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Harnessing the power on our plates: sustainable dietary patterns for public and planetary health

Jayne V. Woodside[1,2]*, Leona Lindberg[1,2] and Anne P. Nugent[2,3]
[1]*Centre for Public Health, School of Medicine, Dentistry and Biomedical Sciences, Queen's University Belfast, Belfast BT12 6BJ, UK*
[2]*Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, Belfast, UK*
[3]*Institute of Food and Health, School of Agriculture and Food Science, University College Dublin, Dublin, Ireland*

Globally, diet quality is poor, with populations failing to achieve national dietary guidelines. Such failure has been consistently linked with malnutrition and poorer health outcomes. In addition to the impact of diet on health outcomes, it is now accepted that what we eat, and the resulting food system, has significant environmental or planetary health impacts. Changes are required to our food systems to reduce these impacts and mitigate the impact of climate change on our food supply. Given the complexity of the interactions between climate change, food and health, and the different actors and drivers that influence these, a systems-thinking approach to capture such complexity is essential. Such an approach will help address the challenges set by the UN 2030 Agenda for sustainable development in the form of the sustainable development goals (SDG). Progress against SDG has been challenging, with an ultimate target of 2030. While the scientific uncertainties regarding diet and public and planetary health need to be addressed, equal attention needs to be paid to the structures and systems, as there is a need for multi-level, coherent and sustained structural interventions and policies across the full food system/supply chain to effect behaviour change. Such systems-level change must always keep nutritional status, including impact on micronutrient status, in mind. However, benefits to both population and environmental health could be expected from achieving dietary behaviour change towards more sustainable diets.

Dietary intake: Non-communicable disease risk: Public health: Planetary health: Sustainable diets: Food systems: Socioeconomic inequalities

Food systems face increasing challenge in terms of the impact the food we eat has on both human and planetary health. Globally, diet quality is poor, with populations failing to adhere to national dietary guidelines[1]. Such failure has been consistently linked with poorer health outcomes[2,3]. Low-quality diets have been estimated to contribute to more than a quarter of deaths globally, mostly from diet-related chronic diseases which usually require

Abbreviations: ASF, animal-source food; FBDG, food-based dietary guidelines; GHGE, greenhouse gas emission; HIC, higher income countries; LMIC, low- and middle-income countries; PBD, plant-based diet; SDG, sustainable development goal.
***Corresponding author:** Jayne V. Woodside, email j.woodside@qub.ac.uk

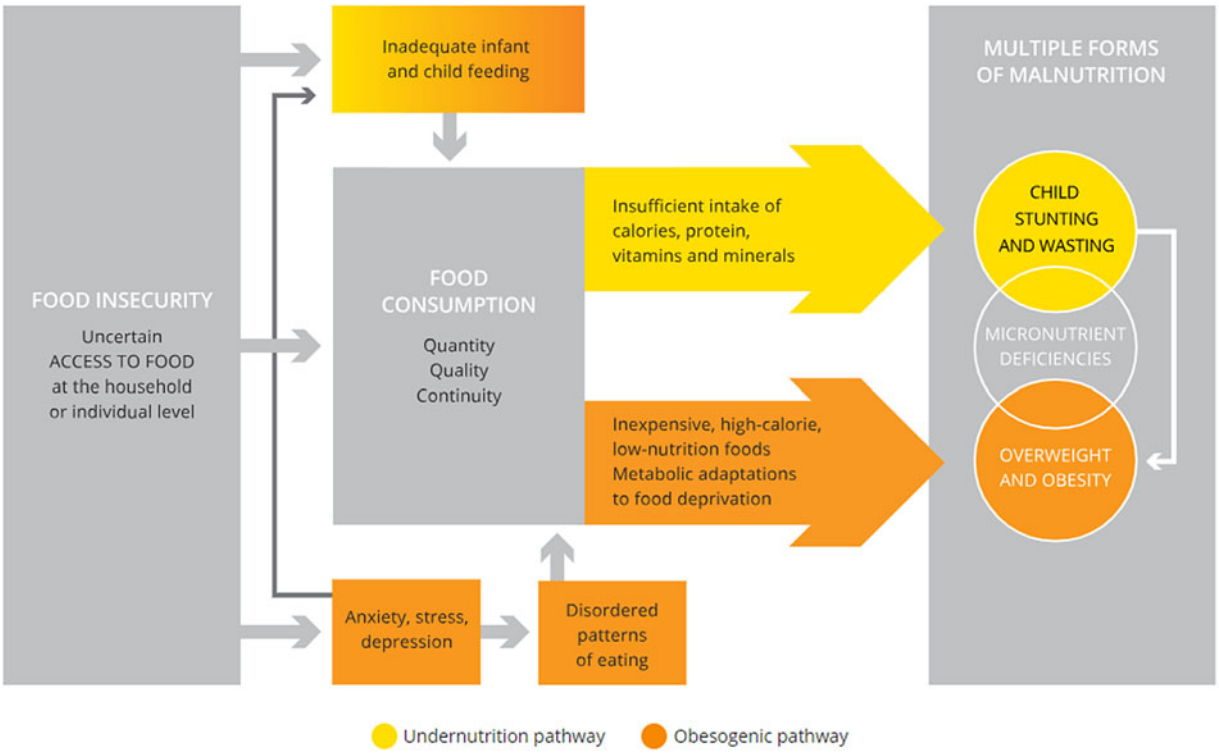

Fig. 1. Pathways from inadequate food access to multiple forms of malnutrition[1].

costly intervention and management[4]. Poor dietary quality is strongly socio-economically patterned, as is health[5].

Low-diet quality can lead to malnutrition. Malnutrition has a broad definition and includes both under and overnutrition – undernutrition includes both acute and chronic malnutrition, with the likelihood of hidden hunger, i.e. specific micronutrient deficiencies, while overnutrition leads to overweight and obesity, with the concurrent presence of micronutrient deficiency also likely[6,7]. Historically, the most widespread form of malnutrition has been undernutrition, including wasting, stunting and micronutrient deficiencies, but that has changed since the 1980s, with overweight and obesity now posing a significant global health problem[8]. Other commonly occurring examples of malnutrition are micronutrient deficiencies, with iron, vitamin A and iodine deficiencies being the most frequently occurring globally[9]. Malnutrition in all its forms, including obesity, undernutrition and micronutrient deficiency, is a leading global cause of poor health[6,7].

When considering health and dietary inequalities it is important to introduce the formal concept of food insecurity. Food security, as defined at the World Food Summit in 1996, exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life[10]. Food insecurity can be described as chronic or transient and there are different levels of severity[10]. Food insecurity is universally sex-patterned – in every region the prevalence of food insecurity is higher among women than men[11], while sex-based discrimination, or the denial of women's rights, is one of the major causes of poverty and food and nutrition insecurity[12]. Women are more vulnerable, both to chronic food and nutrition insecurity and to food insecurity caused by acute events (illness, disasters or food price rises)[13].

The FAO has highlighted likely pathways from inadequate food access to multiple forms of malnutrition, and these are outlined in Fig. 1. Food insecurity can lead to malnutrition through both an undernutrition path and an overnutrition or obesogenic path, with the route to malnutrition outcomes via food consumption influenced by food quantity, quality and continuity.

