CircHive

Synthesizing landscape of approaches for natural capital accounting (NCA) & biodiversity footprinting (BF) for private & public sectors

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Author:	Ira Bhattarai[1], Joel Houdet[2], Karin Morell[3], Jeanne Barreyre[4], Karim Thibault[5], Matias Piaggio[6], Marion Hammerl[7], Martin Georgiev[8], Fredric Mosley[9], Laura Lahtinen[1], Viktor Lundmark[3], Tatiana Novoa[5], Leander Raes[6], Ivan Paspaldzhiev[8], Michael den Herder[9], Tuija Lankia[1], Lisa Jansson[3], Daniel Kieling[5], Katrin Tomova[8], Oksana Pelyukh[10], Ihor Soloviy[10], Nora Hiller[11], Gabrielle Aubert[11], Friederike Nabrdalik[12], Sarah Köhler[12], Janne Artell[1], Erika Winquist[1] [1] Natural Resources Institute Finland (Luke), [2] The Biodiversity Footprint Company, [3] RISE Research Institutes of Sweden, [4] EcoAct, [5] Biotope, [6] International Union for Conservation of Nature (IUCN), [7] Bodensee Stiftung, [8] denkstatt Bulgaria, [9] European Forest Institute (EFI), [10] Ukrainian National Forestry University (UNFU), [11] Institute for European Environmental Policy (IEEP), [12] DIN Deutsches Institut für Normung
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Abbreviations

AoP – Areas of Protection

AWARE- Available WAter REmaining

BD – Biodiversity

BD Protocol – Biological Diversity Protocol

BDP – Biodiversity Damage Potential

BESS – Biodiversity and Ecosystem Services

BF – Biodiversity Footprint

BFFI – Biodiversity Footprint for Financial Institutions

BIM- Biodiversity Impact Metric

BISI – Biodiversity Indicators for Site-based Impacts

BMS – Biodiversity Monitoring System

BPT – Biodiversity Performance Tool

BS – British Standard

CARE – Comprehensive Accounting in Respect of Ecology

CBD – Convention of Biological Diversity

CBF – Corporate Biodiversity Footprint

CDP- Carbon Disclosure Project

CDSB – Climate Disclosure Standards Board

CF – Characterization factor

CISL – Cambridge Institute for Sustainability Leadership

CSP – Case Study Partner

CSRD – Corporate Social Responsibility Directive

EBV – Essential Biodiversity Variables

EEMRIO – Environmentally Extended Multi-Regional Input Output

EMAS – Eco-Management and Audit Scheme

ENCORE – Exploring Natural Capital Opportunities, Risks and Exposure

EP&L – Environmental Profit & Loss

ESRS – European Sustainability Reporting Standard

FAO – Food and Agriculture Organization

FPD – Land Use Impacts on Functional Plant Diversity

FSA – Farm Sustainability Assessment

FSC – Forest Stewardship Council

FU – Functional Unit

GBS – Global Biodiversity Score

GBSFI – Global Biodiversity Score for Financial Institutions

GEP – Global Extinction Probability

GHG – Greenhouse Gases

GRI – Global reporting Initiative

GTAP – Global Trade Analysis Project

I/O – Input-output

IBAT – Integrated Biodiversity Assessment Tool

ISO – International Standards Organization

IUCN – International Union for Conservation of Nature

KPI – Key Performance Indicator

LCA – Life Cycle Assessment

LCCA – Life Cycle Costing Assessment

LCI – Life Cycle Inventory

LCIA – Life Cycle Impact Assessment

LUIS – Land Use Intensity Specific Biodiversity Footprint

MEA – Millennium Ecosystem Assessment

MRIO – Multi-Regional Input Output

MSA – Mean Species Abundance

NBF – Negative Biodiversity Footprint

NC – Natural Capital

NCA- Natural Capital Accounting

NCP – Natural Capital Protocol

NGO – Non-Governmental Organization

PBF – Positive Biodiversity Footprint

PDF – Potentially Disappeared Fraction of Species

PSL – Potential Species Loss

QALY – Quality Adjusted Life Years

RISE – Response Inducing Sustainability Evaluation

RSPO – Round Table on Sustainable Palm Oil

SAR – Species Area Relationship

SBTN – Sciences Based Targets Network

SDG – Sustainable Development Goal

SEEA – The System of Environmental Economic Accounting

SEEA CF – The System of Environmental Economic Accounting Central Framework

SEEA EA – The System of Environmental Economic Accounting Ecosystem Accounting

SFDR – Sustainable Finance Disclosure Regulation

SMART – Sustainability Monitoring and Assessment RouTine

SME – Small and Medium Sized Enterprise

STAR – The Species Threat Abatement and Restoration

TBF – Total Biodiversity Footprint

TESSA – Toolkit for Ecosystem Service Site Based Assessment

TNFD – Taskforce on Nature-related Financial Disclosures

UN – United Nations

WIOD – World Input Output Database

WWF – World Wide Fund for Nature

1 Introduction

There is an evident need for accurate, science-based methods to assess biodiversity impacts resulting from human activities. In recent centuries, species extinction has occurred at a significantly accelerated rate, ranging from 10 to 100 times higher than the average rate observed over the past 10 million years. We are currently experiencing the sixth mass extinction in the 4.6 billion years-long life of the Earth.[1] Looking at the surface of the earth, more than 77% of land (excluding Antarctica) and 87% of the ocean has been modified by the direct effects of human activities.[2] This transformation is already so wide that it threatens the important buffering capacity of nature against the effects of climate change and other human impacts.

The ongoing global biodiversity loss calls for the worlds' companies and institutions, in all sectors, to mitigate their negative impacts. This requires standardized methods for assessing biodiversity footprints (BF) for products, services and exploitation projects. Today, there are a rising number of suggested methods with different scope, which are built on different datasets, have different geographical and sectoral coverages and more[3,4]. Most are based on three different approaches: (1) Life Cycle Assessment (LCA), (2) Natural Capital Accounting (NCA) and (3) Input-output (I/O) models. The aim of this report is to present opportunities and restrictions of the three different approaches for BF assessments.

This report is the deliverable of Task 2.1 of the EU Horizon project CircHive[5]. The report is divided into six main chapters. The report starts with three background chapters, providing the reader an overview of *terms and definitions* (2), followed by *current biodiversity trends in the business environment* (0), and *initiatives in the field of NCA and BF* (4). In the next sections, we present the results from CircHive's *methods mapping* (reviewing existing methods for BF

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[1] IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673

[2] Watson, J.E.M., Venter, O., Lee, J., Jones, K.R., Robinson, J.G., Possingham, H.P., & Allan, J.R. (2018). Protect the last of the wild. *Comment. Nature, 563,* 27-30. https://www.nature.com/articles/d41586-018-07183-6

[3] Damiani, M., Sinkko, T., Caldeira, C., Tosches, D., Robuchon, M., & Sala, S. (2023). Critical review of methods and models for biodiversity impact assessment and their applicability in the LCA context. *Environmental Impact Assessment Review, 101*, 107134. https://doi.org/10.1016/j.eiar.2023.107134

[4] Horn, R., Hong, S. H., Knüpffer, E., Alvarenga, R., Boone, L., Preat, N., ... & Pihkola, H. (2022). ORIENTING-D1. 1 Critical evaluation of environmental approaches. Technical report. DOI: 10.13140/RG.2.2.19833.75361

[5] Developing & piloting biodiversity footprinting & natural capital accounting via a 'beehive' of sectoral hubs, for sustainable transition to a circular EU bioeconomy – CircHive. https://www.circhive.eu/

and NCA) (5), *tool screening* (screening existing tools related to biodiversity assessments) (6), and finally we present results from the surveys and interviews with our case study partners (7).

