Environmental assessment of diets: overview and guidance on indicator choice

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Comprehensive but interpretable assessment of the environmental performance of diets involves choosing a set of appropriate indicators. Current knowledge and data gaps on the origin of dietary foodstuffs restrict use of indicators relying on site-specific information. This Personal View summarises commonly used indicators for assessing the environmental performance of diets, briefly outlines their benefits and drawbacks, and provides recommendations on indicator choices for actors across multiple fields involved in activities that include the environmental assessment of diets. We then provide recommendations on indicator choices for actors across multiple fields involved in activities that use environmental assessments, such as health and nutrition experts, policy makers, decision makers, and private-sector and public-sector sustainability officers. We recommend that environmental assessment of diets should include indicators for at least the five following areas: climate change, biosphere integrity, blue water consumption, novel entities, and impacts on natural resources (especially wild fish stocks), to capture important environmental trade-offs. If more indicators can be handled in the assessment, indicators to capture impacts related to land use quantity and quality and green water consumption should be used. For ambitious assessments, indicators related to biogeochemical flows, stratospheric ozone depletion, and energy use can be added.

Introduction

Environmental assessments of food products and diets are increasingly used by a wide variety of actors, including the research community across disciplines;[1] public policy makers;[2,3] non-governmental organisations;[4,5] and private-sector food industries, retailers, and consumers.[6–8] Multiple indicators for assessing the environmental performance of individual food items and agricultural systems have been developed,[9,10] but few are in regular use to assess diets,[11] which commonly comprise of hundreds of foods sourced from many locations, with little information on exact origin or production system.

When selecting indicators for environmental assessment of diets, researchers and other actors usually (and understandably) choose those that are well established, which include those related to climate change, water use, and land use;[11,12] however, to capture the overall environmental performance of diets, including potential trade-offs between different environmental aspects, a broader set of indicators is required.[13] If assessment methods for such indicators require data that are commonly unavailable, and give results that cannot easily be communicated, they risk being impractical and ineffective for decision making for a broad audience, so simplification is needed.[14]

Food items in diets are commonly sourced from different locations globally, with effects that vary depending on site-specific conditions and management practices; however, identifying the exact origin or production system for the multitude of foods available and the ingredients that make up these foods is often difficult. This difficulty prevents the use of indicators suggested in current standards for product assessment for assessing diets (eg, the Product Environmental Footprint developed in the EU).[15] Beyond individual food items, providing specific guidance on indicator choice for assessment of environmental sustainability of diets is needed to find the right balance between type and number of indicators to use, and what they can reveal.

In this Personal View we provide an overview of commonly used dietary environmental performance indicators, identify aspects that are missing, and guide readers to a relevant indicator choice that captures the key aspects of the environmental impact. Although we focus on indicators that assess the environmental component of sustainability, we acknowledge that the concept of sustainability goes beyond environmental sustainability and includes a range of socioeconomic aspects that also need consideration when striving to feed future generations sustainably.[16]

Commonly used environmental indicators

We searched the Web of Science Core Collection and Scopus for reviews on indicators for sustainable diets using the Boolean search phrase “indicator* AND sustainab* AND diet*”. Two authors (YR and ER) screened reviews by title and abstract. Full-text and data extraction was done by the same two authors. The search method, screening process, and results are described in more detail in the appendix (pp 3–43). The search generated 109 records after deduplication, of which seven reviews[11,13,14,17–20] met our criteria and assessed the environmental sustainability of diets and synthesised multiple indicators. After identifying relevant reviews, we extracted the indicators identified in each study (appendix pp 31–43). We included indicators “used to assess, compare, and control the impacts on the environment”,[20] and excluded indices that aggregate several environmental and other sustainability impacts. We categorised indicators according to the planetary

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boundaries framework[21] to relate them to biophysical earth system processes, and excluded duplicate environmental indicators with similar definitions and units but different names (eg, land use and land occupation). A summary of the most commonly applied indicators are listed in table 1. Some indicators relate to several boundaries (eg, grey water use relates to both novel entities and biogeochemical flows,[23] and acidification potential relates to atmospheric aerosol loading and biogeochemical flows). Some overlaps are

	Main influence from the food system	Pressure indicators	Impact indicators
Climate change			
Warming of the atmosphere has effects such as increasing the frequency and amplitude of extreme weather events and threats to humans, other species, and ecosystems in oceans, coastal regions, and land	Use of land, animals, energy, and fuels that generate GHG emissions (mainly CO_2, CH_4, and N_2O), and land use change (eg, deforestation) that results in GHG emissions and changes in albedo (reflection of solar radiation)	Not commonly used†	Carbon footprint (measured in kg CO_2 eq)—ie, aggregation of different GHGs into CO_2 equivalents considering their different warming dynamics
Land system change			
Changes in land cover destroy ecosystems, lead to decline and extinction of species, and affect local and global climates and precipitation patterns (eg, the Amazon rainforest risks becoming a semi-arid savannah); land suitable for agricultural production is a finite resource	Expansion of agricultural land through deforestation and conversion of natural grasslands into intensively managed grasslands and cropland, and intensification of land use	Use of cropland or total agricultural land (measured in m² × year)—ie, the amount of cropland (and pasture in terms of total agricultural land) during a certain time (often 1 year) needed to produce the food or diet	Scarcity-related land footprint (measured in m² land eq × year)—ie, the amount of land used for production adjusted for local stress or scarcity over land resources
Freshwater use			
Freshwater use and withdrawal causes local and regional water stress and competition for water resources	Cultivation of food and feed crops that uses rainwater infiltrated as soil moisture (green water) and liquid freshwater resources (blue water) for irrigation, animal drinking, and servicing; water is also used in food and feed processing and preparing	Blue water, green water, or total water footprint (measured in L)—ie, the volume of water used in production	Stress-related water footprint (measured in L water eq)—ie, the volume of water used adjusted for local water stress or water scarcity, as in LCA; and water stress assessment (eg, using SDG indicator 6.4.2[22]) as conducted in environmental footprint assessment
Biogeochemical flows			
Eutrophication of terrestrial, freshwater, and marine ecosystems leads to excessive growth of algae that causes oxygen depletion and death of fish and other freshwater or marine species; and terrestrial eutrophication causes loss of species, changes to ecosystem structure and functioning, and homogenisation of vegetation	Addition of reactive N and P by conversion of atmospheric N_2 into reactive N (mainly through synthetic fertilisers but also cultivation of leguminous crops) and P mining; considerable amounts of N and P end up in the environment, causing eutrophication	New N and P input (measured in kg N and P)—ie, the addition of new N and P‡ to agricultural land; N footprint or N losses (measured in kg N)—ie, reactive N emissions to the environment; P footprint (measured in kg P)—ie, P emissions to the environment; and greywater footprint (measured in L)—ie, the volume of water needed to assimilate a pollutant load that reaches a water body	Eutrophication potential (measured in kg PO_4^{3-} eq)—ie, aggregation of potential impact from N and P emissions based on amounts of these nutrients needed to build phytoplankton biomass; marine eutrophication potential assesses N increase in water by converting emissions of eutrophicating substances into kg N eq; and freshwater eutrophication potential assesses P increase in freshwater by converting emissions of eutrophicating substances into emissions of kg P eq
Atmospheric aerosol loading			
Atmospheric aerosol loading affects the climate system (through cooling and warming) and hydrological cycles (eg, a shift in Asian monsoon circulation), and harms human health (eg, by contributing to cardiopulmonary disease, acute respiratory infections, etc)§	Use of fuels, chemicals, and other compounds that cause air pollution with primary aerosols (fine particulate matter¶ in air) by emissions of black carbon (soot) from activities such as cooking, land clearing, burning biomass, and heating with biofuels	Not commonly used	Particulate matter formation potential (measured in $PM_{2.5}$ eq) measures impacts on human health caused by emissions of fine particulate matter and its precursors (eg, NH_3, NO_x, or SO_2)§
Atmospheric aerosol loading causes damage to vegetation and loss of freshwater fish from acidic precipitation, and harms human health (eg, by contributing to cardiopulmonary disease, acute respiratory infections, etc)§	Emissions of NH_3 from manure management and fertiliser application (and some smaller contributions from SO_2 and NO_x in fossil fuel combustion); secondary aerosols are formed (eg, SO_2 and NO_x from fossil fuel combustion and from NH_3 from manure management and fertiliser application)	Emissions of NH_3, SO_2, or NO_x, or a combination of these	Acidification potential (measured in g SO_2 eq)—ie, aggregation of acidifying substances converted to equivalents of the acidification potential of SO_2; particulate matter formation potential (measured in $PM_{2.5}$ eq) measures impacts on human health caused by emissions of fine particulate matter and its precursors (eg, NH_3, NOx, or SO_2)§||
Atmospheric aerosol loading also causes damage to vegetation (eg, by exposure to ozone) and harms human health (eg, by causing reduced lung function)§	Tropospheric, or ground-level, ozone is formed from NO_x and VOCs (eg, those emitted from engines or power plants) in the presence of sunlight	Emissions of NO_x	Photochemical ozone creation potential (measured in kg ethylene eq/m² ppm) evaluates the contribution of individual substances to ozone formation potential by converting their emissions in parts per million per area to ethylene ozone formation potential equivalents

