NOURISHING PEOPLE AND PLANET

ENVIRO-NUTRITIONAL INSIGHTS INTO LOCAL FOODS FOR POLICY, PROGRAMMES, AND INDUSTRY

GAIN Briefing Paper n°16

SEPTEMBER 2025

Flaminia Ortenzi, Jessica Colston, and Ty Beal

gain
Global Alliance for Improved Nutrition

GAIN Briefing Paper n°16

RECOMMENDED CITATION

Ortenzi F., Colston J., Beal T. Nourishing People and Planet: Enviro-Nutritional Insights into Local Foods for Policy, Programmes, and Industry. Global Alliance for Improved Nutrition (GAIN). Briefing Paper 16. Geneva, Switzerland, 2025. DOI: https://doi.org/10.36072/bp.16

ACKNOWLEDGEMENTS

The authors wish to thank Lucia Dal Balcon and Stella Nordhagen for their valuable contributions to previous versions of this Briefing Paper.

This Briefing Paper has been produced through the Nourishing Food Pathways programme jointly funded by:

In partnership with Canada

Co-funded by the European Union

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Irish Aid
An Roinn Gnóthaí Eachtracha
Department of Foreign Affairs

Ministry of Foreign Affairs

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

The findings, ideas, and conclusions presented here are those of the authors and do not necessarily reflect positions or policies of any of the agencies mentioned above.

All photographs included in this document have been taken with consent for use in publications.

SUMMARY

The world is currently facing two interconnected and severe crises: widespread malnutrition and environmental degradation. Food systems are central to both issues, as they are responsible for a significant portion of greenhouse gas emissions, natural resource depletion, and environmental damage, while simultaneously feeding billions of people. Diets are a crucial link between human and planetary health and have been identified as a key lever to address both the climate and malnutrition crises. However, there are inherent trade-offs between nutritional and environmental goals, making it difficult to find solutions that simultaneously improve both outcomes. This paper introduces nutritional Life Cycle Assessment (nLCA) as an evidence-based tool to guide policy, programmatic, and industry decision-making, and demonstrates how nLCA can provide actionable, context-specific insights that help reconcile (often competing) nutritional and environmental priorities.

nLCA addresses an important limitation of 'conventional' Life Cycle Assessment approaches by incorporating foods' nutritional value into environmental footprint assessments. We highlight four major use cases for nLCA-derived insights. First, the methodology enables stakeholders to make high-level strategic decisions by comparing the combined environmental and nutritional performance of different food groups. For example, policymakers can use this data to inform national dietary guidelines or redirect agricultural subsidies toward target food groups. Second, nLCA can be used to prioritize top-performing items within a specific food category, helping programme managers and health professionals identify the most nutritious and eco-friendly options for community-based interventions and nutrition counselling. A critical third use case is the profiling of foods against multiple environmental indicators. This reveals important trade-offs, showing that a food performing well in one category (e.g., climate change) may score poorly in another (e.g., water use). Finally, nLCA can pinpoint the most environmentally intensive processes in a food's lifecycle. This enables value chain actors to make targeted investments in research and innovation to improve resource efficiency where most needed.

In conclusion, nLCA is a flexible and adaptable tool that empowers a wide range of stakeholders to make informed decisions for a healthier and more sustainable food system. The path forward involves expanding its use, refining its methodology, strengthening capacity among end-users, and fostering partnerships to translate evidence into action.

KEY MESSAGES

- The interconnected crises of malnutrition and environmental degradation demand urgent, integrated solutions. Diets are key levers for positive change, but balancing nutritional and environmental goals is complex and requires context-specific strategies.
- Nutritional Life Cycle Assessment (nLCA) is an evidence-based tool that incorporates foods' nutritional value into environmental footprint assessments.
- nLCA-derived insights into the combined nutritional and environmental performance of foods can be used to (i) inform high-level strategies through cross-food group comparisons, (ii) prioritize top-ranking items within specific food categories, (iii) profile foods against multiple environmental indicators to reveal trade-offs, and (iv) identify 'hotspot' processes in food value chains.
- To effectively transform food systems, it is crucial to expand the application of nLCA, refine its methodology, and strengthen the capacity of policymakers, programme managers, and supply chain actors to effectively use its findings.

BACKGROUND AND OBJECTIVE

Dual global crises: persistent malnutrition alongside growing environmental degradation

A large body of evidence highlights the increasing severity of environmental degradation worldwide, emphasising the growing frequency and magnitude of climate anomalies such as dryland water scarcity, heavy precipitation, heatwaves, and droughts, along with rising greenhouse gas (GHG) emissions and global surface temperatures (1). While agri-food systems feed and support the livelihoods of billions of people globally, they are responsible for an estimated USD 2.9 trillion of environmental damage annually and account for approximately a third of anthropogenic GHG emissions (2,3). Agriculture is a primary driver of land degradation, responsible for 70% of global biodiversity loss (4), 78% of marine and freshwater pollution (5), and 70% of global freshwater resource consumption (6). In addition to causing severe ecosystem disruptions, climate change also negatively affects crop yields and livestock productivity, reduces the nutrient density of staple crops, and threatens food safety. These impacts are projected to result in an additional 8 to 80 million people at risk of hunger by mid-century, concentrated in Sub-Saharan Africa, South Asia, and Central America, thereby exacerbating social and public health inequities (7–10).

With an estimated annual economic cost of USD 3.5 trillion, the double burden of malnutrition affects all countries globally, across income levels and geographic regions, with undernutrition (e.g., stunting, wasting, underweight, micronutrient deficiencies), overweight and obesity, and diet-related non-communicable diseases (e.g., diabetes, cardiovascular disease, certain cancers) co-existing within the same populations, households, and individuals (7,11,12). Recent evidence shows that over 730 million people (about 9% of the global population) are undernourished, approximately 22% of children under five years of age are stunted, and two-thirds of women of reproductive age are deficient in at least one essential micronutrient (11,13,14). At the same time, overweight and obesity have now reached pandemic proportions, with 2.5 billion adults and 37 million children under five being overweight in 2022, and an expected 1 billion obese adults by 2030 (15,16).

The role of diets: opportunities and challenges for reconciling nutritional and environmental goals

Poor diets, widespread malnutrition, and environmental degradation are inextricably linked through the interdependencies of climate, ecosystem services, biodiversity, and agri-food systems. Unhealthy dietary patterns directly contribute to negative human and planetary health outcomes. Given their substantial impacts on both nutrition and health and the environment, diets have been internationally recognised as a key lever and dual solution for simultaneously addressing the intertwined climate and malnutrition crises. A global shift toward healthier and more sustainable dietary patterns is crucial to achieving food systems transformation and meeting the Sustainable Development Goals, thereby making diets a valuable entry point for concrete policy, programmatic, and industry action (7,17,18).

However, concurrently improving human and planetary health outcomes carries inherent trade-offs requiring nuanced decision-making and context-specific strategies. For instance, researchers and policymakers worldwide often recommend the adoption of primarily plant-based diets to reduce global GHG emissions and resource use (18–23). However, some plant-based diets may be nutritionally inadequate, especially if heavily relying on highly processed products and/or lacking a diversity of nutrient-dense whole foods (e.g., pulses, nuts, and seeds; dark green leafy vegetables) (24–26). Thus, their large-scale adoption risks exacerbating widespread micronutrient deficiencies, especially among nutritionally vulnerable population groups (e.g., infants and young children, women of reproductive age, and pregnant and lactating women). Conversely, promoting consumption of minimally processed, nutrient-rich animal-source foods (i.e., meat, eggs, dairy, and fish) would generally result in greater environmental footprints but may yield significant improvements in diet quality and health outcomes where the burden of undernutrition is high and intake of animal-source foods is currently low, including many low- and middle-income countries (24–28).

