Public Health Nutrition: 20(4), 739–757 doi:10.1017/S1368980016002664

Review Article

Operationalising the health aspects of sustainable diets: a review

Elly Mertens[1], Pieter van't Veer[1], Gerrit J Hiddink[2,3], Jan MJM Steijns[4] and Anneleen Kuijsten[1,]*
[1]Division of Human Nutrition, Wageningen University, PO Box 17, 6700 AA Wageningen, The Netherlands: [2]Strategic Communication; Communication, Technology and Philosophy, Centre for Integrative Development (CTP-CID), Social Sciences, Wageningen University, Wageningen, The Netherlands: [3]Manager Research Nutrition and Health, Dutch Dairy Association (NZO), The Hague, The Netherlands: [4]FrieslandCampina, Amersfoort, The Netherlands

Submitted 6 April 2016: Final revision received 12 August 2016: Accepted 17 August 2016: First published online 7 November 2016

Abstract
Objective: Shifting towards a more sustainable food consumption pattern is an important strategy to mitigate climate change. In the past decade, various studies have optimised environmentally sustainable diets using different methodological approaches. The aim of the present review was to categorise and summarise the different approaches to operationalise the health aspects of environmentally sustainable diets.
Design: Conventional keyword and reference searches were conducted in PubMed, Scopus, Web of Knowledge and CAB Abstracts. Inclusion criteria were: (i) English-language publication; (ii) published between 2005 and October 2015; (iii) dietary data collected for the diet as a whole at the national, household or individual level; (iv) comparison of the current diet with dietary scenarios; and (v) for results to consider the health aspect in some way.
Setting: Consumer diets.
Subjects: Adult population.
Results: We reviewed forty-nine studies that combined the health and environmental aspects of consumer diets. Hereby, five approaches to operationalise the health aspect of the diet were identified: (i) food item replacements; (ii) dietary guidelines; (iii) dietary quality scores; (iv) diet modelling techniques; and (v) diet-related health impact analysis.
Conclusions: Although the sustainability concept is increasingly popular and widely advocated by nutritional and environmental scientists, the journey towards designing sustainable diets for consumers has only just begun. In the context of operationalising the health aspects, diet modelling might be considered the preferred approach since it captures the complexity of the diet as a whole. For the future, we propose SHARP diets: environmentally Sustainable (S), Healthy (H), Affordable (A), Reliable (R) and Preferred from the consumer's perspective (P).

Keywords
Health aspects
Environmentally sustainable diet
Approaches
Consumer diet

To provide an adequate diet to the growing world population, estimates indicate that an increase in the global food production is needed at a rate of 1·2 % per year[1]. At the same time, the food production system is recognised as a major threat to the environment, including climate change and depletion of the planet's natural resources[2]. This is partly driven by habitual consumption patterns tending towards a higher consumption of animal-based products[3]. It is thus an important global challenge to secure adequate diets within a sustainable food production system[4]. In this regard, an adequate diet implies that it meets energy requirements and provides sufficient nutrients in line with the dietary guidelines for healthy growth and ageing[5]. Because diet is an important modifiable factor for well-being and disease prevention[6], both the adequacy of nutrient intake and the observed or projected prevalence and/or occurrence of health/disease outcomes are of importance.

Shifting towards a more sustainable food consumption pattern is considered an important factor to tackle the challenge of harmonising the rapidly changing food demand for the larger and more affluent population and its

*Corresponding author: Email anneleen.kuijsten@wur.nl

supply[7]. A recently published review suggested that a reduction of up to 50 % in diet-related greenhouse gas emissions and land use can be realised by dietary changes in areas with affluent diet[8]. Especially the reduction of animal-based products is often regarded as the main option for lowering diet-related environmental impact[2,7,8]. However, severe reductions without the inclusion of appropriate meat and/or dairy substitutes might lead to inadequacies of several nutrients (e.g. vitamin B_{12}, Zn, Fe) across population groups[9]. Therefore, the concept of a sustainable diet, as defined by the FAO, is briefly described as a diet that has a low impact on the planet's resources and the environment, including respectfulness for biodiversity and animal welfare, and contributes to an adequate diet that is promoting a healthy life. Sustainable diets also feature characteristics such as cultural acceptability, accessibility, economic fairness and affordability[10]. This definition highlights the connection between the health, the environmental sustainability and the food production aspects of a diet, with the dietary pattern of consumers as a common denominator. The design of those diets asks for a collaboration between nutritional and environmental sciences along with the agricultural food chain[11].

The aim of the present review is to categorise and summarise the different approaches that are currently used to operationalise the health aspects of environmentally sustainable diets. Also, the relevance of these approaches for research on environmentally sustainable diets is discussed; each approach addresses a particular research question, but is built upon some assumptions that should be taken into account when using the approach. The review provides an overview of the way in which such diets have been addressed in research, particularly the relationship between health and environmental sustainability of a diet. On the basis of this overview, recommendations for future research on designing sustainable diets are given and discussed.

Methods

The literature search was performed in October 2015 and identified relevant articles through conventional keyword searching strategies, using the search terms 'diet' or 'food' and 'climate' or 'greenhouse gas' or 'land' or 'sustain', in PubMed, Scopus, Web of Knowledge and CAB Abstracts, and through bibliographies of published papers. Articles included in the review met the following five inclusion criteria: (i) English-language publication; (ii) published between 2005 and October 2015; (iii) dietary data collected for the diet as a whole at the national, household or individual level; (iv) comparison of the current diet with dietary scenarios; and (v) for results to consider the health aspect in some way. The selection of articles that met the inclusion criteria was based on information available in titles and abstracts of the articles, without restrictions on the geographical location. Given the aim of the review to categorise and summarise the different methodological approaches, some articles that inadvertently may have been missed were not expected to influence the results of the approaches identified.

Results

In the period 2005–2015, we identified forty-nine papers that studied diet as related to health and environmental sustainability.

Dietary data collected for the diet as a whole included food availability estimates at the population and household level, and actual food intake at the individual level. The food availability estimates included data on the food supply at the population level using Food Balance Sheets of the FAO or from the US Department of Agriculture, Economic Research Service[12–27] and data on the food purchases at the household level using Household Budget Surveys[21,28–32]. Regarding individual-level food intake assessments, diet records were the most frequently used dietary survey method[20,33–49] with recording ranging from 2 to 14 d; followed by a single or replicated 24 h recalls[49–56] and FFQ[57–60]. The number of food items in these dietary assessments generally ranged from twenty-five to 100 in Food Balance Sheets, and from 130 in FFQ to 1314 in diet records or 24 h recalls. However, sustainability indicators (e.g. greenhouse gas emissions, land use) were available only for a limited number of foods, meaning a higher food aggregation level had been used. This food aggregation level was specified in forty-five studies, of which only seventeen studies applied a more precise level of aggregation into food items, with the number of food items ranging between seven and 391 food items[12,13,16,35–41,43,45,52–54,56,60]. For two studies, it was specified that this covered 71 % of the total food weight intake (including all solid foods and excluding foods typically consumed as beverages, such as milk, juices and other drinks) and 66 % of total energy intake from all foods and beverages[37,38]. In most studies, food items without a sustainability value were assigned a value from a similar food item within the same food group to cover the total food consumption. Sustainability was mainly operationalised by greenhouse gas emissions[12,15,21,25,26,29–38,40–42,44–48,51–57,60], followed by land use[14–16,40,41,43,50,52,60] and other sustainability indicators including livestock production, biodiversity and use of the planet's resources[12–15,17–30,39,42,49,52,58,59], which is partially biased towards the search terms used to define sustainability.

Approaches for operationalising the health aspect could be categorised into three main categories (Fig. 1 and Table 1): simple approaches focusing on a single nutritional aspect (A); approaches capturing the complexity of the diet (B); and approaches evaluating the health impact (C). More specifically, the simple approach refers to food item

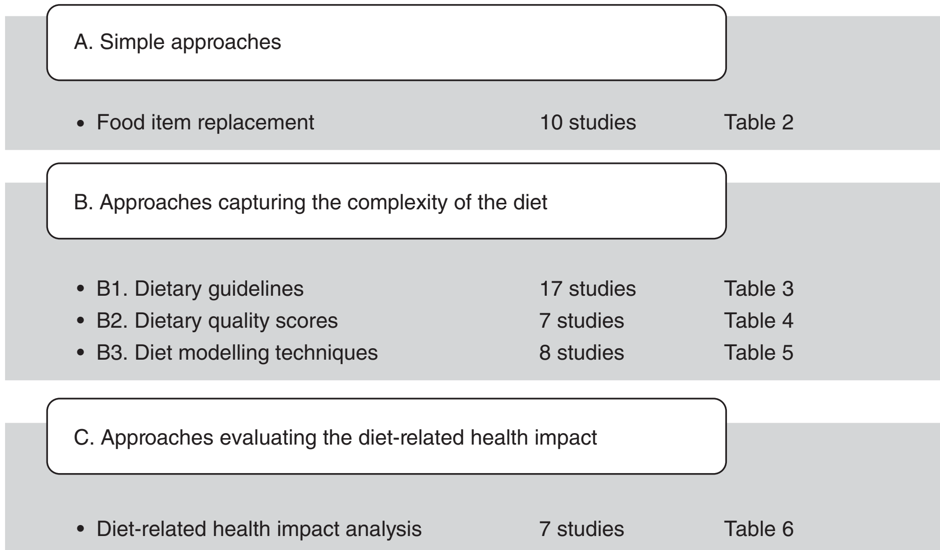

Fig. 1 Conceptual overview showing the approaches used to consider the health aspect in environmentally sustainable diets when using population-, household- or individual-level food intake assessment

replacements. Three approaches were identified to capture the complexity of the diet: dietary guidelines (B1); dietary quality scores (B2); and diet modelling techniques (B3). For diet-related health impact, one approach was identified. Studies generally did not address policy options to achieve dietary changes, the time dimension for environmental effects to occur (except for direct greenhouse gas emissions) or the robustness of alternative dietary options in different socio-economic and ecological contexts.