The review of Task 2.1 forms a basis for the integration, or at least to find connection between, NCA, LCA, and I/O approaches to create one holistic approach in Task 2.2. Even if the approaches would be used independently, it is important to understand the differences, strengths, and weaknesses of the different approaches, to identify the critical risks for the biodiversity assessment in question, and to use the most suitable method accordingly.

2 Terms and Definitions

There are various terms and definitions in the field of biodiversity footprinting. The most frequently used terms with definitions are listed in Table 1 and examples are given in Table 2.

First, it is important to make the difference between the assessment focus of *Impact* and *Impact driver*. With *Impact*, we understand the changes in the state of biodiversity i.e., Essential Biodiversity Variables (EBV)[6]: impact on genetic composition, species populations, species traits, community composition, ecosystem function, and ecosystem structure.

With *Impact drivers*, on the other hand, we refer to the direct drivers (land-/sea-use change; direct exploitation; climate change; pollution; and invasive alien species) resulting from an array of underlying societal causes or business activities that directly or indirectly affect biodiversity.[1] Impact driver has also been referred as Mid-point in LCA methods.

Secondly, the use of the terms *Method* and *Tool* can be confusing. A biodiversity impact assessment method is based on scientific work. It assesses the impact on biodiversity through e.g. a defined equation or model. Whereas a tool is e.g. a software or a web application, which offers a way to perform assessments, and often includes maps, figures, or other visualization features. A tool is always built based on one or several methods.

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[6] Pereira, H. et al. (2013). Essential Biodiversity Variables. *Science, 339*(6117), 277–278. https://doi.org/10.1126/science.1229931

Table 1. List of terms and definitions related to natural capital accounting (NCA), life cycle assessment (LCA), and input – output (I/O) approaches to assess biodiversity footprint (BF).

Term	**Definition**
Biodiversity (BD)	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.[7]
Biodiversity footprint (BF)	The impact of a commodity, company, person, or community on biodiversity, measured in terms of changes in the state of biodiversity as a result of production and consumption of particular goods and services.[8]
Assessment focus	The intended use of the assessment. Can be linked to assessment of Dependency, Impact, or Impact driver. See below.
Dependency	Organization's reliance on, or use of, natural capital (NC).[9]
Impact	Changes in the state of environment due to natural changes, pressures on the environment or human intervention will have impacts on the social and economic functions on the environment.[10] A natural capital impact is the negative or positive effect of an activity, for example of a business, on natural capital.[11]
Impact driver / Pressure	Also called "pressures" in the Drivers, Pressures, State, Impact, Responses (DPSIR) framework. Impact drivers[1] (e.g., land/sea use/use change, direct exploitation, climate change, pollution, invasive alien species) are caused by activities that generate changes in the state of biodiversity, either directly or indirectly.
Performance assessment	The concept is used in method mapping (chapter 5). Performance relates to achieving an objective or target. In the context of biodiversity impact measurement, it involves measuring the actual impacts of the business/organization to assess whether it is successful at implementing mitigation measures and/or reaching biodiversity-specific targets.
Risk assessment	The concept is used in method mapping (chapter 5). Refers to assessing impact drivers/pressures on different scenarios. This is used in the context of identifying potential negative and/or positive consequence for the business/organization and/or its stakeholders.
Scope	Scope refers to the depth and the breadth/width of the study.

[7] Convention on Biological Diversity (1992) Convention on Biological Diversity. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

[8] Modified from IEEP 2021. Biodiversity footprints in policy and decision-making: Briefing on the state of play, needs and opportunities and future directions. Policy report. Institute for European Environmental Policy. /

[9] BS 8632:2021 Natural Capital Accounting. https://www.bsigroup.com/en-GB/standards/bs-86322021/

[10] United Nations et al. (2021). System of Environmental-Economic Accounting— Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available at: https://seea.un.org/ecosystem-accounting.

[11] Natural Capital Protocol. https://capitalscoalition.org/wp-content/uploads/2021/01/NCC_Protocol.pdf

Natural Capital (NC)	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.[7]
Natural Capital Accounting (NCA)	The process of compiling consistent, comparable and regularly produced data using an accounting approach on natural capital and the flow of services generated in physical and monetary terms.[12]
Corporate BD accounting	The systematic process of identifying, measuring, recording, summarizing, and reporting the biophysical state of biodiversity assets, and the periodic and accumulated net changes to those assets.[13]
Life Cycle Assessment (LCA)	LCA is a compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle.[14, 15]
Life Cycle Inventory (LCI)	LCI is a phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.[14, 15]
Life Cycle Impact Assessment (LCIA)	LCIA is a third phase in LCA aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.[14, 15]
Mid-point method	Midpoint methods assess environmental consequences earlier in the cause-effect chain, typically linking the use of natural resources or generation of emissions to an impact on the environment (e.g., climate change, land use, ecotoxicity). Impact is derived using a simple multiplication between the mass of resource use or emissions generated, and specific factors called characterization factors (CFs).[16, 17]
End-point method	End-point methods link the mid-point environmental impact to damages to areas which are important to society (areas of protection, AoP). These AoPs are typically human-health, natural resources, and ecosystem quality. Biodiversity loss, quantified in terms of species loss, is used as the metric to assess damages to ecosystem quality.[16, 17]
Input-output method	Input-output (I/O) models include a system of linear equations describing the economic flows between different sectors of a country in

[12] Lammerant (2019). NCAVES – State of play of business accounting and reporting on ecosystems. https://seea.un.org/sites/seea.un.org/files/background_paper_release_for_unseeaforum.pdf

[13] UNEP-WCMC, Capitals Coalition, Arcadis, ICF, WCMC Europe (2022). Recommendations for a standard on corporate biodiversity measurement and valuation, Aligning accounting approaches for nature. https://knowledge4policy.ec.europa.eu/publication/align-project-recommendations-standard-corporate-biodiversity-measurement-valuation_en

[14] ISO (2006). International Standard ISO 14040. Environmental management - Life cycle assessment - Principles and framework. Available at: https://www.iso.org/standard/37456.html

[15] ISO (2006). International Standard ISO 14044. Environmental management - Life cycle assessment - Requirements and guidelines. Available at: https://www.iso.org/standard/38498.html

[16] Crenna, E., Marques, A., La Notte, A., & Sala, S. (2020). Biodiversity Assessment of Value Chains: State of the Art and Emerging Challenges. *Environ. Sci. Technol., 54*, 9715−9728.

[17] Sala, S., et al. (2019). Consumption and Consumer Footprint: Methodology and Results. Indicators and Assessment of the Environmental Impact of EU Consumption; Publications Office of the European Union: Luxembourg.

	a certain year.[18] The I/O tables provide data on global trade flows and production/consumption recipes.[19]
Method	Method refers to the diverse principles, procedures, and practices that govern empirical research. Research method refers to the practical "how" of a research study. More specifically, it's about how a researcher systematically designs a study to ensure valid and reliable results that address the research aims, objectives and research questions.[20] A biodiversity assessment *method* is always based on scientific work. It assesses e.g. the impact on biodiversity through a defined equation or model.
Tool	A tool is an instrument, device or application used to perform a specific task or function. It can be e.g., a physical object, logical flowchart guiding a thought or measurement process, checklist, or a software application that helps the user to achieve their objectives more efficiently and effectively. A biodiversity assessment *tool* is always based on one or several methods.
Technique	A simple exercise or engagement activity that can be used when implementing a tool.
Measurement / measure	The act or process of measuring. A figure, extent, or amount obtained by measuring. A measure is a unit-specific term which pertains to a single phenomenon of interest. It includes both error (the difference between a measured value and the true value for a measurement) and uncertainty (the range of possible values within which the true value of the measurement lies).[21]
Indicator / metrics	A quantifiable representation of a measurement focus, e.g. kg CO_2-equivalents for climate change.[14, 15] May consist of a single measure or a group of measures contributing to a composite metric or indicator, e.g. Potentially Disappeared Fraction of species (PDF). Below, some clarifications are listed: - A measure could be an indicator, but not all indicators are measures. - A metric is a specific type of indicator. It is used to track and assess the status / trends of a specific process / outcome. - A key performance indicator (KPI) is a type of metric. It tracks something significant.
Supply chain	All stages of producing and delivering a product or service, from sourcing the raw materials to the final delivery of the product or service to end users.[22] Includes direct and upstream operations.
Value chain	Value chain refers to all the upstream and downstream activities associated with the direct operations of the reporting company,

[18] Marques, A., Verones, F., Kok, M.T.J., Huijbregts, M.A.J., & Pereira, H.M. (2017). How to quantify biodiversity footprints of consumption? A review of multi-regional input–output analysis and life cycle assessment. *Current Opinion in Environmental Sustainability, 29*, 75-81.