Given the complexity of balancing (sometimes conflicting) sustainability and nutrition/health priorities, evidence-based, systematic approaches and tools are needed to support integrated decision-making at global, national, and local levels. This involves developing and implementing comprehensive methodologies to holistically evaluate the nutritional value and environmental footprints of foods and diets, while also considering other sustainability dimensions (e.g., affordability, social equity, justice, cultural acceptability, and desirability). The ultimate goal of such wide-ranging assessment methods is to generate context-specific insights that are reflective of the diverse needs and priorities of different countries and population groups (29).

This Briefing Paper aims to introduce nutritional Life Cycle Assessment (nLCA) methodology as an evidence-based tool for guiding policy, programmatic, industry, and investment decisions to simultaneously improve human and planetary health. We use a case study from Indonesia to demonstrate how nLCA can provide actionable, contextually relevant insights for a large variety of applications, ranging from the development of dietary guidelines, to reorienting agricultural subsidies, and informing product and process innovation.

NUTRITIONAL LIFE CYCLE ASSESSMENT: WHAT IS IT AND WHY IS IT RELEVANT?

Life Cycle Assessment (LCA) is a commonly used methodology to systematically quantify and compare the environmental footprints of individual foods, food groups, complex meals, and whole diets throughout their full lifecycle—from primary production to consumption and waste treatment (or 'from cradle to grave'). LCA provides valuable insights into the efficiency and sustainability of food supply chains, by identifying the most impactful processes (or 'hotspots') and most significant environmental footprint categories (e.g., climate change, land or water use) for a given food or dietary pattern (30).

However, LCA approaches have important limitations that warrant caution when interpreting results. A key feature of LCA is the reference unit, which serves as the denominator for measuring and reporting foods' environmental footprints (expressed as impact quantity per reference unit) (31). Commonly employed mass- or energy-based reference units (e.g., 1 kg or 1000 kcal of product) fail to account for variation in nutritional value across foods, resulting in environmental footprint comparisons that are not nutritionally relevant (32). For example, directly comparing the environmental footprint of one kilogram of white rice to one kilogram of spinach is not nutritionally meaningful, as these foods have widely different nutritional value and play completely different roles in diets. Indeed, as shown in Figure 1, a small amount of spinach (~250 g) provides the same nutritional value as a much larger quantity of white rice (~1 kg). This emphasizes the need to develop reference units that comprehensively capture foods' nutritional value, facilitating the effective integration of health and environmental goals within LCAs (33–37).

The emerging field of nLCA aims to overcome the above limitation by adopting reference units based on foods' content in specific nutrients (e.g., protein) or nutrient profiling systems (e.g., the Nutrient Rich Foods Index), rather than kilograms or calories. Incorporating aspects of nutritional value enables comparisons of foods' environmental footprints that are more valuable to a broad range of public, private, and non-profit sector actors aiming to contribute to improving both human and planetary health (30,35–37,39).

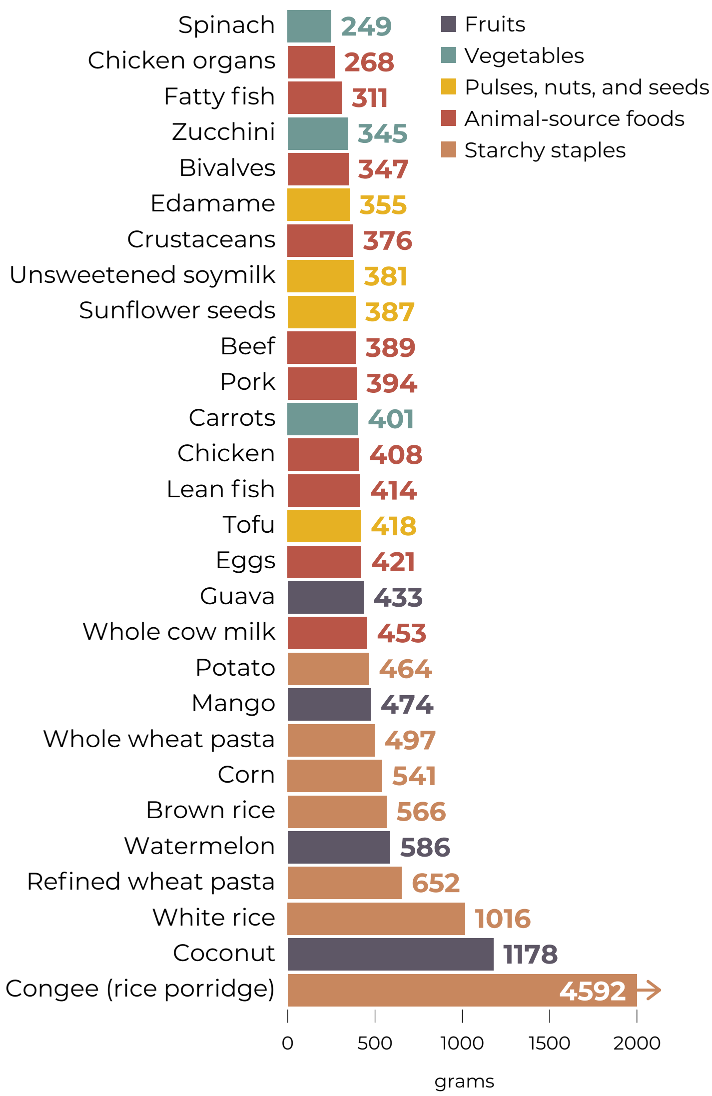


Figure 1: Amount (grams) of common Indonesian foods needed to provide equivalent nutritional value. In this figure, nutritional value was quantified using the Nutritional Value Score rating system (38), which will be introduced in the following sections of this Briefing Paper.

nLCA methodology can be applied at different levels, from the evaluation of single foods' environmental performance to that of multi-ingredient recipes, whole diets, and food systems at large. It can encompass *all* (i.e., 'from cradle to grave') or *some* product life-cycle stages (e.g., 'from cradle to farm-gate', excluding post-harvest processing, retail, consumption, and waste management). nLCA also allows for differential weighing of the environmental footprint categories analysed, based on local agroecological conditions and policy priorities, toward ensuring the contextual relevance of assessment results. Additionally, it can be tailored to different public health and nutrition goals by modifying the dietary factors included in the reference unit and their relative weights. For instance, if focusing on regions with high rates of micronutrient deficiencies, greater emphasis can be placed on micronutrient density when designing the reference unit (30).

The high flexibility and adaptability of nLCA and its ability to incorporate foods' nutritional value alongside assessing their environmental footprints make it a powerful tool for policy-makers, investors, programme implementers, researchers, and value chains actors working towards sustainable food system transformation. Indeed, nLCA-derived *enviro-nutritional* (i.e., combined environmental and nutritional) insights into contextually appropriate foods can meaningfully inform local decision-making and lend themselves to a large variety of applications. To illustrate this, we present data and figures from an Indonesian nLCA case study recently conducted by the Global Alliance for Improved Nutrition (GAIN).

