What should we eat? Realistic solutions for reducing our food footprint

Allenden, Nicole; Hine, Donald W.; Craig, Belinda M.; Cowie, Annette L.; McGreevy, Paul D.; Lykins, Amy D.

Published in:
Sustainable Production and Consumption

DOI:
10.1016/j.spc.2022.05.008

Sustainable Production and Consumption 32 (2022) 541–549

Contents lists available at ScienceDirect

Sustainable Production and Consumption

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

What should we eat? Realistic solutions for reducing our food footprint

Nicole Allenden [a], Donald W. Hine [b], Belinda M. Craig [a,c], Annette L. Cowie [d,f], Paul D. McGreevy [e,f], Amy D. Lykins [a,*]

[a] School of Psychology, University of New England, Armidale, New South Wales 2351, Australia
[b] School of Psychology, University of Canterbury, Christchurch 8140, New Zealand
[c] Faculty of Health Sciences and Medicine, Bond University, Gold Coast, Queensland 4226, Australia
[d] NSW Department of Primary Industries, New South Wales 2351, Australia
[e] Faculty of Science, Agriculture, Business and Law, University of New England, Armidale, New South Wales 2351, Australia
[f] School of Environmental and Rural Science, University of New England, Armidale, New South Wales 2351, Australia

ARTICLE INFO

Article history:
Received 8 January 2022
Received in revised form 19 April 2022
Accepted 5 May 2022
Available online 11 May 2022

Editor: Dr. Wenling Liu

Keywords:
Sustainable diets
Meat consumption
Behaviour change
Behaviour Prioritization Matrix
Life cycle assessment

ABSTRACT

Livestock production systems are associated with climate change, land degradation, and animal welfare concerns, while overconsumption of animal-sourced foods is a major driver of human disease. Thus, shifting towards plant-rich diets is expected to deliver benefits for human health, the environment, and animal welfare. Nevertheless, diets high in animal products are flourishing, especially in high-income countries. Here, we take a novel interdisciplinary approach to evaluating sustainability of diets by assessing five common plant-rich diets (Mediterranean, flexitarian/semi-vegetarian, vegan, vegetarian, and pescatarian) on two metrics. First, we established each diet's environmental, human health, and animal welfare impacts, using quantitative data sourced from a review of the literature, including life cycle assessments. Second, we evaluated the human factor by surveying current consumer dietary preferences (i.e., which diet participants had followed over the past week) and the likelihood of adopting each plant-rich diet in the future, among a sample of Australian adults ($n = 253$). Combining the results from the review and the survey in a Behavior Prioritization Matrix (BPM), the Mediterranean diet was shown to have the greatest projected positive impact, followed by the vegetarian diet. This study is the first to combine assessments of sustainable diets on the three dimensions of environment, human health, and animal welfare *with* probability of adoption. Our findings highlight the necessity of assessing plant-rich diets through a holistic lens when identifying target diets to promote, in order to support sustainable food systems in high-income countries.

1. Introduction

Our current food systems are a significant contributor to global greenhouse gas (GHG) emissions, making them a prime area of focus in tackling the climate crisis (Poore and Nemecek, 2018). With our growing global population, the demand for food is increasing, with certain foods being in greater demand (e.g., meat and dairy) in response to rising urbanisation and individual wealth (FAO, 2017a). Given the many elements of a sustainable food system (e.g., water, biodiversity, energy use, and food security), a holistic approach is clearly needed to achieve sustainability (Béné et al., 2019). While change is urgently needed in agricultural practices, population and social trends reveal that consumer dietary choices also need to be examined given these choices create "demand pull" that in turn influences agricultural systems. Identifying which diets are environmentally sustainable is an important starting point to support consumers in making sustainable dietary choices. Further to the environmental benefits are the equally important human health and animal welfare credentials of specific diets. It is also a waste of precious time and resources to promote diets that most people are not willing to adopt, making population preferences a key factor in sustainable diet change. Combining these key elements enables the development of future behaviour change interventions to support sustainable consumption.

2. Literature review

Food systems account for 26% of global greenhouse gas (GHG) emissions, of which most (59%) comes from livestock production (including

Abbreviations: BPM, Behaviour Prioritization Matrix; CBSM, Community-based Social Marketing; ALYS, animal life years suffered; AL, animal loss; MAL, morally adjusted animal lives.

* Corresponding author.
E-mail addresses: nallende@myune.edu.au (N. Allenden), donald.hine@canterbury.ac.nz (D.W. Hine), bcraig@bond.edu.au (B.M. Craig), annette.cowie@une.edu.au (A.L. Cowie), pmcgree2@une.edu.au (P.D. McGreevy), alykins@une.edu.au (A.D. Lykins).

https://doi.org/10.1016/j.spc.2022.05.008

meat, dairy, seafood, and eggs; Poore and Nemecek, 2018), making the livestock production sector the third largest emitter, following the energy (35%) and transport (23%) sectors (Gerber et al., 2013; IPCC, 2014). The major contributor to GHG emissions from red meat production is methane emitted from the digestive system of ruminants, while other significant sources include methane and ammonia from manure management, and nitrous oxide from feed production (Opio et al., 2013). Further, livestock production uses extensive amounts of land and water resources, and contributes to biodiversity loss, land degradation, and pollution of waterways (FAO, 2017b; Westhoek et al., 2011).

Global meat production is predicted to increase by 76% between 2007 and 2050, associated with increasing adoption of diets high in animal-sourced products in developing countries (Alexandratos and Bruinsma, 2012; OECD/FAO, 2019). Such 'affluent diets' are common in developed Western countries, where meat is traditionally the central component of a meal (Beardsworth and Bryman, 2004).

In response to this urgent need, several initiatives have emerged, ranging from agricultural innovations (Beach et al., 2015; IPCC, 2019) to food technology developments including plant-based meat substitutes and cultured meat (i.e., grown artificially from animal cells; Apostolidis and McLeay, 2016; Bryant and Barnett, 2019). In their report on Climate Change and Land, the IPCC (2019) emphasised that demand management encouraging shifts to sustainable diets rich in plant-based foods could reduce GHG emissions by 0.7 to 8.0 GtCO2 eq yr^{-1}, along with parallel benefits for human health and biodiversity conservation. The potential climate change benefits from supplementing animal protein with plant protein (e.g., tofu, fava beans) are highlighted by Sadhukhan et al. (2020).

While several definitions have been offered, the Food and Agriculture Organization (FAO, 2010, p. ix), states that a sustainable diet is one "….with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations." Recent studies based on life cycle assessment have evaluated the sustainability of various foods and alternative diets (e.g., GHG emissions, water use, and land use; Aleksandrowicz et al., 2016; Batlle-Bayer et al., 2020). Overall, plant-based foods typically have less environmental impact than the lowest-impact animal products (Poore and Nemecek, 2018). So, plant-rich diets—vegan, vegetarian, pescatarian, Mediterranean, or flexitarian/semi-vegetarian—are expected to have reduced impacts on the environment, as these diets reduce or eliminate reliance on livestock. Dietary shift will have the greatest environmental benefits in countries with a high intake of meat and other animal-sourced products (Nelson et al., 2016; Springmann et al., 2018).