[19] Moran, D., Petersone, M., & Verones, F. (2016). On the suitability of input–output analysis for calculating product-specific biodiversity footprints. *Ecological Indicators 60*, 192-201.

[20] Kazdin, A. E. (2016). Methodology: What it is and why it is so important. In A. E. Kazdin (Ed.), Methodological issues and strategies in clinical research (pp. 3–21). American Psychological Association. https://doi.org/10.1037/14805-001

[21] https://www.merriam-webster.com/dictionary/measurement

[22] https://corporatefinanceinstitute.com/resources/management/supply-chain/

	including the use of sold products by consumers and the end-of-life treatment of sold products after consumer use.[23]

For some of the terms described above, there are no standardized definitions. Thus, some terms are – to various degrees – defined and used differently by different actors. Consequently, this has created a rather complex situation for researchers, businesses, policy makers, and other stakeholders in deciding what is the adequate way to use and understand some of the terms. *Method*, *tool*, *indicator*, and *metrics* are examples of misunderstood and confused terms in the field. Thus, we produced the following onion diagram (Fig. 1) to help the readers to better understand the use of these terms.

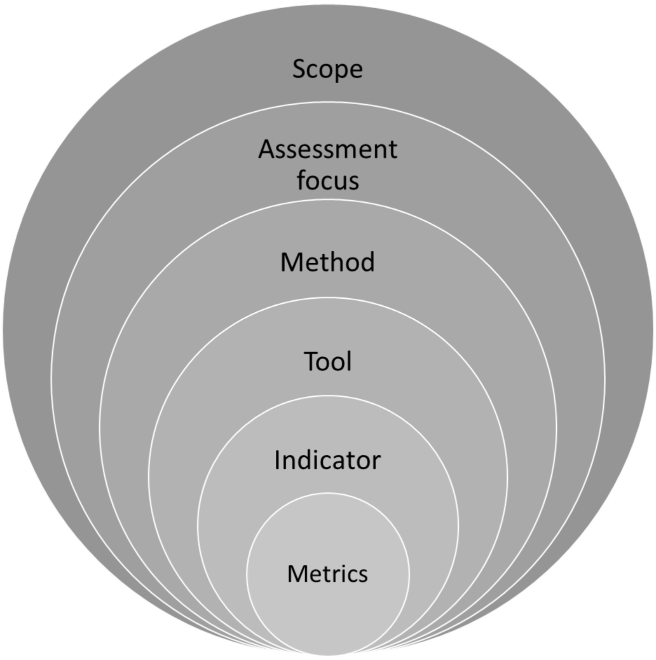

Fig 1. Onion diagram showing the hierarchy between the terms.

In Fig. 1, the terms are placed according to the hierarchy level as follows:

- The outermost layer refers to the *scope of analysis* for e.g., global, national, regional, etc. In LCA, scope refers to the depth and the breadth/width of the study.
- The second layer, the *assessment focus*, refers to whether the analysis is of impact, impact drivers and/or dependencies.

[23] WBCSD (2011). Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard - Supplement to the GHG Protocol Corporate Accounting and Reporting Standard, World Resources Institute (WRI) and WBCSD. https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf

- Moving towards the inner layer, *the method,* defined as diverse principles, procedures, and practices that govern empirical research, is the key layer adding detail to the analytical process.
- Thereafter, *the tool* which is always based on at least one method facilitates and provides users with step-by-step instructions to carry out the assessments.
- The tool comprises of different indicators that constitutes a quantified representations of the study or measurement, while the metrics is the unit of measurement.

NCA and LCA have conceptual overlaps as well as possibilities of fulfilling each other's gaps with a good potential to harmonize the approaches in a single conceptual and methodological framework. For example, in LCA, impact drivers are used to model impacts in LCIA and one of the categories is called impact on ecosystem (BF) while the same is called change in state of natural capital in NCA.

Examples of each term presented in Fig.1 are listed in Table 2 for both approaches, LCA approach and NCA approach. The table presents a non-exhaustive set of examples intended for illustration purpose only.

Table 2. Examples on how a selection of terms can be used within LCA and NCA approaches.

Approach of the biodiversity assessment	**LCA approach**[24]	**NCA approach**[25]
Scope	Country or ecoregion	Specific locations of the organisation, organised according to specific value chain boundaries
Assessment focus	Impact driver: land use (land occupation & land use change)	Impact on biodiversity
Method	Land use intensity specific biodiversity footprint (LUIS)[26]	Biological Diversity Protocol[25]
Tool	SimaPro	ArcGIS (GIS software), excel
Technique	Multiplying area (A) needed for production by characterization factor (CF) for each individual country	Ecosystem mapping, direct measurement of ecosystem state / population size, double entry bookkeeping

[24] Kyttä, V., Hyvönen, T. & Saarinen, M. (2023). Land-use-driven biodiversity impacts of diets—a comparison of two assessment methods in a Finnish case study. Int J Life Cycle Assess 28, 1104–1116. https://doi.org/10.1007/s11367-023-02201-w

[25] The Biodiversity Disclosure Project (2021). The Biological Diversity Protocol (BD Protocol). https://nbbnbdp.org/bd-protocol/

[26] Chaudhary A., & Brooks T. (2018). Land use intensity-specific global characterization factors to assess product biodiversity footprints. *Environ Sci Technol, 52*, 5094–5104. https://pubs.acs.org/doi/10.1021/acs.est.7b05570

Measure	Potential species loss	Extent, condition, population sizes
Indicator	Potential Disappearing Fraction (PDF); species lost	Total Biodiversity Footprint (TBF), Negative Biodiversity Footprint (NBF) and Positive Biodiversity Footprint (PBF)
Metrics	PDF / person / day	PBF / year over a period
KPI	Rate of change in the PDF / year metric	Ratio of PBF / TBF over the years

3 Current trends in business environment

The severity of the ongoing global biodiversity loss is getting increasing attention and reactions. In the EU, *the Biodiversity Strategy for 2030* and *the EU Green Deal* sets the pathway for protecting nature and reversing the degradation of ecosystems. Globally, the *Kunming-Montreal Global Biodiversity Framework* (2022), aims to halt and reverse nature loss by 2030 and ensure that we end the decade with more nature not less. However, these targets cannot be reached by governments and international agreements alone – everyone needs to be involved including businesses and consumers.

The change in the business environment can to a large extent be seen in new policies, new reporting requirements, and on-going standardization activities. In this section, we provide the reader a brief overview of policies (3.1), reporting initiatives (3.2), certification and labelling (3.3), and standardization development (3.4) of relevance for biodiversity footprinting.

3.1 Policies

The EU Green Deal and the EU's Biodiversity Strategy for 2030 provide framing for new policies guiding private and public sectors towards more sustainable use of natural resources and mitigating biodiversity loss. In parallel, in the CircHive task 3.4, a thorough review of existing and upcoming EU policies and legislation related to BF, NCA and sustainable financing is performed, to identify areas of improvement and opportunities for innovation. The first delivery report (D3.4)[27] scopes the role of public policy and of the links between relevant environmental policies and BF/NCA and the task's objective. For this purpose, a policy tracker was created, in the form of an Excel spreadsheet, with a worksheet for each policy identified as potentially relevant for BF and NCA. The outputs of WP3 (in this case WP3.4) are intended to inform the development of WP2 over time and furthermore, the work of WP2 will be used to provide recommendations for the improvement and the use of BF/NCA in EU policy.