USE CASES OF nLCA-DERIVED ENVIRO-NUTRITIONAL INSIGHTS

GAIN's nLCA approach: methodology and proof-of-concept study in Indonesia

GAIN developed a comprehensive, easily adaptable nLCA approach for identifying locally available, commonly consumed foods with the greatest potential to maximise nutritional outcomes while limiting environmental harms to inform country-specific interventions. The methodology employs a novel reference unit to holistically capture foods' nutritional value. This is based on an innovative nutrient profiling system–the Nutritional Value Score (NVS)–specifically designed for use in environmental impact and affordability assessments. The NVS incorporates both essential nutrients of global health priority and dietary factors predictive of non-communicable disease risk, making it suitable for application in countries of all incomes. It ranks foods' nutritional value on a scale of 1 to 100, where 1 represents the lowest nutritional value and 100 represents the highest nutritional value (38). GAIN's nLCA approach quantifies foods' overall and category-specific environmental footprints per 100 NVS (rather than a fixed mass or energy amount), enabling the integration of nutritional and environmental performance assessments. We are currently in the process of applying this nLCA methodology to a growing number of Asian and African countries, including Indonesia.

Indonesia faces a substantial double burden of malnutrition, with about 9% of the population being undernourished, 23% of young children being stunted, and 31% of women of reproductive age suffering from anaemia, while 35% of Indonesians live with overweight or obesity (13,40–43). Widespread environmental degradation further exacerbates nutrition and health challenges in the country, which is subject to significant pressures from land use change and deforestation (44).

Against this background, it is essential to identify 'best-bet' foods for simultaneously optimising nutrition/health and environmental outcomes. We analysed the enviro-nutritional performance of 90 locally available, commonly consumed foods in Indonesia across five food groups recommended in global dietary guidelines: animal-source foods, pulses/nuts/seeds, starchy staples, vegetables, and fruits. The nLCA methodology encompassed seven environmental footprint categories (i.e., climate change, air pollution, soil quality, fresh and marine water pollution, and water and land use) and examined the full lifecycle of foods, from primary production through consumption and waste treatment. The inclusion of a wide spectrum of environmental indicators and adoption of a holistic, nutrition-based reference unit enabled the generation of valuable insights into the enviro-nutritional synergies and trade-offs of Indonesian foods, which could be used to inform local decision-making.

Use case #1: High-level strategies involving cross-food group comparisons

One use case for nLCA is analysing the variation in nutritional value and environmental performance across a (large) selection of items organised in common food groups, to inform high-level decisions concerning all food categories.

In the Indonesian example, when considering the Nutritional Value and overall Environmental Footprint Scores (i.e., across all environmental indicators measured) of food groups (Figure 2), vegetables tend to perform well against both metrics, presenting relatively high nutritional value and low environmental footprints. This is especially true for dark green leafy vegetables, which are top performers against both scores. However, significant variations can be observed within the vegetables group, with some items (e.g., mung bean sprouts, red and green peppers) presenting higher environmental footprints and/or lower nutritional value than others (e.g., pumpkin leaves, water spinach). Fruits typically have low environmental footprints and moderate nutritional value. For instance, this is the case for apples, pears, and citrus varieties, while other fruits (e.g., coconut, watermelon) rank worse in terms of nutritional value. Starchy staples also tend to perform well against environmental indicators, but generally provide moderate (e.g., potato, whole wheat pasta) to low (e.g., rice porridge, white rice) nutritional value, emphasizing their role as environmentally efficient dietary energy sources while revealing their limited potential to significantly contribute to overall diet quality. Animal-source foods and pulses/nuts/seeds tend to have medium-to-high nutritional value, but their environmental footprints show large intra-group variations, ranging from low (e.g., mussels, unsweetened soymilk), to moderate (e.g., lamb, cashews), or high (e.g., beef).

Overall, Figure 2 highlights the absence of a strong correlation between nutritional and environmental performance of common food groups, with highly nutritious options sometimes carrying significant environmental burdens. For example, this is the case of beef, which has a moderate-high NVS (59 out of 100) but is the worst performing food in terms of environmental footprint relative to the set of foods analysed.

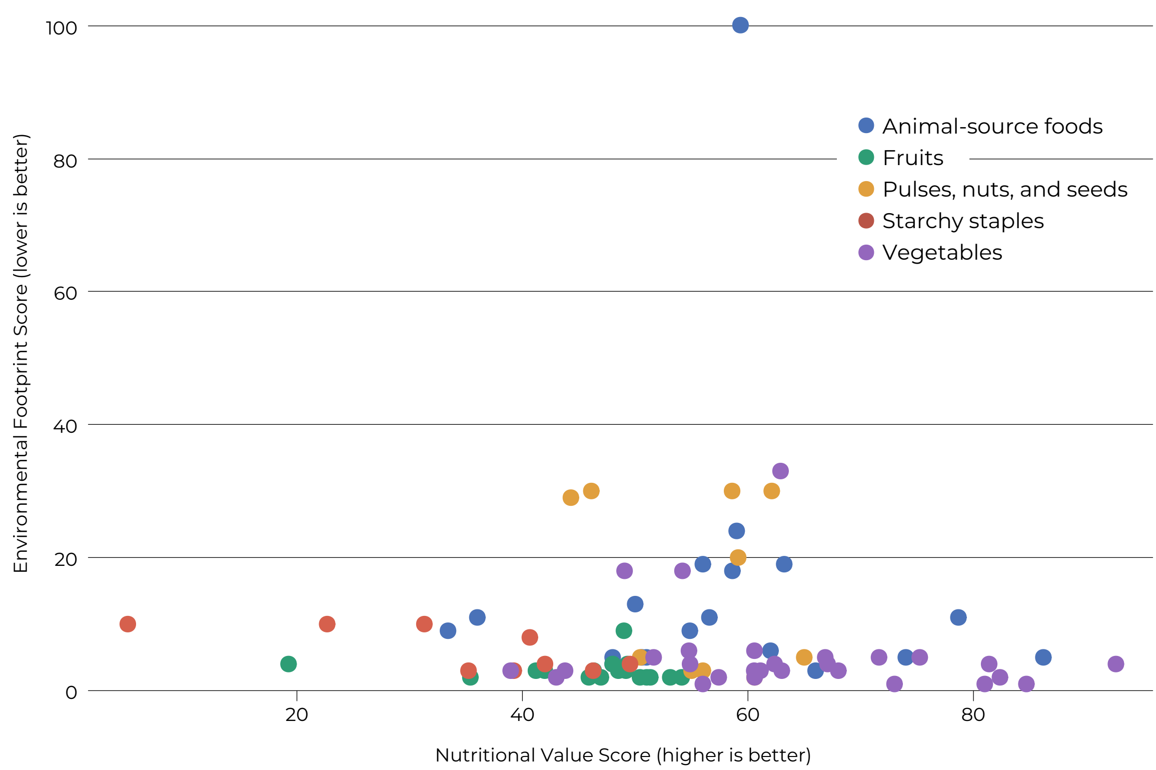


Figure 2: Overall Environmental Footprint and Nutritional Value Scores for 90 foods commonly consumed in Indonesia, organised into five food groups. Environmental Footprint Scores were calculated per unit mass (i.e., 1 kg of food) and normalized on a scale of 1 to 100, where 1 corresponds to the best performing food and 100 to the worst performing. NVSs were calculated per unit mass (i.e., 231 g of food) and energy (i.e., 300 Calories of food), and were normalized on a scale of 1 to 100, where 1 represents the lowest nutritional value and 100 the highest nutritional value.

This type of analysis and way of visualising the findings could be used for a wide range of potential applications concerning a variety of food system stakeholders across disciplines and sectors. Among others, these include:

- **Policymakers**, who may benefit from this kind of assessment for:
  - The development of national healthy and sustainable dietary guidelines, as well as tailored guidance on nutritious and eco-friendly food group options for institutional meal/menu planning (e.g., school and hospital canteens) and nutrition education campaigns.
  - Redirecting agricultural subsidies towards the production of food groups with potential to positively contribute to diet quality with relatively low environmental harms (e.g., vegetables in the Indonesian case study).
  - The establishment of taxation frameworks to disincentivize the production and consumption of food groups with poor nutritional value and environmental performance.
  - The strategic planning of agricultural activities at national level (e.g., crop cultivation, animal husbandry, and fisheries).
- **Food manufacturers**, who may draw from this type of analysis to evaluate the overall positioning of their product lines against nutritional and environmental metrics, and inform portfolio restructuring/diversification decisions.
- **Programme managers** (including those working in international, governmental, non-governmental, and civil society organizations, as well as private sector entities), who could use these insights to identify target food groups for prioritisation in context-specific interventions.

