AGRI-FOOD SECTOR GUIDANCE ON APPLYING THE NATURAL CAPITAL MANAGEMENT ACCOUNTING METHODOLOGY

NCMA Agri-food sector guidance

July 2023

About this document

This document was developed through the EU LIFE program by the Transparent Project.

The document is a work in progress. Detailed feedback from a number of experts has already helped to steer its development. Input from a consultation as well as a piloting process contributed to the presented standardized approach and this documentation.

Disclaimer

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About

The Value Balancing Alliance is a non-profit alliance of more than 25 multinational companies who share a common goal: to develop a standardized methodology of impact measurement and valuation for monetizing and disclosing positive and negative impacts of corporate activity. The objective of such a methodology is to provide guidance on how impacts can be integrated into business decision making to support greater sustainability and transparency in business. Member companies pilot the methodology to ensure feasibility, robustness, and relevance. The Alliance is supported by the four largest professional service networks – Deloitte, EY, KPMG, and PwC – and works in close collaboration with the International Foundation for Valuing Impacts (IFVI).

The Capitals Coalition is a global collaboration redefining value to transform decision making. It sits at the heart of an extensive global network which has united to advance the capitals approach to decision-making. The ambition of the Coalition is that by 2030 the majority of businesses, financial institutions and governments will include the value of natural capital, social capital and human capital in their decision making and that this will deliver a fairer, just and more sustainable world.

The World Business Council for Sustainable Development is the premier global, CEO-led community of over 200 of the world's leading sustainable businesses working collectively to accelerate the system transformations needed for a net-zero, nature-positive, and more equitable future. Since 1995, WBCSD has been uniquely positioned to work with member companies along and across value chains to deliver impactful business solutions to the most challenging sustainability issues.

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LIST OF ACRONYMS

CC – Capitals Coalition

CO_2 – carbon dioxide

EEIO – Environmentally extended input-output model

EEA - European Environment Agency

EMEP – European Monitoring and Evaluation Programme

ENCORE – Exploring Natural Capital Opportunities, Risks and Exposure

EP&L – Environmental Profit and Loss Account

GHG – greenhouse gas

GRI – Global Reporting Initiative

HDPE – high-density polyethylene

IFAC – International Federation of Accountants

IO – input-output model

IPCC – Intergovernmental Panel on Climate Change

ISO – International Organization for Standardization

LCA – life cycle assessment

LCI – life cycle inventory

LCIA – life cycle impact assessment

LDPE – low-density polyethylene

LUC – land-use change

MEA – Millennium Ecosystem Assessment

NCMA – Natural Capital Management Accounting

NOx – nitrogen oxides

OECD – Organization for Economic Cooperation and Development

OEF – Organization Environmental Footprint

PEF – Product Environmental Footprint

PET – polyethylene terephthalate

P&L – profit and loss

SASB – Sustainability Accounting Standards Board

SEEA – System of Environmental Accounting

TEEB – The Economics of Ecosystems and Biodiversity

UNEP – United Nations Environment Programme

USEtox – Characterization factors for human toxicity and freshwater ecotoxicity, based on modeling of environmental fate, exposure, and effect parameters for the substances.

VBA – Value Balancing Alliance

VOC – volatile organic compounds

WBCSD – World Business Council for Sustainable Development

WHO – World Health Organization

1. BACKGROUND

1.1. About Transparent

In line with the ambition of the European Green Deal, Transparent is a public-private partnership to develop standardized natural capital accounting and valuation principles as a means of mobilizing the private sector in support of the green transition. In particular, the Transparent Project supports the call by the European Commission to support businesses and their stakeholders in their efforts to standardize natural capital accounting in the EU and globally.

The partners of the Transparent Project include the Value Balancing Alliance (VBA), the Capitals Coalition (CC), and the World Business Council for Sustainable Development (WBCSD).

Transparent partners successfully tendered for the EC grant for preparatory policy actions funded through the EU LIFE program. To promote the uptake of corporate natural capital accounting (and the insights such accounting brings to decision makers at the executive level), the tender called for the development of a standardized natural capital management accounting methodology that would result in the successful development of Environmental Profit and Loss Accounts that had been successfully developed by several companies. The expectation was that the methodology should cover both impacts and dependencies and should be suitable for integration in corporate strategic decision-making processes rather than focused on external reporting covered by other EU and global initiatives.

As part of the Transparent Project, this sector guidance document provides an overview and additional resources in support of the steps needed for the application of natural capital management accounting that are specific to the agri-food sector. Additional documents provide a standardized methodology for natural capital management accounting (the NCMA methodology), and the NCMA general guidance to support implementation of the methodology.

1.2. About Natural Capital Management Accounting

Natural capital is the stock of renewable and non-renewable natural resources, both biotic and abiotic (e.g., plants, animals, air, water, soils, minerals), that combine to yield a flow of benefits to people. This corresponds to "environmental assets" in the System of Environmental-Economic Accounting (SEEA) framework, which takes a (macro)economic perspective based on national accounts [1]. Changes to natural capital may affect the extent and condition of natural resources as well as the ecosystem services that natural capital provides. For the purposes of understanding, measuring, and valuing the impact of business activities on nature, the NCMA methodology and system of accounting does not attempt to estimate the overall state of natural capital. The focus is on the change in the flow of ecosystem services from one period to the next that affects society. It is only at a national accounts level and in assessing performance against the Sustainable Development Goals that it becomes meaningful and appropriate to consider the "macro" or total impact of human activities on nature.

Natural capital accounting is the compilation of consistent and comparable data on natural capital and the flow of services generated, using an accounting approach to show the contribution of the environment to the economy or business and the impact of the economy or business on the environment [2].

Natural capital management accounting refers to an internal management information system that combines data in support of corporate decision making. Unlike in statutory accounts, the form and content of management accounts are not determined by regulations and/or related to generally accepted accounting principles that are concerned with properly informing external stakeholders about the (financial) position and performance of an entity. Instead, the quality of natural capital management accounting is ensured by applying best practice developed by the business community, and guided by academia and professional organizations such as IFAC, ICOS, and others.

Environmental profit & loss (EP&L) accounting The concept of a "profit and loss" (P&L) is a common business formulation to assess performance. In accounting terms, it is the difference between revenue generated by a business and the related costs incurred. It represents the change in the stock of financial capital for a business resulting from its operations. The calculation of P&L is based on transactions between market actors such as customers and suppliers. It ignores unpriced "transactions" with the environment which include impacts on natural capital. An EP&L is a means of extending the profit calculation to include both monetary value and the price of environmental impacts of business activities. An EP&L can be presented in different ways to help management understand and respond to the total impact of business activities. Some entities now publish such impact statements in various formats to help their stakeholders understand how the business's activities impact nature or lead to other externalities. In profit and loss calculation, caution needs to be taken when offsetting or netting amounts with different characteristics, to address concerns around additivity. For this reason, it is important to display gross amounts and not merely compute a net amount of externalities and other impacts.

Impacts and dependencies, for the purposes of this methodology, refer to relationships a business and its activities have with natural capital. An impact includes externalities or other unpriced effects of business activities on natural capital that result in the consumption or restoration of services provided by natural capital. Impacts are referred to as affecting the "value to society" that results from business activities. Looked at through this lens, business activities have brought about significant improvements in human well-being but often to the detriment of nature and both elements are relevant to understanding the overall performance of a business.

Dependencies refer to the set of relationships that describe the ways a business relies on nature and natural resources to create value. In market economies this "value to business" should be reflected in a business's overall market value (or enterprise value). The concepts of "value to society" and "value to business" are inextricably linked as one cannot exist without the other. Business models employed by business rely on natural, human, and social capital to generate wealth. Beyond market transactions and regulation of economic activity, these dependencies to extract value from the services provided by nature have largely been unaccounted for and taken for granted. It has been assumed that the problem of scarcity can be overcome through globalization and through shifting to new or different locations and methods to extract value from nature. The collapse of biodiversity requires a radical rethinking of the way in which the services provided by nature can continue to generate "value for business" while also safeguarding the possibility of a sustainable future.

