Quantifying the Environmental Impacts of Food

A Review of True Cost Assessment Methods

Members of the research Consortium:

NFP Netherlands Food Partnership

gain Global Alliance for Improved Nutrition

True Price™

ATNi NUTRITION MARKETS IMPACT

ACKNOWLEDGEMENTS

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1. Global Alliance for Improved Nutrition

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3. True Price Foundation

4. Virginia Tech

5. Access to Nutrition Initiative

6. Netherlands Food Partnership

7. Cornell University

DECLARATION OF INTERESTS

Estefania Marti Malvido is employed by the True Price B.V (KVK number: 70048959). All other members of the core research team have no competing interests to declare.

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RATIONALE AND OBJECTIVES

- Several narrative reviews exist on monetisation methods for valuing environmental impacts in **non-food sectors** or within **food systems as a whole**; however…
- …This is the **first structured review** of existing frameworks, approaches, methods, and data sources for quantifying and monetising **both positive and negative** environmental externalities of **foods and diets**, across the **entire value chain**.
- Aims to identify critical evidence gaps and provide recommendations to guide future research and applications.

Sources: de Groot Ruiz et al., 2018; Markandya, 2023; Amadei et al., 2021

METHODS: Process overview (1/2)

- ❑ Chose a structured literature review to balance the need for greater **methodological rigor** than in a narrative review and more **flexibility** than in a scoping / systematic review.
- ❑ Followed a **pre-developed protocol** based on adapted versions of the PRISMA-ScR and Campbell Collaboration materials.

(1) SEARCH STRATEGY

- Searched for relevant records published between **January 1, 2018 & April 11, 2025**
- Comprehensive search strategy comprising 3 key concepts: **TCA; environmental externalities; foods & diets**
- Searched **3 academic** & **8 grey literature databases**

(2) EVIDENCE SELECTION

- Used **Covidence** systematic review software
- Assessed record eligibility against predefined **inclusion & exclusion criteria**
- **Title/abstract & full-text screening** conducted by two independent reviewers, with a third resolving conflicts

Sources: Grant and Booth, 2009; Cornell University Library, 2024; Tricco et al., 2018; Campbell Collaboration

METHODS: Process overview (2/2)

(3) DATA CHARTING

- Employed a **standardised data charting form**
- Variables captured: (1) **Study scope** & context; (2) **Assessment level** & types of foods or diets analysed; (3) **Environmental externalities**; (4) **Monetisation methods** & data sources; (5) Author-stated **strengths, limitations**, & **recommendations**

(4) EVIDENCE SYNTHESIS

- **Descriptive statistics:** Frequencies and percentages to map the evidence distribution
- **Qualitative synthesis:** Thematic analysis to classify and summarise frameworks, approaches, methods, and data sources used

Sources: Grant and Booth, 2009; Cornell University Library, 2024; Tricco et al., 2018; Campbell Collaboration

METHODS: Eligibility criteria

Aspect considered	Inclusion criteria	Exclusion criteria
Population & Context	Records on foods, food groups, meals, or whole diets in any geographical/population settings, covering any number of food system value chain stages, from primary agricultural production to household consumption and waste treatment	Records focusing solely on non-food systems/sectors, non-environmental externalities, or on oral nutritional supplements
Concept	Records discussing methods to quantify and monetise environmental externalities (positive/negative) of foods and diets	Records not including a monetisation component, or that do not explicitly report their methodology for quantifying and valuing environmental impacts
Evidence sources	Academic manuscripts in scientific journals, working/discussion papers, reports, methodological guidelines & tools, books & book chapters from academic publishers	Publication types other than those listed under the inclusion criteria Records for which the full text is not accessible through institutional subscriptions, open-access platforms, or Interlibrary loan services
Timeframe	Records published between January 1, 2018, and April 11, 2025	Records published prior to 2018
Language	English-language records	Records published in languages other than English

Source: Peters et al., 2024

METHODS: Data charting form

Section 1: Record details									
Full citation in Harvard style	Publication type	Geographic focus	Country income group(s)	Value chain stage(s)	Reference period(s) of input data	Primary research question(s)	Secondary research question(s)	Assessment level(s): foods, food groups, meals, whole diets	Food/meal/ diet type(s)

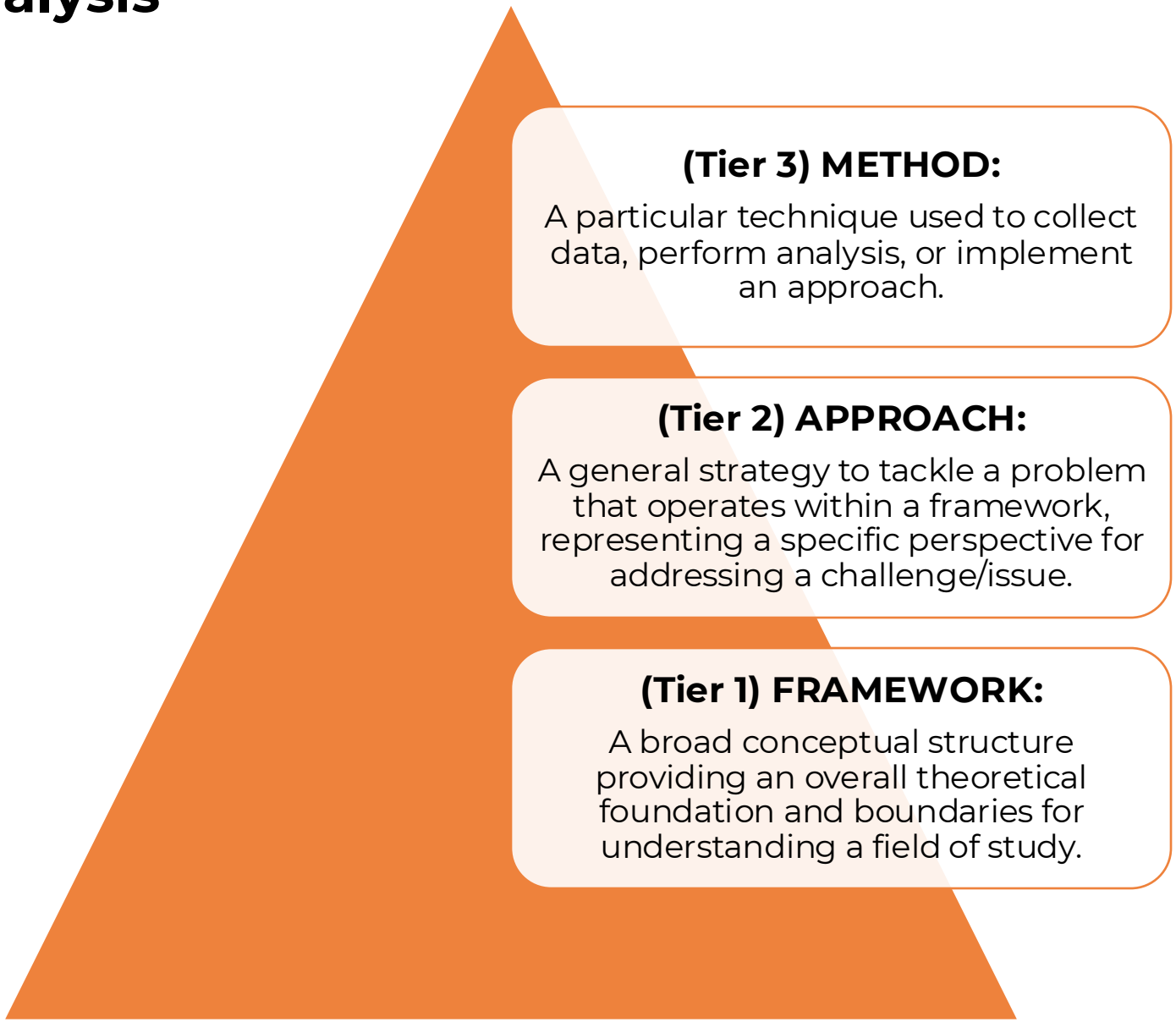
Section 2: Key variables of interest							
Positive environmental externalities	Negative environmental externalities	Monetisation methods	Data sources used (impact quantification)	Data sources used (monetisation factors)	Author-stated strengths of the approach	Author-stated limitations of the approach	Author-stated research recommendations