Use case #2: Prioritisation of top-ranking items within food groups

In addition to enabling cross-category comparisons, nLCA can also be used to analyse the variation in environmental performance among individual items *within* food groups and observe changes in foods' environmental footprints when shifting from mass- or energy-based to nutrition-based reference units. The latter comparison clearly demonstrates the significant influence of the reference unit over the final nLCA results, thereby making the case for moving beyond mass-based environmental footprint assessments to provide food system stakeholders with a more holistic perspective.

Figure 3, drawn from the Indonesian example, shows a comparison of overall Environmental Footprints per unit mass vs. per unit nutritional value for a selection of protein-rich foods. Whilst plant-source foods generally tend to outperform their animal-source counterparts, there are some notable exceptions. For instance, among plant-source options, cashews stand out as one of the worst environmentally performing protein-rich foods (mostly due to high fertilizer use in countries of origin), whereas certain animal products, such as chicken organs, plain whole yogurt, whole cow milk, and tuna, have environmental footprints comparable to those of the best performing plant-source foods (e.g., unsweetened soymilk, tofu, tempeh, peanuts). When comparing mass- vs. nutrition-based Environmental Footprint Scores, the relative ranking of most foods remains unaltered, but the magnitude of impacts for certain items varies significantly. This is the case for beef, cashews, tilapia, pork, mung beans, and red beans, among others.

This type of analysis and the resulting insights could be leveraged by:

- **Policymakers**:
  - » To identify best-bet options within a given food category for simultaneously achieving nutritional and environmental goals, for prioritisation in social protection mechanisms (e.g., food assistance programmes), public procurement strategies (e.g., school feeding and hospital catering services), and nutrition/health education campaigns.
  - » To establish marketing and advertising regulations for food manufacturers and retailers, including stricter policies on the promotion of unhealthy and unsustainable products in public spaces, on mass media, or at points of purchase (e.g., nutrient-poor, environmentally intensive ultra-processed foods).
  - » To inform the strategic planning of agricultural activities (i.e., crop cultivation, animal husbandry, and fisheries).

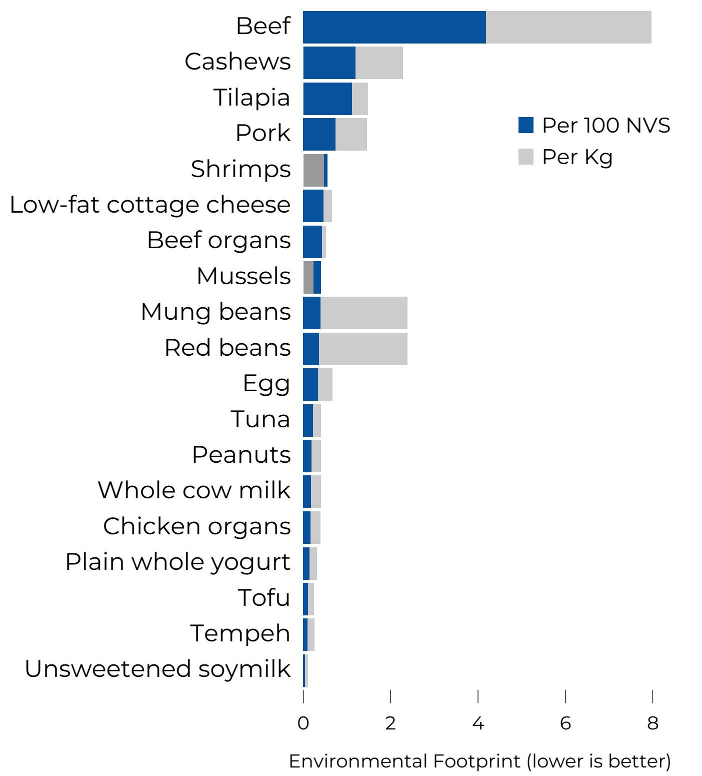


Figure 3: Comparison of overall Environmental Footprint Scores per unit mass (i.e., 1 kg of food) vs. per unit nutritional value (i.e., g required to achieve an NVS of 100) for a selection of protein-rich foods commonly consumed in Indonesia. Both mass-based and nutrition-based Environmental Footprint Scores are expressed in milliPoints (mPt), where the lowest value corresponds to the best performing food and the highest value to the worst performing.

- **Food manufacturers and retailers**:
  - » To benchmark products against nutritional and environmental performance indicators, toward informing process restructuring and/or product reformulation decisions.
  - » To guide the development of in-store and online promotional messages and nudging strategies (e.g., purposeful shelf placement or product positioning in online search results) for influencing consumers' purchasing behaviours.
- **Programme managers and health professionals**:
  - » To raise awareness among consumers (including through nutrition counselling) on top-scoring options within each food group for maximising nutritional benefits with relatively low environmental harms.
  - » To identify highly nutritious and eco-friendly options within a target food group for promotion in supply chain, market-based and community-level interventions (e.g., social and behaviour change communication or demand generation programmes).

Use case #3: Profiling of foods against multiple environmental footprint categories

Another key use case of nLCA is comparing the differential enviro-nutritional performance of individual foods against multiple environmental indicators (e.g., climate change, water and land use, soil quality, etc.). Indeed, foods scoring well on a given environmental footprint category may perform poorly on other indicators.

In Figure 4 (derived from the Indonesian study), spinach clearly illustrates this complexity: while it imposes a relatively low burden on climate change, freshwater pollution, and land use, its production often requires intensive irrigation and relies on substantial use of synthetic fertilizers and pesticides, resulting in high footprints on air and marine water pollution, as well as water use and soil quality. Similarly, tuna scores relatively well on land and water use, and freshwater pollution; however, fuel-intensive aquaculture/farming practices, transportation, and industrial processes associated with the tuna value chain result in poor performance in terms of soil quality, air and marine water pollution, and climate change. These examples demonstrate that overemphasizing climate change contributions (as is common practice in many contexts and sectors worldwide) may lead to neglecting critical trade-offs among different environmental concerns.