(Table 1 continues on next page)

therefore inevitable,[11,14] as indicator categories are not mutually exclusive, which must be considered in indicator choice and interpretation.

We applied the Driver–Pressure–State–Impact–Response (DPSIR) framework[24] to categorise identified indicators, as this framework enables analysis of indicator types along a cause–effect chain in a structured way (appendix pp 46–48). The framework is well suited to our overall objective of providing recommendations to decision makers because it is already used in the context of public policy instruments.[14,25] For environmental diet assessments, primarily the three middle categories of indicators (Pressure, State, and Impact) are relevant to this Personal View, as Drivers include large-scale socioeconomic factors such as farm subsidies, and Responses include policies formulated to address impacts, both of which are beyond the scope of identifying indicators for assessing the environmental sustainability of diets. Pressure indicators measure environmental load or stress caused by human activities through emissions of environmentally damaging substances such as greenhouse gases (GHGs) and nitrogen (N), and use of resources such as land, water, and minerals. State indicators refer to physical, biological, and chemical conditions in an area, for example, concentrations of pollutants in lake water (panel 1). Impact indicators aim to capture what consequences such pressures have on the environment (eg, climate change or eutrophication of waterways[36]), but vary in how far along the cause–effect chain they measure the impact (figure 1, panel 1, appendix p 49). Some indicators, such as how different GHGs contribute to climate change (called midpoint impact indicators in lifecycle assessments [LCAs]), merely aggregate different pressures using an equivalence relationship, whereas others (called endpoint impact indicators in LCAs) aim to quantify the actual impact caused (eg, in terms of damages to ecosystems or human health). Some authors, including van Dooren and colleagues,[14] categorise LCA midpoint impact indicators as pressure indicators, as they do not measure the actual impact of any of the endpoint areas of protection (ie, human health, natural environtment, and natural resources). We refer to them as midpoint impact indicators

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See **Online** for appendix

	Main influence from the food system	Pressure indicators	Impact indicators
(Continued from previous page)			
Biosphere integrity			
Destruction of ecosystems, extinction of species, and decline in genetic diversity reduce the resilience of the biosphere and cause declines in functions provided by biodiversity (eg, pollination)	Fishing, hunting, and use of land for agriculture diminishes wild stocks and harms ecosystems, and contributes to pollution from use of fertilisers, pesticides, and other chemicals	Use of cropland or total agricultural land ($m^2 \times year$)—ie, the amount of cropland (and pasture in the case of total agricultural land) during a certain time (often 1 year) that is needed to produce the food or diet	Biodiversity damage potential, expressed as potentially disappeared fraction|| of species—ie, the fraction of species potentially lost locally, regionally, or globally; potential species loss (number of species)—ie, the number of potential species that will eventually be lost locally, regionally, or globally
Novel entities**			
Release of new substances, new forms of existing substances, and modified life forms negatively affects ecosystems and human health	Use of pesticides and other inputs that include toxic or polluting substances such as microplastics and polycyclic aromatic hydrocarbons	Amount of pesticides used (measured in kg active substance)—ie, the amount of pesticides used to produce the food or diet; greywater footprint (measured in L)—ie, the volume of water needed to assimilate a pollutant load that reaches a water body	Freshwater, marine, and terrestrial ecotoxicity (measured in comparative toxic unit for ecosystems, kg 1,4-dichlorobenzene eq, or kg triethylene glycol eq) estimates the effect of use of toxic substance on organisms
Release of new substances, new forms of existing substances, and modified life forms negatively effects ecosystems and human health	Use of nanomaterials and plastics	Not commonly used	Not commonly used
Stratospheric ozone depletion			
Thinning of the protective ozone layer of the stratosphere causes negative effects on marine organisms and ecosystems and human health	Emissions of CFCs used as a cooling medium in food storage and transport, and emissions of N_2O from soils and manure management; CFCs and N_2O trigger ozone-destroying reactions	Not commonly used	Stratospheric ozone depletion (measured in kg CFC-11 eq)—ie, the aggregation of ozone-depleting substances based on their depletion potential relative to CFC-11

Examples of indicators that are currently used for assessment of environmentally sustainable diets were identified in our synthesis of six key reviews.[11–14,16,17] For a complete list of diet-related environmental indicators, see van Dooren and colleagues.[14] All indicators can be based on different units of assessment (eg, per kg of food); here the denominator was per diet (potentially adjusted to calorie intake or similar). CFC-11= trichlorofluoromethane. CFCs=chlorofluorocarbons. eq=equivalent. GHG=greenhouse gas. LCA=lifecycle assessment. N=nitrogen. NO_x=nitrogen oxides. P=phosphorous. ppm=parts per million. SDG=Sustainable Development Goal. VOCs=volatile organic compounds. *Following Steffen and colleagues,[19] ocean acidification is not included as it is a consequence of CO_2 emissions, covered by climate change. †In environmental footprint assessment, carbon footprint is identified as pollution (pressure) footprint.[23] ‡New N is nitrogen added using synthetic fertiliser or leguminous crops, and new P is added mined phosphorus. New N/P excludes N/P in manure and other organic amendments in which N/P only circulates within the agricultural system. Emissions of N and P occur throughout the food system, also from recirculating nutrients in manure, waste, and crop residues, but high emissions in the long term are only possible through continued inputs of new N and P. Mitigation potential is therefore distributed throughout the food system; however, new N and P inputs are useful indicators of total pressure. §Concerns and indicators related to effects on human health were outside of scope of this study. ¶Small particles of solid or liquid suspended in air. ||Can be calculated as endpoints based on the aggregated impact from other environmental issues (climate change, land use change, disturbances to biogeochemical flows all cause biodiversity loss eventually) or as separate endpoints from different pressures, most commonly land use (discussed further in the section on biosphere integrity and in panel 1). **Novel entities are new substances, new forms of existing substances, and modified life forms with potentially unwanted geophysical and biological effects.[19]

Table 1: **Environmental issues for each planetary boundary,* influences, and indicators**

to distinguish between indicators that merely measure use of a natural resource (eg, water or land) or an emission (eg, NH_3) and indicators that consider some type of impact along the cause–effect chain. The DPSIR framework represents a cyclic process where a driver (in this case, food consumption) is directly linked to the endpoint

Panel 1: Tools and concepts for environmental performance assessment

Lifecycle assessment and environmental footprint assessment

The environmental performance of diets and foods is usually quantified using lifecycle assessment (LCA) or environmental footprint assessment (EFA).[11,13] LCA and EFA of food usually focus on the environmental issues associated with a certain food product (eg, 1 kg of tomatoes) or macronutrient (eg, 1 kg of protein). By multiplying the amounts of foods in a certain diet by per-kilogram LCA or footprint of individual food products, the environmental impacts or pressures of a certain diet can be assessed.