It is imperative that a sustainable diet is also nutritious and healthy. Dietary guidelines provide recommendations for food consumption, including portion sizes for meat and other animal-sourced products. Most guidelines promote high intake of fruit, vegetables, and whole grain foods, with moderate levels of protein (e.g., meat, eggs, and beans) and dairy (National Health and Medical Research Council, 2013; Public Health England, 2018). Specifically, guidelines generally recommend limited consumption of red meat and avoidance of processed meat due to their association with cardiovascular diseases, several cancers, type 2 diabetes, and, for processed meat, higher mortality rates (Demeyer et al., 2016; Li et al., 2018; Micha et al., 2010; Pan et al., 2011). In contrast, a diet high in plant-based food and low in meat (particularly red and processed meat), such as traditional Mediterranean diets, has been associated with reduced all-cause mortality and lower incidence of heart failure, stroke, cognitive decline, and some cancers (Martinez-Gonzalez and Martín-Calvo, 2016; Trichopoulou and Vasilopoulou, 2000). The flexitarian, pescatarian, vegetarian, and vegan diets have also been found to be nutritionally adequate, with the exclusionary diets (vegetarian and vegan) requiring a small number of nutrients to be supplemented (Springmann et al., 2018).

Beyond environmental and human health concerns are the less-discussed animal welfare impacts associated with livestock production. Growing demand generated by higher per capita consumption of animal-sourced products, combined with the increasing human population, has led to intensified livestock farming systems (Gregory and Grandin, 2007; Harrison, 1964; Thompson, 2015). The high stocking densities typical of such systems have been linked to a series of negative welfare effects (Bessei, 2006; Dawkins et al., 2004; Park et al., 2020; Peden et al., 2018), as well as dependence on antibiotics to combat increased disease prevalence and boost food conversion rates—promoting both antibiotic resistance and antibiotic spread through the environment (Kivits et al., 2018). Intensive farming practices also amplify the risk of zoonoses, such as coronaviruses (Allen et al., 2017). Reducing the global consumption of meat and other animal-sourced products could moderate these risks as well as alleviating animal suffering.

Thus, shifting to plant-rich diets brings many environmental, health, and animal welfare benefits and can support a sustainable food system. Clearly, the appeal and the harmful impacts of various diets differ, and some consumers have little choice; however, in high-income countries, education and the availability of alternatives facilitate food footprint reduction. To date, efforts to reduce meat consumption (e.g., Meatless Monday; Laestadius et al., 2013) have not delivered significant behavioural change (Tapsell, 2017). Many people in Western countries continue to over-consume animal-sourced products and under-consume plant-based products (Australian Bureau of Statistics, 2018; WHO, 2019). The impact of dietary shifts is therefore determined both by the sustainability benefits of the target diet, and its level of adoption; both must be aligned to promote the most beneficial, sustainable outcome.

Changing dietary patterns is challenging, and research into reducing consumption of animal-sourced products has identified an extensive list of barriers, including strong cultural and social norms, perception that vegetarian meals are bland, and lack of skill in cooking meat-free meals (Dibb and Fitzpatrick, 2014; Joy, 2011; Malek et al., 2019; Stoll-Kleemann and Schmidt, 2017). Overcoming these barriers will require effective interventions to encourage behaviour change. In the health sector, behaviour models have been effective in changing specific behaviour patterns (e.g., smoking cessation programs, enhancing healthy eating; Michie et al., 2011). Given that pro-environmental behaviours (i.e., behaviours that minimise harm to the environment) also depend on human behaviour patterns, it is appropriate to apply behaviour models in this context to identify which diet(s) to target for maximal environmental benefit (Steg and Vlek, 2009).

Community-based Social Marketing (CBSM) is one model that has been widely used to identify and promote pro-environmental behaviours that support behaviour change (McKenzie-Mohr, 2011). Using a 5-step strategy, CBSM identifies and assesses target behaviours (Step 1), followed by identifying barriers to and benefits of these target behaviours (Step 2), developing interventional strategies (Step 3), conducting a pilot study (Step 4), and broad-scale implementation and evaluation of the strategy (Step 5). This model has been used across various contexts, including pro-environmental palm oil behaviours (Sundaraja et al., 2020), energy behaviour (Frantz et al., 2016), and wild dog management (Hine et al., 2020; Please et al., 2017).

The current study aims to apply the first step of CBSM to evaluate the impact associated with five plant-rich diets (flexitarian/semi-vegetarian, vegetarian, vegan, Mediterranean, and pescatarian) to identify which diet can be promoted in future intervention(s) to deliver the greatest net benefit.

3. Methods

3.1. Community-based Social Marketing (CBSM)

To determine which behaviours to target, CBSM uses a Behaviour Prioritization Matrix (BPM) with three components: 1) calculating how effective each proposed behaviour will be in solving the problem; 2) determining the proportion of the target population already engaged in each behaviour (i.e., penetration); and 3) calculating the likelihood

that the target population will adopt the behaviour (i.e., probability). One of two methods can reveal the effectiveness of possible behaviours, with the first and preferred method being to rate behaviours based on available quantitative information (e.g., emissions reductions associated with washing clothes in cold, rather than hot, water). If reliable information is unavailable, experts can be enlisted to rate the estimated effectiveness of behaviours (as used in Sundaraja et al., 2020). The next two steps—assessing penetration and probability—are critical to ensure the behaviour is not already widely practiced (and thus any efforts to increase the target behaviour would have little net benefit due to ceiling effects) and that people are willing to engage in the behaviour. To rank the behaviours, a total weighted impact score is calculated for each target behaviour by multiplying the effectiveness score by inversed penetration by the probability score, where inversed penetration is the maximum possible penetration minus observed penetration (McKenzie-Mohr, 2011).

Using this BPM formula, the current study evaluated the flexitarian/semi-vegetarian, vegetarian, vegan, Mediterranean, and pescatarian diets (see Table 1). The BPM incorporated the environmental, health, and animal welfare impacts, as well as penetration and probability (as described above). To obtain quantitative data on 'effectiveness', a review of the peer-reviewed literature was conducted to determine the impact of each plant-rich diet on the environment, health, and animal welfare. This was followed by an assessment of penetration and probability among survey participants who were representative of the Australian population. Results from the review and survey were included in the BPM to calculate a total weighted impact score for each diet. The process undertaken is outlined below.

3.2. Environmental, health, and animal welfare impact

A review of the literature was conducted to obtain environmental, health, and animal welfare impact data for each of the five plant-rich diets, in line with CBSM methodology. Three environmental indicators (GHG emissions, water, and land use), two human health metrics (deaths averted and reduction in mortality risk), and three animal welfare measures (animal life years suffered, ALYS; animal loss, AL; and morally adjusted animal lives; MAL) were used for the impact score calculations. Selection of these indicators was based on data available in the literature. An outline of the process undertaken for each impact category is provided below, including study selection and exclusion criteria.

3.2.1. Environmental impact

Searches in Science Direct and ProQuest were conducted using the terms 'greenhouse gas' OR 'land use' OR 'water use' OR 'sustainable diets' AND 'Mediterranean' OR 'vegan' OR 'vegetarian' OR 'pescatarian' OR 'flexitarian' OR 'semi-vegetarian.' A follow-up search of Google Scholar was also conducted using the same search terms. Given the large number of search results, variability in methodology and design (i.e., life cycle assessments of dietary patterns), and that no single study assessed all target diets, a search of review articles was conducted using the terms 'systematic review' OR 'review.' Recognising the benefits of life cycle assessment (LCA; Finnveden et al., 2009; ISO 14040 International Standard, 2006) in evaluating the full environmental impacts of alternative diets, two articles that reviewed relevant LCA studies were selected as the basis of the environmental impact analyses, the first being a systematic review of environmental footprint studies of sustainable diets published from 2000 to 2016 (Aleksandrowicz et al., 2016) and the second, a review of LCA studies comparing alternative diets published between 2017 and 2019 (Batlle-Bayer et al., 2020). Together these articles reviewed an extensive range of relevant literature spanning more than 20 years, reporting quantified changes (i.e., percentage difference in the target environmental variables) between average population-level dietary intake and the five dietary patterns, providing data to distinguish between low/medium/high income

Table 1
Diet definitions and common food types.