Global food production, environmental impact and sustainable diets

In addition to the impact of diet on health outcomes, it is increasingly recognised that what we eat, and the resulting food system, has significant environmental or planetary health impacts, and the health effects of climate change has the potential in the near future to considerably compound existing health challenges.

Springmann *et al.*[14] have suggested that, as a result of changes in the population and income levels between 2010 and 2050, effects of the food system on environmental outcomes could increase by 50–90 % in the absence of any other changes to technology or other successful mitigation of this impact, meaning that levels will be reached which go beyond safe planetary boundaries. The key benchmarks used to assess environmental footprint include measures relevant to the planetary boundaries

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which, if they are exceeded, will destabilise ecosystems and related global regulatory processes. These measures include: biodiversity loss, land-use change, nitrogen cycling, phosphorous cycling, water use and climate change resulting from greenhouse gas emissions (GHGE)[15]. While most studies focus on GHGE, a range of these key benchmarks should ideally be included. Springmann *et al.*[14] analysed several options for reducing the effects of the food system on the environment, including dietary changes towards healthier, more plant-based diets (PBD), improvements in technology and system management and reductions in food loss and food waste. They found that no single measure would be enough to keep the likely impacts within all planetary boundaries simultaneously; suggesting instead that a synergistic combination of measures will be needed to sufficiently mitigate the projected increases in environmental impacts and pressures.

As a result, research activity is rapidly growing to better understand the detail of these impacts, alongside what policy and other interventions are required in terms of consumer behaviour and changes to food systems needed to reduce such impacts.

Sustainable diets have been defined by the FAO[16] as 'diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe and healthy, while optimising natural and human resources'. The FAO has also suggested that sustainable healthy diets are those which 'promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable'[17]. Therefore, a sustainable diet needs to consist of four dimensions: (1) nutrition and health, (2) economic, (3) social and cultural and (4) environmental. Sustainable diets would therefore not only have low environmental impact but would also be healthy, affordable and acceptable to society[17].

Sustainable diets are, however, complex, both in the factors that influence whether a sustainable dietary pattern is followed and what impacts such a dietary pattern has. A number of investigators have attempted to characterise and map this complexity, focusing not only on food security and health, but also on biodiversity, climate and equity[18]. An example of a pictorial representation of the key components, determinants, factors and processes of a sustainable diet is given in Fig. 2[18].

A further contributor to our complex and changing food system is the influence of climate change; environmental degradation is occurring at an alarming rate. The UCL Lancet Commission declared in 2009 that climate change is the greatest global health threat of the 21st century[19,20], with effects being felt globally. In order to remedy this, the Paris Agreement under the United Nations Framework Convention on Climate Change specified that efforts must be made to limit the rise in global temperatures to 1·5°C above pre-industrial levels[21]. To reach this target, technological advances are needed within key sectors contributing to global warming and climate change, as well as major behavioural and lifestyle changes, particularly among populations in middle- and high-income settings[21].

The effects of climate change on temperature, water shortages, etc. are already being felt globally, with even more temperate climates experiencing unusual weather events[22,23]. While the global distribution of carbon emissions that contribute to climate change is coming from higher-income countries (HIC), the impact in terms of climate change-related mortality will disproportionately affect the poorest regions and people who are contributing less[24], as shown in Fig. 3.

There have been some very clear attempts to describe the direct and indirect effects of climate change on health, alongside the social dynamics or factors that influence those effects. Malnutrition has been outlined as one of the many health impacts of climate change[25], as shown in Fig. 4. Significant climate change impacts are increasing food insecurity and undernutrition among vulnerable populations in many low- and middle-income countries (LMIC) due to crop failures, reduced food production, extreme weather events that produce droughts and flooding, increased food-borne and other infectious diseases and civil unrest. The links between food production and food security in any country will be determined by the implementation of policies, regulations and subsidies to ensure adequate food availability and affordable prices. However, even with such measures in place, it is likely that health impacts will be unevenly distributed, with greater risks in LMIC, as previously suggested. Even within countries, specific subpopulations, such as poor and marginalised groups, people with disabilities, older adults, women and young children are likely to bear the greatest burden of risk[26].

Global food production and consumption patterns therefore have a significant environmental impact, with agriculture accounting for approximately 25 % of global GHGE[27], 70–85 % of global freshwater use[27] and 50 % of global habitable land[28]. In addition to this, food systems are a key driving force for deforestation, water pollution, biodiversity loss and soil pollution, all of which are the main components of climate change and environmental degradation. Food systems therefore represent a major threat to climate stability and ecosystem resilience[29].

Current food systems present a major dilemma in the context of a growing world population which is estimated to reach 10 billion by 2050, a projected 30 % increase in current population levels[30]. With this population growth, food demand is predicted to increase by 70 % by 2050[31,32]. Considering this growth in the context of rapidly depleting natural resources, a major overhaul of the current food system is necessary to feed future generations within planetary boundaries while maintaining nutritional status.

Food groups and environmental impact

The impact of food production on the environment varies widely depending on food type[33]. It is well-

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Fig. 2. Key components, determinants, factors and processes of a sustainable diet[18]. GHGE, greenhouse gas emission.

established that, within food systems, the livestock sector has the greatest planetary impact due to a higher GHGE footprint, greater land and nitrogen requirements and significant impacts on biodiversity[33–35]. With the livestock sector accounting for approximately 14·5 % of GHGE[35] and meat and dairy products responsible for roughly 40 % of all food-related emissions[36], it is unsurprising that recommendations towards dietary patterns lower in meat (particularly from ruminant animals) have been deemed crucial to maintain population health within the boundaries of the planet[37].

In addition to putting a burden on the environment, high intakes of red and processed meat are also detrimental to health. Overconsumption of such foods is associated with an increased risk of cancer at particular sites[38,39], CVD[40] and type 2 diabetes[41]. However, while emerging evidence indicates the need for changes in dietary patterns towards more PBD for both environmental and human health, animal-source foods (ASF) are also key contributors to dietary micronutrient intake[42,43]. Therefore, careful consideration has to be given when recommending foods to replace meat in the diet and considering the impact on nutritional status, with ongoing debate in the scientific literature[44,45].

As well as ensuring recommended dietary shifts towards more PBD which are healthful, are nutritionally adequate and have a reduced environmental impact, such recommended foods and diets need to also be socially acceptable, accessible and economically viable in order to meet the FAO definition of a sustainable diet[16,17,46].

Examples of sustainable and healthy reference diets

There are an increasing number of dietary recommendations and guidelines that have taken a holistic approach, including an environmental sustainability element as well as a focus on nutrition.