LCA is a well established method by which emissions (eg, CO_2 and NH_3) and resource use (eg, land, water, and minerals) along the product's whole supply chain, or lifecycle, are quantified and categorised into a set of midpoint impact categories (eg, global warming, eutrophication, ecotoxicity etc) using mostly deterministic and linear cause–effect chains (figure 1). Optionally, but more rarely in the case of diets, the analysis is extended along the cause–effect chain to include the actual final impact on humans and ecosystems (called endpoint impact categories). Such analysis enables aggregation of impacts caused by different damage categories such as global warming, eutrophication, or eco-toxicity into so-called areas of protection:[26] human Health, ecosystem quality,[27] and natural resources.[28]

Although LCA has been standardised generally[29,30] and more specifically for different food items, how LCAs are performed, the environmental impacts included, and the indicators used to describe them still vary considerably.

In EFA, environmental footprint is an umbrella term for the different footprint concepts developed in recent decades, including carbon, water, and land footprint.[31] Footprints are commonly indicators of the pressure of human activities on the environment and, as in LCA, cover emissions and resource use along the whole supply chain from producer to consumer, and sometimes to waste management. Footprints and LCA impact categories sometimes overlap; for example, carbon footprint is the same as the global warming LCA midpoint impact category. On the other hand, water footprint is used to denote water use without considering the impact of water consumption in the landscape,[32] but is also used by the LCA community to denote water scarcity-adjusted use of water.[33]

Driver–Pressure–State–Impact–Response framework

The Driver–Pressure–State–Impact–Response framework (figure 2) developed by the European Environment Agency can be used to illustrate where indicators are placed along the cause–effect chain.[24] A driver indicator could be, for example, the amount of animal protein consumed, as livestock production is a major driver of many environmental impacts. Pressure indicators relate to emissions and natural resource use, which put pressure on ecosystems that leads to different types of damage in different locations and contexts. For example, use of land is a pressure indicator because land is a finite resource and appropriation of land for agriculture puts major pressures on ecosystems in many regions, but to varying extents depending on the location. State indicators measure the properties of ecosystems, such as lake water pH. Impact indicators aim to capture the environmental impacts caused by pressures, such as the temperature change due to greenhouse gas emissions. Response indicators measure the policy responses to impacts caused, such as the ratio of emissions included in tax schemes or cap-and-trade systems.

Impact indicators are usually considered preferable for environmental assessments, as they measure the actual effect caused by drivers and pressures; however, they usually require information on where production takes place and site-specific data for that location that are usually not available for all foods in diets, such as soil and water status. Pressure indicators on the dietary level can still be highly valuable as decision support because they indicate the direction of change needed, but they can be misleading if not appropriately selected for the case at hand (panel 3). Even driver indicators can be useful, and sometimes preferable, due to their ease of assessment and interpretation. For example, the amount or proportion of animal-sourced foods or protein in a diet captures many of the environmental impacts and is easy to calculate and communicate. The framework represents a cyclic cause–effect chain linking drivers, such as animal-sourced food consumption, all the way to the societal response. Different responses, or the absence of a response, to environmental impacts can then be fed back and affect drivers, pressures, states, and impacts, ultimately affecting food availability and diets.

Planetary boundaries

The planetary boundaries framework defines environmental limits within which humanity can operate with low risk of causing destabilisation of the Earth system.[21,34] The framework is based around nine biophysical processes that are important for regulating the stability of the planet, enabling human civilisations as we know them today. The concept has been influential in shaping academic and policy debate globally by reviving the discussion on planetary limits.[35] Although all human activities, including those related to food, housing, energy, industry, and transport, need to be encompassed within the planetary boundaries, Willett and colleagues[22] presented boundaries of the global food system specifically for six Earth system processes, that is, the share of the overall operating space that food systems specifically should respect.

impact and response, which, represented here as damage to ecosystems, can ultimately limit the availability of food and thus, affect the driver of the system (figure 2, appendix p 50).

Our analysis showed that pressure indicators are mostly used for processes that result in local environmental concerns such as water and land use. Using pressure indicators for such local issues can be problematic, as effects are highly dependent on prevailing conditions (panel 2); however, their use is understandable because impact assessment typically requires complicated assessment models and detailed data on locations, production methods, and the local environment, which are seldom available for foods sourced from complex global supply chains.

Indicators related to climate change, land system change, freshwater use, and biogeochemical flows were the most commonly assessed planetary boundaries in the dataset. Midpoint impact indicators were commonly used for climate change, atmospheric aerosol loading, stratospheric ozone, and novel entities, and pressure indicators were used for land system change, freshwater use, and biogeochemical flows (figure 3). The least frequently assessed boundaries were biosphere integrity, stratospheric ozone, and novel entities, confirming previous findings.[36] For biosphere integrity, widely different indicators were used, including indicators of global extinction rates,[22,50] remaining fish stocks,[28,31] and forest cover loss.[51]

State of the art and recommendations for indicator use

In addition to consulting the literature, topic experts were identified to discuss the state of the art and formulate recommendations for indicator use. We conducted