Diet	Definition	Common Food Types	
Omnivore (Goldstein et al., 2016; Springmann et al., 2018; Turner-McGrievy et al., 2017)	Meat (beef, pork, lamb, poultry, fish, seafood) and other animal-based foods (dairy, eggs) one or more times per day; plant-based foods (fruits, vegetables, cereals, legumes, and nuts)	Red meat (beef, pork, lamb) Poultry Fish Seafood	Milk Cheese Potato Eggs Wheat flour Rice
Mediterranean (Bach-Faig et al., 2011; Ulaszewska et al., 2017)	No processed meat; small amounts of red meat (beef, lamb, pork; one serving per week); moderate amounts of fish, seafood, poultry, eggs and dairy (2–3 servings per week); plant-based foods (fruits, vegetables, whole grains, legumes, nuts, and olive oil)	Poultry Fish Seafood Eggs Cheese	Milk Rice Wheat flour Potato Legumes
Flexitarian/semi-vegetarian (Derbyshire, 2017; Hudders and de Backer, 2014; Springmann et al., 2018)	At least three meat-free days per week; no processed meat; small amounts of red meat (beef, lamb, pork; one serving per week); moderate amounts of fish, seafood, poultry, eggs and dairy (2–3 servings per week); plant-based foods (fruits, vegetables, cereals, legumes, and nuts)	Poultry Fish Wheat flour Rice Cheese	Eggs Milk Potato Legumes
Pescatarian (Chen et al., 2019; Springmann et al., 2018)	No red meat (beef, pork, lamb) or poultry; fish, seafood, other animal-based foods (dairy, eggs); plant-based foods (fruits, vegetables, cereals, legumes, and nuts)	Fish Seafood Wheat flour Rice Cheese	Eggs Milk Potato Legumes
Vegetarian (Craig et al., 2009; Springmann et al., 2018)	No meat (beef, lamb, pork, poultry, fish, seafood); animal-based foods (dairy, eggs); plant-based foods (fruits, vegetables, cereals, legumes, and nuts)	Milk Cheese Wheat flour Rice Potato	Eggs Legumes Tofu Soy Beverage
Vegan (Craig et al., 2009; Springmann et al., 2018)	No meat or other animal-based food (beef, pork, lamb, poultry, fish, seafood, dairy, eggs) Plant-based foods (fruits, vegetables, cereals, legumes, and nuts)	Wheat flour Rice Potato Legumes Tofu	Soy Beverage

countries, and assessing the three key environmental indicators. Cross-checking between the original search and articles reviewed in the two articles was also conducted.

Data from only high-income countries (based on The World Bank, 2021 classifications) were included in the impact assessment. This decision was made due to the current study being conducted in a high-income country (Australia) and because the environmental impacts of adopting a diet lower in animal-sourced products differ between high- and low/medium-income countries, with greater benefits reported for high-income countries (Springmann et al., 2018). Diets termed 'meat partially replaced by plant-based food' (per Aleksandrowicz et al., 2016) were classed as flexitarian/semi-vegetarian diets. Percentage differences in the environmental variable (from the studies that met the above criteria) were used to calculate a score out of 10 on each environmental indicator for the target diets. Due to wide variation in the percentage differences among studies, the median was used to enhance internal consistency (per Aleksandrowicz et al., 2016 methodology).

3.2.2. Health impact

Searches in Science Direct and ProQuest were conducted using the terms 'health' OR 'nutrient' AND 'sustainable diets' AND 'Mediterranean' OR 'vegan' OR 'vegetarian' OR 'pescatarian' OR 'flexitarian' OR 'semi-vegetarian.' Several articles from the environmental search also reported health assessments, and thus were also assessed for eligibility. As no single study assessed all the target diets on the basis of deaths averted and all-cause mortality, studies with quantifiable changes in deaths averted and/or all-cause mortality between average population-level dietary intake and the target diets were included in the current calculations (Aleksandrowicz et al., 2016). Total scores were calculated using the median, for internal consistency, due to variability between studies. Only high-income countries were included in the analysis, as per the environmental impact methodology. Furthermore, health impacts also differ between low-, medium-, and high-income countries, with greater benefits accruing when high-income countries adopt plant-rich diets (Springmann et al., 2018).

3.2.3. Animal welfare impact

The animal welfare assessment framework developed by Scherer et al. (2018) was used to calculate the estimated animal welfare impact scores for each target diet. Specifically, the ALYS, AL, and MAL scores from Scherer et al. (2019) were used. These scores were adopted as this study was the only study to date to apply this framework to the dietary guidelines of 37 countries. The researchers calculated country-level per capita ALYS, AL, and MAL for seven animal-sourced food categories (milk, eggs, seafood, poultry, pork, beef, and other meat) using each country's baseline daily diet (obtained from The Food and Agriculture Organization [FAO] of the United Nations) and conditions during farm life including transport and processing stressors (obtained from EXIOBASE v.3.4, a multi-regional input-output database that incorporates a national level animal welfare component based on Scherer et al., 2018 framework). In the current study, the averages of the country level ALYS, AL, and MAL scores for the 28 high-income countries (based on The World Bank, 2021 classifications) were calculated and divided by each country's average consumption levels (of the seven animal categories reported above) to obtain the high-income country per capita ALYS, AL, and MAL scores. These results formed the omnivore ALYS, AL, and MAL scores. The decision to focus only on high-income countries was driven by the need to maintain consistency with the environmental and health impact inclusion criteria. Furthermore, livestock production systems and regulations tend to differ substantially between high- and low-income countries (Gerber et al., 2015), so welfare issues are likely to also differ. The calculated omnivore ALYS, AL, and MAL scores (per above) were converted and then applied to the daily animal consumption levels of four target diets (excluding the vegan diet due to its complete exclusion of animal products). To determine the quantity (grams/day) of animal products in each target diet, studies that had a breakdown of diet composition, from the environmental and health assessment, were used. To support consistency and comparability, all diets were scaled to 2300 cal/day—the upper level of average daily caloric intake for individual energy requirements (Springmann et al., 2016). For internal consistency in the face of variability among studies, the median was used to compute total scores for each target diet. An overall animal welfare loss score (i.e., combined ALYS, AL, and MAL) was calculated for each diet on a scale of 0–1, with 1 representing the greatest animal welfare concerns. In line with the absence of animal products, the vegan diet scored zero on this scale.

3.2.4. Environmental, health, and animal welfare impact scores

The environmental and health scores (i.e., median) and overall animal welfare loss score were converted to a 10-point impact (effectiveness) scale (1 = no effect; 10 = high effectiveness) and used in the BPM calculation. As there were three environmental impact scores (GHG emissions, water, and land use), the overall environmental impact scores for each target diet were calculated using the average of the median scores for each environmental indicator.

3.3. Penetration and probability survey

A pilot study was conducted first to assess the diet definitions and understanding of the survey questions prior to administering the survey to a larger, more representative sample from the community. The pilot sample comprised 131 first year psychology students at a university specialising in distance education located in rural Australia (100 women, 30 men, 1 gender unspecified). Participants were first-year psychology students who self-selected to participate and received research participation credit for completing the survey. Ages ranged from 18 to 58 years, with a mean of 34.63 (SD = 9.31). Most respondents reported consuming an omnivore diet over the preceding week, consistent with other research on Australian dietary behaviours (Malek et al., 2019). We interpret this alignment to indicate that participants understood and were able to differentiate between the diet definitions.