These proposed reference diets come in the form of national dietary guidelines, for example those for Sweden[47] and Brazil[48], and those alongside others summarised by Harrington[49]. Quasi-official guidelines also exist, such as the Nordic Nutrition Requirements 2012[50], which have been recently updated[51] and The Netherlands guidelines for a healthy diet: the ecological perspective[52]. Reference diets from national organisations such as the British Dietetic Association's One Blue Dot[53] have been developed, as well research-led

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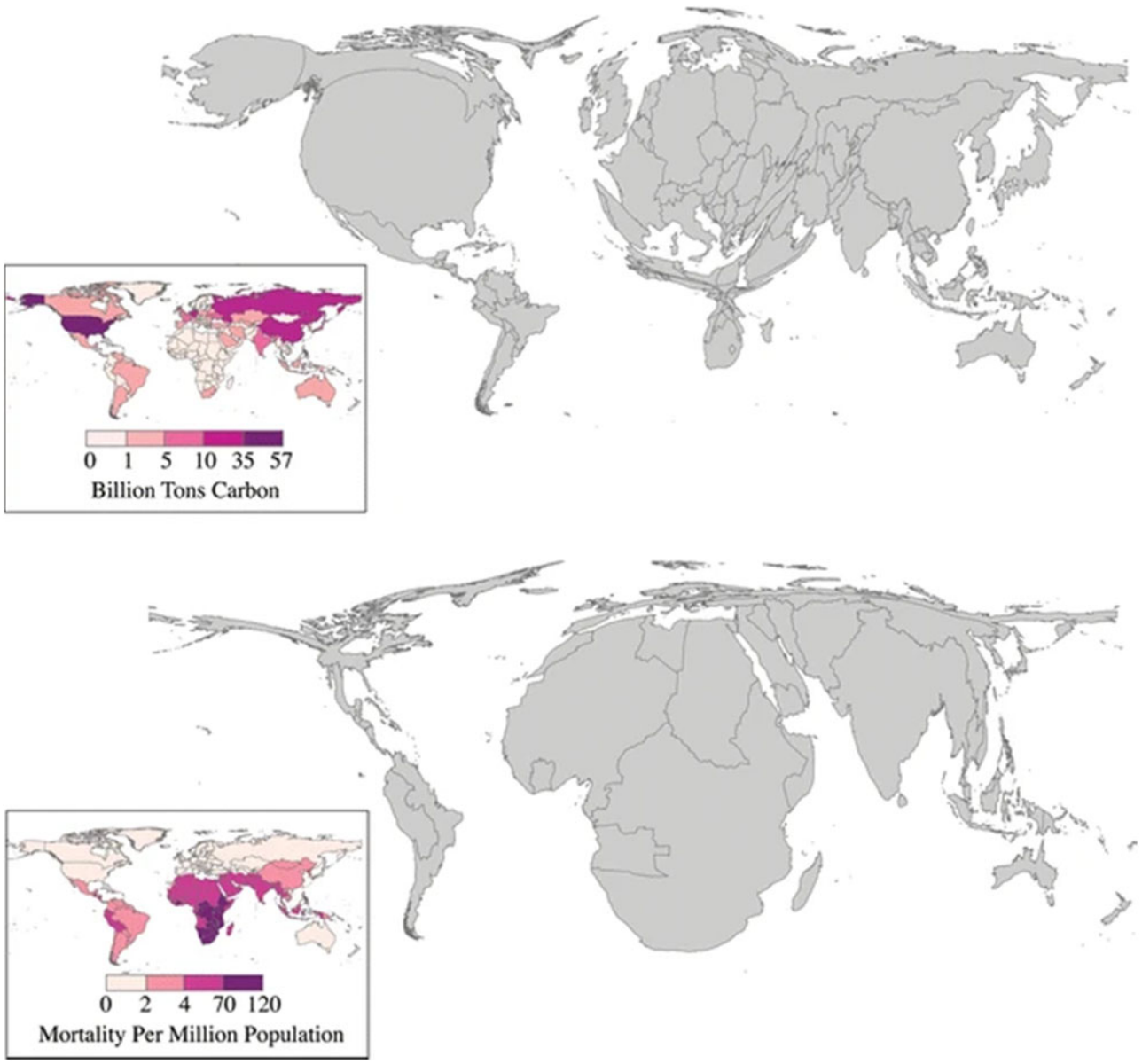

Fig. 3. Comparison of undepleted cumulative carbon dioxide (CO_2) emissions (by country) for 1950 to 2000 *v*. the regional distribution of four climate-sensitive health effects (malaria, malnutrition, diarrhoea and inland flood-related fatalities) – from[24].

investigations of environmental impact of adherence to current dietary guidelines, such as in the UK[54,55] and Ireland[43,56].

In 2019, the EAT-Lancet Commission proposed a global healthy reference diet that each country could modify to meet their specific nutritional and cultural needs while focusing on environmental sustainability[37]. The planetary health diet is a predominantly PBD rich in fruits, vegetables, whole grains, legumes, nuts and unsaturated oils, with a low-to-moderate amount of seafood and poultry, and a small quantity of red meat, milk and dairy products.

The goals and scientific approach have largely been accepted, but there has been debate as to the viability of the required policy changes proposed, as well as stressing the need for adaptation of this global pattern into dietary recommendations, alongside implementation plans (with economic and food production considerations, including costs and impact on jobs and traditional food cultures) at the local level[57].

As part of the WHO's definition of Sustainable Healthy Diets Guiding Principles[17], Kumanyika *et al.*[58] aimed to identify elements of a healthy dietary pattern derived from three complementary evidence-based approaches to defining healthy diets: (1) the WHO recommendations for healthy diets[59]; (2) the global burden of disease (GBD) non-communicable disease (NCD) risk factor[60] study and (3) analysis of health outcomes associated with whole dietary patterns[58]. The consistent shifts towards plant-based foods and away from animal-based foods (excepting fish and seafood) and for changes in food production systems were stated to also have relevance for the sustainability agenda.

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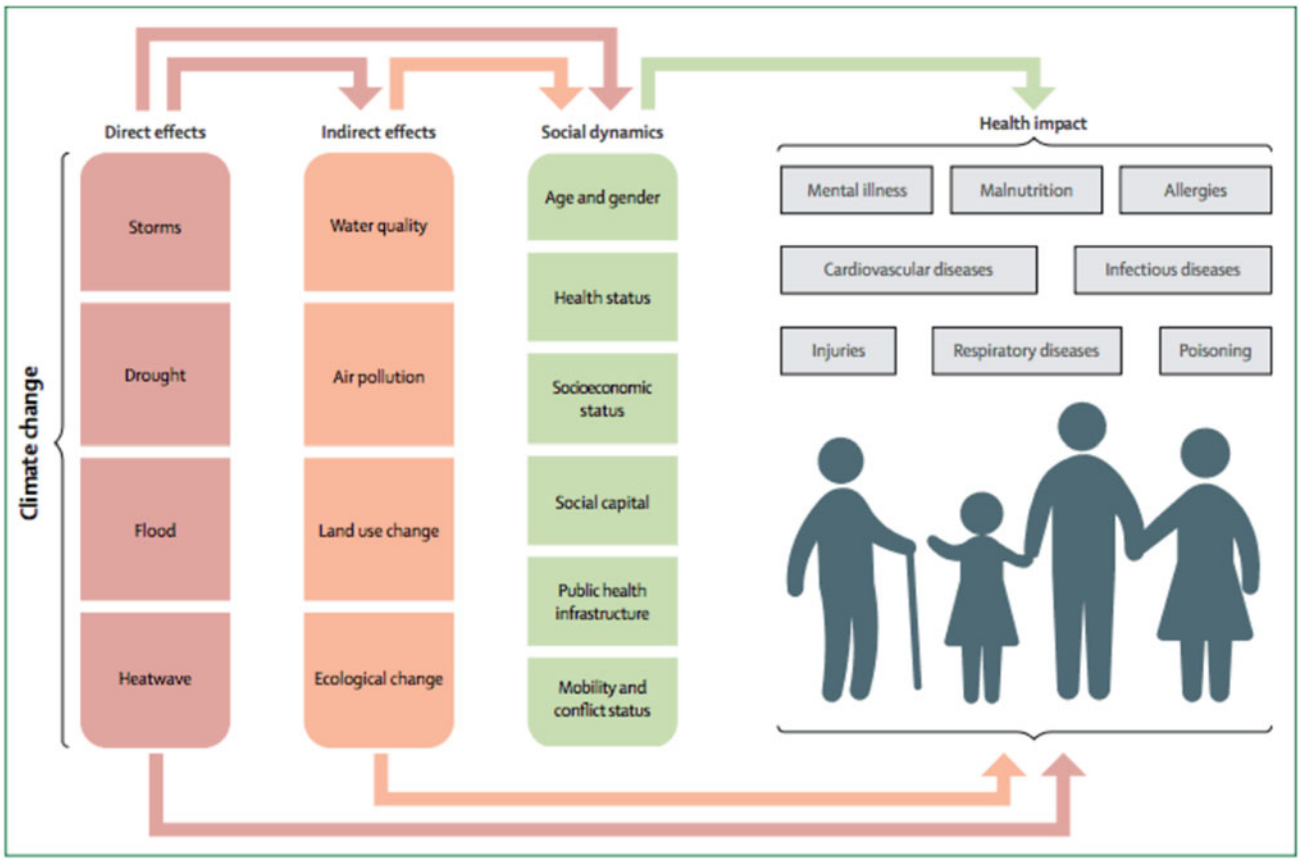