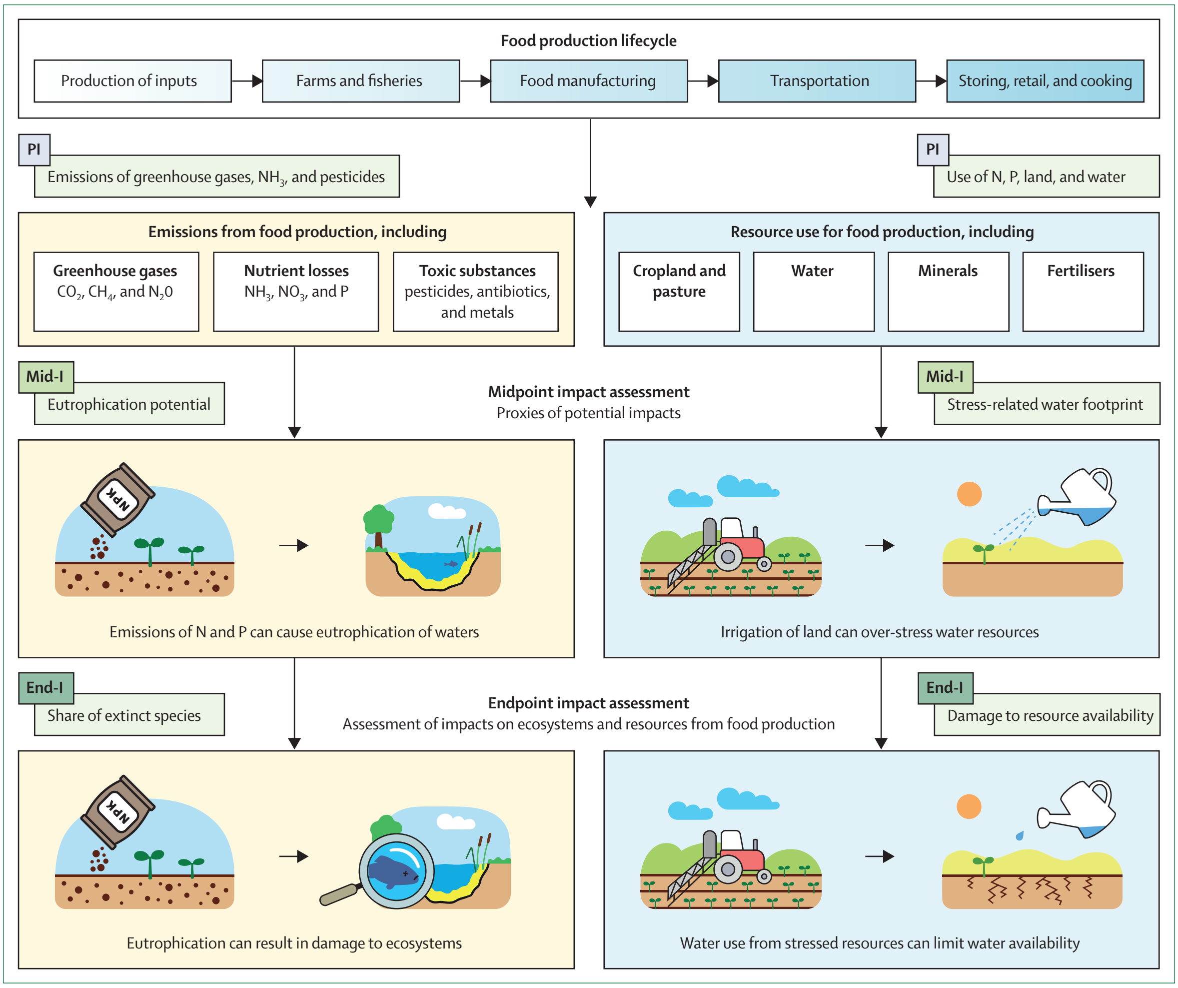

Figure 1: **Environmental assessment of foods and examples of indicators along the lifecycle**

The production lifecycle of the food product is first investigated (top). System boundaries differ, but in LCA studies, emissions and resource use from production to inputs, farming, manufacturing, and transport up to the retail gate are commonly included in the inventory (middle). From the inventory data, pressure indicators can be formulated. In the impact assessment phase (bottom), the midpoint or endpoint impacts, or both, that are caused by the emissions and resource use are modelled and expressed as impact indicators. Illustration by Gunilla Hagström for the Swedish University of Agricultural Sciences. End-I=endpoint indicator. LCA=lifecycle assessment. Mid-I=midpoint indicator. PI=pressure indicator.

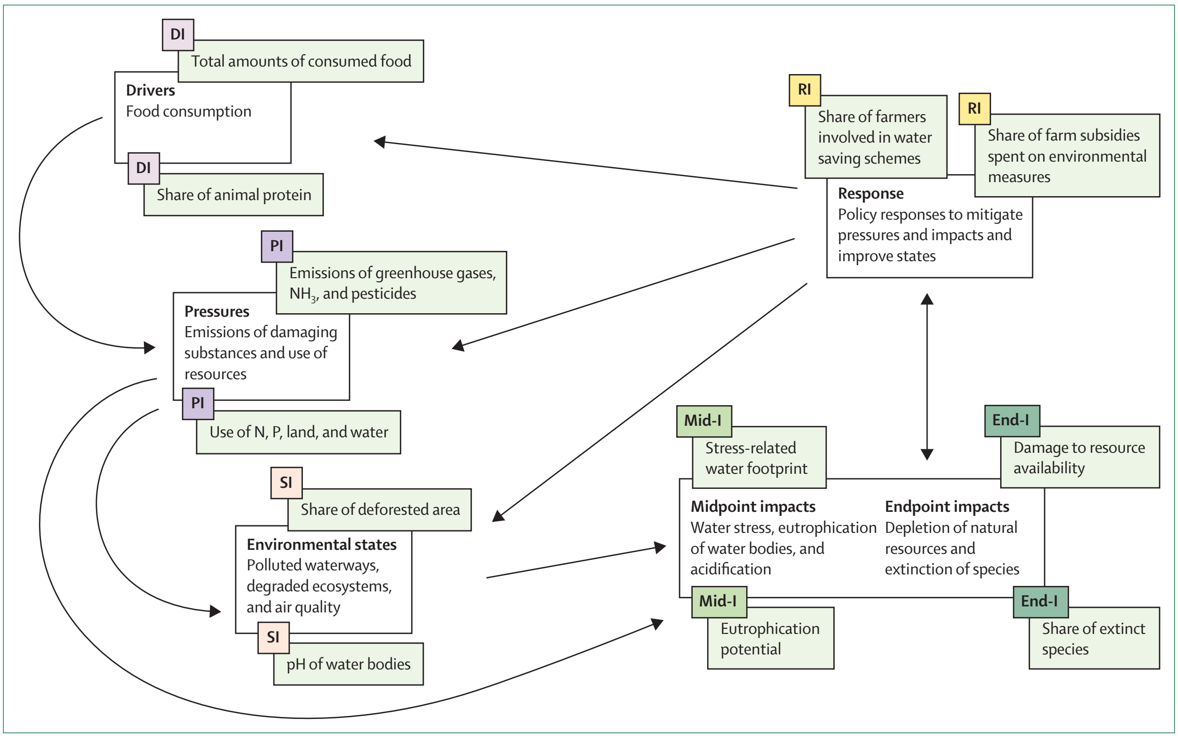

Figure 2: **Examples of Driver-Pressure-State-Impact-Response indicators and policy responses to diets**
Illustration by Gunilla Hagström for the Swedish University of Agricultural Sciences, adapted from Kristensen.[37] DI=driver indicators. End-I=endpoint indicators. Mid-I=midpoint indicators. PI=pressure indicators. RI=response indicators. SI=state indicators.

a workshop with invited experts that covered the key earth system processes and different types of indicators (LCA-based indicators, environmental footprints, etc). This process is described more in the appendix (pp 45–46), and the results from the consultation are outlined in the following sections.

Climate change

State of the art

Many studies assessing environmental performance of diets use the carbon footprint indicator (also called GHG emissions, climate impact, or global warming impact) with global warming potential (GWP, measured as CO_2 equivalents), which is generally used to aggregate impacts from different GHGs. GWP is defined as integrated change in radiative forcing (ie, change in energy flux in the atmosphere, which determines warming) over a specific period after the emission of a certain GHG in the present-day atmosphere, relative to the same quantity of CO_2.[52] The GWP metric requires a choice of time period over which to compare gases. This choice strongly influences the results for products with high methane emissions (eg, rice, dairy products, and ruminant meat), as methane is shorter-lived but has higher radiative efficiency than CO_2. A 100-year period (GWP_{100}) is used in most LCAs, international climate reporting, and many standards,[53–55] but the use of GWP_{100} for foods and diets is debatable (panel 3).