[27] Aubert, G. et al. (2023). Review and recommendations for mainstreaming of biodiversity in EU policy (1st version). Deliverable 3.4 under Horizon Europe project CircHive. Available at: www.circhive.eu

In the complementing step of analysis and review of the information consolidated in the tracker, a comprehensive overview of the state of play of EU policies related to BF and NCA was created. The aim is to present relevant background information as to whether public policy integrates and incentivizes the use of BF and NCA, and whether there remains room for improvement. The following policies were identified as priority policies: *the Corporate Sustainability Reporting Directive (CSRD), the Sustainable Finance Disclosure Regulation (SFDR)*, and *EU Taxonomy*, because these were relatively new or developing legislation with a direct link to BF and/or NCA and holds a lot of potential to mainstream biodiversity into reporting standards. The relevance of the policies is stronger for BF compared to NCA based on the analysis.

3.2 Reporting initiatives

In January 2023, CSRD entered into force, requiring all companies listed or operating in the EU (except for micro-enterprises) to disclose information on a range of ESG topics, including biodiversity. Companies subject to CSRD will have to report following ESRS, adopted as of 31 July 2023. The CSRD aims to ensure that investors and other stakeholders have access to information necessary to assess the impact from a business on people and the environment, and to assess risks and opportunities from ESG issues (including biodiversity). The ESRS do not prescribe specific methodologies for reporting but rather leaves the possibility for companies to use voluntary reporting frameworks to prepare their disclosures (in addition to pointing out certain frameworks in its application requirements as a voluntary option). CSRD aims to reduce reporting costs for companies in the medium to long term by harmonizing the ESG-related information required. An illustration of how the disclosure standard development is connected to policies is given in Fig. 2.

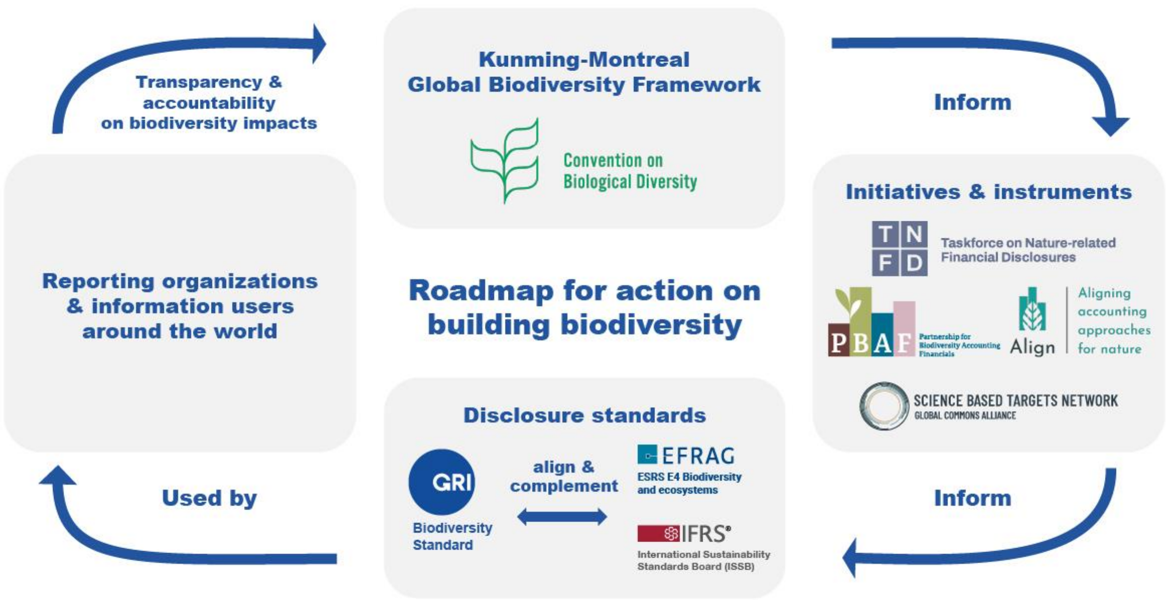

Fig 2. Non-exhaustive conceptual overview of links between global biodiversity goals, ongoing initiatives, disclosure standards, and their use. Source: Global Reporting Initiative (GRI).

Task 3.1 of the CircHive-project focuses on the integration of biodiversity in ESG management. Subtask 3.1.1 has reviewed current ESRS biodiversity reporting requirements, their overlaps with other voluntary (SBTN, TNFD, GRI, CDP) and mandatory (SFDR) reporting requirements, and potential links with BF and NCA concepts. BF methods can be used to assess footprints in the value chain, while NCA is relevant where changes over time and state of living nature need to be tracked. Both approaches will need to be applied at different levels of granularity – from site-level, value chain, to an entire company and financial portfolio levels. When looking at the ESRS mandatory requirements and voluntary requirements related to biodiversity, we see that the application of NCA is of relevance for transition planning and target setting, as companies and other types of organisations will need to report on quantifiable targets and progress towards these. The potential links with BF and NCA are summarized in detail in CircHive's D3.1.1 report[28]. Over time, this work will be extended to consider the potential use of outputs of CircHive's WP2 to improve reporting, including corporate reporting, via the integration of BF/NCA criteria.

3.3 Certification and labelling

There are a range of voluntary labelling and certification schemes (Ecolabels) that are common and familiar tools used by companies to manage sustainability issues. Currently only a few existing labelling and certifications include criteria with relevance for biodiversity[29].

Subtask 3.1.2 focuses on voluntary standards/labels, the inclusion of NC and BD criteria, and development of an "ideal framework" for best-practice inclusion of biodiversity in ecolabelling (incl. drawing on the work of CircHive's WP2). To analyze how, and to what extent, biodiversity is addressed by standards/labels, 21 standards have been screened for the presence of criteria related to biodiversity in their requirements. The matrix elaborated for the screening covers the most relevant aspects related to biodiversity and is clustered according to the drivers of loss of biodiversity. BF and NCA are not currently listed as specific methods in the reviewed standards/labels. However, there are several requirements related to the main drivers of biodiversity loss which could be used for both approaches. Detailed explanation about the linkage between the topics evaluated in the screening matrix and BF and NCA is available in CircHive's D3.1.2 report[30].

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[28] Paspaldzhiev, I. et al. (2023). Review and recommendations for existing and upcoming corporate NC & BD reporting standards. Deliverable 3.1.1 under Horizon Europe project CircHive. Available at: www.circhive.eu.

[29] Lake Constanze Foundation, GNF & RDC Environment (2021). Inclusion of biodiversity in labelling and certification schemes. Tender for the FPS Health

[30] Hammerl, M. et al. (2023). Review of inclusion of NC & BD criteria in labelling and certification schemes, development of "ideal framework". Deliverable 3.1.2 under Horizon Europe project CircHive. Available at: www.circhive.eu.

3.4 Standardization

The standardization activities of the CircHive-project are carried out in Task 5.4. The standardization activities refer to official standardization documents from recognized standardization organizations. In the first step, an overview of the current standardization landscape in BF, NCA and the environment was created. The project partners assessed 257 standards as relevant to the project. The deliverable report D5.4 Standardization landscape[31] explains the basics of standardization and standard research in detail.

In general, there is so far no accepted standard regarding BF or NCA, but standards of importance and high relevance are in development in the ISO technical committees, (1) *ISO/TC 331 Biodiversity* and (2) *ISO/TC 207 Environmental management*.