Simple approach: food item replacements (A)

Food item replacement is a ready-to-use and illustrative approach that addresses the question 'What would be the change in environmental sustainability when replacing a particular food item or food group in the diet by a more environmentally sustainable alternative food item or food group?' Ten studies used this approach and replacement of food items was food weight-based[50], protein-based[14] or energy-based[12,13,15,28,33–36] (Table 2). To develop a more environmentally sustainable diet, all studies focused on a replacement of the animal-based products in the diet, varying from a shift to a moderate reduction or a total elimination of these products. In some replacement diets, total meat consumption was kept constant, shifting the consumption from higher carbon-intensive meats (i.e. beef and lamb) to less carbon-intensive meats (i.e. pork and poultry)[12,34]. More commonly used replacement diets were those in which the total meat consumption was moderately reduced[14,15,28,34,35,50] or completely eliminated[12–14,28,33,34,36,50]; the former decreasing the meat intake by keeping the same types of meat in the diet and the latter being vegetarian or vegan options depending on their dairy content. In these replacement diets, meat (and dairy) substitutes can include either a single food group (e.g. dairy or fruit/vegetables, cereals, etc.)[15,33,35,36] or a combination of different food groups (e.g. pasta, rice, pulses, cereals, breads, salads, fruit and vegetables, dairy, eggs, nuts and seeds, etc.)[12–14,28,33,34,36,50]. However, simple replacement is seldom possible in practice, not only because physiological feedback loops interfere with the total amount of food eaten and/or energy intake; but also due to behavioural feedback loops that affect food choices, nutrient composition and/or energy density of the diet as a whole. Food item replacement is thus likely to modify the dietary pattern as a whole. For example, decreasing meat consumption and replacing it by plant-based substitutes might be beneficial for the environmental sustainability aspect of the diet, but raises concerns about the health aspect, in particular the intake of micronutrients that are largely derived from animal-based products (e.g. vitamin B_{12}, vitamin D, Fe, Zn, Se). Also, from a consumer perspective, questions have been raised about the acceptability of replacing meat, because meat is usually an embedded food item in a consumer's habitual dietary pattern. Nevertheless, nowadays, a substantial number of consumers belong to the segment of meat reducers or flexitarians, showing the feasibility of adopting a lower-level meat consumption[61]. In particular, potential change strategies incorporate the inclusion of meatless days with or without meat substitutes; the promotion of a smaller portion of meat; and, if possible, a combination of using sustainably produced (meat) products and/or a larger portion of plant-based products (i.e. fruits and vegetables)[61–63].

Apart from changing the dietary composition, just proportionally reducing food intake has been shown to lead to less energy while keeping the same overall nutrient

Table 1 Approaches used to consider the health aspect in research on environmentally sustainable diets

Approach	Question addressed by the approach	Considerations for selection
A. Simple approaches		
Food item replacement	What would be the change in environmental sustainability when replacing a particular food item or food group in the diet by a more sustainable alternative food item or food group?	• Omits dietary composition and micronutrient intake • Focuses on sustainability and therefore lacks the consumer's perspective to develop acceptable diets
B. Approaches capturing the complexity of the diet		
B1. Dietary guidelines	What would be the change in environmental sustainability when dietary guidelines are met?	• The recommended diet is considered as the optimised diet for nutritional health, and not necessarily for environmental sustainability • Not yet a consensus on what a healthy diet includes, resulting in a variety of dietary recommendations and thus recommended diets
B2. Dietary quality scores	How is dietary quality – as assessed by a score – related to environmental sustainability?	• One overall score reflects dietary intake as a whole; however, there are score-related limitations • A need for detailed nutritional data to calculate the score • Focus on nutritional health
B3. Diet modelling techniques	What would be the food composition of a diet when aiming at the optimisation of multiple diet-related factors (e.g. health, environmental sustainability, acceptability, affordability, accessibility, etc.)?	• Possibly, the designed diet is still a sub-optimised diet as it is driven by acceptability constraints and the data availability • Outcome of the optimised diet is presented as a list of food items in a specified quantity; hence the need for translation into dietary guidelines that can be communicated in a coherent way to the public
C. Approaches evaluating the diet-related health impact		
Diet-related health impact analysis	What would be the change in health impact based on nutrient adequacy and/or health/disease outcome when individuals adopt a diet that is more environmentally sustainable?	• Health impact analyses are usually based on published meta-analyses by modelling counterfactual diets • Nutrient adequacy and diet-related health/disease outcomes are predictive for the future of dietary change

density, as applied in one study[35]. A shortage of energy is not a common problem in Western countries where overconsumption is contributing to overweight, obesity and related diseases[64]. However, adequate micronutrient intake is still a major challenge in these Western-oriented diets due to their non-optimal composition[65] and micronutrient intake is often neglected in the nutritional evaluation of the 'less meat' diets.

Approaches capturing the complexity of the diet (B)

Dietary guidelines (B1)

Dietary guidelines are considered a descriptive approach that addresses the question 'What would be the change in environmental sustainability when dietary guidelines are met?' Seventeen studies used this approach to compare current diets with the recommendations for a healthy diet with regard to their health and environmental sustainability aspects (Table 3). Dietary recommendations initially provided dietary guidance with the aim to promote health and well-being, and to prevent diet-related conditions and chronic diseases[6], without considering the environmental sustainability of these diets – until recently[66,67]. The design of the recommended diet (e.g. the inclusion of food groups and the quantification of portion sizes) is highly dependent on the dietary guidelines used. However, when studying recommended diets in relation to environmental sustainability, the contribution of the following food groups was usually captured by the various recommended diets: bread, pasta, cereals and potatoes; fruit and vegetables; milk and milk products; meat, fish and egg products; legumes, nuts and seeds; fats and oils; and sugar, whereas alcohol was included only in the Mediterranean diets. Two studies additionally included the guidelines on total energy intake (and macronutrient composition)[16,42] and nine studies constructed multiple recommended diets standardised for energy intake (and protein intake)[18,19,22–26,58,59]; however, only one study focused on guidelines for total energy intake and macronutrient intake to design the recommended diet[27]. None of these studies explicitly addressed the advice on lowering salt intake, while this, in turn, might have an impact on food production, processing and consumption, hence

https://doi.org/10.1017/S1368980016002664 Published online by Cambridge University Press

Table 2 Food item replacement for the development of environmentally sustainable diets based on current diet

		Health considerations					Environmental considerations
Reference	Country	Dietary data	Replacement diets	Replacement compensated by means of	Health evaluation of whole diet based on	Food aggregation level*	Environmental indicator
Eshel *et al.* (2006)[12]	USA	Population level Per capita daily food disappearance data (FAOSTAT 2005)	Lacto-ovo-vegetarian Omnivore with fish Omnivore with red meat Omnivore with poultry	Total energy intake; meat kJ replaced by kJ from dairy and eggs in the lacto-ovo-vegetarian, and by kJ from the sole source given by the diet name	/	7 items	Energy efficiency GHGE
Baroni *et al.* (2007)[13]	Italy	Population level (Eurostat 2000, Euromeat 2001, FAO 2001)	Omnivorous diet Vegetarian diet Vegan diet	Total energy intake; meat and dairy (and eggs) kJ replaced by unspecified plant-based food items	Total energy Macronutrients (protein, carbohydrates, fat) Dietary fibre	18 items	Eco-indicator 99 W (including damages to human health, ecosystems quality and resources)
Collins and Fairchild (2007)[28]	Wales	Household level (Household and Expenditure Survey of Food and Drink 2001)	Organic diet Footprint diets Vegetarian diet	Total energy intake; inorganic food items, food items with an ecological footprint ≥0·006 gha/kg, ≥0·004 gha/kg or ≥0·002 gha/kg, and meat products respectively replaced by organic and low-impact alternatives, and dairy and eggs	Total energy Macronutrients Micronutrients	12 categories	Total ecological footprint (demand from nature)
Stehfest *et al.* (2009)[14]	24 world regions	Population level Per country agricultural production data (FAOSTAT 2006)	No ruminant meat No meat No animal products Less meat	Protein intake; animal proteins from ruminant meat, white meat, milk and eggs respectively replaced by plant proteins from pulses and soyabeans	/	7 crop groups and 5 animal categories	Livestock production Land use Crop production Radiative forcing
Berners-Lee *et al.* (2012)[33]	UK	Individual level 4 d diet record (UK National Diet and Nutrition Survey 2010, scaled to per capita supply intake FAO data)	3 vegetarian 3 vegan	Total energy intake; meat (and dairy) kJ replaced by kJ from dairy or plant-based meat substitutes‡	Macronutrients (protein, carbohydrates, fat) Added sugar Na	61 groups	GHGE
Vieux *et al.* (2012)[35]	France	Individual level 7 d diet record (Individual National Survey and Food Consumption, 2006–2007)	Less meat intake 20 % less Max. 50 g/d	Total energy intake; meat kJ replaced by kJ from fruit and vegetables, milk and dairy, or mixed dishes	Total diet weight Total energy intake Energy density	73 items	GHGE
Hoolohan *et al.* (2013)[34]	UK	Individual level 4 d diet record (UK National Diet and Nutrition Survey 2010, scaled to per capita supply intake FAO data)	Decrease meat Eliminate meat Eliminate ruminant	Total energy intake; meat kJ replaced by kJ from plant-based meat substitutes‡ or by lower carbon-intensive meat products (i.e. pork and poultry)	Macronutrients (protein, carbohydrates, fat) Added sugar Na	61 groups	GHGE

Table 2 *Continued*

		Health considerations					Environmental considerations
Reference	Country	Dietary data	Replacement diets	Replacement compensated by means of	Health evaluation of whole diet based on	Food aggregation level*	Environmental indicator
Temme *et al.* (2013)[50]	Netherlands	Individual level 2 × 24 h recalls (Dutch National Food Consumption Survey 2003)	Less meat and dairy intake 30 % less 100 % less	Diet weight; dairy and meat consumption replaced by the same amount of plant-based dairy or meat-replacing foods§	SFA Total Fe	/	Land use
Werner *et al.* (2014)[36]	Denmark	Individual level 7 d diet record (Danish National Dietary Survey 1995–2006)	6 omnivorous† 1 vegetarian 1 vegan	Total energy intake; dairy (and meat and fish) kJ replaced by kJ from marmalade, soya drinks and/or beans	Macronutrients‖ Micronutrients	71 items	GHGE
Westhoek *et al.* (2014)[15]	EU27	Population level Per capita food supply data (FAOSTAT 2010)	25 and 50 % less livestock Beef and dairy Pig, poultry and eggs All meat, dairy and eggs	Total energy intake; kJ from meat, dairy and eggs replaced by cereals (and pulses if protein intake lower than recommended level)	Protein Saturated fat	12 commodity groups	Feed demand Land use Reactive nitrogen emissions GHGE

GHGE, greenhouse gas emissions.

