

Interim Report I

Literature Analysis of True Cost Accounting Methodologies and Databases for Agri-food Businesses and Products

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Contents

List of tables	iii
List of figures	iii
List of abbreviations	iv
Glossary	v
1. Introduction	1
1.1 About True Cost Accounting (TCA)	1
1.2 About the TCA calculations and data requirements	4
1.3 About TCA policy instruments	7
1.4 About this report and the way forward	9
2. Analysis of TCA methods	10
2.1 Literature review of TCA methods	10
2.2 Overview of identified frameworks and guidelines	13
2.2.1 Capital categories and impact categories considered	15
2.2.2 Inclusion of negative and positive impacts	16
2.2.3 System and system boundaries	17
2.2.4 Sector specificity of frameworks and guidelines	18
2.2.5 Required data type	18
2.2.6 Valuation approaches	18
2.2.7 Methodological detail	20
2.3 Key gaps in existing TCA methods	22
2.4 Online tools for sustainability impact assessment using TCA	23
2.5 TCA reporting formats	26
3. Analysis of TCA databases	28
3.1 Overview of business- and product-specific data collection efforts	29
3.2 Overview of available generic databases	32

3.2.1 Capital categories and impact categories covered	37
3.2.2 Data categories	38
3.2.3 Scope and coverage of databases	39
3.2.4 Coverage of negative and positive impacts	41
3.2.5 Sector specificity of databases	41
3.2.6 Geographical coverage	41
3.2.7 Monetization possibility	41
3.2.8 Accessibility of databases	42
3.2.9 Transparency and documentation	42
3.3 Key gaps in generic databases	42
4. Conclusion	43
References	45
Appendices	49
Appendix I: Tabular overview of methods	49
Appendix II: Tabular overview of databases	49
Appendix III: Reviewed sources for TCA methodology analysis	49
Appendix IV: Reviewed sources for TCA databases analysis	53

List of tables

Table 1. Overview of the 23 identified frameworks and guidelines	13
Table 2. Overview of 21 identified generic databases	33
Table 3. Overview of identified monetization databases	35

List of figures

Figure 1. The four steps of True Cost Accounting	3
Figure 2. The main components of TCA in agri-food systems; adapted from TEEBAgriFood (TEEB, 2020)	3
Figure 3. Overview of TCA steps and data requirement	5
Figure 4. Overview of instruments for internalization of externalities using TCA; adapted from Teufel et al. (2025)	8
Figure 5. Coverage of capital categories in 23 identified frameworks and guidelines	15
Figure 6. Overview of coverage of impact categories in 23 identified frameworks and guidelines	16
Figure 7. Overview of the system of analysis, sector specificity and required data type in the frameworks and guidelines	17
Figure 8. Degree of methodological detail and number of capital categories included across frameworks and guidelines	22
Figure 9. Distribution of data type and capital category across the assessed databases	37
Figure 10. Overview of coverage of impact categories in 26 identified databases	38

List of abbreviations

A4S	Accounting For Sustainability
BMLEH	Bundesministerium für Landwirtschaft, Ernährung und Heimat (German Federal Ministry of Agriculture, Food and Regional Identity)
CAP	Common Agricultural Policy (of the EU)
CSRD	Corporate Sustainability Reporting Directive
EBIT	Earnings Before Interest and Taxes
ESRS	European Sustainability Reporting Standards
EQALY	Expected Quality-Adjusted Life-Year
EU	European Union
FADN	Farm Accountancy Data Network
FAO	Food and Agriculture Organization of the United Nations
FoodSIVI	Food Systems Impact Valuation Initiative
FSDN	Farm Sustainability Data Network
GBD	Global Burden of Disease
GIS	Geographic Information Systems
IFVI	International Foundation for Valuing Impacts
IHME	Institute for Health Metrics and Evaluation
IIRC	International Integrated Reporting Council
ILO	International Labour Organization
INRAE	French National Research Institute for Agriculture, Food and Environment
ISO	International Organization for Standardization
JRC	Joint Research Centre
KTBL	Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V.
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
OEF	Organization Environmental Footprint
PEF	Product Environmental Footprint
PSILCA	Product Social Impact Life Cycle Assessment Database
SAFAD	Sustainability Assessment of Foods and Diets
SDGs	Sustainable Development Goals
SHDB	Social Hotspot Database

SLU	Swedish University of Agricultural Sciences
sLCA	Social Life Cycle Assessment
SMEs	Small and Medium-sized Enterprises
SPA	Sustainable Performance Accounting
SWOT	Strengths, Weakness, Opportunities, Threats
TNFD	Taskforce on Nature-related Financial Disclosures
TCA	True Cost Accounting
TEEB	The Economics of Ecosystems and Biodiversity
TEEBAgriFood	The Economics of Ecosystems and Biodiversity for Agriculture and Food
UBA	Umwelt Bundesamt (Environment Agency of the German Government)
VAT	Value-Added Tax
VBA	Value Balancing Alliance
WBCSD	World Business Council for Sustainable Development

Glossary

Agri-food system	Describes the complex interrelationships and dependencies between the way in which agricultural commodities are produced, processed, transported and ultimately consumed and how food and other agricultural products are handled (Bundesregierung, 2024).
Capital	The various types of resources that represent stocks of value, each capable of generating future benefits that support and enhance human well-being (TEEB, 2018).
Dependencies	The reliance of a system, business or sector on natural, human and economic resources. In food systems, dependencies include seasonal workers, soil health, water availability, pollination and other ecosystem services, which are crucial for sustainable food production.
Externality (or external benefits and costs)	A positive consequence (external benefit) or negative consequence (external cost) of an economic activity or transaction that affects other parties without this

being reflected in the price of the goods or services transacted.

Generic data	Data that is not specific to a particular product, company or region but represents industry averages, estimates or model-based assumptions. Generic data is often used when specific data is unavailable and can be sourced from databases, literature or statistical reports.
Impacts	The effects—positive or negative—that a process, product or activity has on the environment, society and economy. In the context of food systems, impacts can include greenhouse gas emissions, biodiversity loss, labour conditions and public health outcomes.
Impact data	Data that represents environmental, social and economic outcomes of an activity, potentially resulting in future impacts (e.g. the greenhouse gas emissions, expressed in kg of carbon dioxide equivalent, released from livestock farming, which result in climate change impacts). These data are the quantified results derived from impact models.
Impact models	Impact models use specific or generic data to quantify an impact resulting from a certain activity.
Internalization	The process of incorporating external costs or benefits into decision-making through: • Taxation: Taxing those who cause negative externalities • Subsidies: Compensating those who generate positive externalities • Regulations: Creating rules that encourage responsible behaviour • Pricing: Changing prices to reflect the costs and benefits of products and services • Emissions trading: Using market-based mechanisms to manage emissions

Life Cycle Assessment (LCA)	A scientific method used to evaluate the environmental footprint of a product or process across its entire life cycle—from raw material extraction to production, distribution, consumption and disposal. LCA helps identify areas for reducing environmental harm and improving sustainability.
Life Cycle Inventory (LCI)	A Life Cycle Inventory (LCI) is the collection and quantification of inputs and outputs (such as energy, water, raw materials and emissions) for a product, process or system throughout its life cycle.
Materiality analysis	A systematic process used to identify and prioritize the environmental, social, health and economic issues that have the greatest material significance for or influence on stakeholders and decision-makers.
Model data	A set of parameters used in impact models to quantify impacts resulting from the production of a product or from a business's operations.
Monetization	The process of assigning a monetary value to positive and negative externalities. There are four valuation approaches: • Damage-costs approach: This method estimates the costs associated with damages to the environment or society caused by an activity. It measures the costs of remediating these impacts. • Abatement-costs approach: This approach calculates the costs of preventing damage before it occurs, such as via investment in green technologies or pollution control measures. It reflects costs incurred to avoid negative impacts. • Rights-based approach: A rights-based approach considers processes that respect the internationally recognized basic rights of all individuals, including future generations. Remediation costs are calculated as restoration, prevention, compensation (also known as damage costs) or retribution costs, aiming to restore stakeholders' well-being.

- **Contingent valuation:** This method estimates monetary value by asking people how much they would be willing to pay to avoid harm or preserve a benefit.

Specific data Data that is directly linked to a specific product, company or process, often based on primary data collection or direct measurements. Specific data provides more accurate and context-relevant insights compared to generic data.

True Cost Accounting (TCA) A method of measuring the real costs and benefits of economic activities by incorporating environmental, social and health externalities. TCA aims to reveal hidden costs and benefits associated with food systems, guiding decision-makers toward more sustainable practices.

1. Introduction

1.1 About True Cost Accounting (TCA)

True Cost Accounting (TCA) has gained increasing recognition as a critical approach for more holistically measuring and valuing the environmental, social, human and economic impacts—positive (benefits) and negative (costs)—of food systems. In addition to measuring impacts—that is, the effects of food system activities on various forms of capital—TCA also examines the dependencies of food systems on these capital categories, which are essential for food production, distribution and consumption:

- Natural capital: ecosystems, biodiversity, water, soil and climate
- Social capital: societal norms, trust, relationships and networks
- Human capital: labour, health, education and traditional knowledge
- Produced capital: infrastructure, technologies, goods and financial assets

In contrast to conventional accounting practices that frequently neglect external costs—such as environmental degradation, resource depletion and social inequalities—and the associated risks—such as climate-related disruptions, supply chain instability, loss of ecosystem services and social unrest—TCA offers a more holistic and transparent approach. It supports more sustainable decision-making of businesses, policymakers and other stakeholders by accounting for hidden costs, benefits and dependencies. TCA can potentially support the transition to more sustainable food systems in a variety of ways: It could strengthen political processes by helping to reveal market failures and better address trade-offs. Farms and food companies could identify new opportunities for more sustainable strategies through TCA and communicate their sustainability performance more effectively to business partners and consumers. Consumers could benefit from better access to information about hidden food costs, enabling them to make more informed and sustainable purchasing decisions.

The study emphasizes business- and product-level applications of TCA, which are particularly relevant for corporate decision-making. At the product level, TCA can help to develop products with lower environmental, health and social impacts while optimizing resource use. It also allows companies to communicate their sustainability efforts in a clear and accessible way to consumers by integrating TCA results into product labelling and pricing. At the business level, TCA can help increase transparency of a company's overall impact on the environment and society. These insights help organizations assess and manage their overall societal and environmental footprint, identify operational risks and communicate sustainability performance to external stakeholders, including investors.