Recommendation

No metric can adequately capture all climate effects of foods, so choice of metric is heavily dependent on the study aim. For foods and diets, we recommend the use of GWP_{100}, but sensitivity of results to metric choice (including different GWP time periods) should be investigated (panel 3). If the choice of metric changes the overall conclusions, this must be clearly stated and discussed.

Land system change

State of the art

Although under the planetary boundaries framework, land system change focuses primarily on land affecting biogeophysical processes that regulate climate,[21] diet assessments commonly focus on the use of agricultural land used for producing the foods in the diet (called land use, land occupation, land footprint, cropland use, nature occupation, etc). This indicator measures the amount of agricultural land, or a specific land category (eg, cropland or pasture), required during a certain period for production of foods in a diet, which is expressed as hectares×years or m^2×years (table 1). This indicator shows that diets require large amounts of agricultural land, a finite natural resource.[28] Some studies calculate total cropland use relative to global cropland availability, to determine whether a diet is within the sustainable production capacity of cropland.[22,50,66] Land use is relatively

Panel 2: Examples of the importance of choosing appropriate indicators

Example 1: Blue or green water consumption, or both?

Beef production uses a large amount of water. Measuring the environmental impact of this water consumption requires careful indicator selection. When the water footprint of beef is reported as total water consumption, without differentiation between blue, green, and grey water and without considering water scarcity (ie, using a total water footprint),[32] estimates commonly reach 15 000 L of water per kilogram of beef produced, and for pasture-based systems, estimates reach as high as 25 000 L/kg beef produced, compared with 6000 L/kg for pig meat produced and 4000 L/kg for chicken.[38] A dietary recommendation based on this outlook would conclude that it is preferable to eat pork and chicken meat to beef; however, if the cattle are kept on grasslands that are not irrigated and are unsuitable for crop production for human consumption or bioenergy production, the total water footprint of beef then mostly consists of green water that has few other uses for human activities. Use of rainwater under such circumstances would, therefore, not contribute to water shortages for humans. On closer inspection, of the 15 000 L of water required for the production of 1 kg of beef, only about 4% is blue water, and the amounts of blue water required for production of pig and chicken meat are 9% and 7%, respectively. Thus, from the perspective of blue water consumption only, the production of beef requires similar amounts of water as the production of pig meat. However, high consumption of green water indicates that the beef production system captures water that could have been used by natural ecosystems.[39] Hence, indicators for blue and green water consumption provide different, complementary information.

Example 2: Organic comes up short when the perspective is too narrow

Organic agriculture strives to be a production system that sustains the health of soils, ecosystems, and people, and relies on ecological processes, biodiversity, and resource use that is adapted to local conditions.[40] Under this definition, organic agriculture applies a broad sustainability perspective, with restrictions on chemical inputs and a focus on management practices that enhance soil quality and biodiversity. By only assessing the most common indicators for climate change, land use, and freshwater use, studies tend to favour intensive, high-yielding agricultural systems that produce more food per unit of land and water, as opposed to less intensive systems[41] with lower greenhouse gas (GHG) emissions.[42] Positive ecological feedback, such as regained ecosystem services, that would contribute to sustainable crop yields in the long term are generally not accounted for.[43] Therefore, a diet that contains a high amount of organic products, with potentially lower harmful effects on biodiversity, a smaller contribution to chemical pollution, and better soil fertility, would perform worse in an environmental assessment than a diet with more conventional foods. Conversely, if indicators for novel entities and soil health were included, a diet rich in foods from organic production systems could show more favourable results.

Example 3: Baltic Sea herring—climate-friendly and overfished

The environmental impacts from foods from aquatic animals, algae, and plants (farmed and fished, freshwater and ocean) is generally lower than for terrestrial animal products;[44,45] however, the diversity of aquatic foods is enormous, with more than 2500 species farmed or fished globally.[46] Environmental impacts vary substantially among species and production systems. Some types of aquatic foods generally show particularly good performance with low GHG emissions and small effects with respect to other dimensions traditionally measured with lifecycle assessment. Farmed filter feeding organisms (including mussels), seaweed (algae), and wild-caught small pelagic fish (such as mackerel or anchovy) tend to have the least environmental impact in assessments. Small pelagic fish are caught with midwater trawls, requiring little fuel from fishing vessels, and therefore have a small carbon footprint per kilogram of edible weight. Clupeoids (including sardines, anchovies, and herring) are characterised by high but fluctuating recruitment rates and are among the most important commercial fish species globally.[47] Although the carbon footprint is low per kilogram of edible weight, fishing can have other severe effects. The central and western herring stocks in the Baltic Sea have been declining for a long time and are now at record low amounts.[48] Despite this, Baltic Sea herring destined for both human consumption and fish meal and oil is in high demand.[49] This example illustrates that choosing climate-friendly fish does not guarantee that the fish stock is well managed and that biodiversity is considered, indicating the need for a larger set of indicators in diet assessment.

straightforward to calculate, using data on aggregated yields of food and feed crops, which are widely available in databases such as the Food and Agriculture Organization of the UN FAOSTAT database and the Eurostat database. More sophisticated land use indicators consider factors such as land productivity in different regions[67] or geographical scarcity of land.[68] For grazing land, a variety of accounting methods are used.[69]

Human appropriation of land drives biodiversity loss,[70] so land use is commonly used as a pressure indicator for biodiversity loss and ecosystem damage.[71] Endpoint impact methods capturing global biodiversity impacts from land use (eg, number of species at risk of extinction) require the amount of land used as input.[72,73]

Recommendation

Amount of land required to produce a diet (eg, measured in m²×year) is an indicator that can be computed with reasonable accuracy on the basis of existing data, and is easy to interpret. We recommend

For more on the **FAOSTAT database** see fao.org/faostat

For more on the **Eurostat database** see ec.europa.eu/eurostat/web/main/data/database

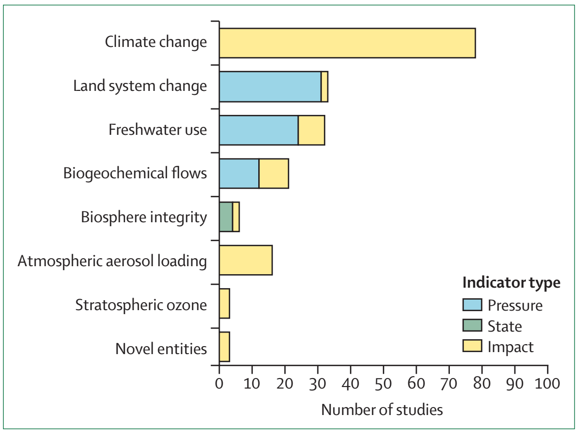

Figure 3: **Assessed planetary boundaries by indicator type**

Number of studies in the review by Harrison and colleagues in 2022[11] assessing each planetary boundary,[21] categorised according to Driver–Pressure–State–Impact–Response indicator type.[24] Some studies assessed several boundaries. Ocean acidification is not included, as it is a consequence of CO_2 emissions covered by climate change.

using this indicator to capture the resource-use aspect of land use. Different types of land (importantly, cropland and pasture), however, should be kept separate. To capture biodiversity impacts specifically related to land use, we recommend the use of endpoint indicators of actual impacts on biodiversity, such as the number of species affected.[72] Capturing biodiversity impacts is highly complex (as discussed in the section on biosphere integrity) and substantial work is needed to improve biodiversity indicators.