2. INTRODUCTION

In addition to the NCMA general guidance document, the Transparent Project is developing sector-specific guidance documents based on the experience of piloting companies. Sector-specific guidance is currently available for the following sectors:

- Agri-food
- Apparel
- Chemicals

The NCMA general and sector-specific guidance documents set out the steps and actions to apply the methodology to measure and value business impacts on society.[1]

2.1. About the agri-food sector guidance

The agri-food sector guidance is intended to complement the NCMA methodology by providing additional detail and resources relative to the agri-food sector and illustrating the outcome of the methodology's use when applied in that sector. The guidance provides industry-specific considerations on:

- Objective of measuring and valuing impact
- Scoping and materiality
- Data availability
- Measuring and valuing impact drivers in monetary values

The guidance provides an example based on the agri-food sector to assist in understanding the impact of sector-relevant business activities across the value chain. In applying the methodology, further breakdowns, changes, and specifications are needed to best reflect agri-food sector business models.

2.2. About the intended users

Similar to the NCMA methodology, this guidance document is primarily intended for those responsible for preparing management information to support internal decision making at the corporate level (see NCMA methodology).

2.3. General management accounting principles

The NCMA methodology is based on general management accounting principles such as relevance, rigor, and replicability (see NCMA methodology). When applying the methodology, we advise following these principles to ensure that the methodology is applied in a sensible manner.

2.4. Basic impact management accounting concepts

Please refer to the NCMA methodology for further details on terminology such as "impact," "impact driver," "impact pathway," and "valuation techniques."

[1] The NCMA methodology is to be used in combination with regulatory sustainability requirements and disclosures to improve business decision making and strategy setting. The methodology is not intended to replace regulatory sustainability requirements and disclosures. At the time of developing this document, there is no legal obligation to disclose the results of natural capital accounting focusing on impact measurement and valuation publicly and it is left to the user of this document to make the decision of publicly sharing the results.

3. OBJECTIVE AND SCOPE

The focus of this section is to outline the steps and actions you will need to take to establish a set of corporate Environmental Profit & Loss accounts based on standardized NCMA methods and guidance developed under the Transparent Project. This section helps you to consider the intended use of your results to guide you in selecting and applying methods most appropriately. It is critical at this stage to make explicit the objective, scope, and assumptions that underpin your measurement and valuation of natural capital (see Figure 1).

Figure 1. Questions on the objective and scope of your accounting

What? to consider for natural capital accounting	**Objective** - What is the purpose?
	Scope - What should be the boundaries?
	Materiality - What are the minimum impact drivers that should be considered during the materiality analysis?

To set up your natural capital accounting we recommend the following phases:

- Define objective and scope
- Engage and train
- Measure and value
- Interpret and test the results
- Take action

For more details, see the NCMA general guidance.

3.1. Objective

While the main objective of the NCMA methodology is to develop an EP&L, you may also choose to apply the NCMA methodology to achieve a specific goal. It is essential to develop and clearly define the objective(s)/goal(s) of your natural capital accounting; for more details and examples, see the NCMA general guidance.

3.2. Scope

Defining the objective(s) of your natural capital accounting facilitates the process of defining/selecting the scope of your application. The focus of this guidance is on the selecting the scope with respect to the value chain boundaries and the impact drivers. For all other aspects to be considered, see the NCMA general guidance.

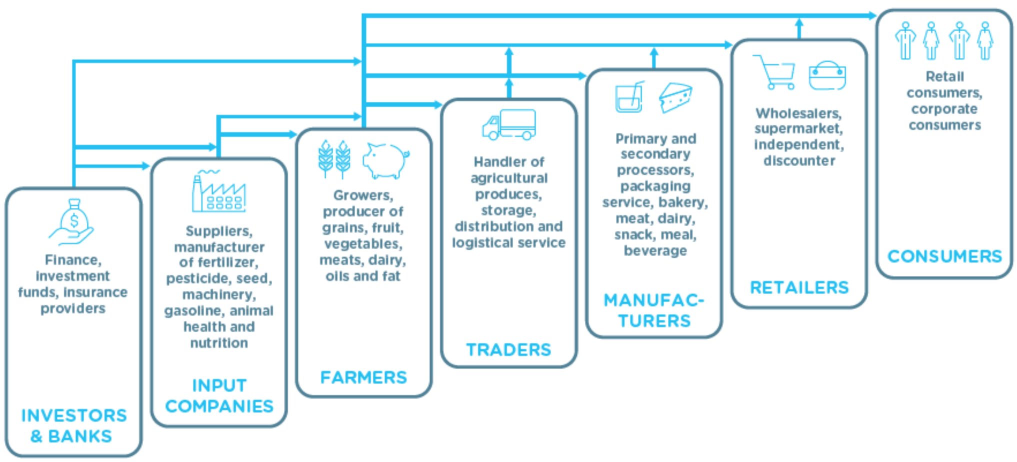
3.2.1. Value-chain boundaries

Setting the scope of your natural capital accounting should be done based on the definition of value chains in the context of the food and agriculture sector. A typical value chain diagram is presented to support practitioners in the definition of natural capital accounting scopes (see Figure 2).

The start of the value chain centers around the farm where food is produced and agricultural activities are carried out. The transportation of commodities and their processing are usually performed by traders, consumer goods companies, and other intermediaries. Retailers are the intermediaries between consumer goods companies and customers buying the food, that operate, for example, supermarkets. Finally, the products are consumed, and packaging/food waste is disposed. The type of waste management depends on the country of consumption.

For the purpose of this guidance, the focus is on the farm level, which often represents the main interest of agri-food companies and the most material stage.

Figure 2. Typical agri-food value chain [3, p.7]



3.2.2. Impact drivers

For first-time preparers, we recommend carrying out your natural capital accounting on all six impact drivers within the scope of the methodology (see NCMA general guidance for more details).

Material impacts should be included as defined by relevant frameworks, standard setters, and initiatives. Analyzed here are key literature and resources to develop a high-level overview of materiality in food and agriculture value chains, which can support you to refine the scope of your accounting.

Material impacts in agri-food value chains have already been assessed in several natural capital and true cost accounting frameworks [3] [4] [5] [6] [7] albeit using different system boundaries. Some of these consider complete value chains (seedling production, inputs, farming activities, processing, retail, consumption activities, and end of life) while others focus on specific stages (upstream and on-farm).

To help practitioners identify materiality for agri-food value chains, an analysis was conducted based on the cited natural capital and true cost accounting frameworks. In this analysis, a relative weight was assigned to each impact driver dependent on:

a) Impact drivers listed as more relevant in the reviewed documents
b) Sufficient evidence (quantification) of impacts compared to other impact drivers
c) The authors' expert judgment based on agri-food practical experience. Three levels of importance were assigned to each impact driver according to the following criteria:

Score	Description
High	Impacts are significant, quantified as potentially more than 20% of the whole value chain.
Medium	Impacts represent less than 20% but more than 5% of the complete value chain.
Low	Impacts do not contribute more than 5% to the complete value chain, or were not included in assessment frameworks due to proven irrelevance.

Table 1 shows a materiality assessment in a typical agri-food value chain. Although some value chains might have differences, material impact drivers are found in upstream activities and during farm-activities. The analysis found that the following value-chain stages are indicative of material drivers:

- **Upstream activities:** Practitioners should consider resource use and inputs to manufacturing as material drivers (e.g., fertilizer and pesticide production, animal feed production, plastic production, land preparation and land clearing (land-use change)). Synthetic fertilizer and pesticide manufacturing are significant sources of GHG emissions. In China, the largest fertilizer consumer in the world, fertilizer manufacturing accounts for approximately 4.3% of total GHG emissions [8]. Water pollution and water consumption are material for upstream activities as well. For example, in crop commodities, such as maize, rice, soybean, and wheat, water pollution and consumption can represent 10% to 20% of environmental impacts [4]. Upstream land-use change can represent up to 20% of total natural capital upstream in cattle production and 10% of total natural capital impacts in crop commodities [4].