Within the ISO/TC 331 four working groups (WG) have been established to develop standards and guidelines. WG1 is currently developing the *ISO/WD TS 13208 – Biodiversity – vocabulary*, as soon as this document is published, the terms used will be adopted by the CircHive project. WG2 focuses on Measurement, data, monitoring and assessment, WG3 works on standards related to Protection, conservation, and restoration, while WG4 on "Organizations, strategies and sustainable use" of biodiversity. Within WG4, an umbrella of biodiversity management standards are under development: 17298 – Biodiversity – Strategic and operational approach for organizations – Requirements and guidelines. The objective of this approach is to enable organizations, based on identification and prioritization of the issues, to avoid or reduce negative impacts on and to act in favor of biodiversity and to improve their environmental, social, and economic performance by linking biodiversity planning, decision-making, action and monitoring to other key issue areas (including for instance climate change, pollution, social equity, and economic value creation). It aims to integrate the issues of conservation, restoration and sustainable use of biodiversity and ecosystem services, which the organization benefits from, into its strategy, through the implementation of a dedicated biodiversity approach.

The development of the following guidelines / Technical Specifications is also planned for 2024 / 2025:

- Biodiversity – Guidance for the characterization of products derived from native species
- Biodiversity and the Food Sector: Guidelines on how to improve biodiversity performance of food companies and food retailers (Biodiversity and the food sector: guideline)

[31] Nabrdalik, F., & Köhler, S. (2023). Standardization landscape. Deliverable 5.4 under Horizon Europe project CircHive. Available at: www.circhive.eu.

- Biodiversity and abiotic raw material: Considering biodiversity protection in the first step of the supply chain – Guidelines on the extraction of abiotic and production of biotic raw material and impacts on biodiversity

CircHive seeks to contribute towards the field of NCA and BF. In the area of NCA, there is the British standard *BS NCA BS 8632:2021 Natural Capital Accounting for Organizations*. ISO/TC 207/SC 1/WG 14 "Natural capital accounting" has recently started work on the following standard with the same title (ISO/AWI 14054 Natural Capital Accounting for Organizations — Specification). CircHive results can be incredibly significant for this work. Biodiversity is a topic in the ISO 14001 Environmental Management System and mentioned as one of the environmental aspects to be considered. But so far, no further information has been given. The framework of the ISO 14001 would be very appropriate to also manage biodiversity aspects, but further guidance should be provided to companies and other organizations. The ISO 331 committee is in exchange with the committee for ISO 14001 and the umbrella management standard 17298 could be the connection between both.

4 Previous and ongoing projects and initiatives in the field of NCA and BF

4.1 Business and biodiversity: initial efforts and limitations

Efforts to help corporations to better manage biodiversity and ecosystem services (BESS) emerged in the 2000s in the context of the Millenium Ecosystem Assessment (2005).[32, 33] Initially, studies aimed to identify and classify biodiversity risks and opportunities for business notably from the perspective of regulations (liability, taxation), industrial standards and norms, stakeholders' pressures and expectations, corporate image or reputation, evolution of customers' needs and wants (market risk), operational management (accidents, availability and costs of resources) and/or cost of capital (financing, insurance and investment risks).[34, 35, 36, 37] For instance, the "Corporate Ecosystem Services Review", a procedural methodology for identifying business risks and opportunities with respect to ecosystem change was developed in 2008.[32]

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[32] Hanson, C., Janet, R., Iceland, C., & Finisdore, J. (2008). The Corporate Ecosystem Services Review: Guidelines for Identifying Business Risks and Opportunities Arising from Ecosystem Change. Washington, DC.
[33] Houdet, J. (2008). Integrating biodiversity into business strategies. The Biodiversity Accountability Framework. FRB — Orée, Paris. 394pp.
[34] ISIS (2004). Is Biodiversity aMaterial Risk for Companies? ISIS AssetManagement plc, London.
[35] Mulder, I. (2007). Biodiversity, the Next Challenge for Financial Institutions? IUCN, Gland.
[36] Tucker, G. (2006). A Review of Biodiversity Conservation Performance Measures. Earthwatch Institute, Oxford.
[37] UNEP FI (2008). Biodiversity and ecosystem services: bloom or bust? A Document of the UNEP FI Biodiversity & Ecosystem Services Work Stream (BESW), Geneva.

To address these risks and seize these opportunities, two complementary approaches were explored. *On the one hand*, existing environmental or sustainability tools were improved at the production, organizational (information systems for decision-making) and institutional (tools for engaging external stakeholder) levels. These included impact assessment procedures and offset measures[38, 39, 40], environmental management systems[33], LCA methodologies (e.g., supply chain impacts of food products[41]), product labels or certification schemes (e.g. BESS criteria for the Forest Stewardship Council), and sustainability reporting guidelines[42, 43, 44, 45]. *On the other hand*, various organizations developed tools directly addressing BESS issues, which lead to a proliferation of indicators, tools, approaches and/or guidance documents focused on impact and/or dependency measurement and valuation.[43, 46, 47]

Yet, recent studies have highlighted the lack of standardized indicators and metrics for BESS dependency and impact measurement, hence providing a substantial explanation for the poor state of corporate biodiversity disclosures.[46, 48, 49] While some have argued that the complexity

[38] Briand, P. (Ed.) (2010). Entreprises et biodiversité: exemples de bonnes pratiques. MEDEF, Paris. 274 pp.

[39] Köllner, T. (2000). Species-pool effect potentials (SPEP) as a yardstick to evaluate landuse impacts on biodiversity. *Journal of Cleaner Production, 8*(4), 293–311.

[40] Anglo Platinum (2009). BBOP Pilot Project Case Study. Potgietersrust Platinums Limited (PPRust), Johannesburg, South Africa. 30 pp.

[41] Jeanneret, P., Baumgartner, D.U., Freiermuth Knuchel, R., & Gaillard, G. (2008). Integration of biodiversity as impact category for LCA in agriculture (SALCA-Biodiversity). 6th International Conference on LCA in the Agri-Food Sector, Zurich. November 12–14, 6 pp.

[42] GRI (2006). Biodiversity — a GRI reporting resource. Global Reporting Initiative. 50 pp.

[43] Houdet, J., Trommetter, M., & Weber, J. (2012). Understanding changes in business strategies regarding biodiversity and ecosystem services. *Ecological Economics, 73*(12), 37-46. https://doi.org/10.1016/j.ecolecon.2011.10.013

[44] Jones, M.J. (2003). Accounting for biodiversity: operationalising environmental accounting. *Accounting, Auditing and Accountability Journal 16*(5), 762–789.

[45] Jones, M.J., & Matthews, R. (2000). Accounting for biodiversity — a natural inventory of the Elan ValleyNature Reserve. ACCA Occasional Research Paper No.29. ACCA, London,UK.

[46] Addison, P.F.E., Bull, J.W., & Milner-Gulland, E.J. (2019). Using conservation science to advance corporate biodiversity accountability. *Conserv. Biol., 33*(2), 307-318. https://doi.org/10.1111/cobi.13190

[47] Waage, S., Armstrong, K., & Hwang, L. (2010). Future expectations of corporate environmental performance. Emerging ecosystem services tools and applications. BSR's Environmental Services, Tools & Markets Working Group. 24 pp.

[48] Adler, R., Mansi, M., Pandey, R. & Stringer, C. (2017). United nations decade on biodiversity: a study of the reporting practices of the Australian mining industry. Account Audit. Account. J. https://doi.org/10.1108/AAAJ-04-2015-2028

[49] UN Environment Programme World Conservation Monitoring Centre (2020). Biodiversity Measures for Business: Corporate biodiversity measurement and disclosure within the current and future global policy context. Cambridge, UK, 60 pp.

of the biodiversity concept itself contributed to this situation[46], others have purported that inadequate accounting systems were at least partially to blame[50].