Freshwater use

State of the art

Water use for diets is often assessed using pressure indicators that measure the total volume of water (in litres) required to produce foods in a diet.[74–76] In this Personal View, we refer to consumptive water use, or water consumption (ie, the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, or consumed by humans or livestock).[77] By contrast, non-consumptive water refers to the amount of water that, despite being withdrawn from the body of water, is later returned to the water system. Water consumption can be assessed as either blue water (eg, surface water and groundwater) consumption, or blue and green water (rainwater available as soil moisture) consumption for crop growth.[78,79] Crops and grass are both major water consumers, as water is essential for plant growth.[79] Rainfed crops receive only green water, whereas irrigated crops receive both blue and green water. Grazing animals require large amounts of green water embedded in grazed biomass and other feedstuffs. Researchers have suggested global sustainable limits for both blue[22] and green[80] water consumption against which diets can be benchmarked; however, preciseness of these limits is highly uncertain, particularly at a local level. In supply chain assessments, including those for diets, blue water consumption (eg, as blue water footprint) is generally used as an indicator to avoid any double-counting of non-consumptive water uses.[81]

To account for environmental impacts of water consumption, indicators that compute water stress can be used;[81,82] however, data availability on where different foods are produced can restrict computation for whole diets, as water stress is highly localised.[83] Average country values on water stress are available,[82] but can obscure the spatial dimension of water stress, which can render country-specific comparisons meaningless as foods can be produced in areas of both low and high water stress within the same country.[84]

Freshwater use estimations can also include a proxy for water pollution as a grey water footprint, which is calculated by how much water is needed to dilute polluted water to a threshold concentration.[32] As grey water is an indicator of pollution rather than water consumption, however, it is better categorised under the planetary boundaries of biogeochemical flows and novel entities.

Recommendation

Blue and green water consumption are meaningful, complementary indicators (panel 2), but the grey water footprint is better positioned under the planetary boundary of novel entities, as it is a theoretical proxy for water pollution rather than actual water consumption. We recommend using both blue and green water consumption indicators but presenting them separately. To relate blue and green water consumption to environmental effects, indicators capturing water stress or scarcity, such as Sustainable Development Goal indicator 642 on water stress[81] or available water remaining factors, can be used;[82] however, using these indicators requires detailed data on food production area, rendering water stress or scarcity indicators less useful. Because data on blue water use are much more widely available than data on green water use,[39] there is a slight preference to focus on blue water consumption.

Biogeochemical flows

State of the art

Effects on biogeochemical flows are most commonly measured by pressure indicators,[11] such as kilograms of N and P (phosphorous) required to produce foods in a diet.[50] Such indicators (sometimes also called N and P application) commonly include only new N and P added (ie, N captured from air in synthetic fertilisers or by legumes and P mined from rock). The rationale for focusing on new N and P is that, although emissions also occur from recirculating so-called old nutrients in manure, waste, and residues, in the long term, emissions are only possible due to the continued input of new N and P to replace the nutrients lost. Therefore, although emissions of N and P do not necessarily occur at the time

Panel 3: Assessing impacts on climate change

Limitations of the GWP_{100} metric had already been acknowledged when it was introduced.[56] One of the most discussed drawbacks is the metric's weighting of short-lived greenhouse gases (GHGs) such as CH_4 and long-lived GHGs such as CO_2. Although a large fraction of CO_2 stays in the atmosphere for millennia, CH_4 is naturally removed with a half-life of approximately 10 years. Due to the integral nature of global warming potential (GWP), it has a long memory of short-lived GHG emissions after their effect has decayed.[57] Alternative metrics have been developed to overcome such limitations, including global temperature change potential (GTP).[58] GTP represents the effect of an emission pulse of a certain GHG on global average surface temperature at a specified point in time after the emission relative to the same quantity of CO_2, thus limiting the so-called memory component of the metric. GTP has its own limitations, however; for example, it only considers warming at a specific time, not before or after that timepoint. For food products from ruminant animals, metric choice is important due to the associated CH_4 emissions. In 2019, Lynch and colleagues[59] showed that beef production using grassfed systems tended to create larger emissions than beef production from non-grassfed systems when using GWP_{100}, but the opposite when using GTP_{100}. However, beef remains vastly higher in climate impact than other meats or plant-based products, independent of metric choice. When using GWP or GTP, the choice of time horizon, a normative decision based on the value placed on near-term versus long-term impacts, strongly affects the results.[60]

The GWP* metric has been proposed to better represent the fundamental difference in short-lived and long-lived GHGs.[61] GWP* compares a one-off emission of CO_2 with a change of rate in CH_4 emissions, which has been shown to better reflect the temperature change contribution of different gases than when these are aggregated using GWP;[62] however, calculating the change in rate of short-lived GHG emissions for GWP* introduces new challenges in relating current emissions to emissions in the past. On a global scale, this challenge is unproblematic, but for smaller entities such as a country, farm, or product, it introduces a need to consider equity or fairness principles.[63] For example, if the rate of change in short-lived emissions is considered on a country level, countries with historically large CH_4 emissions would be favoured. This favouring is equivalent to grandfathering, a principle in climate ethics that is strongly criticised for being unfair.[64] In 2019, Rogelj and Schleussner[63] suggested that GWP* could be used for countries under different equity concepts (eg, by an equal per capita division of emissions or warming) but this usage also reflects moral value judgements, as with choice of time horizon for GWP and GTP. Whether and how GWP* could be meaningfully applied at product level to be useful for decision making related to foods and diets is unclear.

Another aspect to consider when comparing results from different studies is that GWP factors are regularly updated as the composition of the atmosphere changes and methods to establish such factors are improved. For example, the GWP factors in the latest Intergovernmental Panel on Climate Change Working Group 1 report[52] are 27 for biogenic CH_4 and 273 for N_2O, compared with 28 and 265, respectively, in the previous Intergovernmental Panel on Climate Change report that was released 10 years earlier.[65]

and place of new N and P inputs, the new N and P inputs are useful proxies of probable emissions.

Another pressure indicator is the N footprint, defined as total reactive N emissions per unit of consumption.[85,86] An analogous P footprint approach exists.[87,88] These footprint indicators have the advantage over new input of N and P in that they explicitly consider emissions of N and P regardless of whether they are old or new, and therefore more directly account for environmental pressures. Moreover, N footprints are sometimes usefully disaggregated by chemical form or location.[85] Grey water footprint has also been used as a proxy for pollution from biogeochemical flows to water ecosystems in diets.[32,89,90]

These pressure indicators do not measure actual impacts on terrestrial and aquatic ecosystems, but are reasonable proxies for potential impacts, considering the large differences between product categories (beef, pork, chicken, root vegetables, cereals, etc).[85] Considering mined P also captures some geopolitical resource concerns about these non-substitutable nutrients.[91,92]

Actual impacts of N and P emissions can differ widely depending on local and regional conditions, for example, initial water eutrophication status and factors other than application of nutrients to agricultural land.[93] Assessing impacts from N and P use requires spatially detailed data on emissions and other environmental variables,[94] which are usually unavailable for most foods in a diet. Thus, use of impact indicators for biogeochemical flows from diets (eg, using indicators such as marine, freshwater, or terrestrial eutrophication[95] or Eutrophication potential[96]) is not meaningful without data on food origin and local conditions (table 1).

Recommendation

Impact indicators that measure eutrophication, acidification, and other impacts of N and P flows are preferable, as impacts are highly influenced by local conditions; however, for these to accurately reflect impacts compared with pressure indicators, detailed data with high spatial resolution on factors such as the origin of foods and site-specific conditions are required but commonly unavailable. Simpler pressure indicators (eg, inputs of new N and P, N and P footprint) are useful to capture differences across food groups and diets, but should not be used for detailed comparisons within food groups.