*Food aggregation level: the number of food items or groups (depending on author's terminology) for which environmental sustainability data of food intake was available.

†The theoretical diets were based on the current diet adjusted for the Danish Dietary Guidelines: six omnivorous diets with various quantities for dairy; one vegetarian diet with no cheese and meat products; and one vegan diet with no milk products, meat products and fish.

‡Preferably plant-based meat substitutes that might reasonably be considered to be healthy alternatives, i.e. pasta, rice, pulses, cereals, breads, salads, vegetables, fruits, nuts and seeds.

§Replacement with plant-based products that have a similar use to the reference food and therefore assumed to be consumed in similar amounts: liquid dairy foods were replaced by similar soya-based foods; meat products and cheese used as sandwich filling by a variety of other sandwich fillings/toppings; meat products in hot meals by a variety of meat replacers (e.g. vegetarian meat substitutes, egg dishes, pulses or tofu/tempeh); and soft cheese used as snack by popcorn.

‖The nutritional composition of each alternative diet was evaluated against the Nordic Nutrition Recommendations 2004 for macronutrients (protein, carbohydrate, added sugar, fat, saturated fat, mono- and polyunsaturated fat, and alcohol) and micronutrients (including dietary fibre, vitamins A, D, E, C, B_{12}, B_6, thiamin, riboflavin, niacin and folate, and minerals Mg, Fe, Zn, P, Ca, iodine and Se).

https://doi.org/10.1017/S1368980016002664 Published online by Cambridge University Press

Table 3 Dietary guidelines in relation to the environmental sustainability for a descriptive analysis on environmentally sustainable diets

		Health considerations					Environmental considerations
Reference	Country	Dietary data	Recommended diets	Dietary guidelines*	Health evaluation of whole diet based on	Food aggregation level†	Environmental indicator
Gerbens-Leenes and Nonhebel (2005)[16]	Netherlands	Population level (Eurostat 1993, FAO 1999, LEI/CBS 1981/1986/1996/1998, Vereniging voor Nederlandse Koffiebranders en Theepakkers 1961/1998)	Recommended diet, providing nutritional energy and nutrients (Voedingscentrum 1998)	Total energy intake Food group-based	/	25 items	Land requirement
Buzby *et al.* (2006)[17]	USA	Population level Per capita food availability data series (USDA ERS 2003)	2005 Dietary Guidelines for Americans on a 8369 kJ/d (2000 kcal/d) diet	Food group-based‖	/	/	Agricultural needs
Tukker *et al.* (2011)[18] and Wolf *et al.* (2011)[19]	EU27	Population level Per capita daily food supply data (FAOSTAT 2008)	WHO diet World Cancer Research Fund diet Mediterranean diet	Food group-based Total energy intake Protein intake	Protein Total and saturated fat	50 groups 24 commodities	Aggregated environmental impact†† Global warming
Capone *et al.* (2013)[20]	Italy USA Finland	Individual level 3 d diet record (INRAN-SCAI survey 2005–2006, scaled to per capita supply intake FAO data) Population level Per capita daily food supply data (FAOSTAT 2006)	Mediterranean diet model adapted for Italians (Institute of Food Sciences of La Sapienza University)	Food group-based	Food groups	25 groups	Water footprint
Friel *et al.* (2013)[29]	Australia	Household level Per household weekly food purchases (National Nutrition Survey 1995; Household Expenditure data 2003–2004)	Australian Guide to Healthy Eating adapted for environmental sustainability principles	Food group-based	/	7 groups	GHGE Water use Biodiversity
Meier and Christen (2013)[58] and Meier *et al.* (2014)[59]	Germany	Individual level FFQ (fifty-four-item semi-quantitative) (National Nutrition Survey I, 1985–1989) Diet history + 2 × 24 h recalls + 2 × 4 d diet record (National Nutrition Survey II, 2006)	Two recommended diets for Germany Two dietary patterns adopted from USDA/USDHHS guidelines: lacto-ovo-vegetarian and vegan	Food group-based¶ Total energy intake	Food groups	43 commodities	Global warming potential Ammonia emissions Land use Blue water use Phosphorus use Primary energy use
Sáez-Almendros *et al.* (2013)[21]	Spain	Population level Per capita food supply data (FAOSTAT 2007) Household level Per capita daily or monthly food purchases (Household Consumption Survey 2006)	Mediterranean diet using the minimum servings of each food group recommended (New Mediterranean Diet Pyramid)	Food group-based	Food groups	9 groups	GHGE Resource use (including agricultural land use, energy and water consumption)
Saxe *et al.* (2013)[22]	Denmark	Population level Per capita annual food supply data	Nordic Nutrition Recommendations New Nordic Diet based on Danish dietary guidelines and OPUS dietary guidelines	Food group-based Total energy intake Protein intake	Food categories	31 categories	Global warming potential
Vanham *et al.* (2013)[23,24]	EU28 Austria	Population level Per capita annual food supply data (FAOSTAT 2012)	Healthy diet‡ DGE, German dietary recommendations	Food group-based Total energy intake Protein intake	Food groups	9 groups	Water footprint

https://doi.org/10.1017/S1368980016002664 Published online by Cambridge University Press

Table 3 *Continued*

		Health considerations					Environmental considerations
Reference	Country	Dietary data	Recommended diets	Dietary guidelines*	Health evaluation of whole diet based on	Food aggregation level†	Environmental indicator
Germani *et al.* (2014)[42]	Italy	Individual level 3 d diet record (INRAN-SCAI survey 2005–2006)	Mediterranean diet model adapted for Italians (Institute of Food Sciences of La Sapienza University and Livelli di Assunzione di Referimento Di Nutrient ed energia per la populazione italiana)	Food group-based Macronutrient based** Total energy intake	Food groups	19 groups	Carbon footprint Ecological footprint Water footprint
Heller *et al.*[25,26]	USA	Population level Per capita loss adjusted food availability data series (USDA ERS 2012)	2010 Dietary Guidelines for Americans Omnivorous diet on a 10 602 and 8368 kJ/d (2534 and 2000 kcal/d) diet Vegetarian diet Vegan diet Healthy Eating Plate diet (Harvard School of Public Health)	Food group-based Total energy intake	Food groups	100 commodities	GHGE Carbon footprint
Hendrie *et al.* (2014)[55]	Australia	Individual level 1 × 24 h recall FFQ (Australian National Nutrition Survey 1995)	Recommended diet Australian Dietary Guidelines§	Food group-based	Food groups Total energy intake Macronutrients Micronutrients	14 groups	GHGE
Pairotti *et al.* (2015)[30]	Italy	Population Per household monthly food basket of Italian products (National Statistics Institute)	Modern Diet Mediterranean Food Pyramid (National Institute of Research on Food and Nutrition (INRAN)) Healthy diet and vegetarian diet (Italian Nutrition Society (SINU))	Food group-based	Food groups	5 categories	Energy consumption GHGE

USDA, US Department of Agriculture; ERS, Economic Research Service; USDHHS, US Department of Heath and Human Services; GHGE, greenhouse gas emissions.
*When using food-based dietary guidelines, the contribution of the following food groups was usually captured by the various recommended diets: bread, pasta, cereals and potatoes; fruit and vegetables; milk and milk products; meat and meat products, fish and eggs; legumes, nuts and seeds; fats and oils; and sugar; while alcohol was only included in the Mediterranean diets.
†Food aggregation level: the number of food groups, categories or commodities (depending on author's terminology) for which environmental sustainability data of food intake was available.
‡In addition, dietary scenarios such as a healthy diet with no meat and a healthy diet with less meat were investigated, in which the meat products were replaced by pulses and oil crops.
§Additional food groups included in the recommended diet were the non-core foods; for example, snack foods, processed meats, sugar, tea, coffee and miscellaneous, alcohol, and saturated fats and oils. In addition, dietary scenarios such as the current diet with minimal non-core foods and the foundation recommended diet were also investigated. The former scenario contained similar foods and quantities as the current diet with minimal inclusion of energy-dense processed non-core foods, thus excluding processed meat, snack foods, confectionery, soft drinks, saturated fats and oils, and alcohol; and the latter was derived from the recommended diet consistent with Australian Dietary Guidelines, however including only core foods in similar amounts to the recommended diet, while meeting minimum nutrient and energy requirements for the population. All scenarios were evaluated on macro- and micronutrient intakes: energy, carbohydrate, protein, total and saturated fat, dietary fibre, vitamin A, folate, Ca, Mg, Zn and K.
‖The recommended diet was focused only on meeting the guidelines for the intake of fruits and vegetables, total and whole grains, and dairy.
¶Two German dietary recommendations: D-A-C-H (official recommendation of the German Nutrition Society (DGE)) and UGB (alternative recommendations by the Federation for Independent Health Consultation with less meat, but more legumes and vegetables). The lacto-ovo-vegetarian dietary patterns adopted from USDA/USDHHS guidelines excluded the food groups on meat products and fish products, and included an additional food group for nuts and seeds and a separate food group for legumes. The vegan one additionally excluded the food groups on butter, high- and low-fat dairy products, and egg products, and included an additional food group for vegan soya drink products.
**The recommended diet has an energy intake of 8368 kJ/d (2000 kcal/d) with a macronutrient share of 55–60 % of energy from carbohydrates, 10–12 % of energy from proteins and 30 % of energy from fats.
††The aggregated environmental impact includes eight environmental impact categories: abiotic depletion, global warming, ozone layer depletion, human toxicity, eco-toxicity, phytochemical oxidation, acidification and eutrophication, all expressed as the relative changes in impact per dietary scenario to status quo diet 2003. This aggregated environmental impact and the global warming were given in absolute numbers and relative to the status quo diet.

on environmental sustainability. This is because salt possesses certain crucial technological functions in food processing and preservation, and an important sensory function[68]. Additionally, when using the approach of dietary recommendations, the food aggregation level was quantified at a high level of food aggregation (about twenty food groups) which allowed for a rough estimation of the environmental sustainability for a broader range of indicators, not only including greenhouse gas emissions but also the use of natural resources such as land, water, phosphorus and primary energy.