- **On-farm activities:** On-farm activities are highly material, causing most of the environmental impacts of food and agriculture value chains. Land use for animal and crop production reduces land availability for natural processes. Water consumption for irrigation creates water scarcity issues (70-80% of the water used in the world is for irrigation purposes). GHG emissions from fertilizer application (called direct field emissions) and other energy-intensive activities for farm operation create climate change impacts. These issues are well documented in the literature [4] [9].

- **Food processing:** Impact drivers for food processing will vary according to the level of processing, the location, and the type of product. Energy, water consumption, and pollution are the main impact drivers linked to food processing. Despite being less material in general compared to upstream activities, processing activities are typically included in the scope of natural capital accounting, since companies typically have more control over these activities.

- **Downstream activities:** Downstream impacts need to be addressed on a case-by-case basis. There may be significant impacts in the downstream value-chain level when, for instance, freight is required over long distances or via air, or when the weight of packaging is significant compared to the weight of the product. Emissions can also occur during end-of-life of some products, in particular related to packaging waste.

Table 1. Materiality assessment in agri-food value chains from upstream activities (on the left) to downstream activities (on the right) (cradle-to-grave)

Impact driver	Input manufacturing	On-farm activities	Food processing	Packaging	Logistics	Retail	Consumption	End-of-life
GHG emissions	High	High	Medium	Medium	High	Low	Low	High
Non-GHG air emissions	Medium	High	Low	Low	High	Low	Low	Medium
Water consumption	Medium	High	Medium	Low	Low	Low	Medium	Low
Water pollution	High	High	Medium	Low	Low	Low	Low	Low
Land use	High	High	Low	Low	Low	Low	Low	Low
Solid waste	Low	Medium	Medium	Low	Low	Low	Low	High

Table 2 presents a materiality assessment at farm level as this value-chain step represents the most material within agriculture and food value chains and is the focus of this document. These activities are representative of a typical farm, and will vary by farm according to its size, location, crops produced, practices, etc.

Table 2. Materiality assessment for on-farm activities (crop production)

Impact driver	Land-use change	Soil management	Fertilizer application	Pest control	Irrigation	Transportation	Farm machinery	Waste management
GHG emissions	High	High	High	Low	High	Medium	High	Low
Non-GHG air emissions	Medium	Medium	High	Low	High	Medium	High	Low
Water consumption	Low	Low	Low	Low	High	Low	Low	Low
Water pollution	Low	Low	High	High	High	Low	Low	Low
Land use	High	High	Low	High	Low	Low	Low	Low
Solid waste	Low	Low	Low	Low	Low	Low	Low	Medium

Table 3 provides further detail for activities ranked as "high," which represent on-farm activities that typically lead to the most material impact drivers.

Table 3. Summary of material on-farm activities and their connection to impact drivers

Activity	Impact driver
Soil management	Agriculture practices that aim to prepare the soil for crop cultivation can either increase soil organic carbon or release carbon into the atmosphere. GHG emissions from soil management practices are described in the GHG emission section of the NCMA agri-food sector guidance, and the NCMA general guidance.
Fertilizer application	Fertilizer application generates GHG emissions like nitrous oxides and eutrophication impacts from nitrogen and phosphorus pollution.
Pest control	Application of pest control agents is the leading cause of water and land pollution on farms. These chemicals can negatively affect the environment through different impact pathways and lead to biodiversity loss or ecosystem damage, including human health impacts.
Irrigation	Irrigation is one of the most significant impact drivers during farm operations. Irrigation requires a substantial amount of energy which can be supplied either through electricity or from fuel-based motor pumps. It's also the leading cause of water consumption and water pollution (from nutrient and pesticide runoff and leaching to surface and groundwater resources). Although not all crops are irrigated, most of the water used globally is used for irrigation purposes.
Farm machinery	All activities related to mechanized on-farm operations, such as field cultivation, water pumping, irrigation and sprinkler systems, sprayers, balers, ploughing, spreaders, harvesters, cooling, and processing equipment required for animal farms (milk extraction, meat production, etc.) require energy and generate emissions from electricity consumption or fuel use.
Waste management	Impact drivers vary according to farm waste management practices, location, and type of waste. Packaging, plastic mulch, and disposal of chemicals (such as pesticide containers, etc.) sometimes lead to relevant impacts.

Other on-farm activities like animal husbandry, enteric fermentation emissions, and composting or manure management release GHGs and methane into the atmosphere, which contributes to climate change. Other impacts may arise depending on farm management practices. These can be added as potentially material activities for animal production.

4. MEASURE AND VALUE

To measure and value the impacts of business activities in the agri-food value chain, this document provides additional guidance for:

- Data collection needs
- Measuring the physical quantities for each impact driver
- Valuing your measured impacts in monetary terms

The following section provides support in applying the NCMA methodology (see Figure 3).

Figure 3. Questions on the measure and value step of your accounting

How ? to make an informed decision	**Data Collection -** How to gather data for impact drivers?
	Measurement - How to measure impact drivers?
	Valuation - How to value impacts in monetary units?

4.1. Principal accounting modules

4.1.1. Measure your impact driver

To measure the physical quantities of the impact drivers considered in scope, you will use primary data, secondary data, or a combination of both. For more details on typical data sources and additional detail, see the NCMA general guidance.

In addition to the sources listed in the NCMA general guidance, the following data sources are available for the agri-food sector.

Primary data

You may collect primary data on, for example, on-farm activities, packaging, processing, and transportation to clients or storage facilities. A preliminary list of primary data points for the agri-food sector that you can collect in excel-based inventories (such as quantities, volumes, or mass) is provided in Table 4. For a comprehensive list of primary data points, please review the following standards:

- GHG Protocol and the GHG Protocol agricultural guidance [10].
- Capitals Coalition (2020) TEEB for Agriculture and Food: Operational Guidelines for Business Launch [3]

Table 4. Data collection points for agri-food value chains, considering core operations. Based on the GHG Protocol agricultural guidance [10].

Data collection point	Stakeholder responsible	Data sources and modeling approaches
Production volume Crop production volume, product volume, wood harvested	Business owner Administration Agricultural manager	Accounting department
Resource consumption Electricity use, irrigation water consumption, fertilizer and pesticide use, fuel consumption, machinery operation (to model resource consumption), packaging material used (cardboard, PET, LDPE, HDPE)	Business owner Administration Agricultural manager	Accounting department
Enteric fermentation Livestock numbers and age, length of juvenile and adult production, number of livestock managed offsite, sale and purchase of animals, dry matter intake per hectare, type and amount of feed additives	Business owner Administration Agricultural manager	Field measurements
Land management practices Application of synthetic fertilizer and pesticide (kg/ha), application method, land types (ha) and species concerned, tillage practices, soil organic matter content, land-use changes, acres burnt	Agricultural manager	Field measurements
Refrigeration Quantities of product refrigerated, refrigerant fugitive emissions, types of refrigerants used	Agricultural manager	Modelling based on emission factors
Fuel emissions GHG emissions	LCA or GHG consultant	Modelling based on emission factors
Agricultural emissions GHG emissions, N and P released to water	LCA or GHG consultant	Modelling based on emission factors, empirical models, or process-oriented models

Secondary data

In the agricultural sector, many EEIO tables aggregate at a high level and have few sub-sectors such as grains and animals. Be aware of these aggregations when using EEIO for your assessment.

Table 5 summarizes potential data sources based on LCA that reflect agri-food value chains. The listed databases were selected based on comprehensiveness, transparency, and geographic coverage and accessibility. All listed sources can provide useful information (list is not exhaustive).

Table 5. LCA data sources for agri-food value chains

Database	Developer	Processes covered	Comprehen-siveness	Transparency	Geographic coverage	Open source/ licensed
AGRIBALYSE® [11]	ADEME	2,500	Agriculture, food processing, and consumption	Complete transparency	France	Free
Agri-footprint [12]	Blonk consultants	4,000	Feed, food, biomass, agricultural commodities	Complete transparency	Global	Licensed
ecoinvent [13]	ecoinvent	18,000	Agriculture, fisheries, and animal husbandry, forestry and wood	Complete transparency	Global	Open source/ Licensed
ESU World Food LCA Database [14]	ESU Services	2,100	Agriculture, food, processing and consumption activities	No documentation available	Switzerland	Licensed
World Food LCA Database [15]	Quantis	2,300	Agriculture	Complete transparency	Global	Licensed

Note: "Complete transparency" means that full methodological documentation is freely available online.