***Extra:** Additional areas for methodological improvement (not explicitly mentioned by the original authors)

Source: Peters et al., 2024

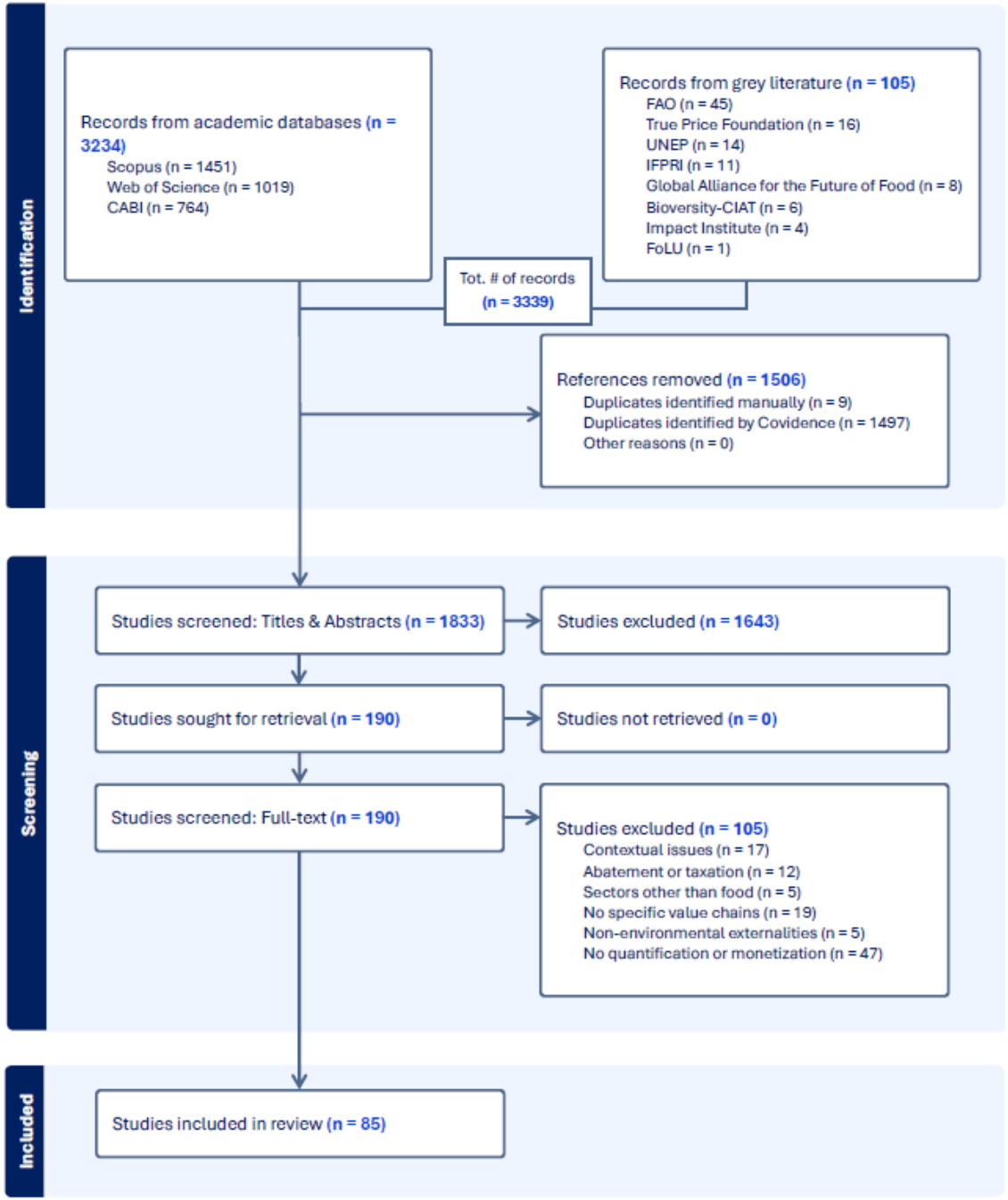
METHODS: Qualitative analysis

Each study was thematically categorised against three levels of analysis



PUBLICATION TYPES & DATA AGE

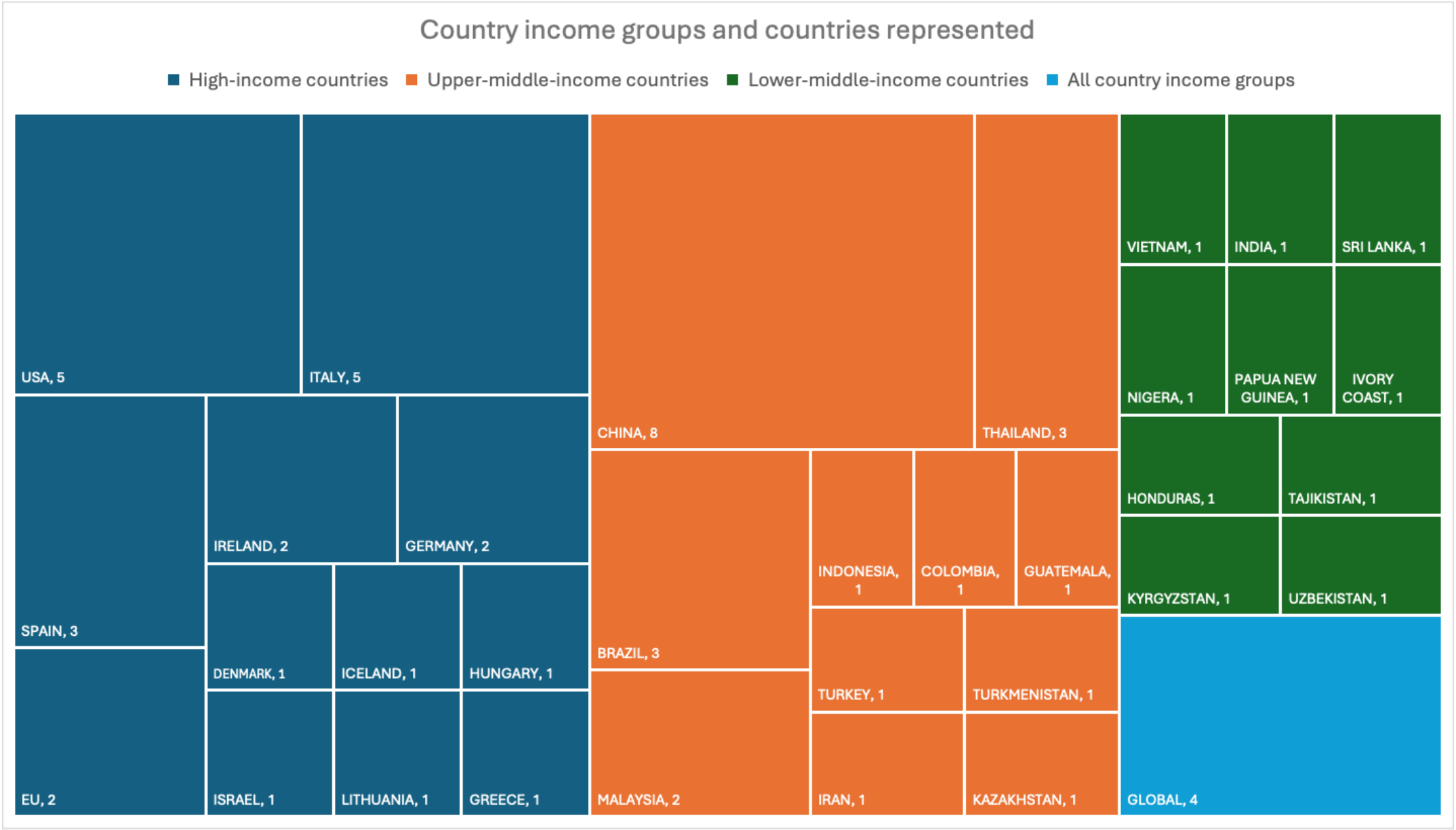
- **Large body of literature**, characterized by **high heterogeneity**.
- **Publication types:** Most records were **academic manuscripts** (83%), followed by technical reports, conference proceedings, working papers, and methodological guidelines.
- **Data age:** About **one-third** (34%) used a **mix of recent** (<10 years) **and older** (>10 years) **data or data of uncertain age**. One-fifth (20%) did not provide information on data age.