The conceptual basis and basic principles of TCA are laid out in the TEEBAgriFood Framework (TEEB, 2018) (see Figure 1 and Figure 2). Since its publication, various frameworks and guidelines have been developed to provide more detailed methodologies and data requirements, supporting the practical implementation of TCA and integration of externalities across the food value chain.

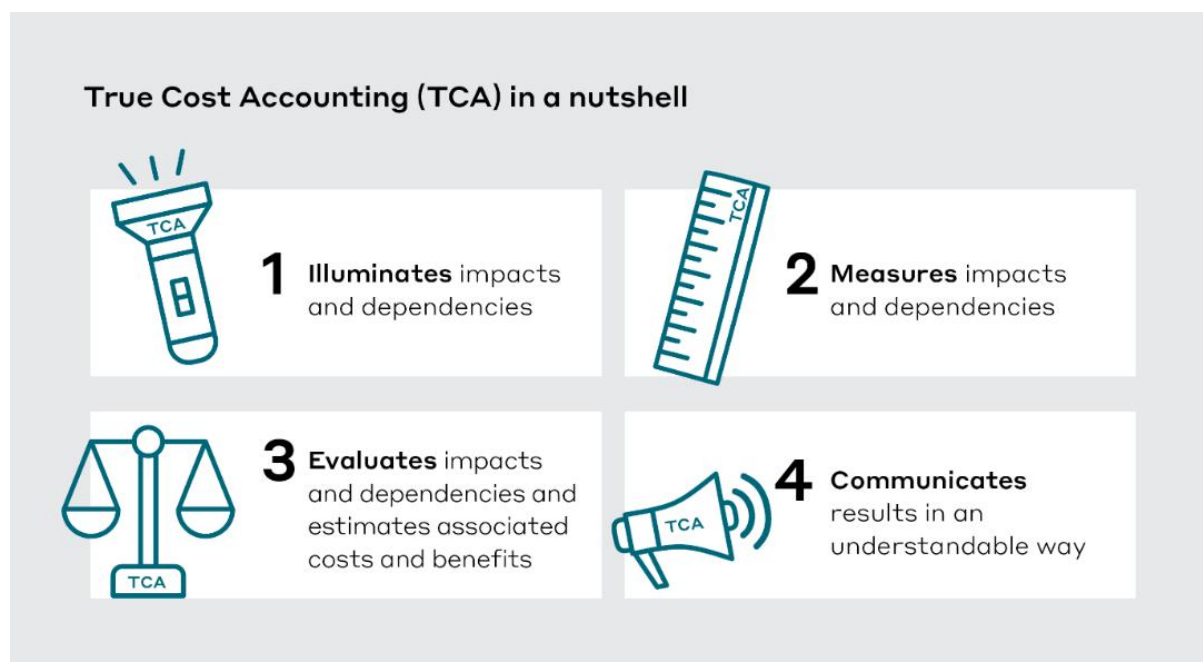


Figure 1. The four steps of True Cost Accounting



Figure 2. The main components of TCA in agri-food systems; adapted from TEEBAgriFood (TEEB, 2020)

Despite its benefits and potential to make agri-food systems more sustainable, the widespread adoption of TCA remains limited. A key barrier is the complexity of its implementation. TCA requires comprehensive and reliable data across multiple dimensions—environmental, social, human and economic—which can be difficult to collect and quantify. The lack of standardized or harmonized methodologies further complicates comparability and credibility across assessments. Moreover, assigning monetary values to non-market impacts such as biodiversity loss, forced labour or human well-being involves ethical considerations and methodological uncertainties affecting the consistency of TCA results.

Organizational and structural limitations also hinder the uptake of TCA. Many organizations lack the necessary resources, infrastructure, tools, capacities, and incentives to implement TCA effectively. Successful adoption requires specific skills and knowledge, including familiarity with TCA principles, impact assessment techniques and monetization methods. TCA is often perceived as complex and resource-intensive, raising concerns about its cost-effectiveness. Some businesses may resist its implementation out of fear that revealing hidden costs may negatively affect their bargaining power and reputation.

1.2 About the TCA calculations and data requirements

Although TCA methods have not been formally harmonized, most approaches follow a similar structured process of identifying, quantifying and monetizing the externalities of food systems (Eigenraam et al., 2020, Soil & More Impacts and TMG Thinktank for Sustainability, 2020). This process requires a broad and diverse set of data spanning environmental, social, human and economic dimensions. This sub-chapter, as well as Figure 3 offers a brief overview of the typical steps involved in TCA calculations and outlines the key data requirements needed to support them.

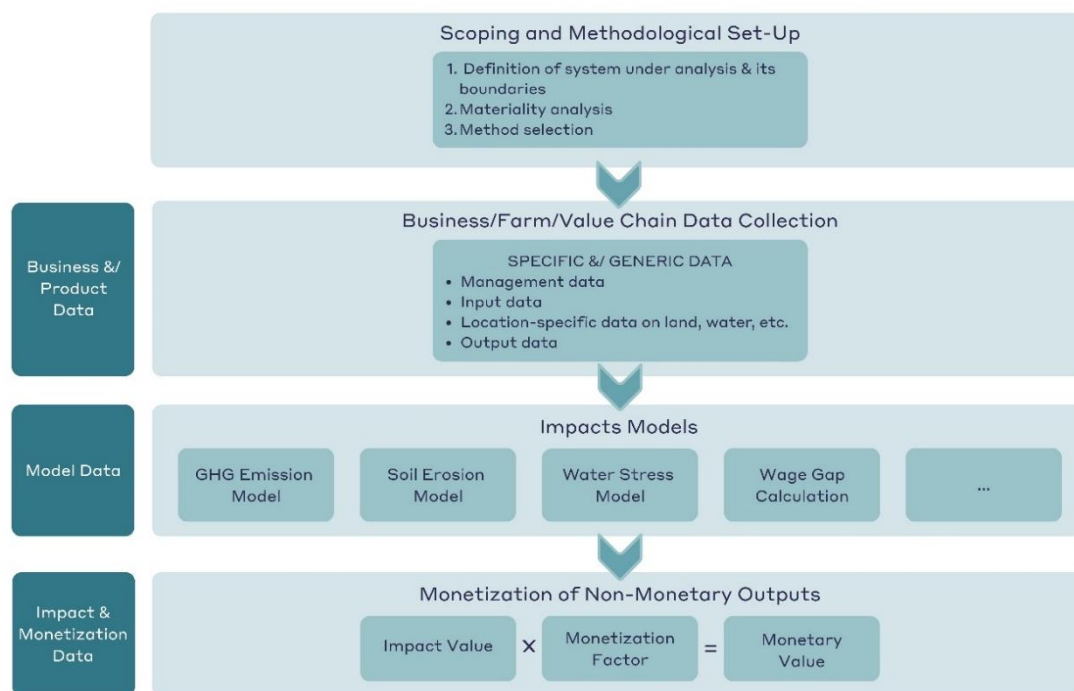


Figure 3. Overview of TCA steps and data requirement

The first step in the TCA process is the scoping and methodological setup. Firstly, one needs to define the system under analysis and its boundaries. This includes specifying whether the focus is, for example, on a single product, a business or the entire food system, and setting its boundaries—such as cradle-to-gate or cradle-to-grave. Once the system and boundaries are established, a materiality assessment is conducted to identify the most relevant environmental, social, human and economic impacts to include in the TCA. Based on the outcomes of this assessment, an appropriate TCA methodology is selected, including the impact models and indicators used to measure or estimate the identified impacts and to calculate the resulting true costs and benefits. The combination of selected impacts and methodological approach determines the data requirements, as each scenario calls for a distinct set of data inputs. For a detailed overview of available TCA methods, see Chapter 2.

In the second step, the necessary data is collected. This may involve a combination of collecting product- and/or business-specific data and the use of generic data from secondary sources. Business-specific data is gathered directly from farms and other value chain actors of interest, covering areas such as management, input, output and location-specific

data. For product-level TCA assessments, more detailed, product-specific data is required from businesses, breaking down business-level data to the level of individual products. Specific data can be obtained directly from measurements by the farm or other value chain actors. This data can be retrieved from business documentation on labour, use of plant protection (i.e. pesticides) and crop yields, but also via direct measurement of water use or soil carbon. Generic data can be used in those cases where primary data cannot be retrieved or is not necessary to be retrieved. For example, location-specific data, such as geological information and water availability, can typically be sourced from secondary data (e.g. from maps) and may not require direct measurement. For management, input and output data, generic data may be used where specific data is not available, though this results in a less precise assessment. Section 3.1 provides information about business- and product-specific data, and Section 3.2 displays databases for generic data.

The third step involves using the data as input for the various impact models. Some impacts can be directly derived from business- or product-specific data (e.g. production value, wages), while others require modelling (e.g. CO₂ emissions, soil erosion, gender wage gap, water stress). Each impact model comes with its own formulas and parameters, referred to as model data. The output from these models is termed impact data. Some of the values may already be in monetary terms (e.g. gender wage gap, living wage gap), while others (e.g. CO₂ emissions, soil erosion, water stress) may need to be monetized to derive true costs and benefits. For a detailed overview of the available TCA databases, see Section 3.2.

In the final step, the impact data is multiplied by monetization factors derived from the literature to calculate the monetary value of each impact. In some TCA approaches, the monetary values for all impact categories may then be summed to determine the total hidden costs and benefits associated with a product or business. Section 3.2 provides more detailed information on the availability of monetization factors.

Once the impact information has been monetized, the results can be reported in different formats. At the business level, TCA results are typically communicated through accounting and financial reporting. For product-level TCA, communication occurs via true pricing, additional price tags or sustainability labelling. Further details on TCA reporting formats are provided in Section 2.5.

1.3 About TCA policy instruments

TCA can support the sustainable transformation of the agri-food sector by informing the design and implementation of policy instruments—particularly by revealing externalities and applying systems thinking. By adopting a systems perspective, TCA helps uncover the interconnections between environmental, social, health and economic impacts across the entire food system. This enables a more holistic understanding of external effects and provides an evidence base for internalizing and/or reducing negative externalities through targeted policy measures. The Environment Agency of the German government (UBA) will publish a report categorizing various instruments for the internalization of environmental externalities (Teufel et al., 2025), some of which can be directly informed by TCA assessments.

Figure 4 presents a revised classification of internalization instruments, highlighting how these measures can be informed by TCA. The instruments fall into three categories: direct behaviour control, indirect behaviour control and non-binding instruments. TCA assessments can support the design and contribute to the justification of policy instruments in all three categories. In particular, the monetization of externalities through TCA can provide a quantitative basis for setting levels or thresholds of policy instruments.