In practice, ecoinvent [13] and the World Food LCA Database [15] (which is now embedded in ecoinvent) are commonly used for assessing the impact of agriculture and food value chains in the private sector.

Table 6 lists several tools that can be used to support your impact driver measurement. These range from open-source tools to online web applications. Some are free while others require a license. The use of these tools is highly specific to your needs (list is not exhaustive).

Table 6. Tools and online resources for agri-food value chains

Tool	Type	Developer	Needs answered	Impact drivers covered that are linked to the NCMA methodology	Geography	Paid or free	Link
Aqueduct Food	Web app	World Resources Institute	Identify current and future water risks to agriculture and food security	Baseline water stress per crop type and other water related indicators relevant for agri-food sector	Global	Free	https://www.wri.org/aqueduct
Cool Farm tool	Web app	Cool Farm Alliance	Model the GHGs of specific crops based on primary data from farms	GHG emissions, water consumption	Global	Free & paid	https://coolfarmtool.org/
FAOstat	Statistical data	FAO	Average national data for crop production, including volumes, yield, inputs, and land-use change	Production and consumption of agricultural commodities, land use, 12fertilizer and pesticide inputs, other sustainability indicators per crop and geographies	Global	Free	https://www.fao.org/faostat
LUC Impact tool	Excel-based tool	Blonk Sustainability	Model GHG emissions from LUC for crops at country level (macro model)	Provides a predefined way of calculating GHG emissions from land-use change at national level (macro level). Does not precisely calculate deforestation linked to a crop, but allocates it based on a macro-level model	Global	Paid	https://blonksustainability.nl/tools/LUC-impact
Water Footprint Assessment Tool	Web app	Water Footprint Network	Water footprint per crop type	Annual country and basin data for blue, grey, and green water footprints per crop and commodity, with global coverage	Under development	Free	https://www.waterfootprintassessmenttool.org/

Allocation (attribution) of impact drivers to business activities

In some cases, farms can have multiple products in the same system. For example, cattle farming can provide meat, milk, and leather, known as coproducts. Allocation is the process of distributing impacts amongst all coproducts using, for example, physical unit or economic criteria (see NCMA general guidance).

A good example to understand allocation in the agri-food sector is sugar and ethanol production in Brazil. Sugarcane mills have multiple output products. In addition to sugar, they can produce ethanol, and thermal and electrical energy, just to mention some of the most important co-products. In Brazil, several sugar mills have recently converted their sugar output from a staple good to an input for ethanol production, which is mainly driven by high demand for biofuel. As production is mostly driven by economic profitability, economic allocation is the more appropriate approach.

As an example, consider the sugarcane production with ethanol byproduct in Brazil based on the dataset provided by ecoinvent [13]. The average sugarcane farm produces around 80-85% sugar and 15-20% ethanol. The commodity price for sugar in 2018 was 436 euro per ton while the price for ethanol was 324 euro per ton. In 2021 the price for ethanol in Brazil reached 436 euro per ton. These values can be used to estimate the economic allocation factors in 2018, which are:

$$\text{For sugar: } €\,436/€\,760 = 57\%$$

$$\text{For ethanol: } €\,324/€\,760 = 43\%$$

In 2021, the economic allocation could reach up to 50% for each commodity.

4.1.2. Measure changes in the state of natural capital

Your quantified impact drivers will lead to changes in natural capital (air, water, land, and biodiversity) that will eventually impact society. For guidance, please see the NCMA general guidance.

4.1.3. Value impacts on society

After measuring your impact drivers, you will calculate the monetary values of your impacts by multiplying the measured physical quantities (e.g., tons of CO_2) by a value factor (e.g., \$/ton CO_2), which reflects the societal impact due to a change in natural capital and its ecosystem services as modeled in impact pathways. For guidance, please see the NCMA general guidance.

In the agri-food sector there are several valuation frameworks that have been published in addition to the ones listed in the general guide (e.g., [6], [7], [16]). Valuation factors have also been reviewed for Life Cycle Impact Assessment methods (e.g., [17], [18]). There is also the ISO standard monetary valuation framework (ISO 14008:2019 – Monetary valuation of environmental impacts and related environmental aspects [19]). Moreover, the Environmental Prices Handbook by CE Delft [20] provides monetary valuation factors per kg of substance released into the environment that can be applied in the case of agricultural crops or animal production. For water pollution, the value factors provided are aligned with the ReCiPe midpoint[2] [21] impact categories for marine and freshwater eutrophication and ecotoxicity.

[2] In life cycle analyses, the term "midpoint" refers to a location on the impact pathway that is an intermediate between the LCI results and the ultimate environmental damage ("endpoints"). Midpoint impact categories are based on indicators that focus on single changes in natural capital, for example climate change or acidification. [75]

4.2. Specific accounting modules by impact driver

This section provides key considerations to take into account when measuring impacts for each impact driver and its related impact pathway when undertaking natural capital accounting using the NCMA methodology.

4.2.1. Greenhouse gas (GHG) emissions

GHG emissions are found across the agri-food value chain. In the upstream value chain, GHG emissions are for example produced from land-use change, pesticide and fertilizer manufacturing, fuel production, and animal feed production. During on-farm activities fertilizer application generates nitrous oxide emissions, animal husbandry creates enteric fermentation (methane) emissions, and other activities like land preparation release carbon into the atmosphere. Overall, agricultural activities are responsible for approximately 20 - 30% of global GHG emissions and are the leading cause of transformation of the world's tropical forests [9].

Table 7 provides a list of important activities in the agri-food sector related to GHG emissions and key methods to measure the impact drivers (list is non-exhaustive).

Table 7. Overview of GHG emission-related activities and key methods to measure impact drivers

Specific activities to consider for GHG emissions	Key methods and data relevant for measuring impact drivers
Upstream production and extraction of inputs and fuels	Secondary data sources: - Life cycle assessment methods and datasets (e.g., ecoinvent 3.8 [13], World Food LCA Database [15]) - Environmental Multi-Regional Input-output models (e.g., Exiobase 3.0 [22], EORA [23])
Land use (release of soil organic carbon) and land-use change (caused by the conversion of native habitats to farmland)	Direct and indirect land use and land-use change emission factors: IPCC 2021 AR6 [24], IPCC 2006 [25] and IPCC 2019 [26], Cool Farm tool [27], Blonk LUC Impact tool [28].
On-farm field emissions from synthetic and organic fertilizer application	Fertilizer emission factors: IPCC 2021 AR6 [24], IPCC 2019 [26], and IPCC 2006 [25], [29], FAO website [30], LCA datasets, secondary data sources
Fossil fuel combustion from mobile and stationary sources	Fuel emission factors: IPCC 2021 AR6 [24]
Enteric fermentation (from animal production)[3]	Enteric fermentation from animal production: IPCC 2021 AR6 [24], IPCC 2019 [26] and IPCC 2006 [25]

[3] Cattle production is one of the main contributors of methane emissions deriving from enteric fermentation. It is estimated that 50% of agricultural emissions are driven by cattle farming [71]. On average, meat from livestock is far more resource intensive than other commonly consumed foods. Beef requires 20 times more land and produces ten times more GHGs per gram of edible protein than chicken. In comparison to plant-based proteins, beef is 20 times more resource intensive [72].

4.2.2. Non-GHG air emissions

Particulate matter and other non-GHG air polluting substances are generated during on-farm operations and processing. Sources of particulate matter pollution include field or orchard operations, unpaved roads, farm equipment exhaust, agricultural burning, processing facilities, pesticide application, livestock, transportation of products, and dust from land management practices. Other sources of particulates like grain dust that is created during harvesting, drying, or grain handling can carry bacteria and fungi that can be a threat to human health. Nitrogen and sulphur oxides as well as VOCs are produced during transportation and in the use of organic solvents.