PRISMA flow diagram of the literature search and selection processes

Sources: Tricco et al., 2018

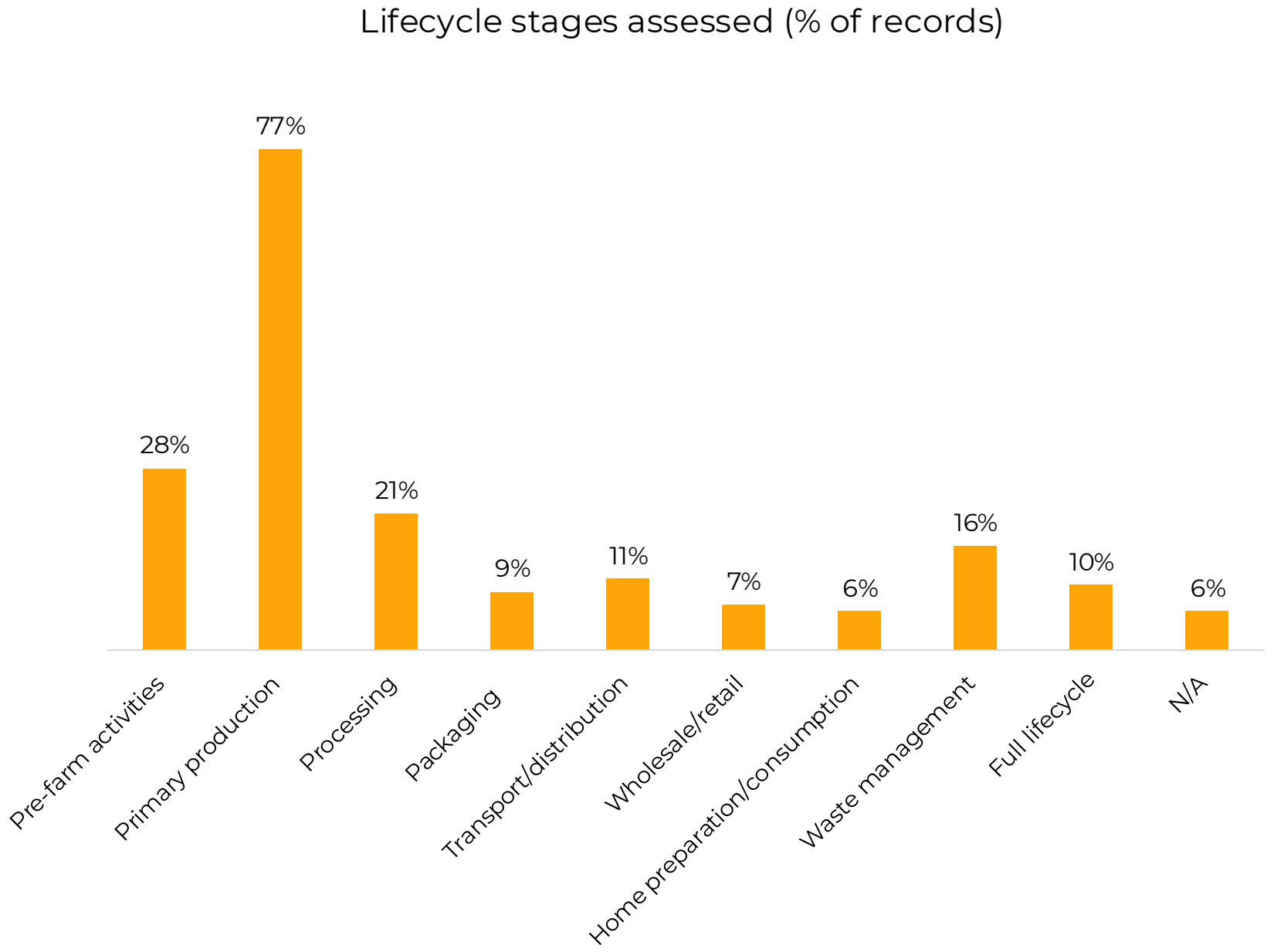
GEOGRAPHIC & INCOME DISTRIBUTION



Source: World Bank, FY 2026

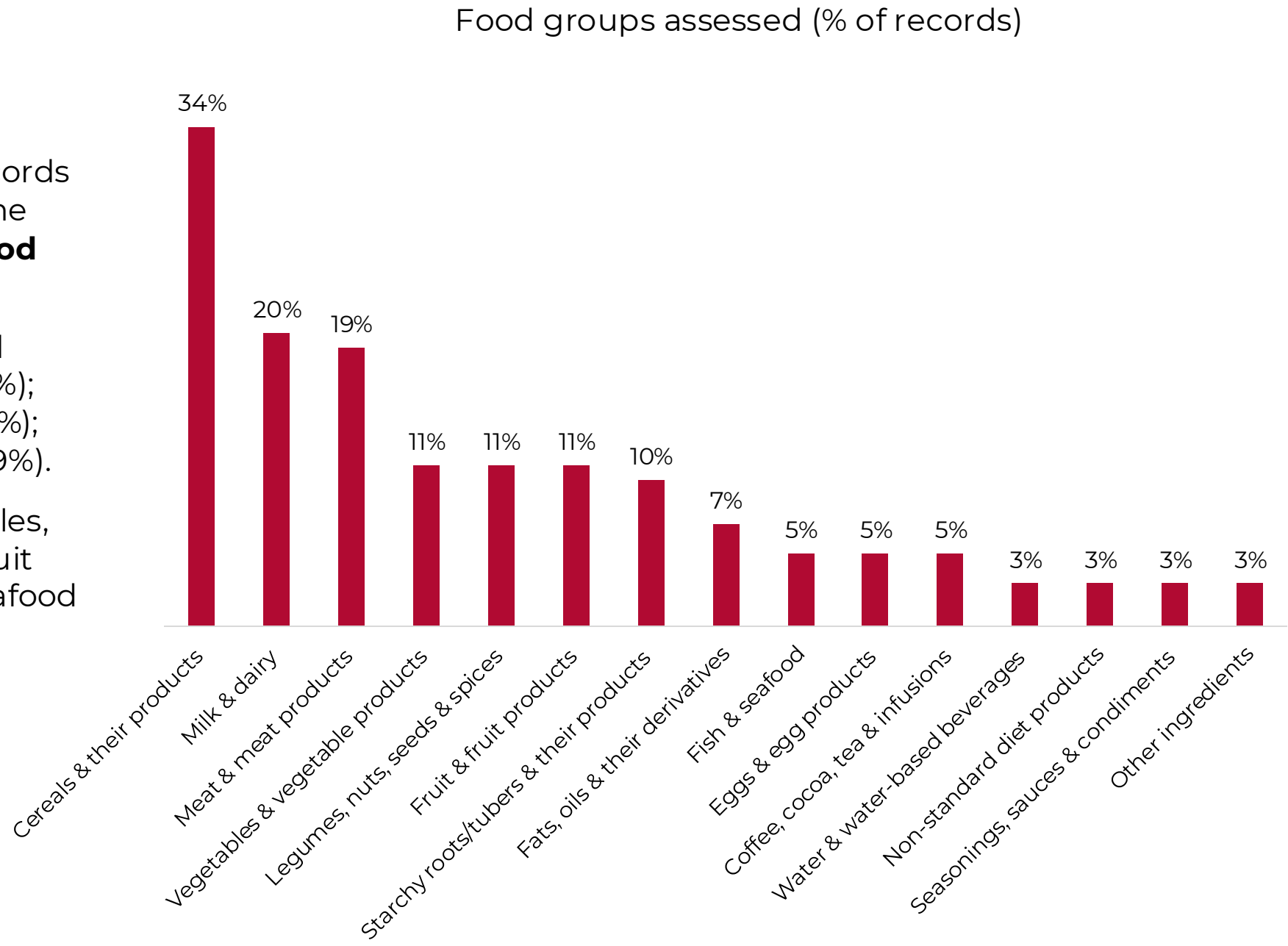
FOOD SYSTEM SEGMENTS

- **Primary production** was the most frequently analyzed lifecycle stage (77%).
- Other common lifecycle stages: **pre-farm activities** (28%) and **processing** (21%).
- **Only 10% of records considered the full lifecycle** ('cradle-to-grave'), revealing a fragmented view of food systems.