Most studies have found that the recommended diet might have a lower environmental impact than the current diet, and thus a shift in the direction of the recommended diet might have beneficial impacts on both health and environmental sustainability. However, it is still open to debate whether the recommended diet might be the ideal solution for health and environmental sustainability combined.

Dietary quality scores (B2)

A dietary quality score (e.g. a diet score[69] or nutrient profile[70,71]) is a summary measure of adherence to a set of dietary guidelines for nutrients and/or food groups. Using this score can be regarded as an application of the dietary guidelines with the aim to identify whether different diets and/or groups of the population are consuming a diet that is close to the dietary guidelines. Seven studies used this score to address the question 'How is dietary quality – as assessed by a score – related to environmental sustainability?' (Table 4). In these studies, this approach was applied merely for descriptive purposes as the aim was to compare nutritional quality of the diet by a score[39–41,51] or by population strata[37,38,57], and subsequently to assess the environmental sustainability of the different diets or population strata. Out of these seven studies, three studies directly investigated the combination of a healthy and an environmentally sustainable diet by applying a dietary quality score and a sustainability score[38,40,41]. This sustainability score was either calculated with a composite score including diet-related greenhouse gas emissions and land use[40,41] or based on strata for the diet-related greenhouse gas emissions[38,54]. For example, Masset *et al.*[38] identified the 'more sustainable' diets by applying both a diet score and a sustainability score, dividing the population into strata of nutritional quality and strata of greenhouse gas emissions in order to describe the diets that were ranked high on both the health and the sustainability aspects of the diet.

While this approach expresses the health aspect of the diet in one overall score, the interpretation is limited by score-related limitations such as the inclusion of a selected number of dietary components, arbitrary penalties for unmet criteria and the failure of the overall score to accentuate specific shortages/deficiencies. However, although such scores summarise pre-existing knowledge of diet–disease relationships, they are considered as less detailed indicators to assess dietary quality, which might result in misclassification of diets and hence weakened associations.

Diet modelling techniques (B3)

Integrating the health aspect into environmental sciences in a more advanced way involves the application of mathematical modelling techniques, which allows for the design of optimised diets on multiple diet-related factors. Eight studies used mathematical modelling techniques including quadratic modelling[27,43], smooth non-linear programming[46] and linear programming[44,45,52,53,56] to address the question 'What would be the food composition of a diet when aiming at the optimisation of multiple diet-related factors?' (Table 5). These studies all aim at optimising the food composition of the diet based on objectives for health and environmental sustainability while minimising the deviation from the habitual food composition of the current diet, regardless of the modelling techniques and mathematical assumptions.

In diet modelling, nutritional constraints are used to ensure nutritional adequacy and are built upon the physiological nutrient requirements, often with the addition of a few food-based dietary guidelines (e.g. on fruit and vegetables, and fish). Additional constraints are added to the model to derive diets that are acceptable to consumers; these acceptability constraints are based on habitual food preferences and therefore intend to minimise the deviation from the current diet. More specifically, constraints on the food quantity force the model to choose for standard usable portion sizes, and force the model to either select food items that would not have been selected because of high environmental sustainability or low nutritional values, or restrict the maximum quantity of food items that would have been selected otherwise[44,45,56]. Instead, constraints on food popularity force the model to minimise the deviations from the current diet[27,45,52,53], whereby popularity is based on either the percentage of the population consuming a particular food item[45] or an arbitrary penalty score for any change from the current diet[27,52,53].

All these modelling techniques describe the optimised diet output in the format of a list of food items that can be consumed in a specified quantity, and it has been demonstrated that from such a list a seven-day-week menu based on three meals per day and in-between snacks can be created while still maintaining dietary preferences (e.g. traditional meal compositions such as milk and breakfast cereals, meat and vegetables and potatoes, etc.)[44,72]. However, the output of the diet model is highly dependent on the availability of an appropriate database, thus bridging dietary composition data with diet-related environmental sustainability data. Also, the acceptability constraints have a major influence on the output of the

Table 4 Dietary quality scores, as an application of the dietary guidelines, in relation to environmental sustainability for a descriptive analysis on environmentally sustainable diets

		Health considerations					Environmental considerations
Reference	Country	Dietary data	Diet scores*	Nutritional indicators in diet scores	Health evaluation of whole diet based on	Food aggregation level†	Environmental indicator
Carvalho *et al.* (2013)[51]	Brazil	Individual level 2 × 24 h recalls (Health Survey for São Paulo 2003–2007)	Brazilian Healthy Eating Index Revised	9 food groups: fruits (total and whole), vegetables (total and dark green/orange vegetables and legumes), grains (total and whole), milk and dairy, meat and eggs and legumes, and oils 2 restricting nutrients: Na and saturated fat 1 other component: energy from solid fat, added sugar and alcohol	Total energy intake Nutrient intake Food group intake	/	GHGE
Vieux *et al.* (2013)[37]	France	Individual level 7 d diet record (Individual National Survey and Food Consumption 2006–2007)	Energy density Mean Adequacy Ratio Mean Excess Ratio	Total energy and diet weight 20 key nutrients: protein, fibre, retinol equivalents, thiamin, riboflavin, niacin, vitamins B_6, B_{12}, C, E and D, Ca, K, Fe, Mg, Zn, Cu, iodine, Se 3 restricting nutrients: saturated fat, Na and free sugars Total energy intake Total diet weight	Total energy intake Total diet weight Nutrient intake	391 items	GHGE
Masset *et al.* (2014)[38]	France	Individual level 7 d diet record (Individual National Survey and Food Consumption 2006–2007)	PANDiet score	20 key nutrients: protein, carbohydrate, fat, polyunsaturated fat, fibre, vitamins A, thiamin, niacin, B_6, folic acid, B_{12}, C, D and E, minerals Ca, Mg, Zn, P, K and Fe 3 restricting nutrients: saturated fat, cholesterol and Na	Total energy intake Total diet weight Food group intake	391 items	GHGE‡
Van Dooren *et al.* (2014)[40] and Van Dooren and Aiking (2014)[41]	Netherlands	Individual level 2 d diet record (Dutch National Food Consumption Survey 1998)	Health score	Total energy 2 key nutrients: total fat and fibre 5 restricting nutrients: total fat, saturated fat, *trans*-fat, free sugars and Na 3 food groups: vegetables, fruit and fish	Total energy intake Food group intake	206 items	GHGE Land use§
Monsivais *et al.* (2015)[57]	UK	Individual level FFQ (130-item, semi-quantitative)	DASH (Dietary Approaches to Stop Hypertension) score	7 food groups: fruits, vegetables, nuts and legumes, whole grains, low-fat dairy, red and processed meat, foods high in added sugar 1 restricting nutrient: Na	Total energy intake	94 commodities	GHGE
Röös *et al.* (2015)[39]	Sweden	Individual level 4 d diet record (Riskmaten 2012)	NRD (Nutrient-Rich Diet) 9.3 NRD 11.4 NRD 10.3	9 to 11 key nutrients: protein, fibre, vitamins A, C and E, Ca, Fe, Mg, K (11.4, plus vitamin D and folate; 10.3, plus vitamin D and folate/fibre) 3 or 4 restricting nutrients: SFA, added sugar, Na (11.4, plus P)	Total energy intake Nutrient intake	90 items	Climate change Land use Biodiversity damage potential

GHGE, greenhouse gas emissions.

*Diet scores are used to subdivide the population into groups of nutritional quality (e.g. Vieux *et al.*[37], created four classes of nutritional quality in which a high-nutritional-quality diet was defined as having a Mean Adequacy Ratio score above the median, a Mean Excess Ratio score below the median and an Energy Density score below the median; Monsivais *et al.*[57], quintiles of DASH scores; Masset *et al.*[38], two groups by median split of PANDiet score). Diet scores are also used for comparison of different dietary scenarios (e.g. Carvalho *et al.*[51], moderate meat consumption pattern with excessive meat consumption patterns (having a red and processed meat intake higher than the World Cancer Research Fund maximum recommended intake of red and processed meat of 500 g/week (≈71·4 g/d)); Röös *et al.*[24], current diet with the Swedish Nordic recommended diet and the low-carbohydrate/high-fat diet applying energy-equivalent scenarios; Van Dooren *et al.*[40] and Van Dooren and Aiking[41], current diet with recommended Dutch diet, semi-vegetarian, traditional vegetarian, vegan, Mediterranean, New Nordic Diet, historical Low Lands and optimised Low Lands diets).

†Food aggregation level: the number of food items or commodities (depending on author's terminology) for which environmental sustainability data of food intake was available.

‡GHGE median cut-off point to define a lower- *v.* a higher-carbon diet, and then in combination with the higher-quality diet (PANDiet above median) the more sustainable diet in this populations has been identified.