Table 8 provides a list of activities in the agri-food sector related to non-GHG air emissions and key methods to measure the impact drivers (list is non-exhaustive).

Table 8. Overview of non-GHG air emission-related activities and key methods to measure impact drivers

Specific activities to consider for non-GHG air emissions	**Key methods and data relevant to measure impact drivers**
PM formation: Land preparation, field operations, agricultural burning, transportation	Primary or secondary data sources from LCA datasets (e.g., ecoinvent 3.8 [13]) to estimate the amount of particulate matter ($PM_{2.5}$ and PM_{10}) in kg emitted to air.
NO_x, SO_x, NMVOCs: Agricultural burning, soil nitrification and denitrification reactions, field equipment like tractors and harvestors, transportation	Primary or secondary data sources from LCA datasets (e.g., ecoinvent 3.8 [13]) or emission factor databases to estimate the amount of NO_x, SO_x, and NMVOCs emitted to air.
NH_3: Manure management	NH_3 from animal husbandry produces N deposition that can be quantified using NH_3 emission models (EMEP/EEA) or Hortifootprint [31]
NO_x, PM_{10}, ammonia, NO_x: Pesticide emissions to air	Depending on the type of chemical, toxic substances from pesticides can be emitted to air. These can be measured using PEF/OEF guidance and other emission factors from secondary data sources.[4]

[4] To estimate changes in natural capital, the USEtox 2.12 [36] model provides and impact quantification model for ecosystems and human health.

Box 1. Reflections on direct field emissions

Application of synthetic and organic fertilizers produces ammonia (NH_3) and nitrous oxide (N_2O), whereas urea application emits CO_2. Direct field measurements are difficult to obtain and therefore emission models are commonly used to estimate emissions indirectly. One of the major shortcomings associated with the use of these models is their specificity for Europe, therefore relevant adjustments must be applied when utilized for different geographies. Ammonia and nitrous oxide emission models are described for the ecoinvent [32] and World Food LCA database [29]. For tropical regions, nitrous oxide emission models have been reviewed [33]. Globally, the IPCC (2006) [34] method provides generic emission factors for livestock and manure management, as well as for fertilizer application.

The use of pesticides in the agri-food sector can lead to material impacts. Thus, it might be important to include impacts due to emissions from pesticides as an additional impact pathway. Emissions from pesticide application are difficult to model because they depend on several factors like the chemical nature of the pesticide, the application method, the binding agent, geographic location, soil properties, and climate variables. The PEF/OEF guidance, currently among the leading LCA guidance in Europe and the world, suggests assigning default emission shares as much as 90% emitted to agricultural soil compartment, 9% to air and 1% to water [35]. The toxicity impact on human health and biodiversity (freshwater in particular) of these emissions can be easily modelled using the USEtox model [36], recommended by the PEF/OEF, which provides impact factors for more than 10,000 different substances.

4.2.3. Water consumption

Water is a critical resource for agriculture. Currently, agriculture accounts for 72% of all fresh water withdrawals worldwide and an even higher share of consumptive water use due to crop evapotranspiration [37]. Irrigated crops are twice as productive as rainfed agriculture per unit of land. Moreover, increasing crop production to feed a growing population and competition with urbanization and industrialization will increase water demand in the future. Water scarcity is one of the main problems in watersheds with intensely irrigated agriculture and densely populated cities that compete for water. Most of the basins affected by high or critical water stress levels are in Northern Africa, North America, Central and South Asia, and the west coast of Latin America [37]. Groundwater depletion for irrigated agriculture accounts for over 30% of agriculture's fresh water withdrawal and continues to grow at around 2.2% per year [37].

Table 9 provides a list of important activities in the agri-food sector related to water consumption and key methods to measure the impact drivers (list is non-exhaustive).

Table 9. Overview of water consumption-related activities and key methods to measure impact drivers

Specific activities to consider for water consumption	Key methods and data relevant to measure impact drivers
Crop irrigation	Quantification of water consumption through water inventories using approaches from Water Footprint Network [38] or ISO 14046 standards [39] for water footprints. Secondary data sources (e.g., ecoinvent 3.8 [13], World Food LCA Database [15], AGRIBALYSE® [11] and Environmental Multi-Regional Input-output models such as Exiobase 3.0 [22] and EORA [23]).
Upstream water consumption	Secondary data sources (e.g., ecoinvent 3.8 [13], World Food LCA Database [34], AGRIBALYSE® [11]and Environmental Multi-Regional Input-output models such as Exoibase 3.0 [22] and EORA [23]).
Process water	Quantification of water consumption through water inventories using approaches from Water Footprint Network [38] or ISO 14046 standards [39] for water footprints. SASB standards Secondary data sources (e.g., ecoinvent 3.8 [13], World Food LCA Database [34], and AGRIBALYSE® [11]).

4.2.4. Water pollution

The use of fertilizers and pesticides to grow crops and waste effluents (from animal production for example) represent some of the biggest impact drivers of water pollution. Water pollution is a global crisis that affects food security. Although there are other activities that contribute to water pollution, agriculture has become the dominant source of pollution in many countries [37].

Agriculture wastewater affects ocean water quality and freshwater lakes, rivers, and aquifers, because agrochemicals, nutrients, and sediments filter into these natural systems. Excess fertilizer runoff accumulates in aquatic ecosystems, leading to decomposition processes that reduce oxygen levels in the water, eventually creating "dead zones." In some countries like China, agricultural runoff is the leading cause of surface groundwater pollution by nitrogen.

In addition, anthropogenic treatment of soils exceeds the capacity of soils to assimilate waterborne pollutants, resulting in widespread elevated nitrogen, salinity, and biological oxygen demand in freshwater bodies [37]. Other water pollutants resulting from agricultural activities include chemical pesticides, livestock pharmaceuticals, and plastics.

Table 10 provides a list of important activities in the agri-food sector related to water pollution and key methods to measure the impact drivers (list is non-exhaustive).

Table 10. Overview of water pollution-related activities and key methods to measure impact drivers

Specific activities to consider for water pollution	Key methods and data relevant to measure impact drivers
Inorganic pollutants, nutrients: Field operations (e.g., land management, crop irrigation, watershed management)	Impact drivers can be modeled based on rates of fertilizer application to farmland. Grey water footprint accounting: Tier 1 supporting guidelines [40]. Provides a method to quantify nitrogen, phosphorus, metals, and pesticide emissions. PEF/OEF guidance, provides methods to estimate nitrogen and phosphorus, metals, and pesticide emissions to water. Secondary data sources (e.g., ecoinvent 3.8 [13], World Food LCA Database [15], and AGRIBALYSE® [11])
Pesticide and heavy metals emissions: Field operations (e.g., land management, crop irrigation, watershed management)	

Box 2. Reflections on direct field emissions

Manure and fertilizer use cause nutrient leaching and runoff to surface waters and groundwater sources. Emissions of nitrogen and phosphorus are challenging to quantify because of climatic parameters, soil types, and land management practices that are site specific. A simplified approach to quantify nitrogen and phosphorus emissions to water is offered by the Water Footprint Network grey water methodology [40].

4.2.5. Land use

Large-scale agriculture and livestock production are the principal agents of land use change and biodiversity loss. The main drivers of tree cover lost are forestry, commodity-driven deforestation, and shifting agriculture. Forestry represents the primary cause of tree cover lost, accounting for around 148 million hectares of tree cover lost in 2001-2022. This is followed by shifting agriculture, commodity-driven deforestation, and wildfires [41].

Food production has an impact on global land occupation as well. It is estimated that between 32 and 40% of Earth's ice-free surface and arable land is dedicated to agriculture [9] [42]. Of that area, 62% is used to produce livestock proteins, including land for animal feedstocks. This means that growing demand for animal proteins will increase pressure on tropical ecosystems. In addition, agricultural commodities are responsible for 80% of forest loss worldwide and by 2050 a further 400 million hectares of natural ecosystems are expected to be converted to agricultural land [9].