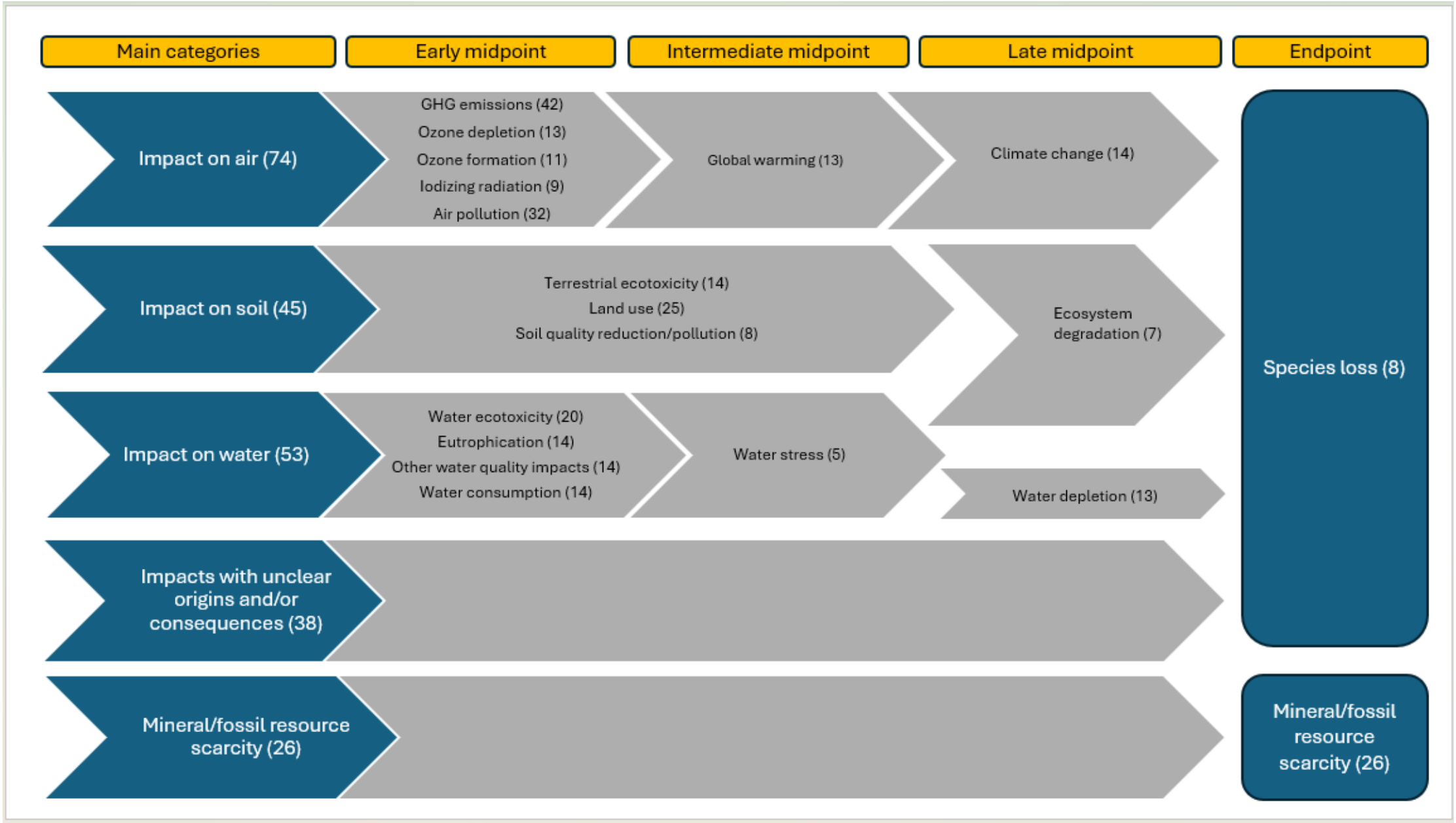
FOOD GROUP CATEGORISATION

- **Assessment level:** Most records quantified externalities at the **individual food (78%) or food group (11%) levels.**
- **Most frequent: cereals and cereal-based products** (34%); milk and dairy products (20%); meat and meat products (19%).
- **Limited attention:** vegetables, legumes/nuts/seeds, and fruit (11% each); eggs and fish/seafood (5% each).

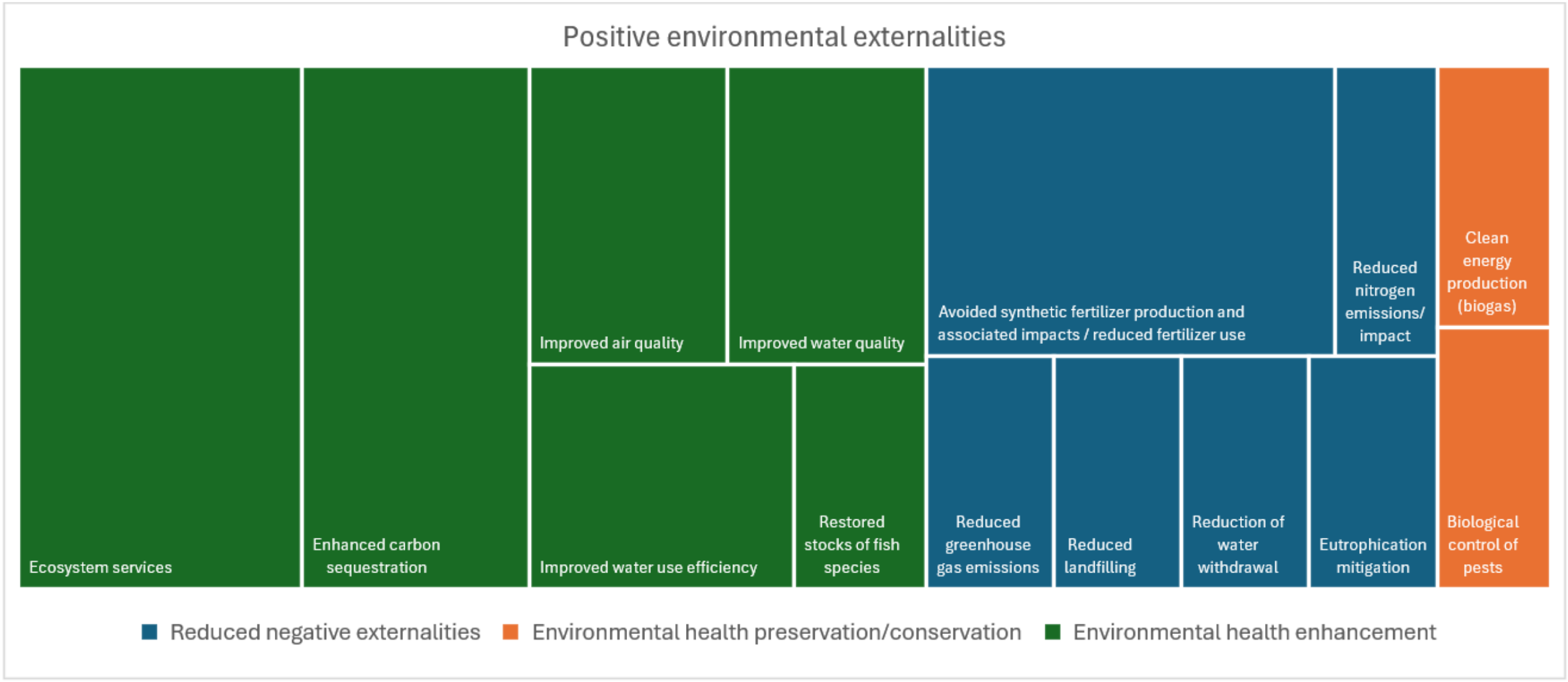


Source: European Food Safety Authority (EFSA), 2015

NEGATIVE ENVIRONMENTAL IMPACTS



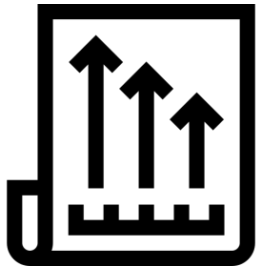
POSITIVE ENVIRONMENTAL IMPACTS



DOMINANT FRAMEWORK

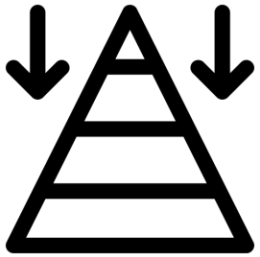
- All reviewed studies can be placed within an **environmental economics framework**.
- **Theoretical foundations:** Rooted in neoclassical economic theory.
- **Perspective:** Environmental externalities are seen as **market failures**.
- **Primary objectives:** Prioritisation of economic growth and **internalisation of externalities** into market prices for more efficient resource allocation.
- **Proposed solutions**: Policy and regulations to **adjust market prices, influence consumer behaviour**, and/or compensate for environmental degradation.