§GHGE and land use are incorporated into a composite sustainability score that is used for the comparison of different dietary scenarios.

https://doi.org/10.1017/S1368980016002664 Published online by Cambridge University Press

Table 5 Diet modelling using mathematical programming techniques for the design of optimised diets for health and environmental sustainability

		Health considerations in the diet modelling					Environmental considerations in the diet modelling
Reference	Country	Dietary data	Nutritional constraints using dietary guidelines (i.e. Recommended Dietary Allowance values)	Acceptability constraints with reference to the current diet	Health evaluation of whole diet based on	Food aggregation level*	Environmental indicator
Arnoult *et al.* (2010)[43]	UK	Individual level 2-week diet record (Expenditure and Food Survey 2003–2004)	UK Department of Health 12 nutrients 1 food group	Yes; similar energy and alcohol intake as current diet	Food group	293 items	Land use††
Macdiarmid *et al.* (2012)[44]	UK	Individual level 7 d diet record (UK National Diet and Nutrition Survey 2000–2001)	UK dietary guidelines for an adult women Total energy 12 nutrients 3 food groups	No and yes; food quantity limits for each food group‖	Food group Energy Macronutrients Micronutrients	82 groups	GHGE, to be minimised
Thompson *et al.* (2013)[45]	France Spain Sweden	Individual level 7 d diet record (INCA 2, France, 2007) 3 d diet record (ENIDE, Spain, 2013) 4 d diet record (Riskmaten, Sweden, 1997–1998)	Dietary guidelines from the French Agency for Food, Food circle with Swedish Nutrition Recommendations Objectified	Yes; food quantity limits‖ and food popularity¶	Food group Energy Macronutrients Micronutrients	68 items for France 277 items for Spain 88 items for Sweden	GHGE, to be reduced by 25 %
Wilson *et al.* (2013)[56]†	New Zealand	Individual level 24 h recalls and questionnaire (New Zealand Adult Nutrition Survey 2008–2009)	New Zealand dietary recommendations for men Total energy intake 14 nutrients	Yes; daily maximum limits for flour, pasta and oats, total vegetable intake and added salt	Food group Energy Macronutrients Micronutrients	76 items	GHGE, to be minimised
Jalava *et al.* (2014)[27]‡	176 countries	Population level Per country annual food supply data (FAOSTAT 2013)	County-specific dietary guidelines for total energy intake WHO dietary guidelines for macronutrient intake, and fruit and vegetables	Yes; food popularity using a penalty score for any deviation from the original diet	Macronutrients	13 groups	Consumptive water use at the global level††
Tyszler *et al.* (2014)[52]§	Netherlands	Individual level 2 × 24 h recalls (Dutch National Food Consumption Survey 2007–2010)	Dutch dietary guidelines for a non-active adult women Total energy All macronutrients All micronutrients Amino acids 2 food groups	Yes; food popularity including portion size by using a penalty score for each change in serving size**	Food group	207 items	pReCiPe, including GHGE, fossil energy use and land use, to be reduced by 30 %

Table 5 *Continued*

		Health considerations in the diet modelling					Environmental considerations in the diet modelling
Reference	Country	Dietary data	Nutritional constraints using dietary guidelines (i.e. Recommended Dietary Allowance values)	Acceptability constraints with reference to the current diet	Health evaluation of whole diet based on	Food aggregation level*	Environmental indicator
Green *et al.* (2015)[46]	UK	Individual level 4 d diet record (UK National Diet and Nutrition Survey 2010–2011)	WHO dietary guidelines 10 nutrients	Yes; similar energy intake as current diet and similar amount of liquids as current diet	Food group	42 groups	GHGE, to be gradually reduced by 10 %‡‡
Van Dooren *et al.* (2015)[53]	Netherlands	Individual level 2 × 24 h recalls (Dutch National Food Consumption Survey 2007–2010)	Dutch dietary guidelines Total energy All macronutrients All micronutrients 1 food group	Yes; food popularity including portion size by using a penalty score for each change in serving size**	Food group Energy Macronutrients Micronutrients	206 items	GHGE, to be reduced by 20 %

INCA 2, Individual and National Study on Food Consumption; ENIDE, Spanish National Diet Survey; GHGE, greenhouse gas emissions.
*Food aggregation level: the number of food items or groups (depending on author's terminology) for which environmental sustainability data of food intake was available.
†Additional diet models were optimised to meet nutrient requirements and: (i) minimise costs; (ii) minimise costs and GHGE; (iii) be relatively healthy, Mediterranean- and Asian-style; and (iv) include 'more familiar New Zealand meals'.
‡Diet was initially optimised in view of dietary recommendations only, thereafter additional diet models were optimised using quadratic programming to meet nutritional constraints along with a forced reduction on the animal-based products, in particular including limits on the protein intake from all animal products and from meat, starting from a limit to 50 % and 16·7 %, respectively, and gradually reducing these to zero.
§Additional diet models were optimised to (i) meet nutritional constraints only, and along with forced reductions on animal-based products (ii) excluding meat, (iii) excluding meat and fish, and (iv) excluding meat, fish, dairy and eggs.
||Food quantity limits (i.e. upper and/or lower bounds) were set for each group to give standard usable portion sizes (i.e. in whole units or in units in which it is sold).
¶For France, acceptability constraints on food quantity for each food item included a minimum value equal to the 5th percentile of consumption observed in the population (non-consumers included) and a maximum value equal to the 95th percentile of consumption observed in the population (non-consumers excluded), to ensure that the number of daily portions is acceptable to consumers. For Spain and Sweden, bounds were based on food popularity including minimum portion sizes. Food popularity (that is related to cultural preferences) was based on the current consumption as observed in the dietary surveys and expressed as the percentage of the populating consuming a particular food item. This resulted in the following acceptability constraints: (i) amounts consumed in a particular food group should at least be 60–80 % of the habitual consumption; (ii) popular foods (eaten by at least 50 % of the population) could be increased by up to four times, but not decreased by 30 % of the habitual consumption; (iii) unpopular foods (eaten by less than 25 % of the population) were limited to no more than twice the habitual consumption; and (iv) other foods could be increased up to three times the habitual consumption.
**Penalty score: any change in serving size as compared with the current diet contributes to an arbitrary penalty score with a penalty contribution that is food- and direction-dependent.
††Diet was optimised in view of dietary recommendations only using quadratic programming; the environmental impact was not considered during the modelling, but estimated afterwards for the optimised diet model.
‡‡Diet was initially optimised in view of dietary recommendations only using smooth non-linear programming; thereafter additional diet models were optimised in view of environmental concerns, in particular a gradual reduction by 10 % of GHGE.

diet model, resulting in a sub-optimised, but more realistic diet in accordance with the current diet.

An approach evaluating the diet-related health impact: diet-related health impact analyses (C)

Diet-related health impact analysis in environmental sciences addresses the question 'What would be the change in health impact based on nutrient adequacy and/or health/disease outcomes when individuals adopt a more environmentally sustainable diet?' Seven studies quantified the diet-related health impact of diets differing in environmental sustainability, either directly by observing nutrient adequacy or chronic disease risk as outcomes[54,60] or indirectly by modelling the expected health impact[31,32,47–49] (Table 6). The direct approach was used by one cross-sectional survey that assessed nutrient adequacy using data from the Dutch National Food Consumption Survey including 3819 subjects aged 7–69 years[54] and by one prospective cohort study that investigated total mortality risk using data from the EPIC-NL (European Prospective Investigation into Cancer and Nutrition–Netherlands cohort) including 35 057 adults with a median follow-up of 16 years[60]. For the indirect approach, five studies did not actually observe nutrient adequacy or risk reductions as outcomes, but they modelled the expected diet-related health impact of the more environmentally sustainable diet based on risk ratios obtained from meta-analysis on diet–disease associations[31,32,47–49].

This approach of linking diet-related health/disease outcomes to environmental sustainability might be considered as suitable evidence to influence food choices and food production, since nutrient adequacy and diet-related health/disease outcomes are predictive for the future healthiness of dietary change. The healthiness of food products has been recognised as an important determinant of food choice, apart from taste and price, whereas sustainability motives are currently not considered substantial influential factors[63,73–75].

Methodological considerations

The design of optimised sustainable diets should take into account certain methodological considerations as presented below. First, the current diet needs to be linked to health and environmental sustainability, whereby this link depends on the assessment method of the current diet. Second, the indicators of 'health' and 'environmental sustainability' must be well defined to support the design of sustainable diets. Third, sustainable diets incorporate more than only health and environmental sustainability, and thus future steps have to be taken to identify the social, ethical[76] and economic[77] indicators related to a sustainable diet, such as the cultural acceptance of a diet, the biodiversity, animal health and welfare, the production of economically fair products that are accessible and affordable for people at all times, etc.

Food availability or food intake – how to connect health with environmental sustainability?

The assessment of the current diet can be based on either food availability related to food production and expenditure, or actual food intake closely related to food consumption and thus the health aspect of the diet. The main questions related to designing sustainable diets are 'How to connect health with environmental sustainability?' and 'What is the influence of the assessment method?'

The quantification of diet-related environmental sustainability should preferably be based on food availability estimates rather than on actual food intake data. The reason for this is that food availability estimates represent the food supply/production or food expenditure/purchases at the national or the household level and thus include food losses at production level and food wastages at consumption level. For example, data on the per capita food supply obtained from the Food Balance Sheets of the FAO reflect the quantity of food products that are produced, used for trade, adjusted for stock changes and non-nutritional use, and expressed in primary equivalents (primary food commodities) per capita per day[78]; whereas data on the household's consumption expenditure obtained from Household Budget Surveys reflect the quantity of food products that enters the households[79]. However, food availability estimates have little connection to the individual dietary pattern and thereby its diet–health relationship, as noticed in the limited health evaluation of the whole diet in studies using population or household measurement level.