There are other side effects to agricultural land use. Forest loss due to intense agricultural systems like palm oil also cause GHG emissions when stored carbon is emitted from above ground biomass and soil. In countries like Malaysia and Indonesia, palm oil production threatens peatland ecosystems, which can store up to a quarter of all soil carbon in the world. Between one and two billion tons of carbon dioxide are lost from peat soils each year when converted to agriculture [9]. Other effects of land-use change are loss of biodiversity and regulating ecosystem services. Loss of biodiversity presents a serious threat to global food security. For example, loss of agrobiodiversity and crop diversity increases the vulnerability of crops to pests, increases the risk of extinction of pollinators, and increases the loss of genetic diversity.

Table 11 provides a list of important activities in the agri-food sector related to land use and key methods to measure the impact drivers (list is non-exhaustive).

Table 11. Overview of land use-related activities and key methods to measure impact drivers

Specific activities to consider for land use	Key methods and data relevant to measure impact drivers
Land occupation and land conversion for animal or crop production	Land occupation can be quantified using area of land used or occupied in the long or short term which prevents other natural processes from taking place (ha or m^2 of land occupied per year). Land conversion can be measured in area of land transformed from an original state of habitat (m^2 or ha of land).

Box 3. Recommendations for Life Cycle Assessment in land use accounting

When using Life Cycle Assessment, a common practice exists that accounts for land use over a time period of 20 years [43] up to a reference year. Any change prior to this time is not considered relevant as the associated impact is not deemed important.

The total impact arising from deforestation over the 20-year period prior to the reference year is then divided by 20 to obtain annual impact results associated, for instance, with crop production. With passing years, and with no new land-use change activities, the impact of such activities will decrease automatically. However, land-use impact has to be accounted for concurrently in your natural capital accounting. The Quantis guidance [44] for measuring GHG emissions from land, forests, and soil across the supply chain provides examples of the application of this general practice.

Some of the commonly used databases to estimate land-use emissions are:

1. Faostat [45] – Land Use and Land-Use Change database
2. Ecoinvent database [13]
3. Global Forest Watch [46]
4. GHG Protocol direct land-use change assessment tool developed by Blonk Consultants [28]

4.2.6. Solid Waste

The use of crop-protecting agents (agricultural pesticides designed to exterminate organisms deemed to pose a threat to crops and livestock), plastic mulch, and pesticide containers can cause serious harm if not properly disposed of. Additionally, along the full value chain of agriculture and food, each actor will have specific waste generation activities, including packaging, food waste, and others.

Table 12 provides a list of important activities in the agri-food sector related to solid waste and key methods to measure the impact drivers (list is non-exhaustive).

Table 12. Overview of solid waste-related activities and key methods to measure impact drivers

Specific activities to consider for solid waste	Key methods and data relevant to measure impact drivers
Packaging, in particular plastic packaging [5]	As indicated in the NCMA methodology, it is recommended to account for waste impact drivers through the other impact drivers, i.e., GHG emissions and non-GHG air emissions. Impacts on society due to leachate release (from landfill) and disamenity (from incineration and landfill) are measured additionally. World Bank data catalogue [47] OECD environmental statistics [48]
Food waste[6]	The FAO Food Loss and Waste database [49] contains data and information from openly accessible databases, reports, and studies measuring food loss and waste across food products, stages of the value chain, and geographical areas. The Food Waste Atlas [50] is another resource that provides data on food loss and food waste.

[5] Packaging and plastics are key contributors to waste streams throughout the value chain of the food and agriculture sector, from the use on field (e.g., input packaging, plastic mulch) to packaging of products (primary packaging, but also secondary and tertiary packaging used for shipping), and end-of-life.

[6] It is well known that food waste is generated throughout the agri-food value chain. UNEP has estimated that 17% of all food produced globally is wasted, and 38% of the energy used by the agri-food sector is lost in the production of food that will never reach the table [70].

5. DEPENDENCIES AND VALUE TO BUSINESS

The scope of this document is to provide guidance on how to use natural capital management accounting to assess the impact on society of a business's activities, based on the piloting experience by companies. Dependencies and value to business are therefore out of scope for this document and left for future development.

6. USING THE RESULTS

After generating your results, you will need to interpret and test them and take appropriate action. You may also report results externally. This step is highly case-specific yet does not differ between sectors. Therefore, please refer to the general guidance for more information.

7. CALCULATION EXAMPLE

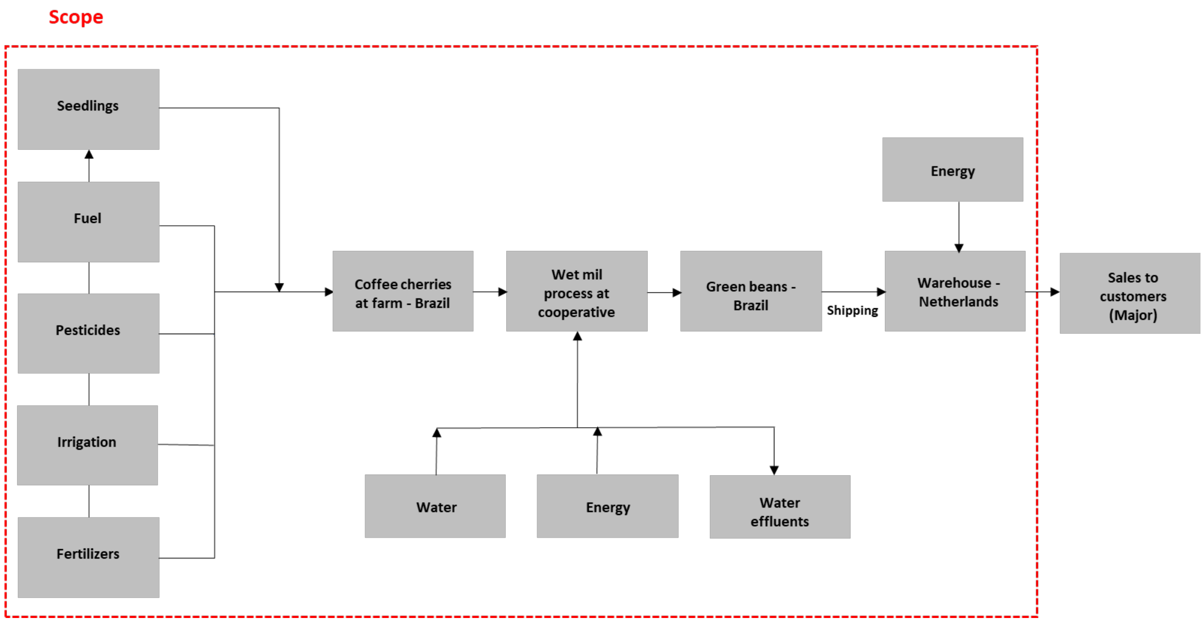
In the following, a simplified example of an agro-commodity trader in the coffee sector is described to illustrate the steps necessary to perform natural capital management accounting. In this example, the company is exporting coffee from Brazil to the European markets, with warehouses in the Netherlands.

The Brazilian coffee farmers produce conventional coffee using fertilizers and pesticides to produce the coffee cherries. The cherries are then processed through a wet mill process at a local cooperative, which utilizes water and energy and discards water effluents (sometimes treated). The drying process, using the sun, does not consume any energy and leads to green beans being produced and ready for exportation. The shipping is done using sea transportation and standard containers to reach the warehouse in the Netherlands. The coffee is then sold to customers, mainly represented by intermediaries who roast the product for retail sale.

7.1. Step one: Objective and scope

The trader company's objective is to assess its supply chain and direct operations impacts at the warehouse, to better manage them and communicate efforts made in this regard with customers. For this reason, the scope of the assessment was set on upstream processes and stops at the warehouse door, before sales to customers, as illustrated in Figure 4.

Figure 4. Example of supply chain mapping for a coffee trader



Using the materiality tables as well as specific knowledge of its supply chain[7], the trader company developed its own materiality table, specific to its value chain diagram (see Table 13). For each step, the assessed materiality for all impact drivers is shown. This information was used to prioritize (primary) data collection on impact drivers. Given the low materiality of solid waste, the trader company decided to exclude this aspect from this first accounting exercise, and will look into it qualitatively.