APPROACH CATEGORISATION



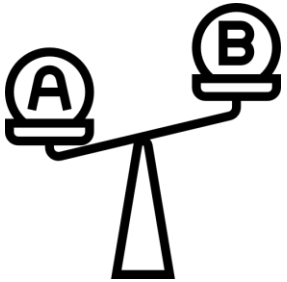
BOTTOM-UP (35%)

- **Primary collection of context-specific data** on environmental impacts.
- Geographic coverage: **subnational or national**.
- Primary input data are often **not made publicly available** due to using Life Cycle Assessment (LCA) databases with restricted access.



TOP-DOWN (31%)

- Reliance on **secondary data sources** for impact quantification, e.g., national statistics, LCA databases, published literature.
- Geographic coverage: **national, regional, or global**.
- Use of published/**pre-defined monetisation factors**, adjusted to a given country context and reference year.



COMPARATIVE (36%)

- Combined use of **primary and secondary data sources**.
- Comparison of **different production or consumption patterns**, to assess costs and benefits under various conditions/assumptions.
- Geographic coverage: **from subnational to global**.
- Includes **scenario modelling**.

METHOD TYPOLOGY	TYPOLOGY DEFINITION
Abatement cost	**Reactive expenses** to reduce/eliminate environmental harm that has already occurred. Includes both the direct costs of **pollution control measures** and any associated **opportunity costs**, such as reduced production efficiency.
Compensation/replacement cost	The monetary amount required to **compensate for or replace a lost environmental resource/service** (e.g., the cost of providing equivalent benefits).
Damage/social cost	The total economic **cost imposed on society** by environmental degradation. **Damage cost** usually includes **direct costs only** (e.g., healthcare, property damage), while **social cost** comprises **both direct and indirect costs** (e.g., lost productivity, reduced quality of life).
Ecosystem services	**Benefits** that humans derive from **functioning ecosystems**. Services included: **provisioning** (food, water, timber), **regulating** (climate regulation, water purification), **cultural** (recreation, spiritual values), and **supporting** (nutrient cycling, habitat provision).
Emission pricing/credit	Consists in assigning a price to GHG emissions or pollutants. Includes **carbon pricing**, **cap-and-trade/credit programmes**, and other financial incentives to reduce emissions.
Market price	A monetary value at which goods or services are traded in a competitive market. This also applies to the **price of natural resources** or environmental goods/services **when traded commercially**.
Prevention/Eco-cost	**Proactive expenses** to prevent environmental damage from occurring in the first place, including investments in cleaner technologies, pollution control, or sustainable practices.
Remediation cost	**Reactive expenses** to repair environmental damage that has already occurred (e.g., soil decontamination, water treatment). Can also include preliminary assessments, site investigations, feasibility studies, and remedial actions as per the True Price Principles and methodology.
Restoration cost	**Reactive expenses** required to return a degraded ecosystem to its natural or desired state, with focus on **rebuilding ecological function**.
Shadow price	The implied cost of **resources currently lacking market prices**, typically equated with marginal abatement cost (i.e., the expense of reducing one additional unit of pollution/damage).
Taxation	**Government-imposed levies** used to internalise environmental externalities and **change behaviour**, including carbon taxes or resource extraction taxes.
Willingness-to-pay	The **maximum amount** individuals or society would be willing to pay for an **environmental benefit** or to **avoid an environmental harm**, often measured through surveys.

