. This analysis aims to present data in an engaging visual format to encourage discussions on individual behavioural actions and promote broader conversations about Integrated Assessment Models and their findings.

The balance of protein in plant and meat-based diets needs to be highlighted and communicated clearly to better inform the selection of dishes people need to choose to better tackle climate change while still making the decision to shift their diets their own. The analysis within the paper provides a potential replicable visual heuristic to better communicate how people's future diets and dishes will consist of in a more understandable and friendly manner compared to the complex modelling outputs created by IAM analysis. The selection of the four regional dishes in this analysis represents potential future dishes that future populations may consume, and further examples of future dish compositions are presented in Supplementary Figures 1A–F and Supplementary Table 7.

The shifting of future diets and the composition of dishes to tackle climate change may be controversial as people are protective of what they eat. The shift in people's diets will face barriers such as increased food costs, changes in habits and preferences, accessibility of plant-based foods and potential cultural and social barriers that may hinder the shift in diets to tackle climate change. However, the use of visual communication frameworks showcased in this paper may help ease the transition to more sustainable diets within communities. The value added from this article highlights that the use of visualisations of future diets and dishes can be a useful tool for improving communication about future diets compared to complex and aggregated modelling outputs from IAMs, while enabling people to make informed decisions about their food choices to tackle climate change and help nations achieve 1.5°C more sustainably.

3.7 Limitations of dish and diet visualisations for communicating integrated assessment model future diet change

The approach taken in this study is notable for its attempt to present model output in a way that non-academics can more easily understand. While the representation of diets as plates is not new, this analysis adapts this familiar visual tool to the specific context of IAM's results. Many countries use similar visual guidelines to depict a healthy diet, often including plates of food. By applying this visual tool to IAM data, the study aims to make model output more accessible to a wider audience, including the general population, academics, and policy-makers.

One of the promising aspects of this method is its potential for automation. The process of creating these visualisations can be automated to depict any dish for any country, allowing multiple countries to apply the engagement technique. This adaptability may offer a flexible approach to communicating dietary changes across various contexts.

The visualisations will be brought to stakeholder engagement workshops to determine their potential impact, underscoring the study's commitment to practical application and dialogue with various stakeholders. The careful consideration of colours and design in the illustrations is a key aspect of this approach. The choice of colour may significantly impact attracting or deterring people, and the study acknowledges this factor in its methodology.

The study's use of dish-based analysis and visualisations opens up the possibility of wider discussions about dietary change. It translates modelled data into an understandable format, complementing other dietary studies, and explores how this visualisation can be used to communicate dietary change.

The research provides insights into the dietary shifts necessary to align with the 1.5°C climate stabilisation goal of the Paris Agreement. The approach contributes to the ongoing dialogue about dietary change, climate goals, and the broader understanding of IAM data by exploring familiar visual representations and the potential for automation.

The study represents an effort to make complex dietary transition data more accessible. Its application of familiar visual tools, combined with its adaptability and exploration of automation, offers a path for future research and communication in the field. Mindful of its approach and existing visualisation methods, the study adds to the ongoing dialogue about dietary change and the understanding of IAM data. It serves as a thoughtful contribution, inviting further exploration and adaptation in various contexts and actively engaging with stakeholders to assess the real-world impact of its findings.

4 Conclusion

This study embarked on the task of translating complex IAM data into accessible visualisations of potential diets and dishes for 2050, utilising the IMAGE LiStCh scenario (Van Vuuren et al., 2018). The analysis, guided by the DDDI framework (De Boer and Aiking, 2019), paints a picture of the dietary transition from 2020 to 2050 in selected countries, including the UK, Sweden, Brazil, and China.

The novelty of this approach lies in adapting a familiar visual tool, the representation of diets as plates, to the specific context of IAM's results. While not a new concept, the study leverages this method to make model output more relatable to a diverse audience, ranging from the general population to academics and policy-makers.

With the translation process now published, the visualisations are set to be brought to stakeholder engagement workshops. This next step underscores the study's commitment to practical application and opens the door for dialogue with various stakeholders to determine the potential impact of the findings.

The study's application of dish-based analysis and visualisations not only opens up the possibility of broader discussions about dietary change but also complements existing dietary studies. Exploring familiar visual representations and the potential for automation, it adds a new dimension to the dialogue about dietary change, climate goals, and the broader understanding of IAM data.

In alignment with the 1.5°C climate stabilisation goal of the Paris Agreement, the research provides valuable insights into the necessary dietary shifts. It serves as a thoughtful contribution to the field, inviting further exploration and adaptation in various contexts.

In conclusion, this study offers a path towards making complex dietary transition data more accessible without claiming to revolutionise the field. Combining familiar visual tools with the exploration of automation adds to the ongoing dialogue about dietary change and the understanding of IAM data. It stands as a testament to innovative thinking, actively engaging with stakeholders, and assessing the real-world impact of its findings.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. MF: Data curation, Formal analysis, Investigation, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. RW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. OE: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MS: Conceptualization, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing. DV: Conceptualization, Investigation, Methodology, Project administration, Validation, Writing – review & editing. CW: Conceptualization, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. JD: Conceptualization, Investigation, Methodology, Project administration, Validation, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was funded by the CAST Centre for Climate Change and Social Transformations (UK ESRC Grant ES/S012257/1). The dish images in Figure 4 were produced by Maddy Vian (Instagram @maddyology) with funding from UKRI Research England QR Strategic Priorities Fund in FY2021-22.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1266708/full#supplementary-material

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