Fig. 4. Health impacts of climate change, including malnutrition (adapted from[25]).

While these different reference diets vary according to the details of the recommendations and the likely cultural acceptability, the main and consistent message is that they all recommend reduced consumption of ASF and increased consumption of plant-based proteins as a means of reducing the environmental impact of dietary patterns while ensuring good health and nutrition. The inclusion of sustainability considerations in dietary guidelines will need to be accompanied by higher level structural intervention in order to promote significant and maintained dietary shifts at the population level[61,62].

There is fair consistency across the proposed reference diets to reduce red and processed meat consumption. However, the recommended amount of red meat intakes suggested varies, with the planetary health diet recommending the lowest amounts at 0–200 g/week[37], while Swedish national dietary recommendations suggest no more than 500 g/week of red and processed meat[47]. In general, proposed reference diets contain less meat and higher amounts of plant-derived foods (vegetables, pulses [beans/lentils], fruit, wholegrains, nuts, seeds) than are usually consumed at the population level and measured in national dietary surveys. Even adhering to current dietary guidelines without any adaptation alongside sustainability principles would likely have positive impacts on the environment (a global average of 13 % lower GHGE)[63] and improve population health. One area of uncertainty is that such changes may not reduce water footprint.

Recommendations in relation to dairy intake do vary; within some reference diets dairy intake is recommended to be reduced due to relatively high environmental impact compared to plant-based foods, yet these foods can make a significant contribution to the intake of key micronutrients[64]. Recommended changes in consumption of milk products and eggs have also been inconsistent in optimisation studies, perhaps reflecting trade-offs between their contribution to nutritional status and environmental impact. Vegetarian and vegan diets may deliver environmental benefits, but are unlikely to be very widely adopted, and may reduce intakes and/or impact on bioavailability of some essential nutrients (e.g. iron, zinc, iodine and vitamin B12). Therefore, if applied at the population level, such dietary patterns may not meet all the domains of a sustainable healthy diet as defined by the FAO; and, as previously discussed, the impact of sustainable dietary patterns on nutritional status and particularly micronutrient status is still subject to debate[44,45].

Shifting dietary patterns to align with current national food-based dietary guidelines (FBDG) has been proposed as a reachable goal in HIC to reduce the environmental impact of diets and improve health outcomes[54,64,65]. As adherence to national dietary guidelines in HIC is generally poor, however, this shift could prove challenging. However, research into bridging the gap between current patterns and dietary patterns which adhere to FBDG is

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ongoing, with a recent review suggesting how communication of FBDG could be improved[55]. Countries, for example Ireland, are now mapping the environmental impact of dietary intake based on representative dietary data, initially only for carbon[43] and then with a more comprehensive range of indicators[56], which will offer a baseline against which it will be possible to track progress towards more sustainable diets. Similarly, investigators are now exploring the environmental impacts of dietary patterns already established to be more health-promoting. For example, in an analysis of the nurses' health II study, dietary patterns that have been associated with better health were demonstrated to have lower GHGE and nitrogenous fertiliser, cropland and irrigation water needs[66]. However, not all PBD conferred the same environmental benefit and the authors urged the need for nuanced consideration of environmental impact[66].

Improving diet quality while simultaneously reducing environmental impact is a major focus globally, but the metrics used to date have typically not included food waste. A recent analysis explored the relationship between food waste, diet quality, nutrient waste and multiple measures of sustainability (i.e. use of cropland, irrigation water, pesticides and fertilisers), finding that US consumers wasted 422 g food per person daily[67]. Such wastage was estimated to account for 30 % of daily energy intake available for consumption, one-quarter of daily food (by weight) available for consumption, and 7 % of annual cropland acreage[67]. Higher-quality diets were associated with greater amounts of food waste and greater amounts of wasted irrigation water and pesticides, but less cropland waste[67]. These figures were largely due to the fruit and vegetable food group. These are health-promoting and require small amounts of cropland, but substantial amounts of agricultural inputs; suggesting a need to increase consumers' knowledge and change behaviours in terms of preparation and storage of fruit and vegetables as a practical solution to reducing food waste[67]. Reducing food waste can also be seen as reducing waste of micronutrients that could otherwise theoretically fill nutritional gaps for those with low micronutrient status/who are malnourished[68].

Sustainable development goals and progress globally

Many governmental bodies and health authorities now recognise the urgency required to tackle this problem. For example, the UN 2030 Agenda for Sustainable Development in the form of the sustainable development goals (SDG) is a call to action to end poverty and inequality, protect the planet and ensure that all people enjoy health, justice and prosperity[69]. In particular SDG 2, zero hunger, includes an aim to achieve food security, improve nutrition and promote sustainable agriculture, although all SDG are inter-related[70]. For example, it has been suggested that nutrition is an enabler for many of the other goals, but particularly good health and well-being[71]. The determinants of health are multi-factorial, but the GBD study has shown that dietary risks make a significant contribution to a range of diseases, including NCD[3]. The UN SDG are aligned with the WHO's Decade of Action on Nutrition, which includes six action areas, namely (1) sustainable, resilient food systems for healthy diets; (2) aligned health systems providing universal coverage of essential nutrition actions; (3) social protection and nutrition education; (4) trade and investment for improved nutrition; (5) safe and supportive environments for nutrition at all ages and (6) strengthened governance and accountability for nutrition[72]. A mid-term review, published in 2020[73], does suggest progress in these action areas, but also identified key priority actions alongside several cross-cutting issues, namely the need for effective partnerships and alliances, a cross-sectoral approach, policy coherence, building national capacity on nutrition, improving national data on nutrition indicators, addressing global nutrition financing and implementation gap and scaling up and accelerating implementation, disseminating the evidence base, exchanging good practice and sharing tools[73].