Atmospheric aerosol loading

State of the art

The effect of atmospheric aerosol loading from diets is usually assessed as negative effects on human health, rather than environmental effects,[11,97] using the LCA midpoint impact indicator of fine particulate matter ($PM_{2·5}$) pollution or respiratory organics (measured in kg $PM_{2·5}$ equivalents [eq]; table 1). Acidification is also a concern classified under the planetary boundary of atmospheric aerosol loading, and is included in some studies as acidification potential (measured in kg SO_2 eq; table 1).[98,99] To capture the creation of ground-level ozone, the indicators of photochemical ozone creation (measured in kg ethylene eq) is used, among others.[98]

Recommendation

How choice of diet drives emissions of fine particulate matter is unknown, which is a reason to include it in future studies on diets. Acidification impacts vary substantially on the basis of the amount of animal products in the diet being assessed, but this aspect will be captured in carbon footprint and land use. NH_3 emissions are commonly covered by biogeochemical flow indicators. Acidification could, therefore, be excluded from environmental assessments of diets to reduce the number of indicators; however, because NH_3 emissions drive processes such as eutrophication, acidification, and fine particulate matter formation, an NH_3 emissions indicator could be warranted, provided overlaps with indicators for biogeochemical flows are avoided.

Biosphere integrity

State of the art

Biosphere integrity (ie, biodiversity) differs from other planetary boundaries in that it is an endpoint affected by all other pressures. Climate change, habitat change, and disturbances to biogeochemical flows, among other factors, all ultimately affect biosphere integrity. Lifecycle impact assessment can be used to model the aggregated effect of different pressures on the ecosystem quality endpoint impact indicator (species×years lost or potentially disappeared fraction×year), combining endpoint impact indicators for climate change, eutrophication, acidification, land use, and water consumption, for example (using methods such as the ReCiPe method,[95] LC-IMPACT,[100] and ImpactWorld+).[101]

Many models for individual impact categories also exist. For land use, one of the most relevant pressures, methods exist for estimating how different species are affected by land management (eg, cropping or pasture) in relation to wild habitats.[72,73] These methods account for impacts of land transformation (eg, land clearance), land occupation (ie, continuous use of land for cropping or grazing that prevents regrowth of natural vegetation), and, in some cases, land fragmentation. Exploitation through fishing, the second largest driver of biodiversity loss,[102] can be modelled with the endpoint impact model recently developed by Helias and colleagues.[3]

Indicators or methods for biosphere integrity give coarse results associated with major uncertainties, due to complex cause–effect chains and spatial variation in biodiversity impacts. For example, many different taxa are affected by many pressures. The results are also affected by the normative choices made in these methods.[103] With some exceptions,[50,104,105] biodiversity assessments are uncommon in studies of diets. Biodiversity aspects related to seafood are commonly not included—a major omission.

Despite uncertainties and limitations, methods with global coverage[72] can be useful in highlighting biodiversity impact hotspots in diets that would be missed if focusing only on one aspect, such as climate change. In a 2020 study on Swedish diets, Moberg and colleagues[50] showed that coffee, tea, and other tropical products made relatively small contributions to the diet's overall climate impact compared with the other food products in the diet, but had large effects on biodiversity.

Coarse indicators cannot capture local biodiversity impacts. For example, the Chaudhary–Brooks[72] method shows higher biodiversity impacts for organic coffee production due to greater land use compared with conventional production,[106] although studies on the actual measured biodiversity on site often show the opposite.[107]

Biodiversity assessment methods operationalised for LCAs and footprinting of complete diets with broad geographical coverage usually only cover species richness, although overall biodiversity comprises three levels: genetic, species, and ecosystem. For some biodiversity drivers (invasive species, noise, light pollution, and overfishing), emerging methods have been applied only in a few case studies.[108] Meaningfully capturing such aspects of biosphere integrity at the food product or diet level might be impossible, as these aspects of biosphere integrity might be too indirect and complex to link to the consumption of specific foods.

Recommendation

Considering the range of aspects affecting biosphere integrity, methods that include many causes of biodiversity loss (eg, lifecycle impact assessment methods) are preferable, but also complex and data-intensive. Methods based on land use with global coverage are straightforward to use and can capture effects of land use in biodiversity hotspots; however, they are not able to capture the nuances of biodiversity impacts associated with different production systems. We recommend their use with the highest possible resolution. Interpretation should acknowledge uncertainties and focus on magnitude and direction of impact, rather than comparing numbers or similar products. Methods based on land use should also be complemented by methods considering biodiversity in freshwater and marine ecosystems.

Novel entities

State of the art

Few environmental assessments of diets include indicators for novel entities, probably due to a shortage of data and the complexity in using models to assess the effects caused, although food production is a major driver of issues such as chemical pollution. Indicators for chemical pollution from agriculture comprise pressure-type indicators measuring use of pesticides by kilogram of active substance applied, without considering the compound used,[109] and impact assessment models in LCAs evaluating the effect of toxic substances on terrestrial or aquatic ecosystems.[110,111] Grey water footprint has also been used as a proxy for pollution to water ecosystems in diets.[32,89,90]

Thousands of novel entities, with specific characteristics and unique effects on organisms and ecosystems, are emitted from global food production systems, and calculating ecotoxicity factors for these is data-intensive and complex.[112] Using pressure indicators for pesticide application only requires data on the total amount of pesticides used, not individual substances and their different factors;[27] however, even the use of pesticides per hectare for different crops is difficult to establish, as these data are not regularly monitored. Moreover, some pesticides are used in very small amounts but are highly toxic (eg, pyrethroids), so the amount used can be a misleading indicator.[113] This misleading indicator is partly avoided by using indicators such as treatment frequency index, based on mean number of treatments weighted by the ratio of pesticide dose used to recommended dose.[114] If indicators for chemical pollution are excluded from the environmental assessment of diets, the benefits of low pesticide use in alternative (eg, organic) farming systems are not captured, which could lead to unfair comparisons[41] (panel 2).

Veterinary antibiotics are a novel entity released from livestock production and aquaculture.[115] Data on toxicological properties are needed for estimating robust impact indicators for antibiotics.[116] Novel entities are also emitted from other processes related to food production, including electricity use.[117] Aggregating such effects with those from pesticide use requires impact indicators, which can be difficult to establish.

Plastic particles varying in size from large particles to nanoparticles are now ubiquitous in nature. Effects on species vary greatly, from physical effects from entanglement or ingestion to toxic impacts.[118] Indicators for occurrence and effects of plastic contamination are emerging,[119,120] but not currently used in assessments of diets.

Recommendation

Indicators that capture toxicity are preferable, as the environmental effect of novel entities varies on the basis of local conditions and substance. For pressure indicators such as pesticide use in kilogram of active substance, results can be misleading because some low-dose pesticides can have high toxicity; however, we still recommend use of pesticide treatment frequency indices or application rates as indicators for novel entities, rather than omitting these completely, especially for assessments including production systems with differing pesticide use (eg, organic and conventional).

Stratospheric ozone

State of the art

Destruction of the ozone layer is seldom included in environmental assessments of diets. When included,[71,98,121] it is often assessed using the midpoint impact indicator of ozone layer depletion potential (measured as CFC-11 eq).[122]

Recommendation

Agriculture is currently a top contributor to ozone depletion due to N_2O emissions.[123] However, N_2O emissions are captured by carbon footprint (N_2O is a major GHG and contributor to global warming), so we recommend omitting ozone layer depletion from assessments of sustainable diets to limit indicator numbers.