In contrast, an individual's diet that is obtained from individual-level food intake assessment methods enables a strong connection with individuals' diet-related factors (e.g. age, sex, socio-economic status) and corresponding health aspects (e.g. nutrient adequacy and/or diet-related health/disease outcomes)[80], but has a less strong connection with the estimation of environmental sustainability (e.g. indicators are typically available only for primary food commodities up to the regional distribution centre). When using individual-level food intake assessment, some underlying methodological issues should be taken into account for assessing the health aspect of a diet at population level, in particular the representativeness of the individual's diet and the sample's representativeness for the population[80]. National survey methods, such as diet records and 24 h recalls, are suitable methods to assess the intake of an unlimited number of food items consumed by an individual over one or more days, with portion sizes and preparation practices; hereby describing habitual intakes at population level, but not linking this with diet-related health/disease outcomes within individuals.

Table 6 Diet-related health impact analyses of environmentally sustainable diets

		Health considerations					Environmental considerations
Reference	Country	Dietary data	Dietary counterfactuals	Dietary exposure	Measure of health impact including the health-disease outcomes under study	Food aggregation level*	Environmental indicator
Friel *et al.* (2009)[49]	UK Brazil	Individual level 4/7 d diet record (UK National Diet and Nutrition Surveys 1998, 2000 and 2003) 1 × 24 h recall (São Paulo Household Health Survey 2006)	30 % decrease in the consumption of animal-based products	Decreased intake in saturated fat with increase in polyunsaturated fat	DALY YLL for IHD	/	Livestock production¶
Aston *et al.* (2012)[47]	UK	Individual level 7 d diet record (UK National Diet and Nutrition Survey 2000–2001)	Counterfactual dietary distribution in which the proportion of vegetarians is doubled and all the non-vegetarians adopt a dietary pattern similar to that of the lowest red and processed meat consumers	Decreased intake of red and processed meat	Potential impact fractions§ for CHD, diabetes mellitus and colorectal cancers	45 categories	GHGE
Scarborough *et al.* (2012)[31]	UK	Household level Per household 2-week food purchases (Family Food Survey 2008)	50 % decrease in the consumption of all meat and dairy products A shift from red to white meat A 50 % decrease in white meat products	Decreased intake of meat and/or dairy, and isoenergetic increased intake of fruit and vegetables, and cereals	Total deaths delayed or averted in the UK under each dietary counterfactual using the DIETRON model‖	256 categories	GHGE
Briggs *et al.* (2013)[32]	UK	Household level Per household 2-week food purchases (Living Costs and Food Survey 2010)	Tax scenarios: a tax of £2·72/t CO_2e per 100 g product applied to all food and drink groups with GHGE above average Tax and subsidy scenario: including subsidies for food groups with GHGE below average	Decreased intake of food items with GHGE above average, and increased intake of food items with GHGE below average	Total death delayed or averted in the UK under each dietary counterfactual using the DIETRON model‖	256 categories	GHGE
Milner *et al.* (2015)[48]	UK	Individual level 4 d diet record (UK National Diet and Nutrition Survey 2010)	Optimised diet to achieve WHO guidelines with no GHGE reduction target and with a 10–60 % reduction target[46]	Decreased intake of red and processed meat, and increased intake of fruit and non-starchy vegetables	YLL for CHD, stroke, type 2 diabetes, cancers of the mouth/pharynx/larynx, oesophagus, lung, stomach and colon/rectum	42 groups	GHGE

Table 6 *Continued*

		Health considerations					Environmental considerations
Reference	Country	Dietary data	Dietary counterfactuals	Dietary exposure	Measure of health impact including the health-disease outcomes under study	Food aggregation level*	Environmental indicator
Temme *et al.* (2015)[54]	Netherlands	Individual level 2 × 24 h recalls (Dutch National Food Consumption Survey 2007–2010)	Population stratification by environmental sustainability (i.e. diets of low, intermediate or high environmental load)	Dietary intake by diets of low, intermediate or high environmental load	Descriptive comparison of the food intake, energy intake and nutrient intake	254 items	GHGE
Biesbroek *et al.* (2014)[60]†	Netherlands	Individual level EPIC-NL FFQ (178-item, semi-quantitative, 1993–1997)	Population stratification by environmental sustainability (i.e. quartiles) Meat-substitution diets; one-third reduction in meat intake (35 g) of the average daily meat intake (105 g)‡	Environmental sustainability or replacement option	Crude and adjusted hazard ratios (for age, sex and energy intake) using Cox proportional hazard models for all-cause mortality Cause-specific mortality (including cancer, CVD, respiratory diseases and other causes)	254 items	GHGE Land use

EPIC-NL, European Prospective Investigation into Cancer and Nutrition–Netherlands cohort; CO_2e, CO_2 equivalents; GHGE, greenhouse gas emissions; DALY, disability-adjusted life years; YLL, years of life lost.
*Food aggregation level: the number of food items or groups (depending on author's terminology) for which environmental sustainability data of food intake was available.
†The analysis of the health impact (i.e. mortality survival analysis) was based on data from 35 057 subjects included in EPIC-NL, a prospective cohort study with a median follow-up of 15·9 years. The main aim was to investigate the relationship between diet-related sustainability and mortality outcomes either by population stratification for the environmental indicators (e.g. GHGE and land use) or by meat-substitution scenarios.
‡In the meat-substitution scenario, the replacement of meat was compensated by means of food weight and the plant-based meat-substitutes were potatoes, total vegetables, total fruit/nuts/seeds, pasta/rice/couscous, cheese, milk-based desserts or fish, representing acceptable alternatives for meat because these foods are consumed in significant amounts in the Dutch diet and can replace meat in a hot meal. The reduction in all-cause mortality risk and environmental impact was estimated separately per meat-substitution option and for an option with no replacement.
§Potential impact fraction was calculated as the difference between current aggregate risk and aggregate risk under counterfactual divided by current aggregate risk, and represents the proportion/percentage of disease in the population that can be attributed to the current diet and therefore could potentially have been avoided under the counterfactual diet.
‖The DIETRON model included the intake of total energy, fruit, vegetables, fibre, total fat, mono- and polyunsaturated, saturated and *trans*-fatty acids, dietary cholesterol and salt as dietary input to estimate the link between food consumption and mortality using age- and sex-specific relative risk estimates from meta-analyses.
¶A 30 % decrease in livestock production is assumed to result in a reduction of equal size in the consumption of animal-based products, and thus a decrease in the dietary intake of saturated fat.

An FFQ that focuses on ranking individuals according to their usual food intake by capturing the intake of food items over a designated time period (e.g. usually varying from the last month to the last year) from a finite list has been commonly used to assess the association between dietary intake and health/disease outcomes in large epidemiological studies. When aiming at estimating the environmental sustainability related to food consumption, the answer to the question which dietary assessment method to use depends on the desired link with health and the desired level of food aggregation, which is not yet available for sustainability indicators on the level of (all) individual food items.

In short, this discrepancy in measurement/aggregation level forms a methodological barrier in connecting both health and environmental sustainability aspects of a diet. Based on the literature review, when aiming to design sustainable diets, dietary data collected at the individual level might be considered the preferred measurement level. The main reason for the selection of this measurement level is the possibility for monitoring health in terms of foods and nutrients, without directly hampering the linkage with environmental sustainability indicators. Foods are the common denominator regardless of the higher aggregation level of sustainability indicators and their conversion into primary commodities[81].

Future perspectives

In a complex field that has emerged from different scientific disciplines, clear definitions of 'health' and 'environmental sustainability' are essential. Health can be defined on the basis of nutrients and foods; the former using dietary reference values related to physiological needs for healthy growing and ageing[82], and the latter using food-based dietary guidelines related to health/disease outcomes[83]. A further issue in this is that nutrient-based and food-based dietary guidelines differ between countries and that they are based on population averages with average energy requirements, whereas physiological nutrient needs vary considerably because of body size, physical activity and phase of the life cycle. Expressing nutritional requirements and intakes in terms of nutrient densities might be helpful to independently address food composition and energy intake[84]. However, when designing an optimised sustainable diet, both facets of nutritional health should be taken into account; i.e. the essential nutrients that are consumed in insufficient amounts or in excess at population level (nutrient adequacy), and the important acceptable foods for maintaining nutrient intake and promoting health (food-based dietary guidelines).

With regard to environmental sustainability, the quantification of this is still in its infancy and driven by present know-how and available measurement equipment. This often results in focusing on the environmental impact of greenhouse gas emissions and land use, while omitting the broader perspective that also includes natural resource use and biodiversity, among others. Because this emphasis on greenhouse gas emissions and land use was included specifically in our search terms, this may have influenced the number of papers within the five approaches identified, but the range of approaches is likely to be covered. Also, the environmental assessment is often restricted to the system boundaries of the life cycle assessment, which in theory cycles from farmer production to final consumption and disposal, but in practice usually stops at the distribution centre or even at the farm gate; thus many studies do address food availability on the basis of food production and/or food purchase data, i.e. addressing food that is produced and/or entering the households, thereby ignoring inedible parts and food waste[85]. Future research is therefore needed to develop quantitative methods for assessing the full picture of diet-related environmental sustainability indicators.

Conclusions

In operationalising the health aspect of an environmentally sustainable diet, the first priority will be to define which research questions to address and the second will be to ascertain an appropriate match in the measurement level of health and environmental sustainability. The research questions determine whether to apply a descriptive or an analytical outline. The descriptive outline refers to the comparison of different diets based on dietary guidelines, dietary quality scores and diet-related health-impact analysis, while the analytical outline refers to the design of alternative diets based on food item replacement and diet modelling techniques. Therefore, in the context of operationalising the health aspect when designing sustainable diets, diet modelling might be considered the preferred approach since it captures the complexity of the diet as a whole. Hence, there is a need for individual-level dietary data related to the food consumption with regard to food and nutrient intakes. It is important to recognise that the concept of sustainable diets is used across multiple fields and not only includes food and nutrition as such, but also the environment, agriculture, animal sciences, social and economic sciences, which need to be taken into account when designing sustainable diets for the future.