4.2 NCA for Business: The parallel rise of corporate natural capital assessments

Parallel to the growing interest in BESS, was the need to provide an overarching framework for all corporate approaches dealing with environmental or natural issues. In 2016, The Natural Capital Protocol began harmonizing a great deal of knowledge. In doing so, it explicitly used the term "assessment" to capture the broad array of methods being used and/or developed, from quantitative impact measurements (e.g., GHG Protocol) to monetary valuation of externalities (Environmental Profit & Loss).

These natural capital assessment methods, sometimes referred to as *corporate natural capital accounting*, have been developed in an *ad hoc* manner to address various natural capital challenges and opportunities related to different business applications (Table 3). Typically, specific measurement (physical aspects of the environment) and valuation (i.e., qualitative, quantitative, monetary) methods[51] are associated with different business applications. For example, the business application group "comparing options" contains cost-benefit analysis methods while carbon accounting methods may be used to measure emissions of greenhouse gases (business application number 5 in Table 3).

Biodiversity impact assessment methods have different:

- areas of focus (e.g., product, production site, value chain),
- target audiences (e.g., internal decision makers, external stakeholders),
- purpose for the use of the results (e.g., product development, certificate),
- understandings of the relationships between corporations and natural capital (e.g., dependency, impact, impact drivers),
- contributions from experts from different disciplines (e.g., ecologists, economists) and
- level of data (primary/secondary) and accuracy of the results.

This has led to a diversity of methods which use disparate data and generate results that are not consistent, difficult to compare and challenging to integrate with one another.[52]

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[50] Houdet, J., Ding, H., Quetier, F., Addison, P., & Deshmukh, P. (2020). Adapting double-entry bookkeeping to renewable natural capital: An application to corporate net biodiversity impact accounting and disclosure. *Ecosyst. Serv. 45*, 101104. https://doi.org/10.1016/j.ecoser.2020.101104
[51] Natural Capital Coalition & eftec (2019). What is a Natural Capital Approach? URL: https://naturalcapitalcoalition.org/wp-content/uploads/2019/06/NCC-WhatIs-NaturalCapitalApproach-FINAL.pdf
[52] Capitals Coalition (2022). Time to Take Stock version 2.0. https://pointadvisory.com/wp-content/uploads/2022/11/Time-To-Take-Stock-version-2.0.pdf

To support permit applications, corporations may (1) measure impact drivers (e.g., emissions, effluents) and impacts (e.g., changes in ecosystem condition); (2) value ecosystem services used by the corporation or external stakeholders or (3) assess expenses and liabilities (e.g., wetland offset costs, emissions control equipment costs). With respect to external disclosures, corporations use a range of methods. Some may elect to apply the Global Reporting Initiative's (GRI) standard and thus disclose biophysical measurements (e.g., cubic meters of water consumed, tons of CO_2 eq., surface area of impacted ecosystems). By contrast, the Taskforce on Nature-related Financial Disclosures (TNFD) guidance focuses on financial implications (e.g., asset impairment, contingent liabilities) of specific physical environmental measures. Comparing natural capital datasets and performance can thus be challenging.

For example, the Aligning accounting Approaches for nature (Align)[53] project has worked on providing an agreed set of principles and technical criteria setting out 'what' elements of biodiversity should be measured and valued and 'how' this should be done in different decision-making contexts. The *Recommendations for a standard on corporate biodiversity measurement and valuation, aligning accounting approaches for nature*[13] was published in 2022 and made several key recommendations, including:

- The business context is important to determine appropriate measurement methods,
- The concept of 'double materiality' should be used to prioritize effort and attention,
- Indicators of ecosystem extent and condition should form the core of assessments of impact and dependencies.
- The need to move beyond ad hoc assessments towards quality corporate biodiversity accounting to demonstrate performance, notably whether targets are met on the ground.

Table 3. Business applications for corporate natural capital assessments. Adapted from Capitals Coalition (2022)[52].

Business application group	**Business application**
Compliance with laws and regulations	1. Permitting related to the environment (e.g., water quality, endangered species) 2. Compensation for damages (e.g., loss of ability to fish or recreate)
External disclosures and assurance	3. Voluntary disclosures (e.g., GRI, CDSB, CDP) 4. IFRS or GAAP aligned financial disclosures (e.g., contingent liability from oil spill)
Assessing past, current and future corporate performance (a.k.a. net impact)	5. GHG emissions across sites and value chains 6. Environment profit & loss (e.g., net acres of crops in a product)
Tracking progress to targets	7. Carbon neutrality targets for direct operations 8. Net positive impacts on biodiversity for greenfield projects

[53] https://capitalscoalition.org/project/align/

Comparing options	9. Product, service or process design and development 10. Comparing risks at different greenfield sites 11. Comparing technical options (e.g., wetland vs. built wastewater treatment facility)
Certification or audit	12. Forest management or Chain of Custody certification (e.g., FSC) 13. Environmental management systems (e.g., ISO 14001)
Third party engagement and rating	14. Comparative natural capital performance (e.g., CDP) 15. Databases and key performance indicators (e.g., Planet Tracker)
Product development	16. Efficiency of resources use/unit
Risk and opportunity assessments	17. Direct measurement of impacts and dependencies 18. LCA, input-output modelling 19. Mass balance measures 20. Estimations or industry averages from literature or databases 21. Productivity modelling

4.3 International standards on NCA consistent with national accounting

The System of Environmental-Economic Accounting (SEEA) is the first international standard for environmental-economic accounting. It was developed and released under the auspices of international organizations, including the United Nations (UN), the European Commission, the Food and Agriculture Organization of the United Nations (FAO), the Organization for Economic Co-operation and Development (OECD), the International Monetary Fund (IMF), and the World Bank Group (WBG).

SEEA serves as the accepted international standard for environmental-economic accounting, offering a framework for organizing and presenting statistics on the environment and its relationship with the economy. The scale of such accounts typically ranges from national to regional. However, the same principles can be implemented on other scales and for different actors, such as businesses or municipalities, among others. The SEEA brings together environmental and economic information in an internationally agreed set of standard concepts, definitions, classifications, accounting rules and tables to produce internationally comparable statistics. It consists of two main frameworks:

- *The SEEA Central Framework (SEEA CF)*[54]: adopted by the UN Statistical Commission in 2012 as the first international standard for environmental-economic accounting. SEEA CF provides a statistical standard to measure environmental flows, i.e., the flows of

[54] UN (2014). The SEEA Central Framework (SEEA CF). https://seea.un.org/content/seea-central-framework

natural inputs, products and residuals between the environment and the economy, and within the economy including:

- stocks of environmental assets (the stocks of individual assets, such as water or energy assets) and
- economic activity related to the environment (monetary flows associated with economic activities related to the environment, including spending on environmental protection and resource management, and the production of environmental goods and services).

- *The SEEA Ecosystem Accounting (SEEA EA)*[10]: complements the central framework and was adopted by the UN Statistical Commission in 2021. It takes the perspective of ecosystems and considers how individual environmental assets interact as part of natural processes within a given spatial area. The SEEA EA provides an international standard to ecosystems extent, condition, and their services both in physical terms, and principles and guidance to measure ecosystem services and assets in monetary terms.

In addition, SEEA developed several thematic accounts, including species accounts. For example, accounting for the abundance and/or persistence of the species important for provisioning services, such as concerning harvest of fish and timber; are well established in the SEEA Central Framework[54]. The assessment of species stock and rate of extraction using the accounting frameworks allows to understand if species are being harvested on a sustainable basis. Species accounts relevant for ecosystem services accounting and biodiversity footprint can go beyond the harvest of species for provisioning services; like population of pollinator species as a regulating service; or iconic animals for recreational activities.