3.3.1. Participants and procedure

Participants (n = 253) for the community online survey were recruited by an online panel provider and survey administrator, Qualtrics™ (2020). Sample size was determined based on similar studies, ranging from 150 and 300 participants (Kneebone et al., 2017; Please et al., 2017; Sundaraja et al., 2020). Quota sampling was applied for gender to enhance representation, and participants who were below 18 years of age and/or provided partial responses were screened out. A soft launch with 43 participants was conducted and the median time to complete was calculated. Participants who completed the survey in less than half the median time (less than 120 s) were automatically screened out. Participants completed the survey after providing informed consent. Ethics approval was received from the Human Research Ethics Committee of the University of New England (Approval No. HE19-254). Most participants (92.5%) had completed Grade 12 and/or tertiary and trade qualifications, with 60.1% stating they earned an income less than AUD80,000 (35.2% reporting greater than $80,000 and 4.7% preferring not to say). Gender, age, income, and education were nationally representative of the Australian population (Australian Bureau of Statistics, 2017). Couples with children (29.2%) represented the most common household type, followed by couples (26.5%), single households (17.8%), share houses (11.5%), single parents with children (8.3%), and extended family living situations (children, parents, grandparents; 6.7%).

3.3.2. Measures

A quantitative research design was used to assess existing penetration levels for each diet and the likelihood of adoption (i.e., probability). Specifically, participants were presented with definitions of each of the diets - omnivore, Mediterranean, pescatarian, vegan, flexitarian/semi-

vegetarian, or vegetarian (see Supplementary data for a copy of the survey) and asked to select which diet best represented what they had eaten over the past week. The likelihood of adopting each diet was assessed by asking participants how likely they were to follow each diet in the future, using an 11-point scale, where 0 = not at all likely, and 10 = extremely likely (Sundaraja et al., 2020). Diets were presented in a randomised order throughout the survey.

3.3.3. Statistics

Descriptive statistics and the average probability and penetration scores were calculated for each target diet. The effectiveness rate of each target diet (calculated in the review) and the survey results (penetration and probability) were applied in the BPM calculation, using the formula presented above.

4. Results

4.1. Environmental, health, and animal welfare impact results

The environmental impact calculation (based on Aleksandrowicz et al., 2016; Batlle-Bayer et al., 2020) included 31 studies for the GHG emissions impact assessment, 14 studies for the land-use impact assessment, and 13 studies for the water-use impact assessment (see Supplementary data for list of individual articles). Compared with the baseline omnivore diet, all diets had lower GHG emissions (median −11% to −48%) and land-use (−10% to −44%), with the vegan diet having the greatest median reduction. All diets used less water than the baseline omnivore diet (−6% to −37%), with the exception of the vegan diet (+1.5%).

For health impacts, six studies (Biesbroek et al., 2014; Mitrou et al., 2007; Orlich et al., 2013; Sabate et al., 2015; Soret et al., 2014; Springmann et al., 2018) were included in the scores for all-cause mortality and deaths averted, with all diets reducing mortality compared with the baseline omnivore diet (median ranging from −10% to −21%), and the Mediterranean diet having the greatest change (see Supplementary data for list of individual articles).

Six studies (Bryngelsson et al., 2016; Goldstein et al., 2016; Meier and Christen, 2013; Springmann et al., 2018; Ulaszewska et al., 2017; Veeramani et al., 2017) provided a breakdown of animal products (grams/day) and were included in the animal welfare scores. The Mediterranean diet was included in one study, the flexitarian/semi-vegetarian in two studies, and the pescatarian and vegetarian in two and five studies, respectively. Significant variations among studies were observed in the amount of animal products in the same diet (e.g., dairy consumption for the vegetarian diet ranged from 170 to 827 g/day). All diets scored lower (i.e., better) on the combined animal life years suffered, animal loss, and morally adjusted lives score (0–0.36) than the baseline omnivore diet, with the exception of the pescatarian diet (0.63) primarily due to a higher AL score (see Supplementary data for list of individual articles and calculations). Environment, health, and animal welfare impact scores are shown in Table 2.

Table 2
Environment, health, and animal welfare impact calculations for each diet, with higher scores equating to greater benefits.

Metric	Impact scores (1–10)					
	OMN	MED	PESC	FLEX/SV	VEG	VGN
GHG emissions	1.00	3.06	6.81	3.44	7.19	10.00
Land use	1.00	7.55	7.75	3.09	9.59	10.00
Water use	1.35	5.56	5.09	2.75	10.00	1.00
Total environmental effectiveness[a]	1.12	5.39	6.55	3.09	8.93	7.00
Health impact (mortality/deaths averted)	1.00	10.00	9.14	5.29	6.36	9.23
Animal welfare impact	2.12	4.86	1.00	6.64	9.14	10.00
Total effectiveness (environmental, health, animal welfare)	1.41	6.75	5.56	5.01	8.14	8.74

Notes: OMN = Omnivore; MED = Mediterranean; PESC = pescatarian; FLEX/SV = flexitarian/semi-vegetarian; VEG = vegetarian; VGN = vegan.
[a] Average of GHG emissions, land use, and water use impact scores.

4.2. Penetration and probability survey

The survey revealed that 70.8% of participants reported consuming an omnivore diet over the past week, followed by flexitarian/semi-vegetarian (14.2%), Mediterranean (5.5%), pescatarian (4.3%), vegetarian (3.6%), and vegan (1.6%) diets. The Mediterranean diet had the highest probability of adoption in the future, rating 5.63 on a scale from 0 to 10, followed by the flexitarian/semi-vegetarian (4.93), pescatarian (3.64), vegetarian (3.14), and vegan (2.63) diets (see Fig. 1; see Supplementary data for participant characteristics).

4.3. Behaviour Prioritization Matrix (BPM)

Results from the impact assessment and survey (penetration and probability) were applied in the BPM to obtain a total weighted impact score (see Table 3). Based on the BPM, the Mediterranean diet emerged as the diet with most overall beneficial impact, followed by the vegetarian diet. While the Mediterranean diet had the third greatest total weighted impact score, it had the highest probability of adoption. In contrast, the vegan diet had the greatest total weighted impact score, but the lowest probability of adoption. The diet rated the least beneficial was the pescatarian diet, with both moderate effectiveness and probability scores.

5. Discussion

The overall aim of the current study was to assess common diets on three major dimensions (environmental, human health, and animal welfare), existing penetration, and probability of future adoption to rank their overall merit in anticipated behaviour change initiatives. Despite the Mediterranean diet being only moderately effective in reducing environmental/heath/animal-welfare impacts (relative to the standard omnivore diet), it had the highest overall weighted impact score, largely by virtue of its relatively high probability of adoption. Notably, the sustainable diets with the greatest health, environmental, and animal welfare benefits (e.g., vegan and vegetarian) had the lowest probability of adoption. This result is not surprising, given that most participants identified as meat-eaters, in alignment with previous research assessing meat consumption in Australia (Malek et al., 2019). Further, only 29% of participants reported consuming one of the sustainable diets, thus confirming the need to target the reduction of meat consumption in Australia.

For most Australians, the Mediterranean diet represents a smaller shift in dietary patterns. Despite this diet having only a moderate impact

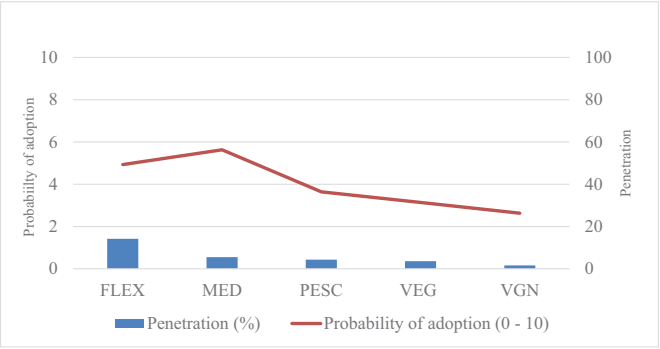

Fig. 1. Penetration and probability of adopting five plant-rich diets.
Notes: MED = Mediterranean; PESC = pescatarian; FLEX/SV = flexitarian/semi-vegetarian; VEG = vegetarian; VGN = vegan.