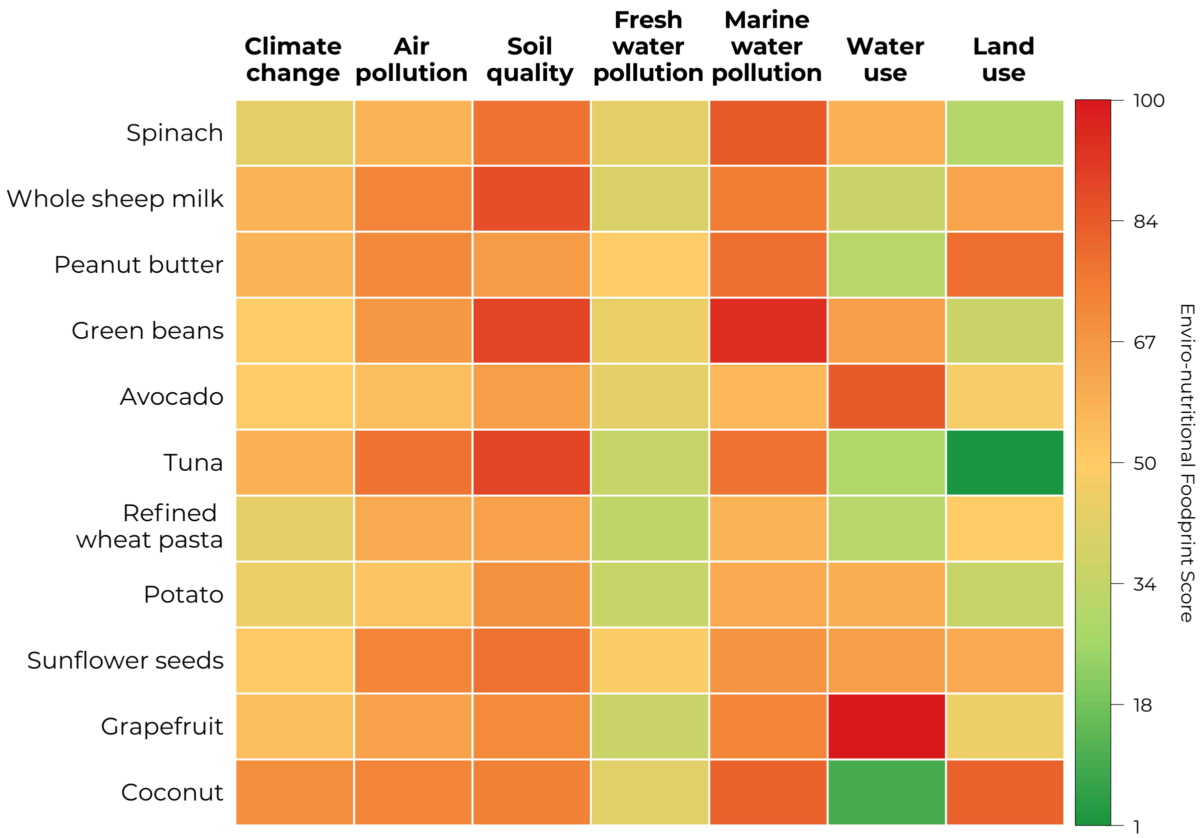


Figure 4: Enviro-Nutritional Footprint Scores across seven environmental indicators analysed for a selection of foods commonly consumed in Indonesia from all five food groups considered. Enviro-Nutritional Footprint Scores were calculated per unit nutritional value (i.e., g required to achieve an NVS of 100) and normalized on a scale of 1 to 100, where 1 (dark green) corresponds to the best performing food and 100 (dark red) to the worst performing.

Figure 5 shows the environmental footprint profiles of four protein-rich foods commonly consumed in Indonesia, to illustrate the heterogeneous environmental burdens imposed by different items on various sustainability dimensions. This highlights the potential for complementarity of ecosystem benefits and risks across foods within the context of healthy and sustainable diets. For instance, while cashew production primarily affects marine ecosystems and soil quality, tilapia supply chains contribute more significantly to freshwater and air pollution, as well as water use. Thus, diversifying protein sources and strategically combining protein-rich foods with complementary environmental footprint profiles may contribute to effectively reducing overall food system-related ecological pressures, while simultaneously promoting dietary diversity.

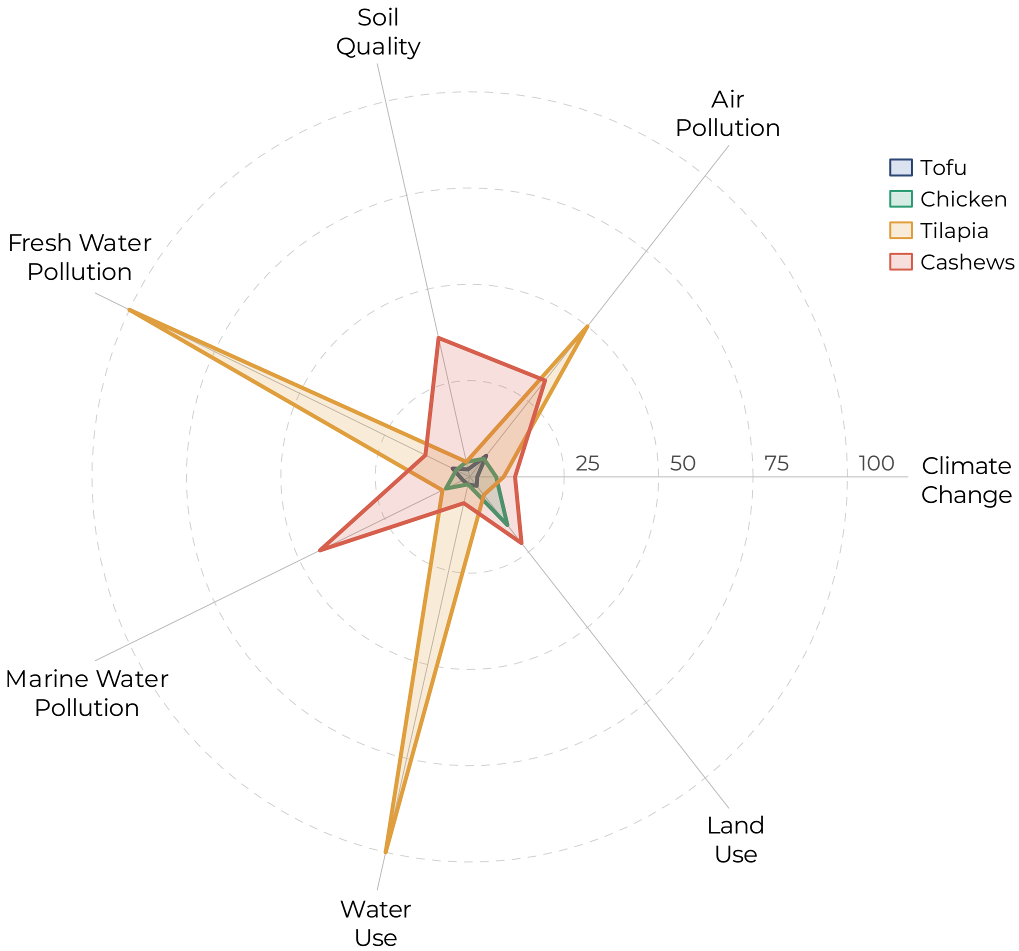


Figure 5: Enviro-Nutritional Footprint Scores across seven environmental indicators analysed for four protein-rich foods commonly consumed in Indonesia. Enviro-Nutritional Footprint Scores were calculated per unit nutritional value (i.e., g required to achieve an NVS of 100) and normalized on a scale of 1 to 100, where 1 corresponds to the best performing food and 100 to the worst performing.

Insights from large-spectrum environmental profiling of single foods, like those presented for Indonesia, could inform the development of context-specific policies and interventions for addressing the most pressing local sustainability priorities. Stakeholders who may benefit from this type of analysis for various applications include:

- **Policymakers**, who could leverage these findings for:
  - » Making nutrition-sensitive and environmentally informed agricultural planning decisions, by selecting crop and animal species based on high-burden ecological concerns. For instance, in areas of Indonesia facing extensive soil degradation, policymakers may consider disincentivizing cultivation of soil-depleting crops (e.g., green beans, spinach).
  - » Establishing standards and regulations across all supply chain stages, such as the enforcement of 'ecological thresholds' for priority environmental footprint categories within a given context.
- **Supply chain actors** (including producers, food manufacturers, distributors, vendors, and waste management operators), who could draw from this kind of assessment to:
  - » Design front-of-package labelling systems, as well as in-store and online marketing and nudging strategies for shifting consumers' choices.
  - » Inform the development and implementation of targeted optimization strategies aimed at mitigating foods' contributions to the most impacted environmental sustainability dimensions.
  - » Benchmark products against multiple environmental indicators, enabling more nuanced evaluation and comparison of items to guide reformulation and product innovation decisions.