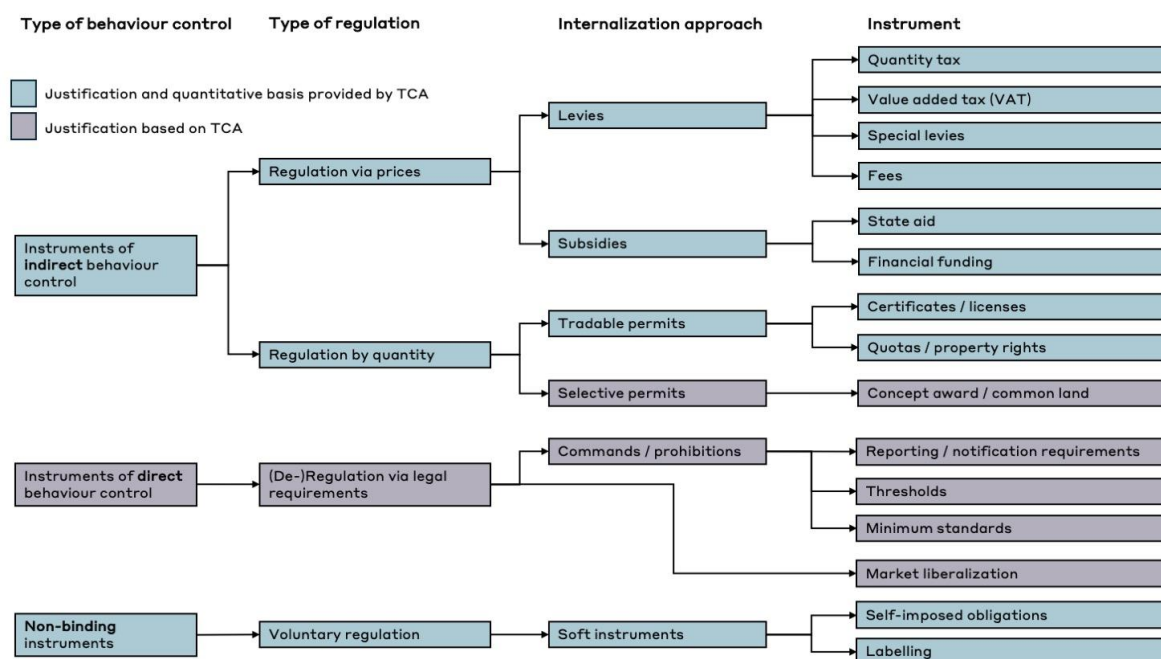


Figure 4. Overview of instruments for internalization of externalities using TCA; adapted from Teufel et al. (2025)

Indirect behaviour control instruments that operate through prices are particularly well-suited for integrating TCA in their design. All four instrument types within this category can be designed to internalize environmental, social and human costs and benefits by drawing on TCA assessments. A widely discussed example is the adjustment of value-added tax (VAT), such as by reducing VAT for organic products or by increasing VAT for animal products. In the case of subsidies, TCA can be used to assess and quantify the public benefits provided by a business, allowing for targeted financial compensation. This approach could be integrated into the EU's Common Agricultural Policy (CAP) to more effectively reward farmers and other producers for delivering environmental and social goods and services. For tradable permits, an instrument that operates through regulating quantities, TCA can inform pricing strategies of certificates by calculating the full societal costs of emissions or resource use. For example, carbon credit prices could reflect not only environmental but also associated social and health impacts per ton of CO₂ equivalent. Similarly, farms that sequester carbon should be financially rewarded for the public services they provide.

Beyond regulatory tools, TCA can also inform non-binding instruments, such as self-imposed obligations and labelling. Examples of self-imposed obligations include documenting TCA assessments in annual business reports or voluntarily charging the true price of products to reinvest additional revenues into reducing public costs. In terms of labelling, this might involve dual pricing (e.g. a second price tag) or TCA-based labels indicating the true cost behind a product. These voluntary approaches are described in more detail in Section 2.5 on reporting formats. In addition to policy instruments, governments can use insights from TCA to shape awareness campaigns, helping consumers make more informed and responsible purchasing decisions.

1.4 About this report and the way forward

This first interim report marks an initial step in developing a roadmap for the implementation of TCA in the German food and agricultural sector. It provides a structured overview of existing TCA methodologies and the current data landscape.

The report begins with an analysis of existing TCA frameworks and guidelines relevant to the agri-food sector, with a particular focus on their applicability at the business and product levels. It assesses methodological foundations, scope, coverage of the four capital categories and valuation approaches. While TCA can be used to assess both dependencies and impacts, this study focuses solely on the calculation of environmental, social, economic and health impacts.

The report then reviews the availability and suitability of data for conducting TCA, identifying key sources that align with the characteristics of the methods under review. By establishing the current state of TCA methods and data in the agri-food sector, this report lays the foundation for the second interim report. Here, we will conduct a SWOT analysis, identifying key strengths and weaknesses of TCA methods and databases as well as opportunities and threats associated with the implementation of TCA in the German agri-food sector. The third interim report will examine the political relevance and applicability

of TCA-informed policy instruments and provide a potential timeline for the implementation of TCA in the German context.

The remaining report is structured into three chapters. Chapter 2 presents the analysis of the TCA methodologies, Chapter 3 presents the analysis of the data situation, and Chapter 4 provides a conclusion and outlook for the second report.

2. Analysis of TCA methods

2.1 Literature review of TCA methods

TCA methodologies relevant to the food sector were identified through a systematic literature review. Additionally, a survey was conducted in both German and English, inviting national and international stakeholders to contribute their knowledge of TCA methods and databases in order to potentially include novel, unpublished or less well-known approaches.ⁱ

The search focused on German and English-language literature from the past ten years, including online sources and publications specializing in TCA methodologies. The goal was to identify TCA and TCA-related approaches relevant to the agricultural and food sector that are transparent and well-documented.

The literature review began with the publication *The Current Field of True Cost Accounting* (Impact Institute, 2023), which assessed 35 initiatives and publications and their relevance to TCA. After screening this documentation and building upon this foundation, further research was carried out to identify recent frameworks, guidelines and initiatives, resulting in the final selection of 23 frameworks and methodological guidelines relevant to the agri-food sector for analysis. This literature analysis involved a systematic selection of TCA-related methodologies based on predefined criteria:

ⁱ However, the survey results did not provide any new information beyond what was already known from the literature review.

- **Relevance to the agri-food sector:** Frameworks and guidelines applicable to food systems were included.
- **Applicability to businesses or products:** Frameworks and guidelines providing guidance for the analysis at the company or product level were included.
- **European and German context:** Framework and guidelines relevant to the EU or Germany were included, ensuring practical application in these regions.
- **Contemporary context:** Frameworks and guidelines published within the last ten years were included.

All frameworks and guidelines were subsequently examined based on the following characteristics:

- **Capital categories and impact categories considered:** The capital categories and impact categories included in the respective frameworks and guidelines were recorded. Capital refers to the different types of resources and assets that a business relies on or impacts, including natural, social, human and economic. According to TEEB (2018), the capital categories are defined as follows:
 - **Natural capital:** The limited stocks of physical and biological resources found on earth and of the limited capacity of ecosystems to provide ecosystem services.
 - **Human capital:** The knowledge, skills, competencies and attributes embodied in individuals who facilitate the creation of personal, social and economic well-being.
 - **Social capital:** Encompasses networks, including institutions, together with shared norms, values and understandings that facilitate cooperation within and among groups.
 - **Produced capital:** All manufactured capital, such as buildings, factories, machinery, physical infrastructure (roads, water systems), as well as all financial capital and intellectual capital (technology, software, patents, brands, etc.).

Furthermore, the assessment provides an overview of the impact categories under the four capital categories considered in the frameworks and guidelines.

- **Inclusion of negative and positive impacts:** It was analyzed whether the assessment includes both positive and negative impacts of activities to provide a complete and transparent assessment.
- **System and system boundaries:** It was examined at which system level the TCA assessments can be conducted, whether at the business level or product level, or at different stages of the value chain.
- **Sector specificity** (general vs. agri-food specific): It was assessed whether the frameworks and guidelines are cross-sectoral (general) or specifically tailored to the unique environmental, social and economic challenges of the agri-food sector.
- **Required data type** (specific vs generic): It was examined which type of data is required for the analysis. Specific data is collected directly from operations, suppliers or stakeholders, while generic data is obtained from external sources such as reports, databases or industry benchmarks.
- **Valuation approaches** (qualitative, quantitative, monetary): It was recorded which method is used to value impacts. Qualitative valuation methods are used to inform the potential scale of costs and/or benefits expressed through qualitative, non-numerical terms (e.g. increase in air emissions, decrease in social benefits of recreation). Quantitative valuation methods focus on numerical data that are used as indicators for costs and/or benefits (e.g. tons of pollutants, number of people benefitting from recreation). Monetary valuation methods translate quantitative estimates of costs and/or benefits into a single common currency (Natural Capital Coalition, 2016).
- **Level of methodological detail** (low, intermediate, high): The degree of guidance provided for impact measurement was assessed. Approaches with low-level detail offer broad principles,

those with intermediate-level detail provide some specifics, and those with high-level detail give step-by-step instructions for impact measurement and valuation.

2.2 Overview of identified frameworks and guidelines

The analysis of frameworks and guidelines provides insights into the current landscape of TCA methodologies relevant to the agri-food sector. An overview of the respective characteristics (outlined above) of the analysed frameworks and guidelines is summarized in this section and presented in full in Appendix I. While these frameworks and guidelines vary in scope, valuation approaches and methodological detail, they can all be used to assess and account for the different levels of environmental, social, human and economic impacts of food systems.