Table 13. Materiality assessment of an agro-commodity trader in the coffee sector exporting coffee from Brazil to Europe

Impact drivers	Coffee producer	Wet mill process	Shipping	Warehouse
GHG emissions	High	Low	Medium	Medium
Non-GHG air emissions	High	Low	Medium	Low
Water consumption	High	Medium	Low	Low
Water pollution	High	Medium	Low	Low
Land use	High	Low	Low	Low
Solid waste	Low	Low	Low	Low

[7] Materiality assessment tools like ENCORE [73] can help identify some impact drivers in case further support is required. See Table 5 of the NCMA general guidance for a more extensive overview of materiality assessment tools.

7.2. Step two: Measure and value

An LCA database was used for quantification of environmental impacts with 1 kg of coffee beans taken as the functional unit. The environmental flows per kg of coffee are shown in Table 13 and taken from the database ecoinvent 3.8 [13]. The impact drivers cover water use, land use (based on LANCA® [51]), climate change (Global Warming Potential), and water pollution (eutrophication).

GHG emissions:

For producing 1 kg of coffee beans, 0.3 kg of CO_2 is released. Based on our assumed production of 10 tonnes of coffee beans, 3,000 kg CO_2 eq. are released.

Additionally, the production of 1 kg of coffee beans results in 0.00227 kg emissions of dinitrogen monoxide, thus producing 10 tonnes results in 23 kg of dinitrogen monoxide. Multiplying these emissions with the Global Warming Potential of 265 kg CO_2eq/kg results in 6,016 kg CO_2eq.

Therefore, total quantified GHG emissions will be the sum of these two: **9,016 kg CO_2 eq**.

Water consumption:

For producing 1 kg of coffee beans, 1.1 m^3 water is required for irrigation. Scaling this to our assumed production capacity of 10 tonnes leads to **11,114 m^3** of water in total.

Water pollution:

Water pollution is calculated based on eutrophication (phosphorus content).

For producing 1 kg of coffee beans, 0.00018 kg of phosphorous are released to water. Scaling this pollution to our assumed production capacity of 10 tonnes, gives us 2 kg phosphorous (Peq/kg).

Land use:

To produce 1 kg of coffee, 5.57m^2 are needed per year (5.57m^2a). Applying the LANCA® method results in the quantification of different impact drivers as displayed in Figure 5 (e.g., biotic production loss potential and erosion potential).

Figure 5.: Illustration of impact drivers quantification for 10 tonnes of green bean coffee produced in Brazil

Coffee producer			Impact drivers quantification factors		Impact quantification
Environmental flows	**Quantity/per kg**	**Total**	**Impact pathway**	**Factor**	**Impact**
Inputs					
Water for irrigation	1.1 m^3	11,114 m^3	**Water consumption**	1 m^3	11,114 m^3 H_2Oeq
Land use	5.57 m^2a	55,700 m^2a	**LANCA**		
			Biotic production loss potential	0.94 kg/(m^2a)	52,081 kg
			Erosion potential	17 kg/(m^2a)	933,348 kg
			Groundwater regeneration reduction potential	0.07 m^3/(m^2a)	3,851 m^3
			Filtration reduction potential	4.56 m^3/(m^2a)	254,131 m^3
Output			Physicochemical filtration reduction potential	13 mol/m^2	743,452 mol
Coffee, green beans	1 kg	10 t			
Carbon dioxide, fossil, to air	0.3 kg	3,000 kg	**Global Warming Potential (100 years)**[1]	1 kg CO_2eq/kg	3,000 kg CO_2eq
Dinitrogen monoxide, to air	2.27E-03 kg	23 kg	**Global Warming Potential (100 years)**[1]	265 kg CO_2eq/kg	6,016 kg CO_2eq
Phosphorus, to water	1.80E-04 kg	2 kg	**Eutrophication**[2]	1 kg Peq/kg	1.80 kg Peq/kg

1: Global warming potentials for a 100 year time frame from IPCC 5th assessment report
2: Fresh Water Eutrophication Potential, taken from ReCiPe 2016 midpoint impact assessment method.

The impact quantification provides a range of quantitative results which are not easily interpreted, unless a single impact driver or environmental impact is considered. This is where impact valuation proves very useful, by translating various impact indicators and units into a simpler measure of value expressed in monetary units. The monetary value factors in Table 14 were used.

Table 14. List of monetary valuation coefficients by impact driver

Impact drivers	**Value factor**	**Unit**	**Reference year**	**In 2022 values (inflation-adjusted[8])**	**Source**
GHG emissions	0.185	\$/kg CO_2	2020	0.212	[52]
Water consumption	0.07	\$/m^3	2020	0.08	[53]
Water pollution	7.32	EUR/kg of phosphorus equivalent	2015	8.47	[20]
Land use*	1.38 for biotic production loss potential	\$/kg per year	2020	1.58	[45]
	0.06 for erosion potential	\$/kg soil	2020	0.07	[54]
	0.072 for groundwater regeneration reduction potential	\$/m^3 water demand	2020	0.0824	[53]
	1.56E-04 for filtration reduction potential	\$/m^3	2015	0.000193	[55]
	0.0000008 for physiochemical filtration reduction potential	\$/mol	2015	0.000001	[55]

** Applying the LANCA method results in various impact drivers that are valued based on the value factors shown in the table.*

For water consumption, total costs to reduce water scarcity in Brazil are taken from the Strong et al. 2020 dataset [53]: 5,000 billion USD for a water demand of 69,432 billion m^3 per year. This results in a value factor of 5,000 billion USD / 69,432 billion m^3 = 0.07 USD/m^3 water demand.

For a first, high-level insight on water pollution due to nutrients, the company used the value factor from the CE Delft Environmental Prices Handbook [20] noting that this number will not reflect local circumstances. The value factor used is 1.86 EUR per kg of phosphorus equivalent.

[8] Inflation adjustments for Europe based on Destatis [76], and for the US based on the Bureau of Labor statistics [77].

7.3. Step three: Using the results

To communicate the results, the coffee trader decided to display them in a dashboard that includes information on both the quantified impact drivers, as well as the monetarily valued impacts.

Figure 6. Impact valuation results of 10 tonnes of green been coffee produced in Brazil

Coffee producer			Impact drivers quantification factors		Impact quantification	Valuation	Total Value
Environmental flows	**Quantity/per kg**	**Total**	**Impact pathway**	**Factor**	**Impact**	**Monetization factor**	**Total (USD)**
Inputs							
Water for irrigation	1.1 m^3	11,114 m^3	**Water consumption**	1 m^3	11,114 m^3 H_2Oeq	0.08 \$/m^3 water demand	\$ 889
Land use	5.57 m^{2}a	55,700 m^{2}a	**LANCA**				
			Biotic production loss potential	0.94 kg/(m^{2}a)	52,081 kg	1.58 \$/kg per year	\$ 82
			Erosion potential	17 kg/(m^{2}a)	933,348 kg	0.07 \$/kg soil	\$ 65
			Groundwater regeneration reduction potential	0.07 m^3/(m^{2}a)	3,851 m^3	0.0824 \$/m^3 water demand	\$ 317
			Filtration reduction potential	4.56 m^3/(m^{2}a)	254,131 m^3	1.93E-04 \$/m^3	\$ 49
Output			Physicochemical filtration reduction potential	13 mol/m^2	743,452 mol	1.00E-06 \$/mol	\$ 1
Coffee, green beans	1 kg	10 t					
Carbon dioxide, fossil, to air	0.3 kg	3,000 kg	**Global Warming Potential (100 years)**[1]	1 kg CO_2eq/kg	3,000 kg CO_2eq	212 \$/t C	\$ 636
Dinitrogen monoxide, to air	2.27E-03 kg	23 kg	**Global Warming Potential (100 years)**[1]	265 kg CO_2eq/kg	6,016 kg CO_2eq	212 \$/t C	\$ 1,275
Phosphorus, to water	1.80E-04 kg	2 kg	**Eutrophication**[2]	1 kg Peq/kg	1.80 kg Peq/kg	8.64 \$/kg Peq	\$ 16
							\$ 3,331

1: Global warming potentials for a 100 year time frame from IPCC 5th assessment report
2: Fresh Water Eutrophication Potential, taken from ReCiPe 2016 midpoint impact assessment method.