Table 3
Behaviour Prioritization Matrix (BPM).

Plant-rich diets	Impact scores	Community online survey		Total weighted impact
	Environmental, health, animal welfare benefits (1–10)	Inversed penetration (0–1)	Probability score (0–10)	
Mediterranean	6.75	0.94	5.63	35.90
Vegetarian	8.14	0.96	3.14	24.54
Vegan	8.74	0.98	2.63	22.53
Flexitarian/Semi-vegetarian	5.01	0.86	4.93	21.24
Pescatarian	5.56	0.96	3.64	19.43

Notes: Sample size = 253; higher total weighted impact = greater benefits.

assessment result, its appeal of requiring only a relatively small shift in eating habits from our participants' typical diet suggests that it is more likely to be adopted, and therefore more likely to make a sustained difference (Park and Barker, 2020). In contrast, a vegan diet requires greater dietary shifts with the exclusion of all animal-sourced products and the addition of fortified foods and/or supplements to ensure adequate nutrition. Such a significant shift in dietary patterns in countries with a long history of eating animal-sourced products appears less feasible for most of the population and therefore less impactful from an intervention perspective (van Dooren et al., 2014).

Assessing the overall effectiveness of each sustainable diet highlights the importance of evaluating diets through a holistic lens. While the vegan diet provided the highest environmental benefits on the GHG emissions and land-use scales, it performed worse than the baseline omnivore diet on water-use. This result is due to foods common in a vegan diet (e.g., legumes, vegetables, fruit, and nuts) demanding high levels of irrigation (Meier and Christen, 2013; Springmann et al., 2018).

Large variations in water-use were found between the studies (from 107% increase to 22% decrease, with median 1.5% increase), partly due to differences in the reference diet between countries, but also due to use of different metrics to quantify the water footprint of foods (Berger and Finkbeiner, 2013). Nevertheless, the current results highlight the importance of assessing a range of environmental factors to determine the true environmental impacts of different sustainable diets and effectively support the development of behaviour change interventions.

The pescatarian diet performed the poorest on the animal welfare assessment, having a lower score than the baseline omnivore diet due to a high animal loss (AL) score. This result is consistent with Scherer et al. (2019), who reported that high seafood intake countries, such as China, Norway, and Japan, generated notably high animal welfare concerns due to high AL. While this is a new framework that has been applied to only one life cycle assessment (Scherer et al., 2019), these results further highlight the importance of applying a holistic approach when assessing the effectiveness of sustainable diets to promote dietary change. There may not be any reasonable “one size fits all” approach in this context, given the variation in typical diets cross-culturally, and the differences in worldview between individuals and societies with respect to welfare of fish in comparison with other livestock (Röcklinsberg, 2015).

The Mediterranean diet had the greatest human health benefits (i.e., deaths averted and reduction in mortality risk), followed closely by the vegan and pescatarian diets. These results are generally consistent with past research showing the Mediterranean diet to have better health outcomes than the other sustainable diets (e.g., van Dooren et al., 2014). Furthermore, the Mediterranean diet is often recommended by health professionals (e.g., British Heart Foundation, 2022; The Royal Australian College of General Practitioners, 2014).

5.1. Implications for interventions

To the authors' knowledge, this is the first study to assess the impact of a variety of sustainable diets on all three major relevant dimensions - environment, human health, and animal welfare *together with* existing human behaviour assessments of current (penetration) and future (likelihood of adoption) consumption patterns. Assessing impacts and adoption together enables policymakers and researchers to make informed decisions on which sustainable diets to target for interventions aimed at reducing the consumption of animal-sourced products. Further, using a behaviour model enhances the likelihood of successfully shifting peoples' dietary behaviours. Clearly, less restrictive diets, such as the Mediterranean diet, are more agreeable to people in high-income countries and should be the focus of interventions in Australia and other similarly high-income, high meat consumption countries. Despite this, life cycle assessments have often focused on elimination diets such as vegan and vegetarian diets, though the inclusion of other sustainable diets in life cycle assessments is increasing (e.g., Chen et al., 2019; Kim et al., 2020; Springmann et al., 2018; van Dooren et al., 2014). The flexitarian/semi-vegetarian diet is one that may benefit from additional life cycle assessment research, given its high probability of adoption as revealed in the current study. While it was the least effective of the sustainable diets, this in part may have been due to the varied definitions and therefore dietary compositions in the literature, resulting in a range of effectiveness results.

Given the urgent changes needed to our food systems to address agriculture's contributions to climate change and environmental degradation, it is important that these shifts occur sooner rather than later, particularly in high-income countries (IPCC, 2019). Thus, the focus should be not only on the effectiveness of different diets, but on the willingness of consumers to shift and maintain these dietary changes, particularly given the challenges learned from the health field around changing eating habits (Van't Riet et al., 2011). Despite the rapid need for shifts in diet preferences, as highlighted above, we recognise that any diet changes will have follow-on effects on local agricultural production, economic, and social systems (Springmann et al., 2018). While beyond the purview of the current study, these factors also need to be considered and addressed to support sustainable food systems.

5.2. Limitations and future directions

It is important to note that extensive variability existed in the literature assessing the effectiveness of each sustainable diet. To minimise the risk of over- or under-reporting, only peer-reviewed review articles were used. The recent publications of these articles and extensive nature of their reviews indicate they present a comprehensive overview of the published literature. Limited health information was available for comparison across all the sustainable diets, which was due, in part, to a range of scales in the literature used to assess health. Specifically, only one health study was used for the Mediterranean health calculation, which contrasts with three or four studies available for the other sustainable diets. Despite limited data, the Mediterranean health benefits in the current study are consistent with past research using other health measures (Chen et al., 2019; Clarys et al., 2014; Rosi et al., 2017; van Dooren et al., 2014).

A further consideration is that farming practices, and their associated environmental and animal welfare impacts, vary between countries. For example, the greenhouse gas emissions from beef and milk production are substantially higher in low- to middle-income regions

than in high-income regions (Harrison et al., 2021). While some of the studies used in our literature review incorporated varied farming practices in their assessments, the studies assessing only one country were specific to that country's farming practices (Rosi et al., 2017; Springmann et al., 2018; Veeramani et al., 2017). To improve consistency, only high-income countries were included in the effectiveness calculations. As such, the environmental, health, and animal welfare impact calculations reported in this study could be applied to other high-income countries. Meat consumption patterns in Australian are also similar to many other high-income countries (FAO, 2021), so the probability and penetration results reported here may be consistent with, and therefore applied to, other high-income countries.

Given the Mediterranean diet was identified as the most beneficial sustainable diet to target, it is recommended that future research further assess drivers and barriers to consuming this diet, through a behaviour model lens. To date, most research in this area has been conducted without the use of an empirically-driven behaviour change model, which is considered essential for developing successful interventions (Michie et al., 2011). Furthermore, research assessing the Mediterranean diet is limited and often focused on 'at-risk' populations (e.g., older adults, high cardiovascular risk; Davis et al., 2015; McEvoy et al., 2018; Zacharia et al., 2020) as distinct from all population groups. The Behaviour Change Wheel (BCW) is a comprehensive behaviour model that could be used to assess the Mediterranean diet in this manner. This model assesses behaviours in terms of capability, opportunity, and motivation, otherwise known as the COM-B, which then informs which of the nine identified intervention functions to apply. The BCW has also been utilised within health and environmental fields to shift behaviours and inform policy makers (McEvoy et al., 2018; Sundaraja et al., 2021).