4.4 Biodiversity Footprint

Biodiversity is a complex concept made of three parts: genes, species, and ecosystems, combined with various spatial and dynamic biotic and abiotic functions, interconnections, and features. Due to this complexity, measuring the extent of biodiversity loss is very challenging. Additionally, there are multiple drivers for biodiversity loss to consider and the impact is local rather than global (in comparison to climate change), which adds on to the complexity. The term footprint is defined in many ways depending on the need of the study. However, we define footprint as metrics that include both direct and indirect impacts of an activity transferred along the supply chain. The impact of, or change in the state of, biodiversity of a commodity, company, or community on global biodiversity is known as a *biodiversity footprint* (BF).[8] BF includes either parts of or the whole value chain of production and consumption of goods, services and/or exploitation activities. There is no standardized one for all methodology or guidance to measure the impact of economic activities on biodiversity. Based on recent scientific works, research, and publications (1) *Life Cycle Assessment* (LCA) and (2) *Input-Output* (I/O) *model* are identified as two of the common approaches used for the purpose of measuring and quantifying impacts on biodiversity. An overview of the two approaches and applications for biodiversity are described below.

4.4.1 Life Cycle Assessment

LCA is a methodology for systematically evaluating the environmental aspects of a product or service system through all stages of its life cycle. ISO 14040 has defined LCA as "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its lifecycle". ISO 14040[14] and ISO 14044[15] have specified the data requirements, steps, and principles for LCA. The main objective of LCA is to determine the environmental impact hotspot in the product value chain which can be further compared to different product scenarios. This is done following the four steps defined by ISO 14040: (1) *Goal definition* (2) *Life Cycle Inventory analysis* (3) *Life Cycle Impact assessment* (4) *Interpretation of Results.*

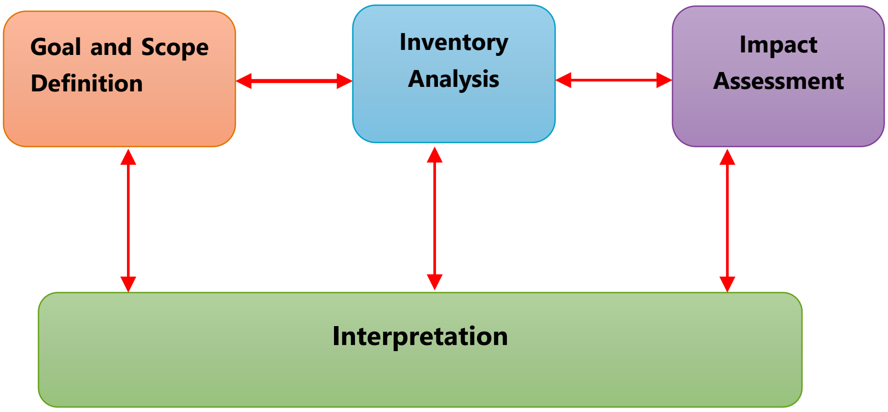

Fig. 3. Stages of an LCA Adapted from ISO 14040[14].

Climate change, land use change, pollution, over exploitation and invasive alien species are identified as the five main drivers of biodiversity loss.[55] LCA assesses the impacts either with mid-point impacts or with end-point impacts. Midpoint methods assess environmental consequences earlier in the cause-effect chain, typically linking the use of natural resources or generation of emissions to an impact on the environment (e.g., climate change, land use, ecotoxicity).[16, 17] Impact is derived using a simple multiplication between the mass of resource use or emissions generated, and specific factors called characterization factors (CFs). Endpoint methods link the midpoint environmental impact to damages to areas which are important to society (areas of protection, AoP). These AoPs are typically human-health, natural resources, and ecosystem quality.[7, 14]

Biodiversity loss, quantified in terms of species loss, is used as the metric to assess damages to ecosystems and is named as ecosystem quality among several endpoint indicators in LCA. LCA models have so far covered only climate change, loss of habitat/habitat change and

[55] Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. https://www.millenniumassessment.org/documents/document.356.aspx.pdf

pollution. Overexploitation/unsustainable use has been covered indirectly through other indicators e.g., water depletion potential implicitly considers overexploitation; AWARE is defined as total water use versus available water use, etc. but has not been directly represented through any impact categories or indicators. Furthermore, the invasive species are not covered at all in the standard practice although included as part of impact drivers. Pressures on biodiversity e.g., land use, water use, etc. are represented under mid-point impact categories while the overall biodiversity is represented under end-point category as ecosystem health/quality.[56] So far, though the endpoint category is said to be representing the overall biodiversity, only the impacts on species diversity are presented in the form of PDF, species richness, etc. Indicators covering all 3 levels of biodiversity still do not exist and thus, is a big challenge in fully integrating biodiversity into LCA. There are several research activities seeking to get this overall biodiversity perspective incorporated into LCA for e.g., EU horizon project BAMBOO[57].

4.4.2 Input-Output Model

I/O models include a system of linear equations describing the economic flows between all sectors/regions of a country in a certain year.[58] The I/O tables provide data on global trade flows and production/consumption recipes.[59] The I/O analyses are called Multi-Regional Input-Output (MRIO) analysis or EEMRIO (environmentally extended) analysis depending on the extent of the analysis or the coverage of the analysis. The MRIO/EEMRIO analyses are used to identify the consumption drivers of environmental impacts.

The use of I/O to trace important environmental flows has been developed since the 1940s. While the biodiversity aspect was probably first integrated in I/O in 2012, where trades and flows of commodities around the world was linked to spatial species and habitat data by an Australian research group[60], to understand patterns of international trading-induced species threats. The approach has later been developed and replicated in other studies.[58, 59] The I/O analyses follow the Leontief mathematical method. The models use industry aggregates or industry average data. Thus, I/O methods are used for supply chain level analysis and not product level.

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[56] Winter, L., Lehmann, A., Finogenova, N., & Finkbeiner, M. (2017). Including biodiversity in Life Cycle Assessment – State of the art, gaps and research needs. Environmental Impact Assessment Review, 67, 88–100. https://doi.org/10.1016/j.eiar.2017.08.006

[57] https://bamboo-horizon.eu/impact_ecosystem.html

[58] Marques, A., Verones, F., Kok, M.T.J., Huijbregts, M.A.J., & Pereira, H.M. (2017). How to quantify biodiversity footprints of consumption? A review of multi-regional input–output analysis and life cycle assessment, *Current Opinion in Environmental Sustainability, 29*, 75-81.

[59] Moran, D., Petersone, M., & Verones, F. (2016). On the suitability of input–output analysis for calculating product-specific biodiversity footprints. *Ecological Indicators, 60*, 192-201.

[60] Lenzen, M., Moran, D., Kanemoto, K. et al. (2012). International trade drives biodiversity threats in developing nations. *Nature, 486*, 109–112. https://doi.org/10.1038/nature11145

In this report, we have considered databases (Table 4) that include environmental extension in the original I/O model and known as EEMRIO. The I/O databases are the databases of pressures such as land use, water use, etc., through which pressure footprints can be calculated. The environmental extension helps to understand the connection between the economic activities and downstream environmental impacts and measures the direct impacts/pressures of a production sectors in a certain country or region.[58]

Table 4. I/O Database Summary table. Adapted and modified from A. Marques et al. (2017).[58]

Name of the Database	Spatial scale	Land use	Water use	Carbon emissions	Pollution	Access
EORA	187 countries/26-511 sectors	Y	Y	Y	Y	Free access for degree granting academic institutions
EXIOBASE	44 countries/5 regions/163 sectors/200 products	Y	Y	Y	Y	Free
WIOD	40 countries/1 region/35 sectors	Y	Y	Y	Y	Free
GTAP 9	122 countries/18 regions/57 sectors	Y		Y		Ownership based
GRAM	54 countries/1 region/48 sectors			Y		NA

5 Mapping existing methods

5.1 Review of NCA, LCA and I/O assessment -based methods

We performed a review of existing methods (Annex 3), with the aim to provide an overview of what has been done so far and what kinds of methods and tools exist in the field of biodiversity impact assessment. A selection of NCA, LCA and I/O-based methods were reviewed with focus on: (1) the method, (2) how it can be implemented, as well as (3) possibilities and restrictions on how to use the method. As part of the reviewing, we classified each method into different assessment approaches, types, focus, scope as well as output type (Table 5).