An avenue for future research in designing sustainable diets: the SHARP diet

In the context of developing a future vision for designing optimised sustainable diets, the broader concept of sustainable diets as defined by the FAO[10] should be considered when aiming at diet optimisation in a multidimensional way. We, therefore, propose the concept of a diet that is SHARP: environmentally Sustainable (S),

https://doi.org/10.1017/S1368980016002664 Published online by Cambridge University Press

Healthy (H), Affordable (A; accessible for consumers yet also supporting the agriculture food sector), Reliable (R; stable in its supply and safe) and Preferable (P; consistent with cultural norms and food preferences). This SHARP diet would be in line with the wider definition of sustainability by including its social, ecological and economic dimensions. This requires further exploration of mapping these diet-related dimensions into objectives/constraints for the diet model that aims at an optimised sustainable diet for all diet-related sustainability perspectives.

Diet modelling might be the preferred approach to analyse current and design future diets as multiple diet-related aspects (e.g. health, environmental sustainability, affordability, accessibility and acceptability) can be taken into account simultaneously. The output of the diet model (i.e. food list with specified quantities) is highly dependent on the constraints included and the diet-related sustainability data available. As different parameter settings for these constraints might have major effects, the robustness of such diet models needs attention, especially with respect to the trade-off between conflicting objectives and exploring adaptiveness to future changes in environmental sustainability options (e.g. improved food production processes), food consumption patterns (e.g. innovative new food products) and/or other diet-related factors (e.g. accessibility and affordability). A major challenge with analysing potential trade-offs to identify preferred scenarios is, however, to fully understand the interaction across all indicators of a sustainable diet within the different socio-economic and environmental contexts[86]. Importantly, the output of the diet model should not be viewed as achieving one optimum, but rather a set of preferred dietary options dependent on the optimisation aims of the different stakeholders (e.g. consumers, agricultural sectors, food industries and politicians).

Acknowledgements

Acknowledgements: The authors acknowledge Professor Toon van Hooijdonk (Food Quality and Design, Wageningen University; FrieslandCampina, Amersfoort, The Netherlands) for interesting academic partners and food industries in joint research into healthy, sustainable and consumer-friendly diets. *Financial support:* Funding was obtained from the Dutch Dairy Association (NZO) and the European Union's H2020 Programme (grant agreement number 633692, SUSFANS); preparatory work was funded by the Graduate School VLAG, Wageningen. The funders had no role in the design, analysis or writing of this article. *Conflict of interest:* The authors have no personal or financial conflicts of interest. *Authorship:* P.v.V., G.J.H. and J.M.J.M.S. initiated the topic of the review. P.v.V. supervised the conduct of the review by E.M. and A.K. and the draft of the manuscript by E.M. The draft was critically evaluated and refined by P.v.V. and A.K. G.J.H. and J.M.J.M.S. evaluated the manuscript for internal coherency. All authors read and approved the final submission of the paper. *Ethics of human subject participation:* Not applicable.

References

1. Tilman D, Balzer C, Hill J *et al.* (2011) Global food demand and the sustainable intensification of agriculture. *Proc Natl Acad Sci U S A* **108**, 20260–20264.
2. Vermeulen SJ, Campbell BM & Ingram JSI (2012) Climate change and food systems. *Annu Rev Environ Resour* **37**, 195–222.
3. Alexandratos N & Bruinsma J (2012) *World Agriculture Towards 2030/2050: The 2012 Revision*. *ESA Working Paper* no. 12-03. Rome: FAO.
4. Godfray H, Beddington J, Crute I *et al.* (2010) Food security: the challenge of feeding 9 billion people. *Science* **327**, 812–818.
5. Maynard LA (1959) An adequate diet. *J Am Med Assoc* **170**, 457–458.
6. World Health Organization (2003) *Diet, Nutrition and the Prevention of Chronic Diseases. Joint WHO/FAO Expert Consultation*. *WHO Technical Report Series* no. 916. Geneva: WHO.
7. Garnett T (2011) Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy* **36**, Suppl. 1, S23–S32.
8. Hallström E, Carlsson-Kanyama A & Börjesson P (2015) Environmental impact of dietary change: a systematic review. *J Clean Prod* **91**, 1–11.
9. Craig WJ & Mangels AR (2009) Position of the American Dietetic Association: vegetarian diets. *J Am Diet Assoc* **109**, 1266–1282.
10. Burlingame B & Dernini S (editors) (2012) *Sustainable Diets and Biodiversity: Directions and Solutions for Policy, Research and Action. Proceedings of the International Scientific Symposium Biodiversity and Sustainable Diets United Against Hunger, 3–5 November 2010, FAO Headquarters, Rome*. Rome: FAO.
11. United Nations Environment Programme. (2012) *Avoiding Future Famines: Strengthening the Ecological Foundation of Food Security through Sustainable Food Systems. A UNEP Synthesis Report*. Nairobi: UNEP.
12. Eshel G & Martin PA (2006) Diet, energy, and global warming. *Earth Interact* **10**, 1–17.
13. Baroni L, Cenci L, Tettamanti M *et al.* (2007) Evaluating the environmental impact of various dietary patterns combined with different food production systems. *Eur J Clin Nutr* **61**, 279–286.
14. Stehfest E, Bouwman L, van Vuuren D *et al.* (2009) Climate benefits of changing diet. *Clim Chang* **95**, 83–102.
15. Westhoek H, Lesschen JP, Rood T *et al.* (2014) Food choices, health and environment: effects of cutting Europe's meat and dairy intake. *Glob Environ Chang* **26**, 196–205.
16. Gerbens-Leenes W & Nonhebel S (2005) Food and land use. The influence of consumption patterns on the use of agricultural resources. *Appetite* **45**, 24–31.
17. Buzby J, Wells H & Vocke G (2006) *Possible Implications for US Agriculture from Adoption of Select Dietary Guidelines*. *Economic Research Report* no. ERR-31. Washington, DC: US Department of Agriculture, Economic Research Service.
18. Tukker A, Goldbohm RA, de Koning A *et al.* (2011) Environmental impacts of changes to healthier diets in Europe. *Ecol Econ* **70**, 1776–1788.
19. Wolf O, Pérez-Domínguez I, Rueda-Cantuche JM *et al.* (2011) Do healthy diets in Europe matter to the environment? A quantitative analysis. *J Policy Model* **33**, 8–28.