6. Conclusions

The urgent need to shift to plant-rich diets is now considered a vital strategy in achieving a global sustainable food system and in combating an important driver of climate change. Our findings indicate that, from the diets assessed, the Mediterranean diet has the greatest potential for improving sustainability of high-income country diets, specifically those with high meat intake patterns, based on: (1) its effectiveness in reducing negative environmental, human health, and animal welfare impacts; (2) its relatively low current adoption rates in the population; and (3) its relatively high probability of being adopted by the target population. Our evidence demonstrates the importance of assessing diet effectiveness within a human context to determine not only which diets people should eat, but which diets people are willing to eat. Without these crucial elements, any attempt to change people's dietary patterns is at risk of failure. By using a behaviour prioritization model that combines social, environmental, human health, and animal sciences, a more complete picture emerges, whereby pitfalls and realistic solutions can be identified. Given the urgent need to shift our eating habits, this research delivers the much-needed starting point on the demand-side road map to building a more sustainable food system in high-income countries.

Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2022.05.008.

References

Aleksandrowicz, L., Green, R., Joy, E.J.M., Smith, P., Haines, A., 2016. The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: a systematic review. PLoS ONE 11, e0165797. https://doi.org/10.1371/journal.pone. 0165797.

Alexandratos, N., Bruinsma, J., 2012. World Agriculture Towards 2030/2050: The 2012 Revision. FAO Agricultural Development Economics Division No. 12-03.

Allen, T., Murray, K.A., Zambrana-Torrelio, C., Morse, S.S., Rondinini, C., Di Marco, M., Breit, N., Olival, K.J., Daszak, P., 2017. Global hotspots and correlates of emerging zoonotic diseases. Nat. Commun. 8, 1124. https://doi.org/10.1038/s41467-017-00923-8.

Apostolidis, C., McLeay, F., 2016. Should we stop meating like this? Reducing meat consumption through substitution. Food Policy 65, 74–89. https://doi.org/10.1016/j.foodpol.2016.11.002.

Australian Bureau of Statistics, 2017. 2016 Census QuickStats: Australia. http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/0/. (Accessed 29 July 2020).

Australian Bureau of Statistics, 2018. National Health Survey: First Results, 2017-2018. https://www.abs.gov.au/ausstats/abs@.nsf/mf/4364.0.55.001/. (Accessed 29 July 2020).

Bach-Faig, A., Berry, E.M., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., Medina, F.X., Battino, M., Belahsen, R., Miranda, G., Serra-Majem, L., Mediterranean Diet Foundation Expert Group, 2011. Mediterranean diet pyramid today. Science and cultural updates. Public Health Nutr. 14, 2274–2284. https://doi.org/10.1017/S1368980011002515.

Batlle-Bayer, L., Aldaco, R., Bala, A., Fullana-i-Palmer, P., 2020. Toward sustainable dietary patterns under a water–energy–food nexus life cycle thinking approach. Curr. Opin. Environ. Sci. Health 13, 61–67. https://doi.org/10.1016/j.coesh.2019.11.001.

Beach, R.H., Creason, J., Ohrel, S.B., Ragnauth, S., Ogle, S., Li, C., Ingraham, P., Salas, W., 2015. Global mitigation potential and costs of reducing agricultural non-CO2 greenhouse gas emissions through 2030. J. Integr. Environ. Sci. 12, 87–105. https://doi.org/10.1080/1943815X.2015.1110183.

Beardsworth, A.D., Bryman, A., 2004. Meat consumption and meat avoidance among young people. Br. Food J. 106, 313–327. https://doi.org/10.1108/00070700410529573.

Béné, C., Prager, S.D., Achicanoy, H.A.E., Toro, P.A., Lamotte, L., Bonilla, C., Mapes, B.R., 2019. Global map and indicators of food system sustainability. Sci. Data 6, 279. https://doi.org/10.1038/s41597-019-0301-5.

Berger, M., Finkbeiner, M., 2013. Methodological challenges in volumetric and impact oriented water footprints. J. Ind. Ecol. 17, 79–89. https://doi.org/10.1111/j.1530-9290.2012.00495.x.

Bessei, W., 2006. Welfare of broilers: a review. Worlds Poult. Sci. J. 62, 455–466. https://doi.org/10.1017/S0043933906001085.

Biesbroek, S., 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. https://doi.org/10.1186/1476-069X-13-27.

British Heart Foundation, What is the Mediterranean diet? https://www.bhf.org.uk/informationsupport/heart-matters-magazine/nutrition/mediterranean-diet. (Accessed 11 May 2022)

Bryant, C.J., Barnett, J.C., 2019. What's in a name? Consumer perceptions of in vitro meat under different names. Appetite 137, 104–113. https://doi.org/10.1016/j.appet.2019.02.021.

Bryngelsson, D., Wirsenius, S., Hedenus, F., Sonesson, U., 2016. How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. Food Policy 59, 152–164. https://doi.org/10.1016/j.foodpol.2015.12.012.

Chen, C., Chaudhary, A., Mathys, A., 2019. Dietary change scenarios and implications for environmental, nutrition, human health and economic dimensions of food sustainability. Nutrients 11, 1–21. https://doi.org/10.3390/nu11040856.

Clarys, P., Deliens, T., Huybrechts, I., Deriemaeker, P., Vanaelst, B., De Keyzer, W., Hebbelinck, M., Mullie, P., 2014. Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diet. Nutrients 6, 1318–1332. https://doi.org/10.3390/nu6031318.

Craig, W.J., Mangels, A.R., American Dietetic Association, 2009. Position of the American Dietetic Association: vegetarian diets. J. Am. Diet. Assoc. 109, 1266–1282. https://doi.org/10.1016/j.jada.2009.05.027.

Davis, C.R., Bryan, J., Hodgson, J.M., Wilson, C., Murphy, C.J., 2015. Older Australians can adhere to a traditional Mediterranean style diet over two weeks: a pilot dietary intervention study. BMC Nutr. 1, 28. https://doi.org/10.1186/s40795-015-0021-y.

Dawkins, M.S., Donnelly, C.A., Jones, T.A., 2004. Chicken welfare is influenced more by housing conditions than by stocking density. Nature 427, 342–344. https://doi.org/10.1038/nature02226.

Demeyer, D., Mertens, B., De Smet, S., Ulens, M., 2016. Mechanisms linking colorectal cancer to the consumption of (processed) red meat: a review. Crit. Rev. Food Sci. Nutr. 56, 2747–2766. https://doi.org/10.1080/10408398.2013.873886.

Derbyshire, E.J., 2017. Flexitarian diets and health: a review of the evidence-based literature. Front. Nutr. 3, 1–8. https://doi.org/10.3389/fnut.2016.00055.

Dibb, S., Fitzpatrick, I., 2014. Let's Talk About Meat: Changing Dietary Behavior for the 21st Century, London.

van Dooren, C., Marinussen, M., Blonk, H., Aiking, H., Vellinga, P., 2014. Exploring dietary guidelines based on ecological and nutritional values: a comparison of six dietary patterns. Food Policy 44, 36–46. https://doi.org/10.1016/j.foodpol.2013.11.002.

FAO, 2010. International Scientific Symposium Biodiversity and Sustainable Diets: United Against Hunger, Rome.

FAO, 2017a. The Future of Food and Agriculture – Trends and Challenges. http://www.fao.org/3/a-i6583e.pdf. (Accessed 29 July 2020).