Table 1. Overview of the 23 identified frameworks and guidelines

Organization	Frameworks and guidelines
A4S	A4S Essential Guide Series
FoodSIVI	The Food System Impact Valuation Initiative
Sustainable Food Trust	Global Farm Metric
Capitals Coalition	Natural, Social and Human Capital Protocol
TMG Thinktank and Soil & More Impacts	TCA AgriFood Handbook
UN Environment Programme, The Economics of Ecosystems and Biodiversity for Agriculture and Food (TEEBAgriFood)	TEEBAgriFood Evaluation Framework
Capitals Coalition and TEEBAgriFood	TEEB for Agriculture and Food: Operational Guidelines for Business
Capitals Coalition, Value Balancing Alliance (VBA), World Business Council for Sustainable Development (WBCSD), EU LIFE program	Transparent
True Price	True Pricing Assessment Method for Agri-food Products
VBA	Impact Statement
VBA	Valuing Impact Materiality
VBA	Impact Valuation Sprint

IFVI and VBA	Conceptual Framework for Impact Accounting Environmental and Social Topic Methodologies
Valuing impact	eQALY Impact Valuation Method
ISO	ISO 14040 and 14044 Environmental management. Life cycle assessment. Requirements and guidelines
ISO	ISO 14008 Monetary valuation of environmental impacts and related environmental aspects
The Joint Research Center (JRC)	Product Environmental Footprint (PEF) Framework
The Joint Research Center (JRC)	Organization Environmental Footprint (OEF) Framework
International Integrated Reporting Council (IIRC)	International <IR> Framework
EY	Total Value
Task Force on Nature-related Financial Disclosures	Guidance on the identification and assessment of nature-related issues: The LEAP approach
Impact Institute	The Integrated Profit & Loss methodology
Impact Economy Foundation	Impact Weighted Accounts Framework

A total of 23 frameworks and guidelines were analysed (Table 1). These documents were developed by various organizations, including international institutions, private companies, research coalitions and industry groups. The list includes independently developed frameworks and guidelines, as well as those focused on harmonization of methodologies, that is, frameworks or guidelines building on similar concepts and methods. Some frameworks were chosen because they focused on TCA specifically, while others were selected because they specify certain methodological elements (e.g. LCA approach for the impact assessment step of TCA) of common TCA approaches, thereby indirectly offering methodological details on TCA. While the included frameworks and guidelines differ methodologically, they all rely on the same overarching steps of system boundary definition, materiality

assessment, impacts assessment and valuation. However, the application of these steps differs depending on the capital categories included in the framework and the type of valuation approach suggested. Many existing methods are designed to be broadly applicable across different industries rather than being specifically tailored to the unique characteristics and impacts of the agri-food sector.

2.2.1 Capital categories and impact categories considered

The analysed frameworks and guidelines for TCA methodologies for agri-food systems largely focus on natural, social and human capital, with only a few incorporating produced capital. This is because produced capital—which includes manufactured (machinery, buildings and infrastructure), economic and intellectual capital—is already well accounted for in existing accounting standards and is mostly represented in market prices (True Cost Initiative, 2022).

Figure 5 shows a matrix indicating which capital categories are covered by each of the assessed TCA frameworks and guidelines. All (23) include natural capital, and many (16) also address social capital. However, the inclusion of impacts and aspects within social capital varies significantly

Frameworks and Guidelines	Considered Capital			
	Natural	Social	Human	Produced
A4S Essential Guide Series				
The Food System Impact Valuation Initiative				
Global Farm Metric				
Natural, Social, Human Capital Protocols				
TCA AgriFood Handbook				
TEEB AgriFood Evaluation Framework				
TEEB for Agriculture and Food: Operational Guidelines for Business				
Transparent				
True Pricing Assessment method for agrifood products				
Impact statement				
Valuing impact materiality				
Impact valuation sprint				
Conceptual Framework for Impact Accounting Environmental and Social				
Topic methodologies				
eQALY Impact Valuation Method				
ISO 14040 and 14044				
ISO 14008 Monetary valuation of environmental impacts and related environmental aspects				
Product Environmental Footprint (PEF)				
Organisation Environmental Footprint (OEF)				
International <IR> Framework				
Total Value				
Guidance on the identification and assessment of nature-related issues: The LEAP approach				
The Integrated Profit & Loss methodology				
Impact weighted accounts framework				

Figure 5. Coverage of capital categories in 23 identified frameworks and guidelines

across different frameworks and guidelines. Less than half (11) cover human capital, and less than a third (7) cover produced capital.

Figure 6 illustrates the number of frameworks and guidelines that incorporate different impact categories across the four types of capital. The analysis shows a strong representation of natural capital impact categories, including climate change (21), pollution (21) and depletion of scarce resources (21). Human capital impact indicators are less represented and include, for example, occupational health and safety risks (14), income/wages (12) and production-related health impacts (11). Social capital and produced capital are also less addressed. Within social capital, human rights violations are the most frequently considered impact, appearing in about 50% of the frameworks. However, only a few frameworks address categories such as gender inequality (7), food security (3) and laws and regulations (3). For produced capital, financial performance is the most addressed impact category, covered in ten frameworks.

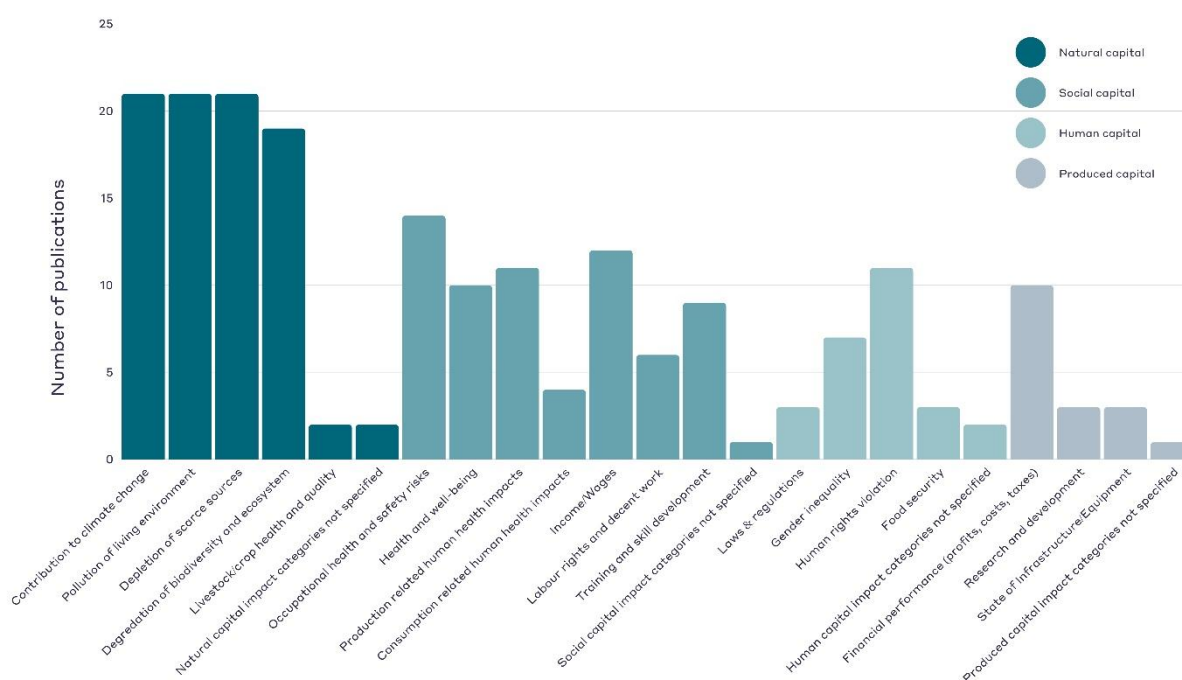


Figure 6. Overview of coverage of impact categories in 23 identified frameworks and guidelines

2.2.2 Inclusion of negative and positive impacts

Among the assessed frameworks and guidelines, 12 address both negative and positive impacts, while 11 focus on negative impacts. In theory, a complete TCA should consider both types of impacts to capture

the balance of externalities of a business or product. Frameworks that provide low-level methodological detail often serve as a conceptual foundation, typically addressing both positive and negative impacts. However, those offering high-level methodological guidance tend to focus primarily on negative impacts.

2.2.3 System and system boundaries

Figure 7 presents the assessed frameworks and guidelines categorized by level of analysis, sector specificity and the types of data they use.

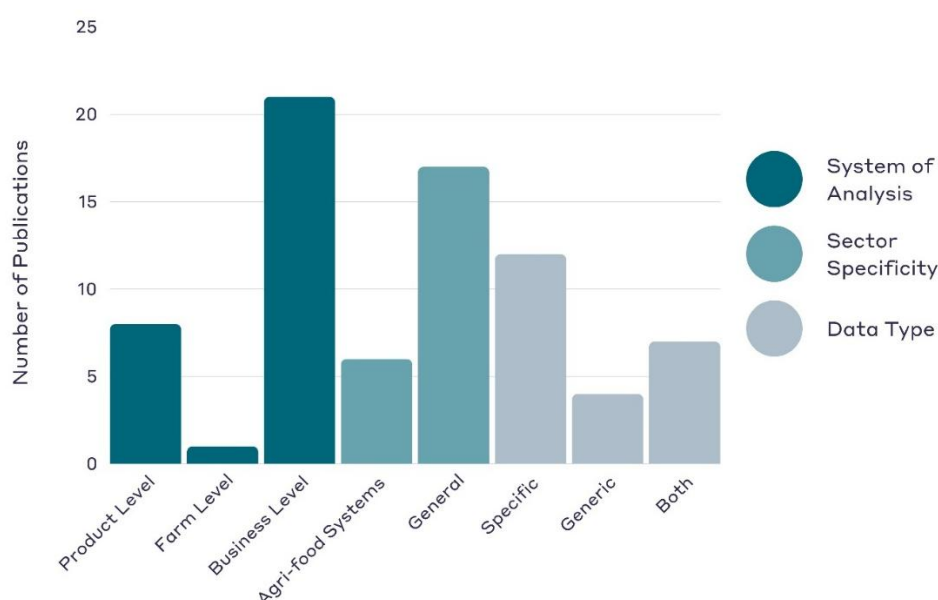


Figure 7. Overview of the system of analysis, sector specificity and required data type in the frameworks and guidelines

Of the 23 assessed frameworks and guidelines, eight are applicable to TCA at the product level (e.g. True Pricing Assessment Method for Agri-food Products). Additionally, some frameworks designed for impact assessment at the product level (e.g. PEF) can support TCA applications. Seven can be applied at both the business and product level, while most emphasize business-level assessments (e.g. Natural Capital Protocol). Certain frameworks, such as TEEBAgriFood, provide flexibility across organizational, value chain and product-level assessments. Meanwhile, one (The Global Farm Metric) is specifically designed for farm-level impact assessment.

2.2.4 Sector specificity of frameworks and guidelines

The overview shows that six TCA guidelines and frameworks are specific to the agri-food sector (see Figure 7). Other frameworks are more general and can also be applied to other sectors.

2.2.5 Required data type

Figure 7 summarizes the data requirements of the assessed frameworks and guidelines. It shows that 12 frameworks and guidelines require specific data for implementation. Four impact assessment guidelines can be applied using solely available generic databases, but their scope is limited to natural capital. Seven combine both specific and generic data. The majority of frameworks and guidelines rely on specific data, which limits scalability due to challenges with specific data collection and availability. While generic datasets that could support the assessment of natural, social and human capital for a range of products and systems exist, these datasets are not referred to and systematically integrated into TCA methodologies. There is a lack of methodological guidance within the identified frameworks and guidelines on how to use existing generic data.