Use case #4: Identification of 'hotspot' processes and lifecycle stages for environmental footprints

nLCA also enables conducting Life Cycle Contribution Analysis, which reveals the most impactful stages/processes (or 'hotspots') along food value chains. These could be targeted in interventions, strategic innovation programmes, and investments aimed at improving foods' performance against a given environmental indicator.

Taking climate change as an example within the Indonesian case study (Figure 6), while some variation can be observed in the lifecycle stages contributing the most to this indicator across foods (e.g., primary production, packaging, and waste treatment for mussels; processing for tofu; primary production, distribution, and waste treatment for coconut and durian), primary production accounts for the largest share of climate change impacts for the majority of items analysed. This highlights the need for substantial resource allocation to research, technological advancements, and innovation uptake within this supply chain segment.

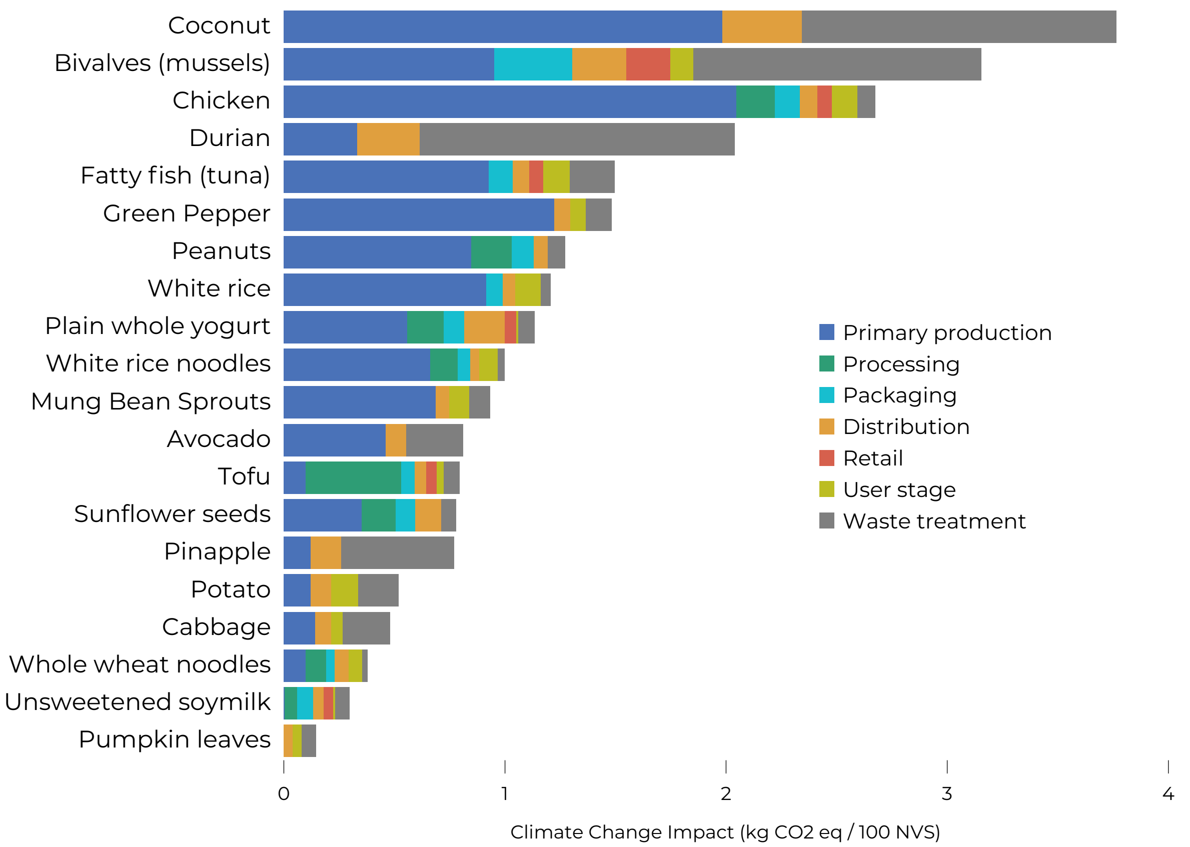


Figure 6: Contribution of different lifecycle stages to Climate Change Impacts (expressed as kg CO_2 eq/100 NVS) for a selection of foods commonly consumed in Indonesia across all five food groups analysed.

Findings from Life Cycle Contribution Analysis could be leveraged by:

- **Policymakers**:
  - » To support the development of commodity- and context-specific production, processing, distribution, selling, and waste management regulations, toward streamlining the adoption of least-harmful practices and ensuring compliance to minimum standards for food systems environmental sustainability.
- **Food manufacturers**:
  - » To benchmark products against competitors and identify hotspots for existing and novel products, thereby informing process optimization and potential reformulation decisions.
- **Value chain actors, academia/research institutes, investors, programme implementers,** and **policymakers**:
  - » To guide effective investments in research and innovation, technological progress, best-practice adoption, and human capital development, toward improving resource efficiency in lifecycle stages contributing the most to a given environmental indicator.
- **Programme implementers**:
  - » To inform the design of awareness raising campaigns, market-based and community-level initiatives for sensitising vendors and consumers around food waste prevention/reduction strategies, in cases where waste treatment accounts for a large share of impacts against a given environmental footprint category.

CONCLUSION AND WAY FORWARD

The interconnected crises of malnutrition and environmental degradation demand urgent, integrated solutions at all levels, from global to local. Food systems and diets significantly impact both human and planetary health, representing key levers for positive change. However, balancing nutritional needs with environmental sustainability is complex and carries inherent trade-offs, requiring nuanced, context-specific strategies. nLCA emerges as a promising evidence-based tool for guiding local decision-making aimed at maximising nutritional/health benefits while limiting environmental harms. It overcomes important limitations in 'conventional' LCA by integrating foods' nutritional value into environmental footprint comparisons.

GAIN's Indonesian case study illustrates nLCA's potential to generate valuable, contextually relevant enviro-nutritional insights for a wide variety of applications across stakeholders and sectors. This approach helps identify best-bet foods for reconciling nutritional and environmental goals, analysing trade-offs among different environmental indicators, and pinpointing value chain hotspots for targeted interventions.

To advance towards healthier diets from more sustainable food systems, the following actions are crucial:

- **Expand the application of nLCA**, by promoting wider adoption in diverse contexts, especially in low- and middle-income countries, to build a global evidence base for localized, integrated solutions.
- **Continue refining nLCA methodology**, including through the development of comprehensive nutrition-based reference units and incorporation of often-neglected sustainability dimensions like biodiversity.
- **Strengthen capacity**, by training policymakers, programme managers, and value chain actors to effectively use and interpret nLCA findings.
- **Move from theory to practice**, through the establishment of partnerships among governments, academia, private sector, and civil society for translating nLCA-derived enviro-nutritional insights into coherent action, including their integration into national dietary guidelines, agricultural planning, public procurement, fiscal measures, and supply chain innovation.

If adequately used, tools like nLCA can empower stakeholders to make informed decisions to transform food systems, with the ultimate goal of nourishing a growing global population sustainably and equitably.