Missing aspects: soils, blue foods, and depletion of natural resources

State of the art

Preventing further degradation of agricultural land is an urgent challenge for long-term food security,[124] but is seldom included in assessments of diets. Kraamwinkel and colleagues[125] suggest soil degradation as the tenth planetary boundary, and soil organic carbon change as an indicator for soil quality. Soil organic carbon changes have been suggested within the EU Soil Mission as one of eight indicators for soil health.[126] How different agricultural practices influence soil organic carbon is highly dependent on factors such as crops, management practices, soil, and weather conditions,[127] for which site-specific information is commonly unavailable; however, gross default factors for different crop types (eg, annual and perennial) can be used. Moberg and colleagues[50] included carbon emissions and sequestration in soil in the carbon footprint but did not report soil organic carbon changes separately as an indicator for soil quality.

The planetary boundary framework includes use of three finite natural resources (water, land, and P); however, other resources should be considered. For example, many sectors compete for renewable energy, and energy use in agriculture and aquatic production is highly variable across diets.[128]

Sustainability issues specifically related to blue foods are often omitted in evaluations of diets.[129] These issues include extraction of wild species, seafloor damage, and competition for space for aquaculture.[130] Extraction of wild species through fishing should be included in assessments of environmental impacts of diets, as it

	Justification	Section
Basic assessment		
Carbon footprint	Well established indicator with relatively good data availability	Climate change, panel 3
Blue water consumption	Captures trade-offs with carbon footprint, as some foods with a low carbon footprint have high blue water consumption (eg, some nuts, fruits, and vegetables); if precise production location for foods in the diet is known, indicators that consider water scarcity or stress provide complementary information	Freshwater use
Biodiversity impact from land use	Captures trade-offs with carbon footprint, as some foods with a low carbon footprint have high biodiversity impacts from land use (eg, products grown in tropical regions)	Biosphere integrity
Ecotoxicity or pesticide use	Capture differences between factors such as organic and conventional production or crops with varying pesticide intensity (eg, forage crops or legumes); impact indicators that cater for toxicity in substances should be selected if data on the substances used are available; otherwise, indicators on amounts or frequency of pesticide use can be used	Novel entities, panel 2
Exploitation of wild fish stock	Captures impact on wild stocks from fishing, which is an important cause of biodiversity loss, and can highlight trade-offs between overfishing and carbon footprint of diets	Missing aspects, panel 2
For more comprehensive assessment		
Land use	Captures use of agricultural land from a resource perspective; if no indicator for biodiversity loss from land use is used, then land use can also function as a pressure indicator of biodiversity impact	Land system change
Soil quality	Captures how the diet affects land quality in terms of soil fertility	Missing aspects
Green water consumption	Complements blue water consumption by accounting also for the rainwater needed for producing the diet; however, green water is correlated with carbon and land footprints on diet level, so green water consumption can be omitted when the number of indicators needs to be reduced	Freshwater use, panel 2
For high-ambition assessment		
New N and P input, N and P footprint, acidification, or NH_3 emissions, or a combination of these	New N and P input or footprint act as a gross proxy of impacts on biogeochemical flows, and NH_3 emissions can be used as a proxy somewhat more specific to acidification, air pollution, and terrestrial eutrophication	Biogeochemical flows
Energy use	Competition for renewable energy justifies keeping track of the total energy used to produce a certain diet	Missing aspects
Impacts on seafloor	Complements the land use indicator and captures an important source of damage to oceans from diets that is not captured by other indicators	Missing aspects

N=nitrogen. P=phosphorous.

Table 2: **Recommendations on choice of indicators for assessing the environmental performance of diets**

poses a major threat to biosphere integrity globally and exploits a natural resource (panel 2).[70] Fisheries that affect non-target species and ecosystems and the target stock can, if managed poorly, be overfished and eventually collapse. LCA indicators that capture effects of wild-caught seafood on overfishing risks and global species loss do exist,[3,131–133] and include methods that consider the depleted stock fraction to quantify effects on ecosystem quality and that assess the maximum sustainable yield to quantify overfishing and lost potential yield. These methods have not, however, been applied in diet assessments. Seafloor impacts related to fisheries can also be quantified using existing metrics,[132,133] and development of additional LCA methods and indicators is ongoing. Diet assessments generally focus on terrestrial food production, but should also cover aquatic food production.

Recommendation

We encourage use of indicators for total energy use (eg, cumulative energy demand)[134] to capture the energy efficiency of diets. For wild-caught seafood, overfishing and impacts on biosphere integrity and seafloors should be considered using available methods.[3,131–133] We also recommend considering how soils and land quality are affected by diets, but acknowledge the challenge involved considering limitations in methods, traceability, and data.

Conclusions

Our recommendations on indicator choice for diet assessment reflect three levels of ambition (table 2). Unlike Doreen and colleagues[14] and Cimini and Moresi,[97] who considered indicators of GHG emissions and land use sufficient for capturing most environmental performance of diets, we believe that environmental assessments of diets should also include indicators relating to biosphere integrity, water consumption, novel entities, and exploitation of wild fish stocks, to capture important trade-offs (table 2). If more indicators can be handled in the assessment, we recommend use of indicators that capture impacts related to the quantity and quality of land use and green water consumption to complement blue water consumption. For an ambitious assessment, indicators related to biogeochemical flows, energy use, and seafloor damage can be added. This ranking does not reflect the importance of different environmental issues; for example, disturbances to biogeochemical flows are a very serious problem.[21] However, the set of indicators we recommend can capture differences in environmental impacts across diets and highlight trade-offs between dietary choices.

Uncertainty in research assessments stemming from a shortage of representative data and variation in impacts from different production systems should be acknowledged and communicated when presenting results (eg, when comparing different diets), by better reporting ranges in primary data[135,136] or performing sensitivity analysis on the most uncertain and impactful assumptions. Statistical inferential methods, such as hypothesis testing or confidence intervals, cannot, however, be used on simulated data.[137] Furthermore, care is needed when communicating indicator results to avoid giving an impression of high certainty (eg, reporting in many digits or ranking diets when the difference in impact is small, and to correctly communicate what the indicator shows (eg, pressure indicators should not be interpreted as reflecting the actual impact).

The promotion of healthy and sustainable diets is urgently needed, and assessing the sustainability of diets should incorporate environmental sustainability. In this Personal View, we identify, analyse, and discuss indicator choice and provide recommendations and guidance as to which indicators to choose, and in conjunction with assessment ambition level, with the aim to unpack some of the complexity of the assessment of the environmental sustainability of diets for those carrying out assessments.

Although challenging, complex, and labour-intensive to implement correctly, inclusion of environmental dimensions in assessments of sustainable and healthy diets for a broad audience is important. We should not let perfect be the enemy of good. Instead, we need to work with what is available under given circumstances in terms of indicators and data. Furthermore, food system actors should join forces to collect more of the data needed for environmental assessments, including data on pesticide use and traceability of food items. Awareness of trade-offs in terms of accuracy and relevance is needed when choosing so-called simpler methods, and better tools for communication, interpretation, and implementation of research results need to be developed.

Contributors

YR, ER, MJ, and CC designed the study and performed the analysis. All authors interpreted results and discussed findings. YR and ER coordinated the development of the first manuscript draft. All authors commented on and edited the draft version and approved the submission of the final version.

Declaration of interests

We declare no competing interests.

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