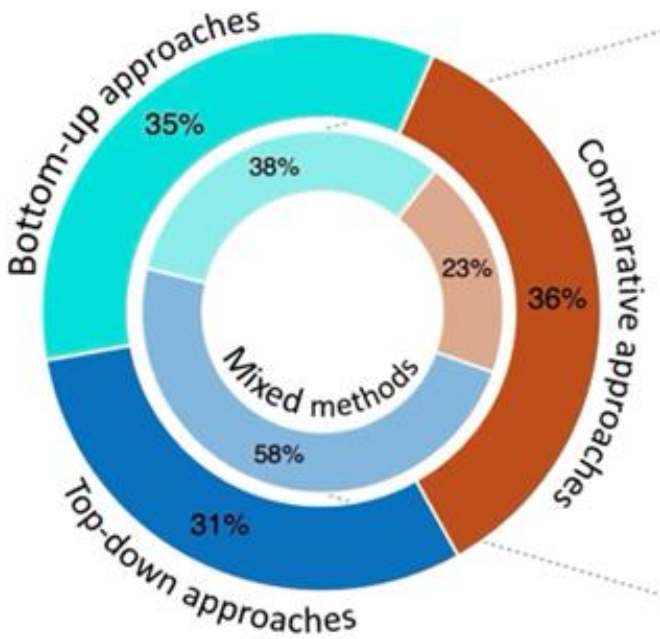
DISTRIBUTION OF APPROACHES AND METHODS

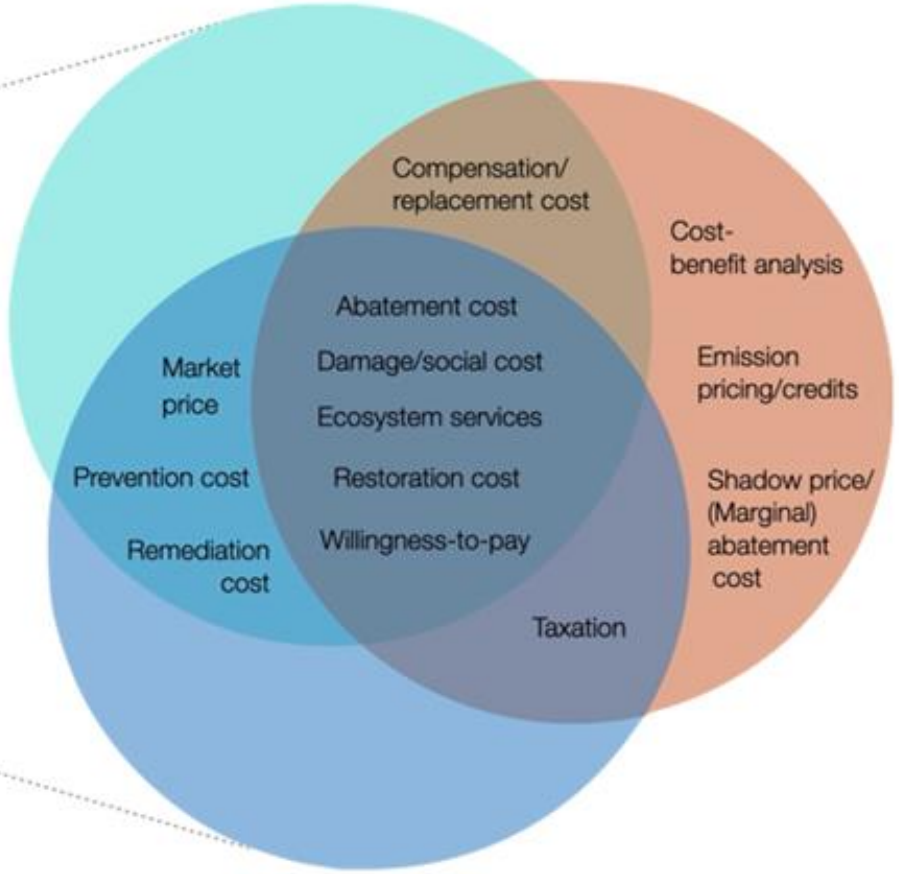
39% of records used a **combination of monetisation methods**; however, **none** of the reviewed studies **provided clear justification** for their choice of methods.

External donut: Frequency of use of approach categories

Internal donut: Frequency of use of mixed monetisation methods across approach categories

Interconnected circles: 13 monetisation methods identified, colour-coded by approach category





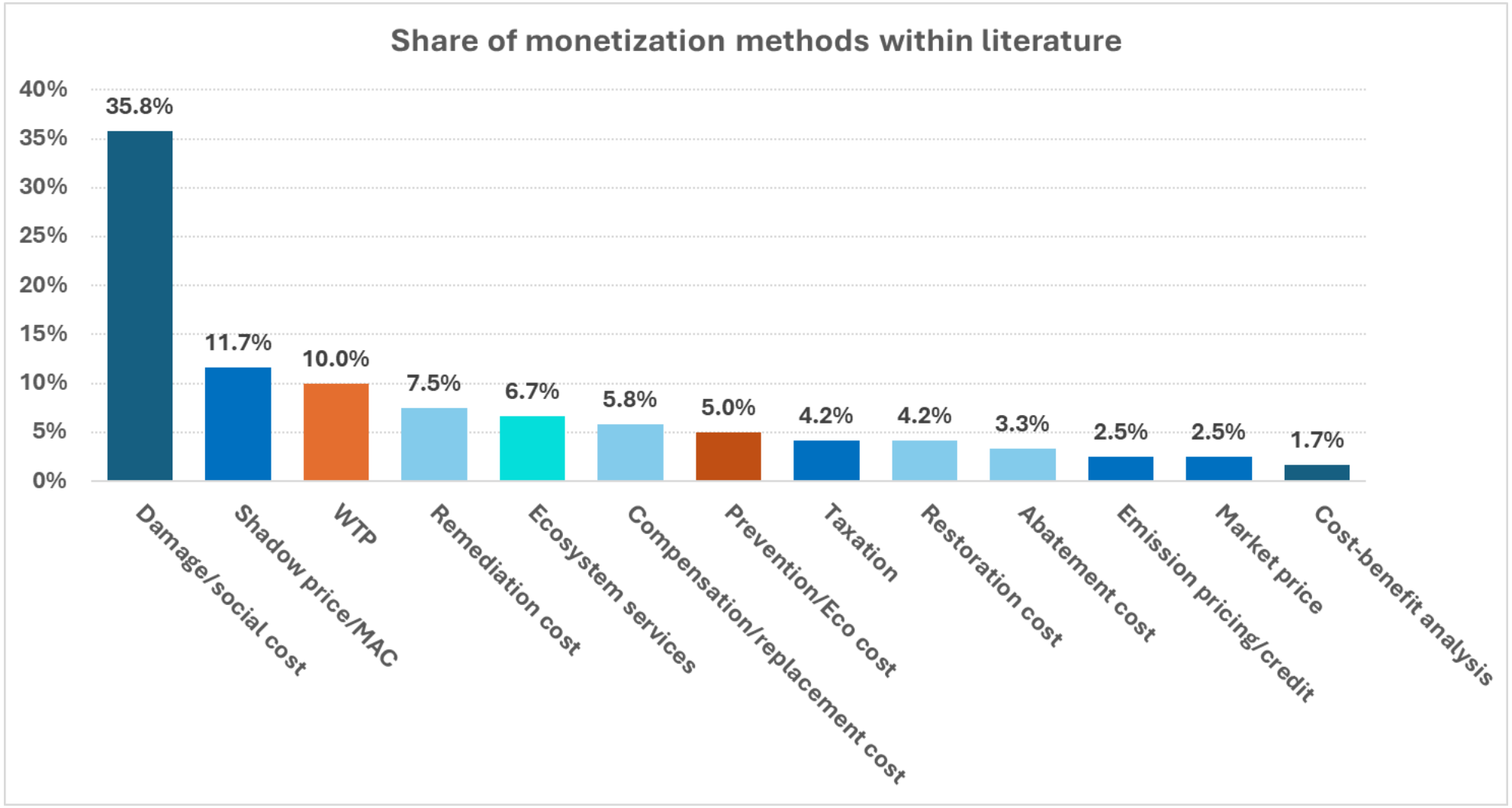
Share of approaches across literature

Share of mixed monetization methods within approaches

Use of monetization methods across approaches

DISTRIBUTION OF APPROACHES AND METHODS

- Only 2 records using damage/social cost applied **progressive cost assumptions** over time.
- While operationalised within an environmental economics framework, two methods can also reflect **ecosystems' inherent value**: prevention/eco-costs and willingness-to-pay.