Each SDG has targets and indicators, which allow progress to be monitored. For example, the UN has defined eight targets and thirteen indicators for SDG 2[74]; targets specify the goals and indicators represent the metrics by which the world aims to track whether these targets are achieved. Progress against SDG has been challenging, with an ultimate target of 2030. Recent data for undernutrition, wasting and stunting in children suggest patterns are similar, with these conditions still predominating in LMIC. The global hunger index (1992–2017) showed substantial declines in mortality in children <5 years across the world, but declines were less substantial in the prevalence of childhood wasting and stunting[75], with the rates of decline in undernutrition for both children and adults still too slow to meet the SDG targets by 2030.

The geographic spread of overweight and obesity is much broader but is certainly no longer simply a condition found in HIC. In the past 40 years of the obesity pandemic, the observed patterns of malnutrition have shifted. Starting in the early 1980s in HIC, rapid increases in the prevalence of overweight and obesity occurred. By 2015, obesity was estimated to affect 2 billion people worldwide[7]. Obesity and its determinants are risk factors for the leading causes of NCD, including CVD, type 2 diabetes and certain cancers[7].

Over- and undernutrition are linked and can co-occur in countries, families and even within individuals[7,8]. Research on the developmental origins of health and disease has shown that fetal and infant undernutrition can be risk factors for obesity and its adverse consequences throughout the life course; hence, it is not always overnutrition that is associated with the overweight or obese phenotype. LMIC carry the greatest burdens of malnutrition. In LMIC, the prevalence of overweight in children less than 5 years is rising, in the context of an already high prevalence of stunting (28 %), wasting (8·8 %) and underweight (17·4 %)[8,76]. To illustrate this, obesity rates in stunted children are 3 %, with this figure being higher among children in middle-income countries than in lower-income countries[76].

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The challenges of tackling obesity are exemplified by the fact that zero countries globally have succeeded in decreasing obesity in the last 33 years[77], and the prevalence of obesity is increasing in every region of the world. This is likely to be due to the systemic and institutional drivers of obesity being largely unchallenged and is accompanied by what the Lancet Commission calls policy inertia[8]. This is defined as the combined effects of inadequate political leadership and responsive policy development, strong opposition to those policies by powerful commercial interests and a lack of demand for policy action by the public. The Lancet Commission highlights that the enormous health and economic burdens caused by obesity are not yet seen as urgent enough to generate the public demand or political will to implement recommendations from expert bodies for effective action[8]. Furthermore, obesity has historically been considered in isolation from other major global challenges, and this hinders progress in addressing these issues which are to a great extent overlapping (e.g. undernutrition and climate change).

As previously stated, malnutrition includes micronutrient deficiencies. A further SDG 2 indicator is prevalence of anaemia and while, according to latest data, many regions are making progress towards reduction of wasting and stunting among children under age 5, anaemia prevalence appears to have changed little globally in the past 20 years and the SDG targets for anaemia reduction is likely to still be beyond reach by 2030[78].

There is no doubt that nutritional challenges and global progress towards SDG targets have been impeded by recent global events, including the coronavirus disease-2019 pandemic, the war in Ukraine and the consequent economic uncertainties; with all of these events influencing food supply and food security. As diet and health status are both socially and economically patterned, such inequalities are likely to have been exacerbated as a result of such events, with the World Food Programme estimating that 45 million children <5 years experienced acute malnutrition in 2023 globally[79].

The World Bank has estimated $70 billion would need to be invested over 10 years to allow SDG targets related to undernutrition to be achieved, but that achieving these targets would create an estimated $850 billion in economic return. Focusing on climate change, economic impacts include the costs of, for example, environmental disasters, habitat changes (e.g. biosecurity and sea-level rises), health effects (e.g. hunger and infections), industry stresses in agriculture and fishery sectors and the costs of reducing GHGE. Swinburn *et al.*[8] suggest that continued inaction towards the global mitigation of climate change is predicted to cost 5–10 % of global gross domestic product, whereas just 1 % of the world's gross domestic product could cease the increase in climate change.

Progress against sustainable development goals: UK

So far, the focus of this review has had a global perspective. It might be expected that many of the SDG and indicators may be relevant for LMIC, yet there are many indicators of relevance to HIC, including the UK. Progress against targets is monitored within the UK, for example, with the most recent measuring up report released in September 2022[80]. Under SDG 2, UK performance was rated as red (major challenges remaining) for targets focused on ending hunger, food insecurity and malnutrition by 2030. The UK food system has undoubtedly, as for others, been influenced by the global pandemic and war in Ukraine[81], but the added context of British exit and the UK's exit from the European Union has had further impacts on food supply, authenticity and costs[82].

This poor progress against SDG in the UK is exemplified by trends in figures for breast-feeding and fruit and vegetable intake. For breast-feeding, the last UK-wide Infant Feeding Survey was conducted in 2010[83]. At that time, breast-feeding initiation was 81 % (up from 76 % in 2005), but exclusive breast-feeding at 6 weeks was 24 % in England compared to 17 % in Wales and 13 % in Northern Ireland, while exclusive breast-feeding at 6 months (as recommended by the WHO) remained at about 1 %.

In terms of fruit and vegetable intake, latest data from the National Diet and Nutrition Survey in the UK highlight that, since 2008, adult intake has remained at approximately four portions daily. In children aged 11–18 years, intake has remained approximately three portions daily over the same timeframe, despite the public health advice, which is widely known to consumers, to consume five portions daily[84]. The same survey suggests a reduction in iron intake over time – over 11 years from 2008 there has been a 0·7–1·1 mg reduction in iron intake for children and older adults. Mean iron intakes for girls aged 11–18 years and women aged 19–64 years were below the reference nutrient intake (RNI) (being 56 and 76 % of the RNI, respectively). Forty-nine per cent of girls aged 11–18 years and 25 % of women aged 19–64 years had low iron intakes (below the lower reference nutrient intake (LRNI)). Iron-deficiency anaemia (as indicated by low Hb levels) and low iron stores (plasma ferritin) in 9 % of older girls, 5 % of adult women and 2 % of older women[85] were indicated by biochemical analysis, and this situation has also been acknowledged within the latest UK SDG measuring up report[80].

Finally, there are some worrying data in relation to the impact of coronavirus disease-2019 on obesity rates. The National Child Measurement Programme data for 2020–2021 revealed increases in rates of overweight, obesity and severe obesity in both reception (aged 4–5 years) and year 6 (aged 10–11 years) children in mainstream state-maintained schools in England, likely to be due to the pandemic[86]. The disparities' gap also widened substantially at this stage, due to larger increases in child obesity prevalence in the most-deprived areas compared to the least-deprived areas[86]. There is evidence that this upturn in obesity levels has reduced within the 2021–2022 data, although not yet returning to pre-pandemic levels[87]. The change in disparities during the coronavirus disease-2019 pandemic means that any nutrition intervention with dietary outcome should assess the possibility of differential effects by relative social disadvantage to ensure that nutrition interventions do not widen inequalities[88].