FAO, 2017b. Global Livestock Environmental Assessment Model (GLEAM). http://www.fao.org/gleam/en/. (Accessed 29 July 2020).
FAO, 2021. FAOSTAT. New Food Balances. http://www.fao.org/faostat/en/#data/FBS/. (Accessed 1 August 2021).
Finnveden, G., Hauschild, M.Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., Suh, S., 2009. Recent developments in life cycle assessment. J. Environ. Manag. 91 (1), 1–21. https://doi.org/10.1016/j.jenvman.2009.06.018.
Frantz, C.M., Flynn, B., Atwood, S., Mostow, D., Xu, C., Kahl, S., 2016. Changing energy behavior through community based social marketing. In: Leal Filho, W., Zint, M. (Eds.), The Contribution of Social Sciences to Sustainable Development at Universities. World Sustainability Series. Springer, Cham, pp. 259–272 https://doi.org/10.1007/978-3-319-26866-8_16.
Gerber, P.J., et al., 2013. Tackling Climate Change Through Livestock – A Global Assessment of Emissions and Mitigation Opportunities. FAO. http://www.fao.org/3/a-i3437e.pdf.
Gerber, P.J., Mottet, A., Opio, C.I., Falcucci, A., Teillard, F., 2015. Environmental impacts of beef production: review of challenges and perspectives for durability. Meat Sci. 109, 2–12.
Goldstein, B., Hansen, S.F., Gjerris, M., Laurent, A., Birkved, M., 2016. Ethical aspects of life cycle assessments of diets. Food Policy 59, 139–151. https://doi.org/10.1016/j.foodpol.2016.01.006.
Gregory, N.G., Grandin, T., 2007. Animal Welfare and Meat Production. CABI, UK.
Harrison, M.T., Cullen, B.R., Mayberry, D.E., Cowie, A.L., Bilotto, F., Brabazon Badgery, W., Liu, K., Davison, T., Christie, K.M., Muleke, A., Eckard, R.J., 2021. Carbon myopia: the urgent need for integrated social, economic and environmental action in the livestock sector. Glob. Chang. Biol. https://doi.org/10.1111/gcb.15816.
Harrison, R., 1964. Animal Machines. CABI, Surrey, UK.
Hine, D.W., McLeod, L.J., Please, P., 2020. Understanding why peri-urban residents do not report wild dog impacts: an audience segmentation approach. Hum. Dimens. Wildl. 1–17. https://doi.org/10.1080/10871209.2020.1735579.
Hudders, L., de Backer, C., 2014. From meatless Mondays to meatless Sundays: motivations for meat reduction among vegetarians and semi-vegetarians who mildly or significantly reduce their meat intake. Ecol. Food Nutr. 53, 639–657. https://doi.org/10.1080/03670244.2014.896797.
IPCC, 2014. Summary for policymakers. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C., Zwickel, T., Minx, J.C. (Eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
IPCC, 2019. Summary for policymakers. In: Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., Malley, J. (Eds.), Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems.
ISO 14040 International Standard, 2006. Environmental Management – Life Cycle Assessment – Principles and Framework. International Organisation for Standardization, Geneva.
Joy, M., 2011. Why We Love Dogs, Eat Pigs and Wear Cows. An Introduction to Carnism Conari Press, San Francisco.
Kim, B.F., Santo, R.E., Scatterday, A.P., Fry, J.P., Synk, C.M., Cebron, S.R., Mekonnen, M.M., Hoekstra, A.Y., de Pee, S., Bloem, M.W., Neff, R.A., Nachman, K.E., 2020. Country-specific dietary shifts to mitigate climate and water crises. Global Environ. Chang. 62, 101926. https://doi.org/10.1016/j.gloenvcha.2019.05.010.
Kivits, T., Broers, H.P., Beeltje, H., van Vliet, M., Griffioen, J., 2018. Presence and fate of veterinary antibiotics in age-dated groundwater in areas with intensive livestock farming. Environ. Pollut. 241, 988–998. https://doi.org/10.1016/j.envpol.2018.05.085.
Kneebone, S., Smith, L., Fielding, K., 2017. The impact-likelihood matrix: a policy tool for behaviour prioritisation. Environ. Sci. Policy 70, 9–20. https://doi.org/10.1016/j.envsci.2016.11.013.
Laestadius, L.I., Neff, R., Barry, C.L., Frattaroli, S., 2013. Meat consumption and climate change: the role of non-governmental organizations. Clim. Chang. 120, 25–38. https://doi.org/10.1007/s10584-013-0807-3.
Li, Y., et al., 2018. Impact of healthy lifestyle factors on life expectancies in the US population. Circulation 138, 345–355. https://doi.org/10.1161/circulationaha.117.032047.
Malek, L., Umbergera, W.J., Goddard, E., 2019. Committed vs. Uncommitted meat eaters: understanding willingness to change protein consumption. Appetite 138, 115–126. https://doi.org/10.1016/j.appet.2019.03.
Martinez-Gonzalez, A.M., Martín-Calvo, N., 2016. Mediterranean diet and life expectancy; beyond olive oil, fruits and vegetables. Curr. Opin. Clin. 19, 401–407. https://doi.org/10.1097/MCO.0000000000000316.
McEvoy, C.T., Moore, S.E., Appleton, K.M., Cupples, M.E., Erwin, C., Kee, F., Prior, L., Young, I.S., McKinley, M.C., Woodside, J.V., 2018. Development of a peer support intervention to encourage dietary behaviour change towards a Mediterranean diet in adults at high cardiovascular risk. BMC Public Health 18 (1), 1194. https://doi.org/10.1186/s12889-018-6108-z. PMID: 30348137; PMCID: PMC6198381.
McKenzie-Mohr, D., 2011. Fostering Sustainable Behaviour: An Introduction to Community-based Social Marketing. third ed. New Society Publishers, Canada.
Meier, T., Christen, O., 2013. Environmental impacts of dietary recommendations and dietary styles: Germany as an example. Environ. Sci. Technol. 47, 877–888. https://doi.org/10.1021/es302152v.
Micha, R., Wallace, S.K., Mozaffarian, D., 2010. Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: a systematic review and meta-analysis. Circulation 121, 2271–2283. https://doi.org/10.1161/circulationaha.109.924977.
Michie, S., Van Stralen, M.M., West, R., 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement. Sci. 6, 42. https://doi.org/10.1186/1748-5908-6-42.
Mitrou, P.N., et al., 2007. A Mediterranean dietary pattern and prediction of all-cause mortality in a US population: results from the NIH-AARP diet and health study. Arch. Intern. Med. 167, 2461–2468. https://doi.org/10.1001/archinte.167.22.2461.
National Health and Medical Research Council, 2013. Australian Dietary Guidelines, Canberra.
Nelson, M.E., Hamm, M.W., Hu, F.B., Abrams, S.A., Griffin, T.S., 2016. Alignment of healthy dietary patterns and environmental sustainability: a systematic review. Adv. Nutr. 7, 1005–1025. https://doi.org/10.3945/an.116.012567.
OECD/FAO, 2019. OECD-FAO Agricultural Outlook 2019-2028. Paris/Food and Agriculture Organization of the United Nations, Rome.
Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B., Steinfeld, H., 2013. Greenhouse gas emissions from ruminant supply chains – a global life cycle assessment. Food and Agriculture Organization of the United Nations, Rome.
Orlich, M.J., et al., 2013. Vegetarian dietary patterns and mortality in adventist health study 2. JAMA Intern. Med. 173, 1230–1238. https://doi.org/10.1001/jamainternmed.2013.6473.
Pan, A., et al., 2011. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. Am. J. Clin. Nutr. 94, 1088–1096. https://doi.org/10.3945/ajcn.111.018978.
Park, R.M., Foster, M., Daigle, C.L., 2020. A scoping review: the impact of housing systems and environmental features on beef cattle welfare. Animals 10, 565. https://doi.org/10.3390/ani10040565.
Park, T., Barker, J., 2020. A menu for change. The Behavioural Insights Team, London.
Peden, R., Turner, S., Boyle, L., Camerlink, I., 2018. The translation of animal welfare research into practice: the case of mixing aggression between pigs. Appl. Anim. Behav. Sci. 9, 1–9. https://doi.org/10.1016/j.applanim.2018.03.003.
Please, P.M., Hine, D.W., Skoien, P., Phillips, K.L., Jamieson, I., 2017. Prioritizing community behaviors to improve wild dog management in peri-urban areas. Hum. Dimens. Wildl. 23, 39–53. https://doi.org/10.1080/10871209.2017.1385877.
Poore, J., Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. Science 360, 987–992. https://doi.org/10.1126/science.aaq0216.
Public Health England, 2018. The Eatwell Guide. https://www.nhs.uk/live-well/eat-well/the-eatwell-guide/. (Accessed 29 July 2020).
Röcklinsberg, H., 2015. Fish consumption: choices in the intersection of public concern, fish welfare, food security, human health and climate change. J. Agric. Environ. Ethics 28, 533–551. https://doi.org/10.1007/s10806-014-9506-y.
Rosi, A., Mena, P., Pellegrini, N., Turroni, S., Neviani, E., Ferrocino, I., Di Cagno, R., Ruini, L., Ciati, R., Angelino, D., Maddock, J., Gobbetti, M., Brighenti, F., Del Rio, D., Scazzina, F., 2017. Environmental impact of and vegan of omnivorous, ovo-lacto-vegetarian, and vegan diet. Sci. Rep. 7, 6105. https://doi.org/10.1038/s41598-017-06466-8.
Sabate, J., Harwatt, H., Soret, S., 2015. Health outcomes and greenhouse gas emissions from varied dietary patterns - is there a relationship? Ann. Nutr. Metab. 67, 547–548.
Sadhukhan, J., Dugmore, T.I.J., Matharu, A., Martinez-Hernandez, E., Aburto, J., Rahman, P.K.S.M., Lynch, J., 2020. Perspectives on "game changer" global challenges for sustainable 21st century: plant-based diet, unavoidable food waste biorefining, and circular economy. Sustainability 12, 1976. https://doi.org/10.3390/su12051976.
Scherer, L., Tomasik, B., Rueda, O., Pfister, S., 2018. Framework for integrating animal welfare into life cycle sustainability assessment. Int. J. Life Cycle Assess. 23, 1476–1490. https://doi.org/10.1007/s11367-017-1420-x.
Scherer, L., Behrens, P., Tukker, A., 2019. Opportunity for a dietary win-win-win in nutrition, environment, and animal welfare. One Earth 1, 349–360. https://doi.org/10.1016/j.oneear.2019.10.020.
Soret, S., et al., 2014. Climate change mitigation and health effects of varied dietary patterns in real-life settings throughout North America. Am. J. Clin. Nutr. 100, 490S–495S. https://doi.org/10.3945/ajcn.113.071589.
Springmann, M., Godfray, H.C.J., Rayner, M., Scarborough, P., 2016. Analysis and valuation of the health and climate change cobenefits of dietary change. Proc. Natl. Acad. Sci. U. S. A. 113, 4146–4151. https://doi.org/10.1073/pnas.1523119113.
Springmann, M., Wiebe, K., Mason-D'Croz, D., Sulser, T.B., Rayner, M., Scarborough, P., 2018. Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail. Lancet Planet. Health 2, 451–461. https://doi.org/10.1016/S2542-5196(18)30206-7.
Steg, L., Vlek, C., 2009. Encouraging pro-environmental behavior: an integrative review and research agenda. J. Environ. Psychol. 29 (3), 309–317. https://doi.org/10.1016/j.jenvp.2008.10.004.
Stoll-Kleemann, S., Schmidt, U.J., 2017. Reducing meat consumption in developed and transition countries to counter climate change and biodiversity loss: a review of influence factors. Reg. Environ. Chang. 17, 1261–1277. https://doi.org/10.1007/s10113-016-1057-5.
Sundaraja, C., Hine, D.W., Lykins, A.D., 2021. Palm oil: understanding barriers to sustainable consumption. PLoS ONE 16, e0254897. https://doi.org/10.1371/journal.pone.0254897.
Sundaraja, C.S., Hine, D.W., Lykins, A., 2020. Confronting the palm oil crisis: identifying behaviors for targeted interventions. Environ. Sci. Policy 103, 99–106. https://doi.org/10.1016/j.envsci.2019.08.004.
Tapsell, L.C., 2017. Dietary behaviour changes to improve nutritional quality and health outcomes. Chron. Dis. Transl. Med. 3, 154–158. https://doi.org/10.1016/j.cdtm.2017.06.005.
The Royal Australian College of General Practitioners, 2014. Mediterranean Diet for Reducing Cardiovascular Disease Risk. https://www.racgp.org.au/clinical-resources/