2.2.6 Valuation approaches

Valuation is the process of estimating the costs or value of impacts and dependencies to society or a business in a specific context. Expressing sustainability information in economic terms can help make the measured impacts understandable to stakeholders. Information of the impacts and dependencies can be presented qualitatively, quantitatively or monetarily. While valuation methods are not standardized,ⁱⁱ all analysed frameworks and guidelines include some form of valuation in their assessments, indicating broad agreement on its usefulness. Three valuation approaches were identified in the literature: qualitative,

ⁱⁱ In the context of TCA, 'standardized' refers to an existing, previously agreed upon, formal, and widely adopted method that is consistently applied across assessments. This differs from 'harmonized,' which refers to reduced variation between methodologies by increasing the compatibility of practices.

quantitative and monetization. Four frameworks and guidelines offer all three valuation methods, leaving the choice to the user; 15 specifically focus on monetization; and four provide a quantitative approach by measuring impacts in terms of mass.

Qualitative valuation assesses impacts and dependencies without numerical measurements but instead through descriptive analysis, stakeholder perspectives and expert judgment. This approach helps provide context and a broader understanding of social, environmental and economic effects. It is particularly useful when precise data is unavailable or when assessing complex, multi-dimensional impacts that are difficult to quantify, such as cultural values, ecosystem services or social well-being.

Quantitative valuation involves the assessment of natural, social and human capital impacts using measurable units, such as numerical scores (e.g. in a composite index), area, weight or volume, to express their magnitude.

Monetization is the process of expressing impacts in monetary terms. By translating diverse impacts into a common unit, it provides a comprehensive representation of costs and benefits to support informed decision-making. Monetization factors convert quantitative estimates of environmental, human health and social impacts into monetary values, reflecting either costs or benefits. These factors are developed by various organizations and differ in their methodologies and applicability. The most common approaches are:

- **Damage-costs approach:** This method estimates the costs associated with damages to the environment or society caused by an activity, such as the level of damages incurred by society because of greenhouse gas emissions and the resulting climate change. It measures the costs of remediating these impacts.
- **Abatement-costs approach:** This approach calculates the costs of preventing damage before it occurs, such as via investment in

green technologies or pollution control measures. It reflects costs incurred to avoid negative impacts.

- **Rights-based approach:** A rights-based approach considers processes that respect the basic rights of all individuals, including future generations. It draws on internationally recognized rights, such as those outlined in the Universal Declaration of Human Rights, which serve as the foundation for defining what should be considered as unsustainable externalities of food production and consumption. This method is developed and used by True Price, and their monetization factors represent the remediation costs associated with negative social, environmental or health impacts, aiming to restore stakeholders' well-being. Remediation costs are calculated as restoration, prevention, compensation (also known as damage costs) or retribution costs, depending on a decision tree that considers the type of impact to be addressed.
- **Contingent valuation:** This method estimates the monetary value by asking people how much they would be willing to pay to avoid harm or preserve a benefit.

2.2.7 Methodological detail

Frameworks and guidelines for TCA vary significantly in the level of methodological detail they provide. While some offer comprehensive step-by-step instructions and formulas, others remain at a conceptual level, requiring users to apply additional expertise and judgment, including specialized expertise in agri-food systems impacts and the ability to adapt and apply available impact assessment methods and calculations to food systems.

The examined frameworks and guidelines can be grouped into three broad categories based on their level of methodological detail:

Low detail: Three frameworks and guidelines provide overarching principles and conceptual approaches to TCA but lack detailed methodological steps. They are useful for organizations looking to

understand systems thinking and for strategic direction but require additional expertise for implementation.

Medium detail: Ten frameworks and guidelines offer more structured guidance than low-level methodologies but do not provide exhaustive step-by-step calculations. They serve as a middle ground, offering flexibility while still requiring interpretation.

High detail: Ten frameworks and guidelines provide highly detailed methodologies with predefined steps, formulas and case study examples. These resources greatly facilitate practical application by specifying impact indicators and data needs, as well as monetization methods in some instances.

Among the high-detail frameworks, some stand out for their comprehensive guidance. For example, the TCA AgriFood Handbook focuses on product-level assessment and offers both theoretical and practical principles on TCA. It defines relevant impact indicators for the agri-food sector, provides monetization factors and demonstrates how to calculate, aggregate and report true costs. The handbook addresses natural, human and social capital, covering contributions to climate change, environmental pollution, depletion of scarce resources, occupational health and safety, income and labour rights and human rights issues. However, it is applicable only to plant-based agriculture and does not evaluate biodiversity impacts. Another example is the Impact Valuation Sprint by the VBA, which focuses on business-level assessments. It outlines detailed steps for estimating selected impacts and includes monetization methods. It covers similar impact categories to the TCA AgriFood Handbook but currently does not include biodiversity. A more detailed analysis of each framework and guideline, including an overview of impacts covered, is provided in Appendix I.

Figure 8 provides a summary of the degree of methodological detail and the number of included capital categories across the reviewed frameworks and guidelines.

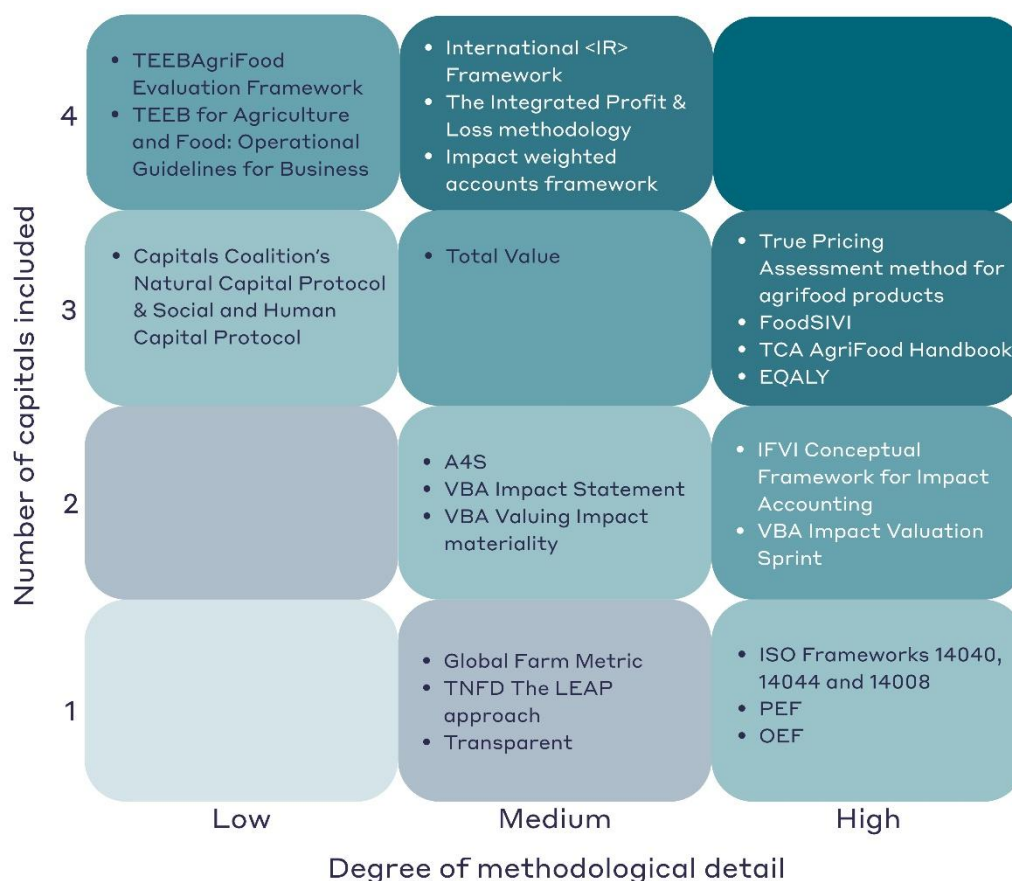


Figure 8. Degree of methodological detail and number of capital categories included across frameworks and guidelines

2.3 Key gaps in existing TCA methods

Limited coverage of social and human capital

- While all frameworks and guidelines address natural capital, the inclusion of social, human and produced capital is inconsistent. There is a significant dearth of methodologies that cover social and human capital. This is due to a lack of well-established methods and data to model the impacts under social and human capital. Further, most of the frameworks and guidelines focus only on negative impacts, with few exceptions.
- Food production relies on and affects multiple types of capital (natural, human, social and produced) that are closely connected. While the frameworks and guidelines outline how to assess each type individually, most do not offer an approach fully integrating all capital categories.

Inconsistent valuation approaches

- While many TCA frameworks and guidelines advocate for monetization as a core valuation approach, they often apply different monetization methods tailored to their specific perspectives, objectives and stakeholder needs. This leads to a diverse range of outcomes across assessments. Insufficient understanding and communication of these methodological differences restrict comparability of results.
- Monetization of social and human impacts remains underdeveloped.
- Some frameworks and guidelines focus on qualitative or quantitative metrics without a direct monetary translation, which makes it difficult to compare impacts across different capital categories.

Data gaps and reliance on specific data

- Most frameworks and guidelines require specific data collection, which can be costly and time intensive.
- TCA methodologies require a large volume of data across different capital categories.

Lack of harmonization

- A lack of standardized methodologies limits comparability between assessments.
- Differences in scope and assessment of the frameworks and guidelines increases inconsistencies between them.

2.4 Online tools for sustainability impact assessment using TCA

Currently, several new impact assessment and valuation software tools are available to help businesses estimate environmental, social and human impacts across their value chain. These tools present impact assessments and provide monetized outcomes. By integrating generic databases, they reduce the burden of data collection from supply chains.

However, in case of generic data use, the impact estimations are typically proxies, and all tools are paid commercial solutions.

WifOR Institute Sustainability Impact Tool (WISIT)

WISIT (WifOR Institute, n.d.) is a web-based application designed to analyse the environmental and social impacts of business activities. It enables impact assessment along the entire supply chain in three key steps: data input, calculation and breakdown of results. The tool requires data on purchase lists, detailing procurement costs for a specific fiscal year. It then connects this data with its extended input-output model, which is built on data from national statistics and scientific publications. An overview of the data sources used for impact assessment is available, but the details of the impact assessment methodology are not publicly accessible. The assessment results include both environmental and social impacts at the business level, which are monetized using WifOR Value Factors (Scholz et al., 2025). The documentation of the impact valuation methodology is publicly available.