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Making progress: capturing complexity and using systems thinking

Given the complexity of these interactions between climate change, other world events, food and health and the different actors and drivers that influence these, a systems-thinking approach to the problem is essential[46]. A systems-thinking approach has been used by the FAO, the Transforming UK Food systems group[89] and the WHO have recently recommended systems thinking for NCD prevention[90], with an example given in Fig. 5. As modelling suggests that no single measure was enough to keep the food system within environmental limits[14], there needs to be a range of intervention opportunities and consideration of the system and its complexity in order to escalate effective population health improvement and food system change[91].

Although focused on food and nutrition rather than explicitly including sustainability, we can still draw on Haddad *et al.*'s global research agenda for food[92], which called for urgent interdisciplinary research to support concerted policy action in order to meet the SDG related to food and nutrition, but also climate change. These include identifying entry points for change, agreement on what constitutes a healthy diet, making dietary data more widely available, simultaneously tackling the multiple forms of malnutrition, identifying economic levers for change and accounting for climate[92].

Beyond dietary guidelines: the global syndemic and required actions

In the Lancet Commissioned report, considering malnutrition (both over- and undernutrition) in more detail,

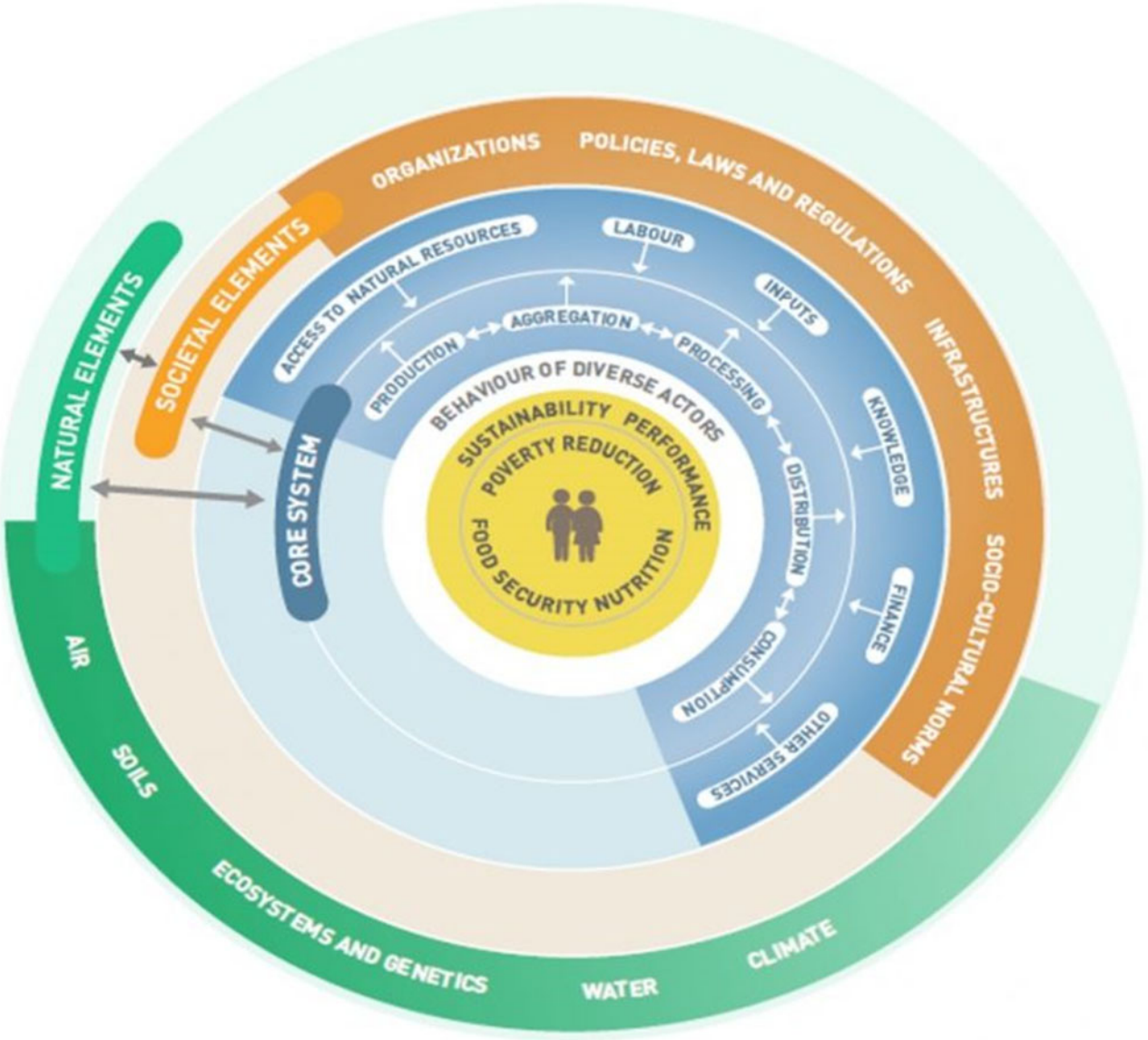

Fig. 5. Food system wheel[1].

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Swinburn *et al.*[8] have described the concurrence of obesity, undernutrition and climate change as a global syndemic, which will affect most people in every country and region across the globe. The term syndemic is used to describe the overlap and interaction of obesity, undernutrition and climate change in terms of time and place, to produce a range of complex consequences, with the three issues sharing common drivers.

The Lancet Commission[8] produced a comprehensive set of recommendations and actions, intended to have multiple impacts because of these shared drivers, and the nine broad recommendations are summarised in Table 1.

While achieving these actions could produce multiple impacts and positive results because of the shared drivers, they are nevertheless difficult to achieve. An example is that of national dietary guidelines which has already discussed, serve as a basis for the development of food and nutrition policies and public education to reduce malnutrition and which are increasingly being extended to include sustainability[49], although the development has been suggested to be subject to political and private sector pressures[8,49,93]. Such dietary guidelines could promote environmentally sustainable diets and eating patterns and also help to ensure food security, improve diet quality, human health and wellbeing and social equity.

The issue is that the dietary guidelines that exist are largely not met, even without sustainability considerations[84]. Individual behaviours are heavily influenced by environments which tend to be obesogenic, food insecure and which promote GHGE[8] and individual, high agency interventions also promote inequity[61]. The Lancet Commission suggests that engagement of people, communities and diverse groups is crucial for achieving changes towards more sustainable dietary patterns[8].

To drive commitment for nutrition within the UN Decade of Action on Nutrition, it has similarly also been accepted that achieving and sustaining significant impacts will require strong commitment from many people and organisations, including policy-makers and governments, implementing agencies and teams, civil society groups, research institutions, businesses and communities[72]. The Lancet Commission suggests that collective actions could generate enough momentum for change, with the influence of individuals, civil society organisations and the public in general able to stimulate the changes in human systems to promote health, equity, economic prosperity, as well as sustainability[8].