20. Capone R, Iannetta M, Bilali HE *et al.* (2013) A preliminary assessment of the environmental sustainability of the current Italian dietary pattern: water footprint related to food consumption. *J Food Nutr Res* **1**, 59–67.
21. Sáez-Almendros S, Obrador B, Bach-Faig A *et al.* (2013) Environmental footprints of Mediterranean versus Western dietary patterns: beyond the health benefits of the Mediterranean diet. *Environ Health* **12**, 118.
22. Saxe H, Larsen TM & Mogensen L (2013) The global warming potential of two healthy Nordic diets compared with the average Danish diet. *Clim Chang* **116**, 249–262.
23. Vanham D (2013) The water footprint of Austria for different diets. *Water Sci Technol* **67**, 824–830.
24. Vanham D, Mekonnen MM & Hoekstra AY (2013) The water footprint of the EU for different diets. *Ecol Indic* **32**, 1–8.
25. Heller MC & Keoleian GA (2014) Greenhouse gas emissions of the US diet: aligning nutritional recommendations with environmental concerns. In *Proceedings of the 9th International Conference on Life Cycle Analysis in the Agri-Food Sector (LCA Food 2014), 8–10 October, San Francisco, USA*, pp. 539–548 [R Schenck and D Huizenga, editors]. Vashon, WA: American Center for Life Cycle Assessment.
26. Heller MC & Keoleian GA (2014) Greenhouse gas emission estimates of US dietary choices and food loss. *J Ind Ecol* **19**, 391–401.
27. Jalava M, Kummu M, Porkka M *et al.* (2014) Diet change – a solution to reduce water use? *Environ Res Lett* **9**, 074016.
28. Collins A & Fairchild R (2007) Sustainable food consumption at a sub-national level: an ecological footprint, nutritional and economic analysis. *J Environ Policy Plan* **9**, 5–30.
29. Friel S, Barosh LJ & Lawrence M (2013) Towards healthy and sustainable food consumption: an Australian case study. *Public Health Nutr* **17**, 1156–1166.
30. Pairotti MB, Cerutti AK, Martini F *et al.* (2015) Energy consumption and GHG emission of the Mediterranean diet: a systemic assessment using a hybrid LCA–IO method. *J Clean Prod* **103**, 507–516.
31. Scarborough P, Allender S, Clarke D *et al.* (2012) Modelling the health impact of environmentally sustainable dietary scenarios in the UK. *Eur J Clin Nutr* **66**, 710–715.
32. Briggs A, Kehlbacher A, Tiffin R *et al.* (2013) Assessing the impact on chronic disease of incorporating the societal cost of greenhouse gases into the price of food: an econometric and comparative risk assessment modelling study. *BMJ Open* **3**, e003543.
33. Berners-Lee M, Hoolohan C, Cammack H *et al.* (2012) The relative greenhouse gas impacts of realistic dietary choices. *Energy Policy* **43**, 184–190.
34. Hoolohan C, Berners-Lee M, McKinstry-West J *et al.* (2013) Mitigating the greenhouse gas emissions embodied in food through realistic consumer choices. *Energy Policy* **63**, 1065–1074.
35. Vieux F, Darmon N, Touazi D *et al.* (2012) Greenhouse gas emissions of self-selected individual diets in France: changing the diet structure or consuming less? *Ecol Econ* **75**, 91–101.
36. Werner LB, Flysjo A & Tholstrup T (2014) Greenhouse gas emissions of realistic dietary choices in Denmark: the carbon footprint and nutritional value of dairy products. *Food Nutr Res* **2014**, 58.
37. Vieux F, Soler LG, Touazi D *et al.* (2013) High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults. *Am J Clin Nutr* **97**, 569–583.
38. Masset G, Vieux F, Verger EO *et al.* (2014) Reducing energy intake and energy density for a sustainable diet: a study based on self-selected diets in French adults. *Am J Clin Nutr* **99**, 1460–1469.
39. Roos E, Karlsson H, Witthoft C *et al.* (2015) Evaluating the sustainability of diets – combining environmental and nutritional aspects. *Environ Sci Policy* **47**, 157–166.
40. van Dooren C, Marinussen M, Blonk H *et al.* (2014) Exploring dietary guidelines based on ecological and nutritional values: a comparison of six dietary patterns. *Food Policy* **44**, 36–46.
41. Van Dooren C & Aiking H (2014) Defining a nutritionally healthy, environmentally friendly, and culturally acceptable Low Lands Diet. In *Proceedings of the 9th International Conference on Life Cycle Analysis in the Agri-Food Sector (LCA Food 2014), 8–10 October, San Francisco, USA*, pp. 1427–1438 [R Schenck and D Huizenga, editors]. Vashon, WA: American Center for Life Cycle Assessment.
42. Germani A, Vitiello V, Giusti AM *et al.* (2014) Environmental and economic sustainability of the Mediterranean Diet. *Int J Food Sci Nutr* **65**, 1008–1012.
43. Arnoult MH, Jones PJ, Tranter RB *et al.* (2010) Modelling the likely impact of healthy eating guidelines on agricultural production and land use in England and Wales. *Land Use Policy* **27**, 1046–1055.
44. Macdiarmid JI, Kyle J, Horgan GW *et al.* (2012) Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet? *Am J Clin Nutr* **96**, 632–639.
45. Thompson S, Gower R, Darmon N *et al.* (2013) *A Balance of Healthy and Sustainable Food Choices for France, Spain and Sweden*. Godalming: WWF-UK.
46. Green R, Milner J, Dangour AD *et al.* (2015) The potential to reduce greenhouse gas emissions in the UK through healthy and realistic dietary change. *Clim Change* **129**, 253–265.
47. Aston LM, Smith JN & Powles JW (2012) Impact of a reduced red and processed meat dietary pattern on disease risks and greenhouse gas emissions in the UK: a modelling study. *BMJ Open* **2**, e001072.
48. Milner J, Green R, Dangour AD *et al.* (2015) Health effects of adopting low greenhouse gas emission diets in the UK. *BMJ Open* **5**, e007364.
49. Friel S, Dangour AD, Garnett T *et al.* (2009) Public health benefits of strategies to reduce greenhouse-gas emissions: food and agriculture. *Lancet* **374**, 2016–2025.
50. Temme EH, van der Voet H, Thissen JT *et al.* (2013) Replacement of meat and dairy by plant-derived foods: estimated effects on land use, iron and SFA intakes in young Dutch adult females. *Public Health Nutr* **16**, 1900–1907.
51. Carvalho AMd, César CLG, Fisberg RM *et al.* (2013) Excessive meat consumption in Brazil: diet quality and environmental impacts. *Public Health Nutr* **16**, 1893–1899.
52. Tyszler M, Kramer G & Blonk H (2014) Just eating healthier is not enough: studying the environmental impact of different diet scenarios for the Netherlands by linear programming. In *Proceedings of the 9th International Conference on Life Cycle Analysis in the Agri-Food Sector (LCA Food 2014), 8–10 October, San Francisco, USA*, pp. 1367–1376 [R Schenck and D Huizenga, editors]. Vashon, WA: American Center for Life Cycle Assessment.
53. van Dooren C, Tyszler M, Kramer G *et al.* (2015) Combining low price, low climate impact and high nutritional value in one shopping basket through diet optimization by Linear Programming. *Sustainability* **7**, 12837.
54. Temme EH, Toxopeus IB, Kramer GF *et al.* (2015) Greenhouse gas emission of diets in the Netherlands and associations with food, energy and macronutrient intakes. *Public Health Nutr* **18**, 2433–2445.
55. Hendrie GA, Ridoutt BG, Wiedmann TO *et al.* (2014) Greenhouse gas emissions and the Australian Diet – comparing dietary recommendations with average intakes. *Nutrients* **6**, 289–303.
56. Wilson N, Nghiem N, Mhurchu C *et al.* (2013) Foods and dietary patterns that are healthy, low-cost, and

environmentally sustainable: a case study of optimization modeling for New Zealand. *PLoS One* **8**, e59648.
57. Monsivais P, Scarborough P, Lloyd T *et al*. (2015) Greater accordance with the Dietary Approaches to Stop Hypertension dietary pattern is associated with lower diet-related greenhouse gas production but higher dietary costs in the United Kingdom. *Am J Clin Nutr* **102**, 138–145.
58. Meier T & Christen O (2013) Environmental impacts of dietary recommendations and dietary styles: Germany as an example. *Environ Sci Technol* **47**, 877–888.
59. Meier T, Christen O, Semler E *et al*. (2014) Balancing virtual land imports by a shift in the diet. Using a land balance approach to assess the sustainability of food consumption. Germany as an example. *Appetite* **74**, 20–34.
60. Biesbroek S, Bueno-de-Mesquita H, Peeters P *et al*. (2014) Reducing our environmental footprint and improving our health: greenhouse gas emission and land use of usual diet and mortality in EPIC-NL: a prospective cohort study. *Environ Health* **13**, 27.
61. de Bakker E & Dagevos H (2012) Reducing meat consumption in today's consumer society: questioning the citizen–consumer gap. *J Agric Environ Ethics* **25**, 877–894.
62. de Boer J, Schösler H & Aiking H (2014) 'Meatless days' or 'less but better'? Exploring strategies to adapt Western meat consumption to health and sustainability challenges. *Appetite* **76**, 120–128.
63. Verain MC, Dagevos H & Antonides G (2015) Sustainable food consumption. Product choice or curtailment? *Appetite* **91**, 375–384.
64. World Health Organization (2010) *World Health Statistics 2010*. Geneva: WHO.
65. Mensink GB, Fletcher R, Gurinovic M *et al*. (2013) Mapping low intake of micronutrients across Europe. *Br J Nutr* **110**, 755–773.
66. Health Council of the Netherlands (2011) *Guidelines for a Healthy Diet: The Ecological Perspective*. The Hague: Health Council of the Netherlands.
67. Reynolds CJ, Buckley JD, Weinstein P *et al*. (2014) Are the dietary guidelines for meat, fat, fruit and vegetable consumption appropriate for environmental sustainability? A review of the literature. *Nutrients* **6**, 2251–2265.
68. Hutton T (2002) Sodium technological functions of salt in the manufacturing of food and drink products. *Br Food J* **104**, 126–152.
69. Wirt A & Collins CE (2009) Diet quality – what is it and does it matter? *Public Health Nutr* **12**, 2473–2492.
70. Drewnowski A & Fulgoni V 3rd (2008) Nutrient profiling of foods: creating a nutrient-rich food index. *Nutr Rev* **66**, 23–39.
71. Van Kernebeek HRJ, Oosting SJ, Feskens EJM *et al*. (2014) The effect of nutritional quality on comparing environmental impacts of human diets. *J Clean Prod* **73**, 88–99.
72. Macdiarmid J, Kyle J, Horgan G *et al*. (2011) *Livewell: A Balance of Healthy and Sustainable Food Choices*. Godalming: WWF-UK.
73. Roininen K, Lähteenmäki L & Tuorila H (1999) Quantification of consumer attitudes to health and hedonic characteristics of foods. *Appetite* **33**, 71–88.
74. Verbeke W (2008) Impact of communication on consumers' food choices. *Proc Nutr Soc* **67**, 281–288.
75. Grunert KG, Hieke S & Wills J (2014) Sustainability labels on food products: consumer motivation, understanding and use. *Food Policy* **44**, 177–189.
76. Coff C, Korthals M & Barling D (2008) Ethical traceability and informed food choice. In *Ethical Traceability and Communicating Food*, pp. 1–18 [C Coff, D Barling, M Korthals *et al*., editors]. Dordrecht: Springer.
77. Oosterveer P & Sonnenfeld DA (2012) *Food, Globalization and Sustainability*. Abingdon: Routledge.
78. Food and Agriculture Organization of the United Nations (2016) Supply Utilization Accounts and Food Balance Sheets – background information for your better understanding. http://www.fao.org/economic/the-statistics-division-ess/methodology/methodology-systems/supply-utilization-accounts-and-food-balance-sheets-background-information-for-your-better-understanding/en/ (accessed January 2016).
79. Trichopoulou A (1992) Monitoring food intake in Europe: a food data bank based on household budget surveys. *Eur J Clin Nutr* **46**, Suppl. 5, S3–S8.
80. Thompson FE, Subar AF, Coulston A *et al*. (2008) Dietary assessment methodology. In *Nutrition in the Prevention and Treatment of Disease*, 2nd ed., pp. 3–39 [AM Coulston and CJ Boushey, editors]. San Diego, CA: Academic Press.
81. Herforth A, Frongillo EA, Sassi F *et al*. (2014) Toward an integrated approach to nutritional quality, environmental sustainability, and economic viability: research and measurement gaps. *Ann N Y Acad Sci* **1332**, 1–21.
82. European Food Safety Authority, Panel on Dietetic Products, Nutrition and Allergies (2010) Scientific Opinion on principles for deriving and applying Dietary Reference Values. *EFSA J* **8**, 1458.
83. World Health Organization (2003) *Food-based Dietary Guidelines in the WHO European Region*. Copenhagen: WHO Regional Office for Europe.
84. Backstrand JR (2003) Quantitative approaches to nutrient density for public health nutrition. *Public Health Nutr* **6**, 829–837.
85. Finnveden G, Hauschild MZ, Ekvall T *et al*. (2009) Recent developments in life cycle assessment. *J Environ Manage* **91**, 1–21.
86. Lock K, Smith RD, Dangour AD *et al*. (2010) Health, agricultural, and economic effects of adoption of healthy diet recommendations. *Lancet* **376**, 1699–1709.