Impact Suite

Impact Suite by Impatec (Impatec, n.d.) is another impact assessment tool that provides monetized environmental and social impact results. This AI-supported toolkit automates hotspot analysis using a comprehensive library of impact calculations. There is no publicly available documentation on the impact calculation methodology of this tool. The platform is described as allowing users to create and refine impact models, minimizing data entry errors and promoting consistent outcomes. It provides specific and generic data points in the relevant units, simplifying data collection and analysis. The monetization of impacts is based on the True Price monetization database (Galgani et al., 2023).

GIST Impact

GIST Impact (GIST Impact, n.d.) offers measurement, monetization and management of the impacts of business activities. The tool is described as assessing both positive and negative impacts across natural and social

dimensions. The tool relies on specific data related to businesses' operations and outputs while also integrating generic data to fill primary data gaps. The documentation on the methodology of impact assessments is not publicly available. GIST Impact's approach aligns with established frameworks and guidelines, such as those developed by the Capitals Coalition and the VBA, and it collaborates with the WifOR Institute on methodologies and monetization factors.

Regionalwert Leistungsrechnung

Regionalwert's sustainable performance calculator ('Leistungsrechner') is an online tool developed to assess the sustainability performance of farms (Regionalwert Leistungen GmbH, n.d.). It calculates the value of a farm's services for the environment, society and the regional economy. The assessment focuses on a farm's existing potential and how it can be further developed. Farmers enter their data through an online form, which captures approximately 400 key indicators across the three above-mentioned categories. Based on this data, the tool evaluates the farm's performance and translates it into a monetary value, reflecting the farm's contributions to maintaining livelihoods and the common good. In addition, the analysis provides a sustainability score. The assessment is carried out using the QuartaVista method developed by Regionalwert AG. This approach evaluates a business's impacts across four key dimensions: ecology, knowledge, society and finance. Within these dimensions, it considers a range of factors and their associated costs, including CO₂ emissions, working conditions, wages, regional gross value added and trainee quotas. To monetize the impacts, QuartaVista introduces its own monetization approach, which can be defined as an expenditure-costs method. This method translates impacts into monetary terms based on real expenditures. In the project's closing report, QuartaVista provides some examples of how selected impacts are monetized. For example, to monetize the trainee quota, the calculation involves converting the trainee wage and the costs of supervision by instructors into a monetary value. This is done by taking the total trainee wages, applying a predefined monetization rate and

then adding the cost of instructor time, calculated by multiplying the instructor's hourly wage by the number of hours spent on training and the number of trainees (QuartaVista, 2021). However, the report does not provide a comprehensive explanation of the assessment methods or monetization approaches for all dimensions, and this information is not currently publicly available.

2.5 TCA reporting formats

The information obtained from the TCA assessment should be shared with relevant stakeholders. The target groups differ between TCA assessments conducted on the business or product levels.

Business-level assessment

The main target audience of business-level TCA assessment are shareholders, creditors, supervisory authorities, the financial administration, business associates, employees and the interested public (True Cost Initiative, 2022). The analysis allows businesses to actively measure and monitor their sustainability performance. The reporting aims to reveal an organization's impact on natural, social and human capital, as well as the financial risks that come with it. TCA can play an important role in monetizing sustainability costs and benefits. The TCA Handbook points out that, according to the German Accounting Standard, TCA indicators used for business steering must be reported in companies' management reports. They can be classified as quantitative 'non-financial' key performance indicators (KPIs) or financial KPIs if they have a direct impact on financial accounting data or enterprise value reporting.

Businesses can use multiple recently developed approaches to report the true costs and benefits of the business. The first approach worth highlighting is based on Sustainable Performance Accounting (SPA), which enables the integration of environmental, social and governance aspects in bookkeeping. In addition to EBIT ('earnings before interest and taxes'), as a key monetary figure that describes the economic performance of a business, sustainability EBIT (S-EBIT) can be

calculated (Henkel et al., 2024). A second approach, called the Framework for Impact Statements—Beta Version (FIS Beta), outlines a standardized structure for impact statements (Impact Institute, 2019). They suggest using an integrated profit and loss method, which extends the traditional method by looking at the financial and non-financial value created for all stakeholders instead of focusing only on shareholders. In addition to the Integrated Profit and Loss Statement, there are four components to the financial reporting: the Investor Value Creation Statement, the Stakeholder Value Creation Statement, the External Cost Statement and the Sustainable Development Goals (SDG) Contribution Statement. A third approach called the Impact Statement was developed by VBA and proposes the integration of financial, natural, human and social capital in business accounting and reporting (VBA, 2024). The results of the impact assessment and its monetization are presented in an impact table along three dimensions: capital categories (environmental, social and human, economic), value chain stages (upstream, own operation, downstream) and metrics (item, measure, metric and monetary value).

Regionalwert's calculation tool provides an online dashboard for farmers. The benefits are monetized and categorized based on a percentage scale. The percentages translate into a colour scale ranging from green for 'strongly sustainable' and red for 'not sustainable'. Farms can use the results from the dashboard to communicate their sustainability contribution to processors, retailers and consumers.

Product-level assessment

TCA on the product level addresses consumers and downstream value chain actors who are interested in the sustainability impacts of the products they purchase. On the product level, the true costs and benefits can be communicated through internalization into consumer prices, a second price tag or other sustainability labelling. In the Netherlands, an initiative was established that allows for in-store true price payment for selected products (True Price, 2025). True Price differentiates between three types of true pricing: standard true price payment, voluntary true price payment and other payment strategies (True Price, 2024). A

supermarket in Berlin known as Penny Grüner Weg displayed a second price tag for one week to inform consumers about the additional social and environmental agricultural cost for 16 selected food items. The second price tag approach was solely informative and did not require additional payment. The aim of this initiative was to assess the potential influence of this information on consumer decisions (Michalke et al., 2022). Alternatively, TCA information could be communicated through sustainability labels. As an alternative to certification-based labels, the Eco Food Choice project is developing a European harmonized LCA-based ecolabel system (Cicek et al., 2024). It would be conceivable to expand this initiative by converting the results of the environmental LCA into monetary values based on established monetization factors. Additionally, social and human impacts could be included in the LCA and monetized for the purpose of food labelling.

3. Analysis of TCA databases

TCA methodologies consist of four key steps: materiality assessment, impact measurement, monetization and communication of the results (see Figure 1). All four steps rely heavily on the availability and quality of data affecting the applicability of TCA methods and the accuracy of results. TCA data can be categorized into two types: specific data, which is gathered directly from the business/operation, and generic data, which is sourced externally but considered representative of the sector. Some TCA methodologies rely exclusively on one type, while others integrate both (see Section 2.2.5). At both the product and business level, various data categories are needed for TCA assessments, including input data (e.g. material flows, energy use), output data (e.g. yield), management data (e.g. farming practices, labour conditions) and impact data (e.g. greenhouse gas emissions). The monetization of impacts involves applying monetization factors, which convert impacts into monetary values. The monetization factors are commonly generic data from the existing literature but can also be directly modelled for specific cases.

This chapter examines the availability and relevance of both specific and generic data sources in relation to the data requirements of TCA.

3.1 Overview of business- and product-specific data collection efforts

There is currently neither a standardized approach for data collection nor existing data pools of specific data in the agri-food sector. Moreover, there is no specific data that has been systematically collected and made available explicitly for the purpose of conducting product- and business-level TCA assessments. Some frameworks and guidelines have introduced protocols for sustainability data collection. For example, the Capitals Coalition's Protocols on Natural Capital and Social and Human Capital include a chapter on data collection for measuring and valuing natural, social and human capital. It highlights the importance of collecting the right data for comprehensive analysis and provides a simple overview of specific and generic data (Natural Capital Coalition, 2016). However, this guidance is not specific to the agri-food sector and requires prior knowledge of relevant data points within the food supply chain and existing generic databases.

In 2022, the Task Force on Nature-Related Financial Disclosures (TNFD) conducted research on the natural capital data landscape (TNFD, 2022). The study identified four key challenges:

- Gaps in data coverage across nature categories
- Inconsistencies in measurement approaches
- Spatial and temporal inconsistencies in the data
- Limited accessibility of data for decision-making

Based on this, TNFD later published a roadmap study on improving market access to nature-related data (TNFD, 2024). Their roadmap concluded that there is a gap in accessible nature-related data and that an open-access global data facility could be beneficial. To advance this initiative, TNFD plans to launch a pilot phase in 2025, collaborating with partners across the nature data value chain. Although these efforts encourage data collection, reporting and public access, they primarily

focus on natural capital and do not specifically address the agri-food sector.

Efforts to collect farm-level specific data in the EU and Germany remain limited. At the EU level, the European Commission launched the Farm Accountancy Data Network (FADN), a voluntary data repository where farmers can report their economic data. From 2025 onwards, the Farm Sustainability Data Network (FSDN) replaces the FADN, additionally collecting sustainability data on economic, environmental and social factors. Between 2014 and 2016, the European Commission funded the FLINT project, aiming to establish an up-to-date farm-level data infrastructure with sustainability indicators. FLINT collected 33 farm-level indicators across three major domains: environmental, economic and social sustainability. Germany was among the nine participating countries, but the project results are not publicly available, limiting its use. Another EU initiative, the DESIRA project, focused on the digital transformation of the agri-food sector and its socio-economic and environmental impacts. Germany was one of the participating countries, and the project concluded in 2023. Despite the efforts to improve rural and agricultural data governance and management in Germany, a significant data and research gap regarding farm-level data collection, transparent and standardized reporting practices and data repositories remains.

The efforts from mandatory sustainability reporting in the EU could have served as a starting point for specific data collection on farms and in other agribusinesses. The Corporate Sustainability Reporting Directive (CSRD) was initially expected to impact farms and agribusinesses, particularly those operating within supply chains of larger or listed businesses that are required to comply with mandatory sustainability reporting obligations. As part of the European Sustainability Reporting Standards (ESRS), sector-specific standards for the agriculture, farming and fishing sector and the food and beverage sector were being developed. These reporting obligations would require companies to collect specific data to accurately reflect their sustainability efforts in

the reporting process. However, in response to calls for reducing bureaucracy, the Omnibus package presented by the European Commission in February 2025 suggests significant changes to reporting requirements. Under the updated rules, small and medium-sized enterprises (SMEs) as suppliers of larger firms, including many farms, would no longer be required to provide mandatory sustainability information. Instead, these businesses will have the option to voluntarily engage in reporting activities. Additionally, the previously planned sector-specific standard requirements under the CSRD have been discarded. In the absence of mandatory reporting regulations, farms generally do not report specific impact data on a regular basis, leading to a lack of readily available data for TCA assessments.