DATA SOURCE CATEGORY	MAIN PURPOSE OR USE CASE	IMPACT QUANTIFICATION: % OF RECORDS	MONETISATION FACTORS: % OF RECORDS
Academia and research institutes	To obtain parameters like relative risks, dose-response functions, emissions, characterisation factors, and economic values from scientific literature, published studies and datasets.	64%	53%
National/regional institutional databases and resources	To obtain official (sub)national and/or regional statistics on demographics, dietary patterns, economic indicators, food systems performance, and environmental impacts.	59%	40%
LCA frameworks, databases, and inventories	To source Life Cycle Inventory input and output data, characterization factors, and methodological guidance for conducting LCAs.	45%	12%
Resources by UN agencies	To use technical reports, guidelines, conceptual frameworks, and standardised databases produced by UN agencies to obtain methodological guidance and internationally comparable data across sectors.	36%	9%
Primary data	To collect new, context-specific information directly from target populations or entities through surveys, interviews, or direct measurement/observation.	26%	0%
Non-LCA environmental impact databases and inventories	To source specific data on environmental processes, emissions, and impacts from specialised databases.	14%	4%
Datasets for foresight modelling	To obtain specific input data and parameters for running future-oriented simulation models.	9%	7%
Non-governmental (NGOs) and civil society (CSOs) organizations	To use methodological guidelines, conceptual/theoretical frameworks, programmatic reports, datasets, and other resources published by NGOs and CSOs, including on specific local contexts and target population groups.	6%	0%
Market data and consumer insights	To obtain data on market prices, consumer behaviour, and industry trends from market research firms and commercial data providers.	5%	9%
TCA and True Pricing databases and inventories	To use pre-existing environmental impact data and monetary values from established TCA and True Pricing frameworks and initiatives.	2%	25%

AUTHOR-STATED STRENGTHS, LIMITATIONS, & RECOMMENDATIONS

Strengths	%	Limitations	%	Research recommendations	%
Ability to calculate a 'comprehensive' true cost of food production	**28%**	Uncertainties in methodological approaches and/or data modelling	**21%**	Expanding scope/coverage, by including under-researched lifecycle stages and/or externalities	**52%**
Compatibility of methods & results with LCA and/or Life Cycle Costing approaches	**11%**	Narrow scope/coverage of externalities and lifecycle stages	**17%**	Improving research infrastructure, data availability, quality, and context specificity	**49%**
Reliance on established/reputable data sources	**11%**	Use of proxy/global data instead of (sub)national or regional inputs	**15%**	Considering a larger variety of production systems and food products (including novel foods)	**39%**
Ability to compare environmental costs and benefits	**7%**	Uncertainties in monetisation factors due to heavy reliance on assumptions	**10%**	Systematically addressing uncertainty & transparently reporting on assumptions	**38%**
Identification of lifecycle hotspots	**7%**	Limited representativeness or generalisability of assessment results	**8%**	Expanding the application of TCA to underrepresented geographic regions	**32%**
Use of empirical data	**6%**	No author-reported limitations	**11%**	Methodological standardisation to enable cross-study comparability	**16%**
Integration of farm-level data	**5%**			Capturing positive externalities and quantifying longer-term impacts	**11%**
No author-reported strengths	**17%**			No author-reported recommendations	**16%**

REVIEWER-IDENTIFIED AREAS FOR REFINEMENT OF METHODS

ENVIRONMENTAL IMPACT ASSESSMENTS

- Few records quantified **endpoint impacts** (e.g., species loss).
- **No clear rationale/justification** for indicator and impact assessment choices.
- Reliance on **outdated**, non-applicable, and/or non-public **data**, as well as outdated LCA **models**.
- **Direct conversion of methane** from ruminant enteric fermentation or flooded rice paddies **into climate change impacts**.
- Quantification of total freshwater use instead of critical, **non-renewable water use**.
- **Land use** reported as a **distinct impact category**.
- Lack of meaningful **regional findings** in global studies, like critical nitrogen and phosphorus surplus.

IMPACT MONETISATION

- Risk of **obscuring impact-specific solutions** through aggregation of externalities from multiple domains.
- **Subjective weighing** of different impacts.
- Few studies explicitly addressed the **ethical dilemma** of monetising environmental health.
- Repeated confusion around **definitions of monetisation methods** (e.g., social vs. abatement cost; abatement vs. prevention cost).
- Ecotoxicity assessments relying on **broad spatial averages** rather than detailed regional estimates, and/or monetising total freshwater use instead of **unsustainable consumption shares**.
- No accounting for **dynamic changes** in demand and availability when monetising **resource scarcity**.

DISCUSSION: Main challenges in the field

1. LACK OF GLOBAL APPLICABILITY

- Heavy concentration of research and reliance on data from high-income countries.
- A substantial proportion of the world's food is produced by informal smallholders and manufacturers.

2. METHODOLOGICAL ERRORS & INCONSISTENCIES

- The wide variety of approaches & methods, and lack of a clear rationale for selection makes cross-study comparisons difficult.
- Widespread confusion around greenhouse gas, water use, and land use change accounting.

3. INCOMPLETE, STATIC PICTURE

- Positive impacts, downstream environmental hotspots, and the dynamic & interconnected nature of food systems are largely overlooked.

4. REACTIVE OVER PROACTIVE

- The prevalence of damage/social cost assessment methods may reflect practical constraints rather than theoretical preference.

5. LACK OF EMPIRICAL EVIDENCE

- Critical literature gap on whether TCA applications can influence producer behaviour, consumer choices, and environmental outcomes in the real world.

DISCUSSION: A Path Forward

1. EXPAND GEOGRAPHIC COVERAGE

- Prioritize expanding geographic coverage with methodologies adapted to diverse production systems and locally important foods in low- and middle-income countries.

2. IMPROVE METHODS AND TRANSPARENCY

- Develop standardised protocols for method selection and implementation, while allowing for contextual flexibility.
- Increase transparency through data sharing and explicit reporting of assumptions and uncertainties.

3. BROADEN SCOPE & INTEGRATE SYSTEM DYNAMICS

- Expand the analytical scope to incorporate positive externalities & additional lifecycle stages, capture longer-term consequences, and reflect dynamic changes in food value chains.

4. EMBRACE PROACTIVE METHODS

- Move away from reactive social/damage cost assessment and invest in methods that focus on prevention and restoration.

5. VALIDATE IN REAL-WORLD SETTINGS

- Build evidence through case studies that test the effectiveness of food-related TCA in different decision contexts.

CONCLUSION:
Take-home messages

- TCA provides a **promising approach** for making environmental costs visible in food system decision-making. However…
- …its potential is currently limited by a narrow scope, **large applicability gap**, widespread **methodological inconsistencies**, fundamental technical flaws, and lack of empirical evidence.
- Future research should prioritize ongoing **methodological refinement**, expanded geographic coverage, and real-world validation.
- The path forward requires a **collaborative effort** to provide more robust evidence for a sustainable and equitable food system transformation.