In a realist review and framework synthesis of the nutrition policy literature to inform the UN Decade of Action on Nutrition, Baker *et al.*[94] suggested that, in terms of driving commitment to nutrition politically, and based on seventy-five included studies, there are eighteen factors that drive commitment (see Table 2). The authors organised these into five categories: actors; institutions; political and societal contexts; knowledge, evidence and framing and capacities and resources[94] (Table 2). What featured consistently as commitment drivers, regardless of country context, were: effective nutrition actor networks, strong leadership, civil society mobilisation, supportive political administrations, societal change and focusing events, cohesive and resonant framing and robust data systems and available evidence. Studies in LMIC also frequently reported international actors, empowered institutions, vertical coordination and capacities and resources. In studies in HIC, private sector interference was reported as frequently undermining commitment. The authors suggest that political commitment can be created and strengthened over time through strategic action, but that generating this commitment will require a core set of actions with some context-dependent adaptations and that cohesive, resourced and strongly led nutrition actor networks, responsive to the multifactorial, multilevel and dynamic political systems in which they operate, will be essential[94]. Understanding the flow from evidence and independent recommendation/review to policy is sometimes complex, as evidenced by the recent UK government food strategy which appeared after an independent review of the UK food system[95].

The potential impact of change economically is substantial. The Lancet Commission[8] suggested that the current costs of obesity are about $2 trillion annually from direct health-care costs and lost economic productivity (2·8 % of the world's gross domestic product); these are roughly equivalent to the costs of smoking or armed violence and war. Economic losses attributable to undernutrition also exist; these are equivalent to 11 % of gross domestic product in Africa and Asia, or approximately $3·5 trillion annually[8].

Table 1. Recommendations and actions from the Lancet Commission to tackle the global syndemic (Swinburn *et al.*[8])

Recommendations and actions
Think in global syndemic terms to create a focus on common systemic drivers that need common actions.
Join up the silos of thinking and action to create platforms to work collaboratively on common systemic drivers and double-duty or triple-duty actions.
Strengthen national and international governance levers to fully implement policy actions which have been agreed upon through international guidelines, resolutions and treaties.
Strengthen municipal governance levers to mobilise action at the local level and create pressure for national action.
Strengthen civil society engagement to encourage systemic change and pressure for policy action at all levels of government to address the global syndemic.
Reduce the influence of large commercial interests in the public policy development process to enable governments to implement policies in the public interest to benefit the health of current and future generations, the environment and the planet.
Strengthen accountability systems for policy actions to address the global syndemic.
Create sustainable and health-promoting business models for the 21st century to shift business outcomes from a short-term profit-only focus to sustainable, profitable models that explicitly include benefits to society and the environment.
Focus research on the global syndemic determinants and actions to create an evidence base of systemic drivers and actions, including indigenous and traditional approaches to health and wellbeing.

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Table 2. Factors identified as driving political commitment for nutrition (adapted from Baker *et al.*[94])

Category	Factor and description
Actors	(*1*) *Nutrition actor network (NAN) effectiveness:* effectiveness of NAN, the individuals and organisations operating within a given jurisdiction who shared common principles, causal beliefs and/or interest in tackling malnutrition and who acted collectively to do so.
	(*2*) *Strength of leadership:* presence of committed and politically savvy individuals, within or outside of government, recognised as strong champions for nutrition.
	(*3*) *Civil society mobilisation:* extent to which civil society groups mobilised to address malnutrition, including non-government organisations and social movements collectively representing the interests of citizens.
	(*4*) *Supportive international actors:* degree to which actors with an international scope of operations and/or membership initiated, championed and/or supported nutrition policy and programming responses.
	(*5*) *Private sector interference:* degree to which mobilised private interest groups undermined effective nutrition policy responses, including food producers, retailers, marketers and their representative peak bodies.
Institutions	(*6*) *Strength of institutions:* extent to which coordinating agencies and institutional systems mandated to address malnutrition were empowered to effectively coordinate multisector/multilevel responses and advocate for sustained attention and resources.
	(*7*) *Effective vertical coordination:* degree to which nutrition policies were effectively coordinated, implemented and monitored across levels of governance, particularly regarding the incentives of subnational actors to adopt, progress and benefit from central government policies.
	(*8*) *Legislative, regulatory and policy frameworks:* degree to which national nutrition policies, operational plans and enabling legislation were well-designed and enacted, and/or the alignment of nutrition objectives with broader policy agendas and regulatory frameworks.
Political and societal contexts	(*9*) *Supportive political administrations:* degree to which members of the executive (e.g. head of state, ministers), legislative (e.g. parliamentarians) and administrative (e.g. agency heads, senior officials) branches of government initiated and championed nutrition responses.
	(*10*) *Societal conditions and focusing events:* extent to which changing societal conditions (long-duration phenomena) or focusing events (short-term processes) focused attention onto nutrition or closely related issues and presented opportunities or impediments to commitment-building.
	(*11*) *Ideology and institutional norms:* extent to which entrenched belief systems and practices predominant within political systems, policy-making institutions and/or in society-at-large, negatively skewed perceptions about malnutrition problems and undermined effective policy responses.
Knowledge, evidence and framing	(*12*) *Credible indicators and data systems:* availability of credible indicators and high-quality data systems for monitoring nutrition problems, informing policy design, tracking progress and empowering accountability systems.
	(*13*) *Evidence:* extent to which robust evidence on the causes, manifestations and consequences of malnutrition and the efficacy and cost-effectiveness of interventions was available, clearly communicated and accepted.
	(*14*) *Internal frame alignment:* degree to which NAN were aligned about a common interpretation and narrative of a given malnutrition problem including its definition, magnitude, causes and solutions for resolving it.
	(*15*) *External frame resonance:* degree to which NAN publicly portrayed (i.e. framed) nutrition problems and solutions in ways that resonated with and motivated action by external audiences, and countered the frames deployed by opponents.
Capacities and resources	(*16*) *Strategic capacities:* degree to which NAN members possessed 'soft-power' skills including the capacity to generate consensus, resolve conflicts, respond to recurring opportunities and challenges, build strategic alliances, undertake strategic communications and related tasks.
	(*17*) *Organisational capacities:* degree to which NAN members possessed the technical knowledge and skills, administrative systems and human resources required to generate commitment, including through the effective management of nutrition policy and programming responses.
	(*18*) *Financial resources:* degree to which nutrition budgetary commitments and financing systems incentivised multisector/multilevel coordination, ensured successful policy implementation and created ownership and entitlements among political elites, policy-makers, citizens and other stakeholders.

Sustainable diets: recent scientific progress

There are still areas of scientific uncertainty regarding sustainable diets, their composition, their impact on diet quality and nutritional status, their environmental impact and how to achieve behaviour change. For example, to date evidence for the development of sustainable diets has been built on modelling studies of food consumption and environmental impacts. Experimental data from real-world settings to investigate the acceptability, effectiveness and nutritional adequacy of a population shift towards a sustainable diet are limited. Observational and intervention studies conducted to date have been systematically reviewed and highlight previously stated concerns in terms of micronutrient intake and status[96]. One human study tested the impact of three diets differing in protein composition (70:30, 50:50 or 30:70 animal:plant protein as a per cent of total protein intake) over 12 weeks on bone formation, bone resorption, mineral metabolism markers and nutrient intakes in healthy adults[97]. Partial replacement of animal proteins with plant-based proteins increased

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markers of bone resorption and formation, indicating a possible risk for bone health[97]. In terms of nutrient intake and status, marked decreases in the intake and status of vitamin B12 and iodine, although not for iron, were seen[98]; an increased fibre intake and improved dietary fat quality was seen as well as blood lipoprotein profile (reductions in total and LDL-cholesterol)[99].