REFERENCES

1. Lee H, Romero J. IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Internet]. Geneva, Switzerland: IPCC; 2023. p. 35–115. Available from: https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf
2. Food and Agriculture Organization of the United Nations (FAO). Greenhouse gas emissions from agrifood systems—Global, regional and country trends, 2000–2022. [Internet]. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2024. (FAOSTAT Analytical Brief Series). Report No.: 94. Available from: https://openknowledge.fao.org/items/74bfebdb-3272-4e6a-98f4-ee36c7146d44
3. The State of Food and Agriculture 2023: revealing the true cost of food to transform agrifood systems. In: The State of Food and Agriculture 2023: revealing the true cost of food to transform agrifood systems. 2023. p. 150 pp.-150 pp.
4. WWF. Farming with Biodiversity. Towards nature-positive production at scale. [Internet]. Gland, Switzerland: WWF International; 2021. Available from: https://wwfint.awsassets.panda.org/downloads/farming_with_biodiversity_towards_nature_positive_production_at_scale.pdf
5. Ritchie H, Rosado P, Roser M. Environmental Impacts of Food Production [Internet]. Our World in Data; [cited 2025 June 13]. Available from: https://ourworldindata.org/environmental-impacts-of-food
6. Ritchie H, Roser M. Water Use and Stress [Internet]. Our World in Data; 2024 [cited 2025 June 13]. Available from: https://ourworldindata.org/water-use-stress
7. The state of food and agriculture 2024: value-driven transformation of agrifood systems. In: The State of Food and Agriculture 2024—value-driven transformation of agrifood systems. 2024. p. xxvii-+ 140 pp.
8. Bezner Kerr R, Hasegawa T, Lasco R, Bhatt I, Deryng D, Farrell A, et al. Food, Fibre and Other Ecosystem Products. In: Climate Change 2022—Impacts, Adaptation and Vulnerability Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Internet]. Cambridge University Press; 2023. p. 713–906. Available from: https://www.cambridge.org/core/books/climate-change-2022-impacts-adaptation-and-vulnerability/food-fibre-and-other-ecosystem-products/16B2DB8BEC0790EA6DB2856CD8897DFF
9. Owino V, Kumwenda C, Ekesa B, Parker ME, Ewoldt L, Roos N, et al. The impact of climate change on food systems, diet quality, nutrition, and health outcomes: A narrative review. Front Clim [Internet]. 2022 Aug 16 [cited 2025 June 13];4. Available from: https://www.frontiersin.org/journals/climate/articles/10.3389/fclim.2022.941842/full
10. Mirón IJ, Linares C, Díaz J. The influence of climate change on food production and food safety. Environ Res. 2023 Jan 1;216:114674.
11. The State of Food Security and Nutrition in the World 2024 [Internet]. FAO; IFAD; UNICEF; WFP; WHO; 2024 [cited 2024 Sept 29]. Available from: https://openknowledge.fao.org/handle/20.500.14283/cd1254en

12. Davis JN, Oaks BM, Engle-Stone R. The Double Burden of Malnutrition: A Systematic Review of Operational Definitions. Curr Dev Nutr [Internet]. 2020 Sept 1 [cited 2025 June 13];4(9). Available from: https://cdn.nutrition.org/article/S2475-2991(22)12061-5/fulltext

13. Development Initiatives Poverty Research Ltd. 2022 Global Nutrition Report: Stronger commitments for greater action. [Internet]. Bristol, UK: Development Initiatives Poverty Research Ltd.; 2022. Available from: https://globalnutritionreport.org/reports/2022-global-nutrition-report/

14. Stevens GA, Beal T, Mbuya MNN, Luo H, Neufeld LM, Addo OY, et al. Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys. Lancet Glob Health. 2022 Nov 1;10(11):e1590–9.

15. World Health Organization (WHO). Fact Sheet: Obesity and Overweight [Internet]. World Health Organization (WHO); 2025 [cited 2025 June 13]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

16. World Health Organization (WHO). WHO acceleration plan to stop obesity [Internet]. Geneva, Switzerland: World Health Organization (WHO); 2023. Available from: https://www.who.int/publications/i/item/9789240075634

17. Food and Agriculture Organization of the United Nations (FAO). Climate action and nutrition—Pathways to impact [Internet]. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2023. Available from: https://doi.org/10.4060/cc8415en

18. Li Y, He P, Shan Y, Li Y, Hang Y, Shao S, et al. Reducing climate change impacts from the global food system through diet shifts. Nat Clim Change. 2024 Sept;14(9):943–53.

19. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet. 2019 Feb 2;393(10170):447–92.

20. Albaladejo RA. EU protein strategy [Internet]. Brussels, Belgium: European Union; 2023 [cited 2025 Aug 20]. Available from: https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/751426/EPRS_BRI(2023)751426_EN.pdf

21. 2025 Dietary Guidelines Advisory Committee. Scientific Report of the 2025 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Health and Human Services and Secretary of Agriculture. [Internet]. U.S. Department of Health and Human Services; 2024 [cited 2025 Aug 20]. Available from: https://doi.org/10.52570/DGAC2025

22. Springmann M. Valuation of the health and climate-change benefits of healthy diets. Background paper for The State of Food Security and Nutrition in the World 2020. [Internet]. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2020. (FAO Agricultural Development Economics Working Paper). Available from: https://openknowledge.fao.org/server/api/core/bitstreams/6a4499f3-93b2-4eb6-967b-ebf318afec64/content

23. Gielen B, Thewissen K, Jaspers S, Rubens K. A new narrative for the protein shift [Internet]. Departement Omgeving, Vlaamse overheid; [cited 2025 Aug 20] p. 2023. Available from: https://omgeving.vlaanderen.be/sites/default/files/2024-05/EIWITSHIFT_Eindrapport_ANewNarrativeForTheProteinshift_ENG_0.pdf

24. Leonard UM, Leydon CL, Arranz E, Kiely ME. Impact of consuming an environmentally protective diet on micronutrients: a systematic literature review. Am J Clin Nutr. 2024 Apr 1;119(4):927–48.
25. Beal T, Ortenzi F, Fanzo J. Estimated micronutrient shortfalls of the EAT–Lancet planetary health diet. Lancet Planet Health. 2023 Mar 1;7(3):e233–7.
26. Beal T, Gardner CD, Herrero M, Iannotti LL, Merbold L, Nordhagen S, et al. Friend or Foe? The Role of Animal-Source Foods in Healthy and Environmentally Sustainable Diets. J Nutr. 2023;153(2):409–25.
27. Ortenzi F, Beal T. Priority Micronutrient Density of Foods for Complementary Feeding of Young Children (6–23 Months) in South and Southeast Asia. Front Nutr. 2021;8:1161.
28. Beal T, Ortenzi F. Priority Micronutrient Density in Foods. Front Nutr [Internet]. 2022 Mar 7 [cited 2025 June 13];9. Available from: https://www.frontiersin.org/journals/nutrition/articles/10.3389/fnut.2022.806566/full
29. Webb P, Livingston Staffier K, Lee H, Howell B, Battaglia K, Bell BM, et al. Measurement of diets that are healthy, environmentally sustainable, affordable, and equitable: A scoping review of metrics, findings, and research gaps. Front Nutr. 2023 Apr 3;10:1125955.
30. McLaren S, Berardy A, Henderson A, Holden N, Huppertz T, Jolliet O, et al. Integration of environment and nutrition in life cycle assessment of food items: opportunities and challenges [Internet]. Food and Agriculture Organization of the United Nations (FAO); 2021 [cited 2025 June 13]. Available from: https://openknowledge.fao.org/handle/20.500.14283/cb8054en
31. International Organization for Standardization (ISO). ISO 14040:2006 Environmental management—Life cycle assessment—Principles and framework [Internet]. 2nd edn. Geneva, Switzerland: International Organization for Standardization (ISO); 2006 [cited 2025 June 13]. 20 p. Available from: https://www.iso.org/standard/37456.html
32. Grigoriadis V, Nugent A, Brereton P. Working towards a combined measure for describing environmental impact and nutritive value of foods: A review. Trends Food Sci Technol. 2021 June 1;112:298–311.
33. Katz-Rosene R, Ortenzi F, McAuliffe GA, Beal T. Levelling foods for priority micronutrient value can provide more meaningful environmental footprint comparisons. Commun Earth Environ. 2023 Aug 12;4(1):287.
34. Heller MC, Keoleian GA, Willett WC. Toward a life cycle-based, diet-level framework for food environmental impact and nutritional quality assessment: a critical review. Environ Sci Technol. 2013;47(22):12632–47.
35. Hallström E, Davis J, Woodhouse A, Sonesson U. Using dietary quality scores to assess sustainability of food products and human diets: A systematic review. Ecol Indic. 2018 Oct 1;93:219–30.
36. McAuliffe GA, Takahashi T, Lee MRF. Applications of nutritional functional units in commodity-level life cycle assessment (LCA) of agri-food systems. Int J Life Cycle Assess. 2020 Feb 1;25(2):208–21.
37. McAuliffe GA, Takahashi T, Beal T, Huppertz T, Leroy F, Buttriss J, et al. Protein quality as a complementary functional unit in life cycle assessment (LCA). Int J Life Cycle Assess. 2023 Feb 1;28(2):146–55.