clinical-guidelines/handi/handi-interventions/nutrition/mediterranean-diet-for-reducing-cardiovascular-dis/. (Accessed 29 July 2020).
The World Bank, 2021. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519. (Accessed 26 August 2021).
Thompson, P., 2015. From Field to Fork: Food Ethics for Everyone. Oxford University Press, New York.
Trichopoulou, A., Vasilopoulou, E., 2000. Mediterranean diet and longevity. Br. J. Nutr. 84, 205–209. https://doi.org/10.1079/09658219738855.
Turner-McGrievy, G., Mandes, T., Crimarco, A., 2017. A plant-based diet for overweight and obesity prevention and treatment. J. Geriatr. Cardiol. 14, 369–374. https://doi.org/10.11909/j.issn.1671-5411.2017.05.002.
Ulaszewska, M.M., Luzzani, G., Pignatelli, S., Capri, E., 2017. Assessment of diet-related GHG emissions using the environmental hourglass approach for the Mediterranean and new nordic diets. Sci. Total Environ. 574, 829–836. https://doi.org/10.1016/j.scitotenv.2016.09.039.
Van't Riet, J., Sijtsema, S., Dagevos, H., Bruijn, G., 2011. The importance of habits in eating behavior. An overview and recommendations for future research. Appetite 57 (3), 585–596. https://doi.org/10.1016/j.appet.2011.07.010.
Veeramani, A., Dias, G.M., Kirkpatrick, S.I., 2017. Carbon footprint of dietary patterns in Ontario, Canada: a case study based on actual food consumption. J. Clean. Prod. 162, 1398–1406. https://doi.org/10.1016/j.jclepro.2017.06.025.
Westhoek, H., Rood, T., van den Berg, M., Janse, J., Nijdam, D., Reudink, M., Stehfest, E., 2011. The Protein Puzzle: The Consumption and Production of Meat, Dairy and Fish in the European Union. PBL Netherlands Environmental Assessment Agency, The Hague.
WHO, 2019. Increasing Fruit and Vegetable Consumption to Reduce the Risk of Noncommunicable Diseases. https://www.who.int/elena/titles/fruit_vegetables_ncds/en/. (Accessed 29 July 2020).
Zacharia, K., Patterson, A.J., English, C., MacDonald-Wicks, L., 2020. Feasibility of the Ausmed diet program: translating the Mediterranean diet for older Australians. Nutrients 12, 1044. https://doi.org/10.3390/nu12041044.