We also need to consider what is currently known about consumer behaviours and attitudes towards sustainable healthy diets. A recent scoping review[93] considered and synthesised the evidence on consumers' attitudes and behaviours towards more sustainable diets. The authors considered a range of factors, considerations and proposed strategies that could help contribute to building the societal-level support for urgent and systems-level changes. Findings suggested that consumers, insofar as they are interested in sustainability and have the capacity to engage with the concept, primarily approach the concept of sustainable diets from a human health perspective. However, the interconnectedness of human health and well-being with environmental health was largely poorly understood and underresearched, in the context of consumer behaviours and attitudes towards sustainable diets. These findings highlight the need for (1) sustained efforts from public health professionals to encourage a realignment of the term sustainable diet with its multidimensional meaning by championing an ecological public health approach in all efforts aimed at promoting more sustainable consumption, from awareness raising to policy development; (2) a broader research lens focused on the multidimensional concept of sustainability in the literature exploring consumer attitudes and behaviours and (3) the development of multidisciplinary, clear and evidence-based sustainable-eating messages, including holistic sustainable dietary guidance to address knowledge gaps, minimise conflicting narratives and build consumer agency. These findings can be used to establish how support can be generated for the necessary structural and system-level changes to support behaviour change towards sustainable diets[93].

If consumer understanding is low, we also have to consider how to provide that information and the use of food labels to convey both nutrition and environmental messaging has been explored[100]; expression of food-based environmental impact on labels is increasingly being adopted, yet the calculation and metrics of such impact are complex[101–103]. In any case, the evidence base for consumer response to labels and changing purchasing behaviour is mixed[101] and therefore the introduction of any separate or combined index should be thoroughly evaluated in terms of impact on consumer behaviour. Interventions to reduce food waste are also currently being explored[104], while settings-based or interventions focused on particular age groups may also be effective[105,106].

It is also important to understand recent changes in consumer behaviour – currently, 16 % of British consumers are flexitarians (up by 1·6 % *v.* 2021), 5·6 % are vegetarians (flat over time) and only 0·8 % are vegan (up by 0·3 %)[107]. In 2021, one in three British adults drank plant-based milk alternatives and 44 % of adults aged 25–44 years were plant-based milk users; sales of plant-based milk doubled from 2019 to –2020[108]. Such changes are important to monitor alongside any related changes in nutrient intakes, e.g. iodine[108].

Similarly, sales of plant-based meat alternatives in the European Union and UK have more than doubled in the last decade and are expected to reach 2·5 billion euros by 2025, a 47 % increase in 2020 sales, almost doubling the meat alternative share of the meat industry to 1·3 %[109]. The same trajectory is expected for the UK, where a 49 % increase in market value is expected by 2025 compared to 2019[110]. According to a survey conducted by the UK Food Standards Agency, about a third of respondents reported eating meat alternatives[111]. Of these respondents, just over a third (34 %) reported habitual consumption, having meat alternatives greater than or equal to two to three times weekly, while 45 % of respondents reported occasional consumption of meat alternatives, eating these products about greater than or equal to two to three times per month[111]. With the meat alternative sector focusing on increasing product familiarity and accessibility, improving user experience and reducing the price gap between meat alternatives and meat, it is likely that more consumers will enter into the market as these are the main barriers to consumption currently[109]. In a recent global analysis, almost half of FBDG that included consideration of environmental sustainability incorporated meat and dairy alternatives[112]. In HIC there is a growing consumer base for plant-based alternatives, and a concurrent expansion of the range of plant-based alternatives available. However, due to the heterogeneity in the nutritional profile and environmental impact of plant-based alternatives, consideration of the messaging about the recommended consumption of these products is essential to avoid potentially negative repercussions to population nutrient status and health. Klapp *et al.*[112] have proposed the inclusion of clear guidance in FBDG on the plant-based alternatives which should and should not be part of the habitual diet, such as vitamin B12 and calcium-fortified plant-based milk, as opposed to non-fortified plant-based milk.

To inform this guidance, more robust research on the nutritional, health, environmental and economic implications of including more plant-based alternatives and less ASF in our diets is needed. While research has shown that, overall, meat alternatives tend to be lower in energy, protein, fat and saturated fat and higher in fibre, salt and sugar compared to meat products, considerable variability in energy and nutrient content exists between products and product categories, making it difficult to provide recommendations on the consumption of these products as a whole[113–118]. Fortification of meat alternatives with micronutrients such as vitamin B12 and zinc is not currently widespread[114,119]. Since ASF are important contributors to micronutrient intake in the UK[84], careful guidance is needed when reducing ASF in the diet and replacing with meat and dairy alternatives to avoid potentially negative consequences to nutrient intake and status, and some modelling studies have considered this[120–123]. A further consideration is that many

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meat and dairy alternatives available in the UK are considered 'ultra-processed foods' according to the NOVA food classification system, due to the use of protein isolates and additives used in the formulation of these products[124]. Given this classification, and a relative lack of human studies to date[125–127], more human studies are needed to determine what effect these products have, at different levels of consumption, on nutritional status, health and environmental outcomes.

There is certainly potential for plant-based alternatives to facilitate a shift away from ASF by providing familiar, acceptable and convenient substitutes to ASF in a way that legumes, nuts and seeds may not. However, while these products could be an effective vehicle to reduce ASF consumption and dietary environmental impact, the focus now needs to be on enhancing their nutrient profiles through fortification and reformulation, developing and disseminating guidance to consumers on how to choose healthier products, and creating a price parity between alternatives and ASF, so that they are economically viable and accessible to all socio-economic groups. Dietary guidelines include food groups to allow the achievement of optimal nutrient intake and any dietary choices which remove these food groups must consider the potential implications of such restrictions on nutritional status.

Conclusion

The global population is growing, leading to increased demand for food and food security and sustainability challenges facing the food system, placing further pressure on finite resources. The SDG aim to achieve a better and more sustainable future for all, yet progress against SDG, with an ultimate target of 2030, has been challenging. The annual report of the FAO on the state of food security and nutrition in the world concludes that any lingering doubts that the world is moving backwards in its efforts to end hunger, food insecurity and malnutrition in all its forms should be removed, with the distance to reach many of the SDG 2 targets growing wider each year[1]. There are efforts to make progress towards SDG 2, yet they are proving insufficient in the face of a more challenging and uncertain context. This includes conflict, climate variability and extremes, economic slowdowns and downturns and unaffordability and inaccessibility of healthy diets, set against a background of underlying causes of poverty and inequality.

Opportunities for changing food supply/systems are complex and this complexity needs to be accounted for, with the adoption of systems science to fully understand this and establish the impact of any interventions. Changes to the food system as part of efforts to meet SDG need to take account of socio-cultural interactions, issues of equity and in particular the needs of the poorest who spend the greatest proportion of their income on food. Interventions and policies need to be multi-level, coherent, sustained and structural, occurring across the full food system/supply chain to instigate shifts in dietary patterns. Such efforts, if successful, could have a significant impact as benefits to both population and environmental health could be expected from achieving dietary behaviour change towards sustainable diets.

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