38. Beal T, Ortenzi F. Nutritional Value Score rates foods based on global health priorities [Internet]. Research Square; 2025 [cited 2025 June 13]. Available from: https://www.researchsquare.com/article/rs-3443927/v2

39. Sonesson U, Davis J, Flysjö A, Gustavsson J, Witthöft C. Protein quality as functional unit—A methodological framework for inclusion in life cycle assessment of food. J Clean Prod. 2017 Jan 1;140:470–8.

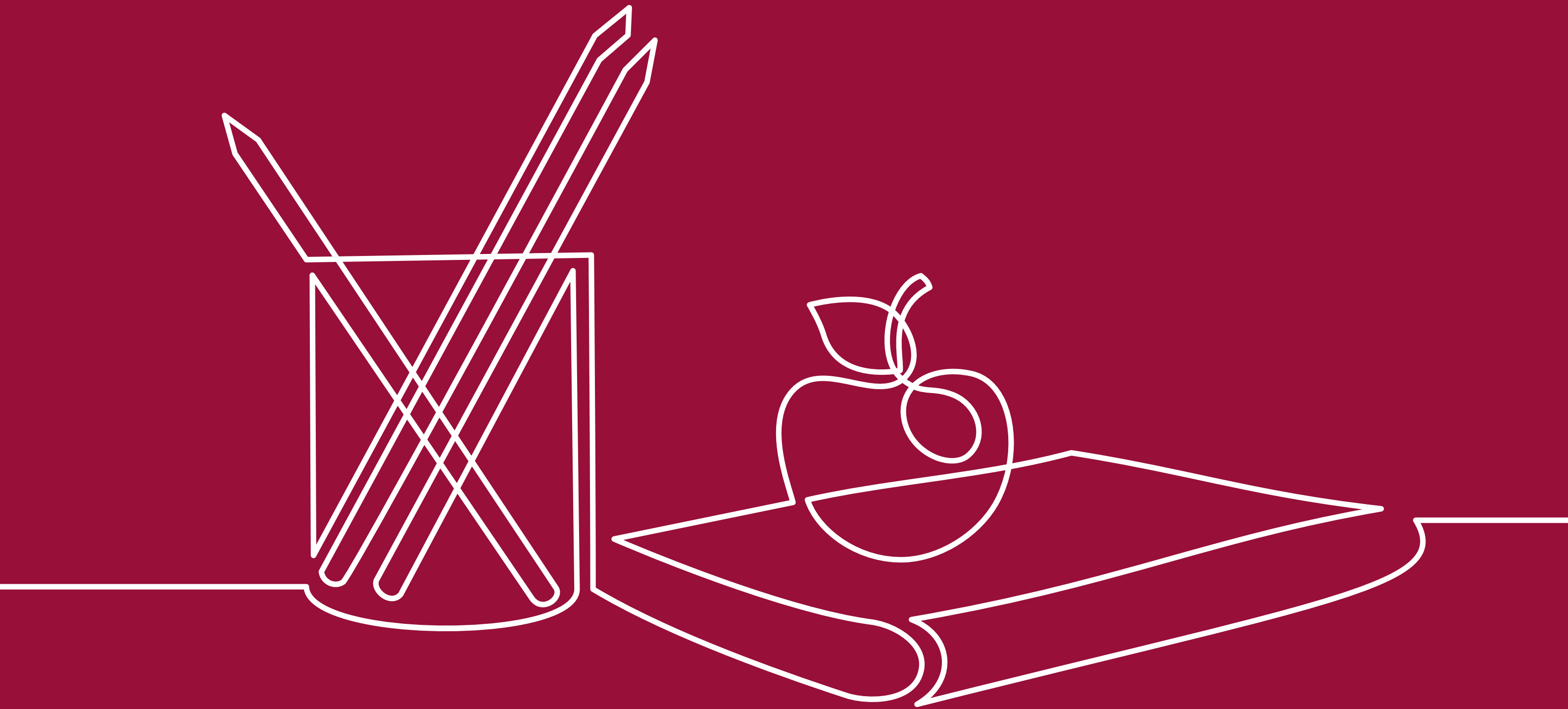
40. World Food Programme (WFP). WFP Indonesia Country Brief: November 2024-January 2025 [Internet]. WFP Indonesia Country Brief November 2024-January 2025; 2025. Available from: https://reliefweb.int/attachments/208aa775-7502-4759-a8e2-1565986a04ff/IDN%20CB%202024%2011-2025%2001.pdf

41. United Nations Children's Fund (UNICEF). Landscape analysis of overweight and obesity in Indonesia [Internet]. Jakarta, Indonesia: United Nations Children's Fund (UNICEF); 2022. Available from: https://www.unicef.org/indonesia/media/15481/file/landscape-analysis-overweight-obesity-Indonesia.pdf

42. World Health Organization (WHO). The Global Health Observatory (GHO): Indicators [Internet]. [cited 2025 June 13]. Available from: https://www.who.int/data/gho/data/indicators

43. FAO, IFAD, UNICEF, WFP, WHO. The State of Food Security and Nutrition in the World 2025—Addressing high food price inflation for food security and nutrition. [Internet]. Rome, Italy; 2025. Available from: https://doi.org/10.4060/cd6008en

44. Asian Development Bank (ADB), Kementerian PPN/Bappenas, International Food Policy Research Institute (IFPRI). Policies to Support Investment Requirements of Indonesia's Food and Agriculture Development during 2020– 2045 [Internet]. Metro Manila, Philippines: Asian Development Bank (ADB); 2019. Available from: https://www.adb.org/publications/indonesia-food-agriculture-development-2020-2045



ABOUT GAIN

The Global Alliance for Improved Nutrition (GAIN) is a Swiss-based foundation launched at the UN in 2002 to tackle the human suffering caused by malnutrition. Working with governments, businesses and civil society, we aim to transform food systems so that they deliver more nutritious food for all people, especally the most vulnerable.

ABOUT THE GAIN BRIEFING PAPER SERIES

GAIN Briefing Papers provide essential information in a succinct, accessible form to support informed decision making by stakeholders in the food system to improved the consumption of nutritious, safe food for all people, especially the most vulnerable. The full series may be accessed at https://bit.ly/gainpub

The Global Alliance for Improved Nutrition

Rue de Varembé 7 1202 | Geneva | Switzerland | info@gainhealth.org

www.gainhealth.org
GAINalliance
GAINalliance
Gainadm
GAINalliance
Global Alliance for Improved Nutrition