Currently, there is no standardized framework in Germany defining which sustainability data farmers should collect. This makes it difficult to evaluate which specific data is already available for TCA assessments at the farm level. However, farms are subject to several reporting obligations and engage in documentation activities for operational planning. A study by KTBL and Regionalwert Leistungen GmbH shows that farms collect sustainability data for different purposes such as accounting, management activities, funding applications and certification (Grün et al., 2023). The study examines whether the key figures required to calculate selected economic, environmental and social sustainability indicators are being collected on three case study farms in Germany. The findings provide valuable insights into the specific data documentation practices at the selected farms but do not allow for broad conclusions about the availability of farm-level sustainability data across Germany. The results indicate that the case study farms already document a significant portion of the required key figures, with the remaining data considered to be undocumented knowledge that can be provided by the farm manager. Only 18% of the key figures were entirely unavailable at the case study farms. The data sources include plot records, financial documentation, funding applications, livestock records, certifications, personnel documentation, resource planning, geographic

information systems (GIS), administrative documents, contracts and laboratory or research data.

Sustainability assessment is an increasingly pressing issue in the agri-food sector, yet there is still no widely accepted, science-based assessment standard. A current project by the Thünen Institute, the MinKriSet project, aims to develop a minimum set of criteria for evaluating sustainable practices at the farm level. The resulting minimum criteria set has the potential to harmonize data collection efforts at the national level and may make it possible to use the sustainability information for TCA.

The lack of standardized specific data collection and publicly accessible repositories presents a major barrier to comprehensive TCA assessments at the product and business levels. The complexity of agri-food supply chains—ranging from local to global levels and through various stages of production, processing, transportation and consumption—makes collecting comprehensive data difficult. Current databases primarily focus on natural capital, overlooking critical social and human capital data. To address these gaps, TCA efforts can initially rely on generic data where specific data is unavailable, ensuring somewhat representative results.

3.2 Overview of available generic databases

Where specific data is not available, TCA assessment can be implemented with generic data representative of the agri-food sector. Generic databases can contain all data categories needed for TCA assessment in the agri-food sector, namely input, output, management and impact data, as well as monetization factors. These databases provide information at different levels (product, business and country level), represent different stages of the supply chain and focus on various aspects of sustainability relevant to TCA assessments at the product or business level.

Based on the following criteria, 21 generic databases (shown in Table 2) were identified as suitable for TCA assessment:

- **Relevance to the agri-food sector:** Databases that align with frameworks and guidelines or methodologies applicable to food systems were included.
- **Applicability to businesses and products:** Databases providing guidance at the business or product level were considered.
- **European and German context:** Databases relevant to the EU or Germany were selected to ensure practical applicability in Germany.

Table 2. Overview of 21 identified generic databases

Data category	Data	Organization	Databases	Geographic coverage	Capital categories
Production-related input data	Industry-level labour statistics	International Labour Organization (ILO)	ILOSTAT	Global coverage including Germany	Social
	Living wage data	VBA	Global Living Wage Dataset	Global coverage including Germany	
		Global Living Wage Coalition	Living wage data estimations	56 countries excluding Germany	
		KTBL	KTBL-Datensammlung: Betriebsplanung Landwirtschaft 2024/25	Germany specific	Natural, social
	National agricultural statistics	FAO	FAOSTAT	Global coverage including Germany	Natural
		FAO	AQUASTAT	Global coverage including Germany	
		EUROSTAT	EUROSTAT	European countries including Germany	
Management data	Operational and financial data	KTBL	KTBL-Datensammlung: Betriebsplanung Landwirtschaft 2024/25	Germany specific	Natural, Social

Output data	Global/national health statistics	IHME	Global Burden of Disease	Global coverage including Germany	Social, human
	National agricultural statistics	FAO	FAOSTAT	Global coverage including Germany	Natural
		FAO	AQUASTAT	Global coverage including Germany	
		EUROSTAT	EUROSTAT	European countries including Germany	
Model data	Life Cycle Inventory (LCI) data	ADEME	Agribalyse	France	Natural
		Ecoinvent	Ecoinvent	Global coverage including Germany	
		Quantis	World Food LCA Database	Global coverage including Germany	
		Blonk Sustainability	Agri-footprint	Global coverage including Germany	
		Sustainable Impact Metrics	Idemat	Global coverage including Germany	
		SLU	SAFAD	Global coverage including Germany	
		Oxford Martin School	HESTIA	Global coverage including Germany	
		SHDB	Social Hotspot Database	Global coverage including Germany	
		Green Delta	PSILCA	Global coverage including Germany	

Impact data	Pre-calculated impact data	Oxford Martin School	HESTIA	Global coverage including Germany	Natural
		SLU	SAFAD	Global coverage including Germany	
		J. Poore and T. Nemecek	Poore and Nemecek, 2019.	Global coverage including Germany	
		FAO	FAOSTAT Climate Change Domain	Global coverage including Germany	
		INRAE	Agribalyse	France	

A variety of reports provide monetization factors to support TCA implementation. These databases differ in their geographical scope, types of capital covered and valuation approaches. Some offer country-specific values, while others provide global estimates. Table 3 presents key sources for monetization factors that can be used for TCA assessments.

Table 3. Overview of identified monetization databases

Organization	Database name	Capital categories covered	Valuation approach	Scope of monetization factors
Umwelt Bundesamt (UBA)	Methodological Convention 3.2 for the Assessment of Environmental Costs	Natural	Damage costs	Germany specific
WifOR	WifOR value factors	Natural Social Human	Damage costs Abatement costs	Country specific (28 countries)
CE Delft	CE DELFT value factors	Natural	Damage costs	EU average and Netherlands specific

True Price	True Price value factors	Natural Social Human	Rights based	Global averages
Sustainability impact metrics	Eco cost value	Natural Social Human	Abatement costs	Global averages
IFVI	Global Value Factor Database	Natural	Damage costs Contingent valuation	Global average and country specific (218 countries)
FoodSIVI	SPIQ-FS	Natural	Damage costs Abatement costs	Country-specific (158 countries)

To further evaluate the databases, they were assessed based on several key criteria:

- **Capital categories and impact categories covered:** Identifying the capital categories (natural, social, human and/or produced capital) and related impact categories covered by the databases.
- **Data categories:** Assessing the availability of data categories (input/output, management, model, impact and monetization) relevant for TCA assessment within and across databases.
- **Scope and coverage of databases:** Determining whether the database provides product- or country-level information, including details on production type (e.g. organic, conventional, agroforestry), the industry branch (e.g. plant, animal, aquaculture, fishery) and the supply chain stage (e.g. primary production, processing, consumption).
- **Coverage of negative and positive impacts:** Assessing the data availability to measure both positive and negative material impacts.
- **Sector specificity:** Differentiating between general databases and those specific to the agri-food sector.
- **Geographical coverage:** Identifying the regional representation of the available data.

- **Monetization possibility:** Evaluating whether impacts calculated through the databases can be monetized.
- **Accessibility of databases:** Determining whether data can be easily retrieved, including any permission requirements or paywalls.
- **Transparency and documentation:** Availability of the documentation regarding data sources and methodologies.

A tabular overview of the generic databases and the evaluation criteria can be found in Appendix II. The findings are summarized below.

3.2.1 Capital categories and impact categories covered

Generic databases mostly cover natural capital and lack data on social and human capital. Natural capital is the most represented capital, with Agribalyse, Ecoinvent, Agri-footprint and FAOSTAT offering data on input/output, environmental impacts and resource use. Social capital is covered by the Social Hotspot Database (SHDB), Product Social Impact Life Cycle Assessment Database (PSILCA), International Labour Organization (ILO) and the Global Living Wage Coalition, focusing on labour conditions and wages. Human capital is the least covered, with only the Global Burden of Disease database providing health-related data.

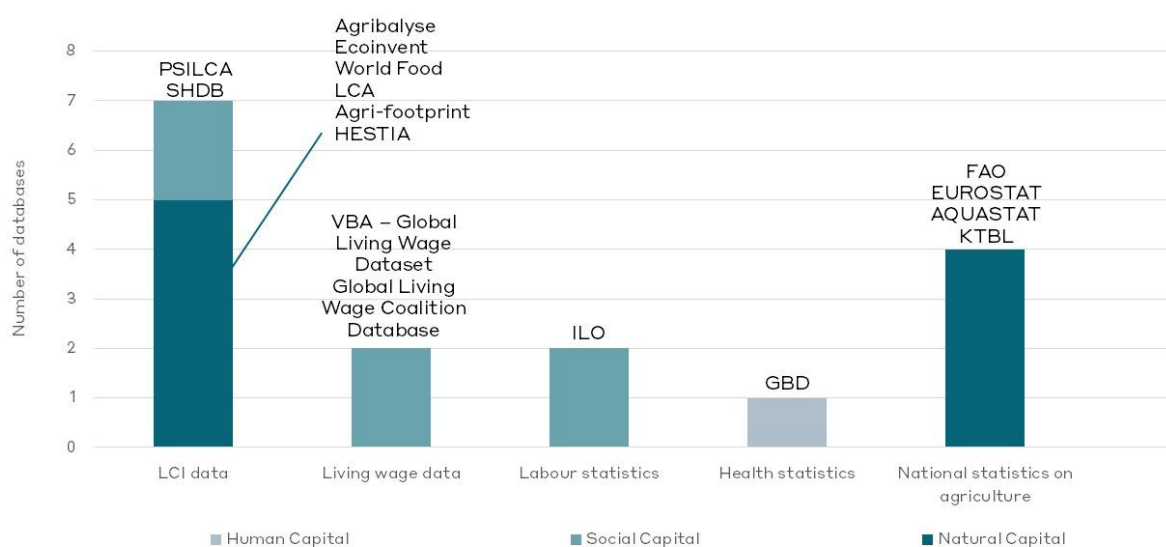


Figure 9. Distribution of data type and capital category across the assessed databases

Figure 9 illustrates the distribution of data type and capital category across the above-mentioned databases.

Figure 10 presents the number of databases that cover different impact categories under the four capital categories. The analysis shows that natural capital is the most covered, with impact indicators like climate change (19 databases), depletion of scarce resources (18) and pollution (17) appearing most frequently. Human capital impacts are less addressed, covering the most production-related health impacts and income/wages (11 each), but areas such as training and skill development (1) and health and well-being (2) are rarely included. Social capital coverage is also limited, with human rights violations and gender inequality appearing in six databases, while food security is not addressed at all. Produced capital is the least represented, with only financial performance (2) and infrastructure/equipment (1) showing minimal coverage.