$1.02 USD/EUR used for currency exchange

GLOSSARY

Baseline	In the Natural Capital Protocol [44], the starting point or benchmark against which changes in natural capital attributed to your business's activities can be compared.
Biodiversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems [45].
Business application	In the Natural Capital Protocol [44], the intended use of the results of your natural capital assessment, to help inform decision making.
Counterfactual	A form of scenario that describes a plausible alternative situation, and the environmental conditions that would result if the activity or operation did not proceed (adapted from [46]).
Economic value	The importance, worth, or usefulness of something to people—including all relevant market and non-market values. In more technical terms, the sum of individual preferences for a given level of provision of that good or service. Economic values are usually expressed in terms of marginal/incremental changes in the supply of a good or service, using money as the metric (e.g., $/unit).
Ecosystem	A dynamic complex of plants, animals, and microorganisms, and their non-living environment, interacting as a functional unit. Examples include deserts, coral reefs, wetlands, and rainforests [47]. Ecosystems are part of natural capital.
Ecosystem services	The most widely used definition of ecosystem services is from the Millennium Ecosystem Assessment [48]: "the benefits people obtain from ecosystems." The MEA further categorized ecosystem services into four categories: • Provisioning: Material outputs from nature (e.g., seafood, water, fiber, genetic material). • Regulating: Indirect benefits from nature generated through regulation of ecosystem processes (e.g., mitigation of climate change through carbon sequestration, water filtration by wetlands, erosion control and protection from storm surges by vegetation, crop pollination by insects). • Cultural: Non-material benefits from nature (e.g., spiritual, aesthetic, recreational, and others). • Supporting: Fundamental ecological processes that support the delivery of other ecosystem services (e.g., nutrient cycling, primary production, soil formation).
Environmentally extended input-output models (EEIO)	Traditional input-output (IO) tables summarize the exchanges between major sectors of an economy [61]. For example, output from the footwear manufacturing sector results in economic activity in associated sectors, from cattle ranching to accounting services. Environmentally extended input-output models (EEIOs) integrate information on the environmental impacts of each sector within IO tables [62] [63].

Externality	A consequence of an action that affects someone other than the agent undertaking that action, and for which the agent is neither compensated nor penalized. Externalities can be either positive or negative [52].
Impact	See "natural capital impact."
Impact driver	In the Natural Capital Protocol [44], an impact driver is a measurable quantity of a natural resource that is used as an input to production (e.g., volume of sand and gravel used in construction) or a measurable non-product output of business activity (e.g., a kilogram of NO_x emissions released into the atmosphere by a manufacturing facility).
Impact pathway	An impact pathway describes how, as a result of a specific business activity, a particular impact driver results in changes in natural capital and how these changes in natural capital affect different stakeholders.
Life cycle assessment	Also known as life cycle analysis. A technique used to assess the environmental impacts of a product or service through all stages of its life cycle, from material extraction to end of life (disposal, recycling, or reuse). The International Organization for Standardization (ISO) has standardized the LCA approach under ISO 14040 [53]. Several life cycle impact assessment (LCIA) databases provide a useful library of published estimates for different products and processes.
Materiality	In the Natural Capital Protocol, an impact or dependency on natural capital is material if consideration of its value, as part of the set of information used for decision making, has the potential to alter that decision [54] [55].
Materiality assessment	In the Natural Capital Protocol [44], the process that involves identifying what is (or is potentially) material in relation to the natural capital assessment's objective and application.
Measurement	In the Natural Capital Protocol [44] , the process of determining the amounts, extent, and condition of natural capital and associated ecosystem and/or abiotic services, in physical terms.
Monetary valuation	Valuation that uses money (e.g., $, €, ¥) as the common unit to assess the values of natural capital impacts or dependencies.
Natural capital	The stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people [68] [69](adapted from [68]).
Natural capital assessment	The process of measuring and valuing relevant ("material") natural capital impacts and/or dependencies, using appropriate methods.
Natural capital dependency	A business reliance on or use of natural capital.
Natural capital impact	The negative or positive effect of business activity on natural capital.
Natural Capital Protocol	A standardized framework to identify, measure, and value direct and indirect impacts (positive and negative) and/or dependencies on natural capital.
Organizational focus	In the Natural Capital Protocol [44], the part or parts of the business to be assessed (e.g., the company as a whole, a business unit, or a product,

	project, process, site, or incident). For simplicity, these are grouped under three general headings as below: • Corporate: assessment of a corporation or group, including all subsidiaries, business units, divisions, different geographies or markets, etc. • Project: assessment of a planned undertaking or initiative for a specific purpose, and including all related sites, activities, processes, and incidents. • Product: assessment of particular goods and/or services, including the materials and services used to produce these products.
Price	The amount of money expected, required, or given in payment for something (normally requiring the presence of a market).
Primary data	Data collected specifically for the assessment being undertaken.
Qualitative valuation	Valuation that describes natural capital impacts or dependencies and may rank them into categories such as high, medium, or low.
Quantitative valuation	Valuation that uses non-monetary units such as numbers (e.g., in a composite index), area, mass, or volume to assess the magnitude of natural capital impacts or dependencies.
Scenario	A storyline describing a possible future. Scenarios explore aspects of, and choices about, the future that are uncertain, such as alternative project options, business as usual, and alternative visions.
Scoping	In the Natural Capital Protocol [44], the process of determining the objective, boundaries, and material focus of a natural capital assessment.
Secondary data	Data that were originally collected and published for another purpose or a different assessment.
Spatial boundary	The geographic area covered by an assessment, for example, a site, watershed, landscape, country, or global level. The spatial boundary may vary for different impacts and dependencies and will also depend on the organizational focus, value-chain boundary, value perspective, and other factors.
Stakeholder	Any individual, organization, sector, or community with an interest or “stake” in the outcome of a decision or process.
Temporal boundary	The time horizon of an assessment. This could be a current “snapshot”, a 1-year period, a 3-year period, a 25-year period, or longer.
Validation	Internal or external process to check the quality of an assessment, including technical credibility, the appropriateness of key assumptions, and the strength of your results. This process may be more or less formal and often relies on self-assessment.
Valuation	In the Natural Capital Protocol [44], the process of estimating the relative importance, worth, or usefulness of natural capital to people (or to a business), in a particular context. Valuation may involve qualitative, quantitative, or monetary approaches, or a combination of these.
Valuation technique	The specific method used to determine the importance, worth, or usefulness of something in a particular context.
Value (noun)	The importance, worth, or usefulness of something.

Value perspective	In the Natural Capital Protocol [44], the perspective or point of view from which value is assessed; this largely determines which costs or benefits are included in an assessment. • Business value: The costs and benefits to the business, also referred to as internal, private, financial, or shareholder value. • Societal values: The costs and benefits to wider society, also referred to as external, public, or stakeholder value (or externalities).
Value transfer	A technique that takes a value determined in one context and applies it to another context. If contexts are similar or appropriate adjustments can be made to account for differences, value transfer can provide reasonable estimates of value.
Value-chain boundary	The part or parts of the business value chain to be included in a natural capital assessment. For simplicity, the Natural Capital Protocol [44] identifies three generic parts of the value chain: upstream, direct operations, and downstream. An assessment of the full lifecycle of a product would encompass all three parts. • Upstream (cradle-to-gate): covers the activities of suppliers, including purchased energy. • Direct operations (gate-to-gate): covers activities over which the business has direct operational control, including majority-owned subsidiaries. • Downstream (gate-to-grave): covers activities linked to the purchase, use, reuse, recovery, recycling, and final disposal of the business's products and services.
Verification	Independent process involving expert assessment to check that the documentation of the assessment is complete and accurate and gives a true representation of the process and results. "Verification" is used interchangeably with terms such as "audit" or "assurance."

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