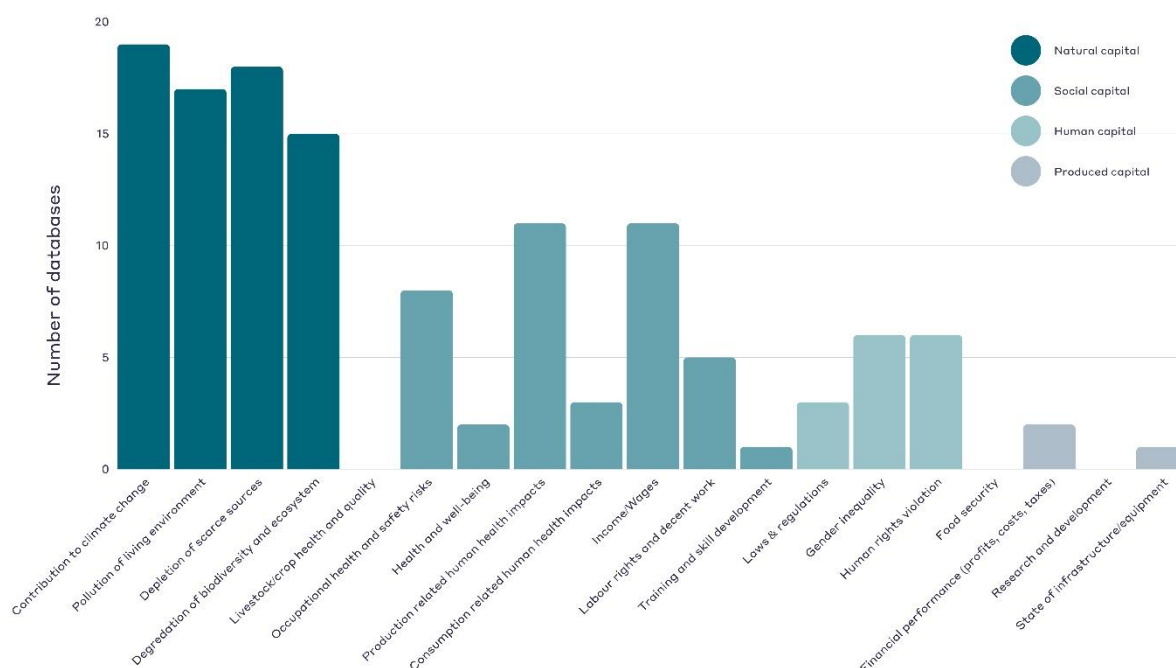


Figure 10. Overview of coverage of impact categories in 26 identified databases

3.2.2 Data categories

The availability of data relevant to TCA varies significantly across data categories. Production-related input data is generally well covered, particularly for natural capital. In contrast, management data is more

limited, with KTBL being the only known source in Germany, and access restricted by a paywall. Model data, such as that found in LCI databases, offers relatively high availability for natural capital, but data relevant to social capital is less common and lacks detail. Impact data is available for natural capital through several databases. Monetization data is available from a range of organizations for various capital categories and valuation approaches. Most databases provide monetization factors for natural capital, with more limited availability for social and human capital. Overall, data availability across data categories is strongest for natural capital and notably limited for other capital categories. No single database provides all the necessary data points for a complete TCA assessment. Multiple data sources must be combined to cover the necessary information.

3.2.3 Scope and coverage of databases

The data coverage of systems (e.g. product, business), production type (e.g. organic, conventional, agroforestry), the industry branch (e.g. plant, animal, aquaculture, fishery) and the supply chain stage (e.g. primary production, processing, consumption) differs widely across the various sources.

LCI databases such as Agribalyse, Agri-footprint and Ecoinvent are tailored to product-level assessment throughout an entire supply chain. They provide detailed process-specific input and output data for impact assessment to derive impact data (e.g. greenhouse gas emissions). These databases generally focus on conventional production systems, with limited coverage of organic systems, while agroforestry systems are generally underrepresented. They typically provide data for plant-based and livestock production. Assessment of fish and aquaculture products is possible but significantly more limited. SHDB and PSILCA also enable product-level and business-level assessments, offering input and output data across multiple sectors and covering the entire supply chain, although their data is designed for social risk assessment rather than quantifiable impacts.

Other databases containing input, output and management-level data, such as FAOSTAT and AQUASTAT, can be used to support product-level assessments and primarily cover farm-level activities, including country-level statistics on crop yields, livestock numbers, production areas and agricultural inputs for crop and livestock production. The KTBL-Datensammlung: Betriebsplanung Landwirtschaft provides detailed input, output and management data at the farm level but only applies to the primary production stage of the supply chain.

Health statistics from the Global Burden of Disease database do not focus specifically on agri-food systems but are relevant for assessing health impacts related to food consumption, occupational risks and exposure to pollution. It supports business- and product-level assessments at the production and post-production stages of the value chain and offers insights into various health conditions and health risk factors at global and national levels, which can be used to assess health impacts.

Although wage datasets and labour statistics (ILO) provide general data across various sectors and countries, they can support business-level assessments by offering insights into labour costs and working conditions.

Available impact data includes pre-calculated environmental impacts (e.g. greenhouse gas emissions) of food products and agricultural activities. The readily available Agribalyse dataset and Poore and Nemecek (2019) offer product-level impact data, which can be used as proxies for product-level TCA assessment. The extent of supply chain coverage varies between impact databases. For example, Poore and Nemecek's dataset includes impacts from primary production through processing, packaging, transport and retail, while Agribalyse provides farm-level impact data for raw materials and complete supply chain impact data for processed food products.

3.2.4 Coverage of negative and positive impacts

While generic databases adequately support the measurement of negative impacts—such as emissions, social risks and health burdens—they lack the necessary data to capture positive impacts.

3.2.5 Sector specificity of databases

Of 21 reviewed databases, 11 are specifically tailored to the agri-food sector, while the remaining databases cover multiple sectors, including data relevant to agri-food.

3.2.6 Geographical coverage

Most databases have global coverage, providing data that is to some extent representative for different countries and regions. One database, Agribalyse, is specifically developed for France but can be used as a proxy for other European countries due to similarities in production systems. The database from KTBL provides Germany-specific data at the management level. The geographical coverage of monetization factors varies, with some sources providing global averages while others offer country-specific data. The Environmental Agency of the German Government (Umweltbundesamt, UBA) provides monetization factors for environmental costs specific to Germany.

3.2.7 Monetization possibility

Monetization potential varies across databases, as not all data types can be directly converted into monetary values. LCI databases that provide input, output and management data can be used to calculate environmental impacts. These impacts can then be monetized using monetization factors available in the literature. Social data from the SHDB and PSILCA databases only offer risk assessments that are not monetizable due to limitations in the models and a lack of matching monetization factors for the risk scores. Wage data is already expressed in monetary terms and can be directly used. However, other input/output data from national statistics, such as FAOSTAT, cannot be directly monetized without further transformation to impacts.

3.2.8 Accessibility of databases

Accessibility of data sources varies, with some databases such as FAOSTAT, wage data and labour statistics being freely available, while others, like many LCI databases, are behind paywalls and require a subscription for access.

3.2.9 Transparency and documentation

Databases are generally highly transparent, often providing documentation on data sources and methodologies. Public databases such as FAOSTAT and the Global Burden of Disease database are typically well-documented and openly accessible. LCI databases also offer detailed methodological reports, but full access to their data and methodology may require a subscription.

3.3 Key gaps in generic databases

An analysis of available databases based on the above-mentioned criteria revealed several limitations. While these databases can be used for impact assessment, they vary significantly in terms of data scope, accessibility and applicability for TCA assessment. The main issues include:

- **Limited availability of representative generic data:** Although there is a growing body of data and methodologies concerning the environmental impacts of food production and consumption, data gaps in regard to representing different production modes (e.g. organic) and industry branches of the agri-food sector (e.g. fishery or aquaculture) remain.
- **Limited coverage of social and human impact data:** Most databases primarily focus on environmental impacts, with significantly fewer datasets available on social and human impacts such as labour conditions, contributions to the community and human health. Available social life cycle assessment (sLCA) databases lack details regarding agri-food sector impacts and can often only be used for identifying risks rather than measuring actual impacts.

- **Data fragmentation:** There is no single, comprehensive database that brings together the diverse data categories required for impact assessment for TCA. Instead, relevant data spanning environmental, social and human dimensions is spread across multiple sources and formats.
- **Lack of coverage of positive impacts:** Generic databases can only be used to estimate negative impacts. No database that covers positive externalities exists.
- **Lack of standardization:** Differences in methodologies and reporting formats are observed across databases, resulting in data incompatibility.
- **Restricted access and usability:** Some key databases require subscriptions or licensing fees, limiting accessibility.
- **Regional limitations:** While some databases provide global or European-level data, country-specific datasets, particularly for Germany, are often missing or incomplete.

The analysis highlights a substantial gap in the aggregation, availability and standardization of generic data for comprehensive TCA assessments, particularly regarding social and human capital. While environmental impact databases are well-developed, gaps remain regarding the integration and broader coverage of social and human aspects of sustainability, including representative data for Germany's agri-food sector.

4. Conclusion

Several approaches have been developed to integrate TCA into agri-food systems at both the business and product levels. While significant progress has been made in including natural capital, there are still gaps in integrating social, human and produced capital. The frameworks and guidelines analysed highlight the need for harmonization across methodologies to improve the comparability and consistency of impact assessments. The analysis shows that conducting TCA at both product and business levels requires substantial additional data collection efforts.

When relying on generic secondary databases, assessments are typically limited to certain production systems (mainly conventional) and specific industry branches, such as plant-based and livestock production constraining the applicability of TCA for various production and management practices. The data sources primarily support the assessment of natural capital, while data on social and human capital remains limited, and most monetization factors for the impacts on social and human capital are still underdeveloped. Additionally, many data sources and software tools are behind paywalls, making it difficult to fully assess their coverage across supply chains and industry branches. This analysis lays the foundation for the second Interim Report, which will provide a comprehensive SWOT analysis of implementing TCA within the agri-food sector in Germany. The forthcoming report will analyse the strengths and weaknesses of the TCA methodologies and databases and identify the opportunities and risks for its application at the company and product level.

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Appendices

Appendix I: Tabular overview of methods

A tabular overview of methods is provided in the Excel file titled 'Tabular Overview of Methodologies and Databases' under the tab 'Appendix I'.

Appendix II: Tabular overview of databases

A tabular overview of databases is provided in the Excel file titled 'Tabular Overview of Methodologies and Databases' under the tab 'Appendix II'.

Appendix III: Reviewed sources for TCA methodology analysis

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