The selection of methods was made primarily based the authors' earlier experiences, in combination of screening of research reports, scientific papers, and/or review papers, e.g., Damiani et al. (2023)[3]. In addition, the applicability of methods within the five sectoral case-study hubs in CircHive-projects (agri-food, biomaterials, retailers, investors, cities) was considered. In Annex 3, the full review is presented. The methods' review is critical for further work in CircHive, but also provides a useful insight for the wider community.

Table 5. Classification criteria (and number of methods) in methods' review.

Assessment approach	Assessment type	Assessment focus	Scope	Output type
NCA (10) LCA (31) I/O (5)	Performance assessment (27) Risk assessment (13)	Dependency (7) Impact (31) Impact driver (12)	Product (20) Company/Production site (13) Business sector/investor portfolio (5) Global (2) Country/Region (5) Local (1) All levels (1)	Qualitative (2) Quantitative (36) Monetary (7)

In case of NCA, all the methods that included the biodiversity perspective are reviewed. For LCA, the methods that included minimum one driver of biodiversity loss as defined by IPBES[61] from the LCA perspective are included in the review. Finally, for I/O, since there is no particular I/O method for biodiversity footprinting but rather they are incorporated together with other methods/models such as PDF, MSA etc., for the BF purpose, few (among several) example methods (representing different I/O databases and different incorporated models) were selected and reviewed. Thus, not all I/O methods published were reviewed. In total, 45 methods were reviewed in this first version: NCA (10), LCA (31) and I/O (5) (Table 5). Biodiversity footprint studies are mostly overflowed with LCA studies, but instead very few NCA and I/O studies have been done. Most of the methods reviewed provided quantitative output, but this was also a preference in the methods selection. Most of the methods focused on products, but also company or production site focus was well represented. Less methods could also assess the impacts of a Business sector/investor portfolio or a Country/Region. Implementation examples on different methods are given below.

NCA implementation examples:

[61] https://www.ipbes.net/models-drivers-biodiversity-ecosystem-change

- assessing company's biodiversity impacts/dependencies of direct operations and/or supply chain
- assessing financial sector's dependency on natural capital
- valuing ecosystem assets, extent, and condition of a forest estate
- quantifying restoration/preservation expenses to reach sustainability targets
- accounting for net impact of a biodiversity offset site

LCA implementation examples:

- comparing process design scenarios of a product
- comparing processing options or in agriculture production systems
- calculating biodiversity footprint for a product and comparing products
- comparing biodiversity impacts of different product use cases
- calculating biodiversity footprint for a whole value chain

I/O implementation examples:

- calculating indirect environmental impacts by tracing consumptions drivers
- finding links between biodiversity threats and production activities of certain industries
- calculating biodiversity and ecosystem services impacts per unit of Gross Domestic Product (GDP)
- calculating impact of economic activities of certain sector, industry, region or country on species loss, extinction of species or overall biodiversity loss.

5.2 Learnings from method mapping

Looking into the characteristics of the methods (Annex 3), some of them were more universal, while others addressed one or more specific need(s). The starting point of a biodiversity impact assessment is always defining the need. Is the focus a precise picture of the state of biodiversity for a specific production site? Or is it understanding the risks over an entire value chain? In any case, it would be difficult to propose one single tool or method to meet every need. The Align-project has also recommended the selection of methods/approaches based on the requirement/applicability of the business contexts, according to stakeholder or end-use requirements[13]. Regarding the impact on biodiversity, the focus can be on species and/or ecosystems (Fig. 4). In this method mapping process, the genetic diversity/diversity within species was missing from the assessment methods, thus Fig. 4 was edited, presenting only the aspects that have been so far covered by the reviewed methods. Through method mapping, we tried to understand the typical uses of the methods. Below an overview of insights from this work is provided.

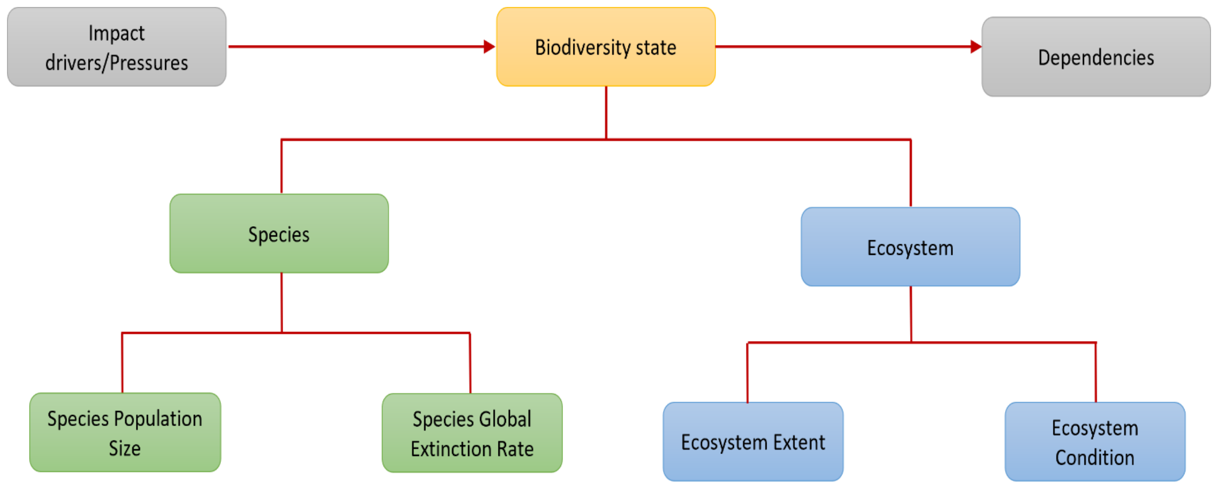

Fig. 4. Assessment focus (Impact drivers -> Impact -> Dependencies) and components of biodiversity. Adapted from Align project (2022)[13].

5.2.1 NCA

NCA methods are mostly used for a performance assessment on some geographical area, e.g. country, region or site. The assessment focus can be either the impact on biodiversity or the company's dependency on natural capital. The best accuracy with a NCA method is obtained with primary data through own data collection.[52] However, there is a trade-off between primary data needed and accuracy of the results, i.e. if more primary data is included, the accuracy may be better, but the assessment is more time and resource-demanding and vice versa.

Often in an NC assessment, but also in an LCA, the current condition is compared with a baseline condition, which in turn often reflects a "natural" or pre-industrial intact condition. The selection of the baseline condition has a profound influence on the results. Instead of using a natural condition it might also be appropriate to use some other baseline condition.[13] Either way, it is important to understand how this affects the results to communicate it adequately.

5.2.2 LCA

LCA methods are used for both risk and impact assessments of a product or a value chain. These assessments focus on impact drivers, which are then converted to biodiversity impacts with characterization factors in end-point methods. The resulting impacts from LCA methods are mostly linked to species loss, e.g., by Potentially Disappeared Fraction of Species (PDF). The current methods are typically focused on terrestrial ecosystems, for which the spatial resolution varies. LCA studies may include information relevant for a particular location, this is typically at the foreground level, while background data from common commercial databases offer very limited location granularity, and impact factors included in common databases and software typically do not include a spatial component (e.g. a single global impact factor for land use)

Most of the LCA methods focus on land use, which is then converted to species loss. Some methods also include other impact drivers. However, there is a risk of double counting (e.g., spatial overlap of changes in biodiversity due to various impact drivers), if each impact driver is assessed one at a time and then converted to the same unit e.g., species loss. On the other hand, without the conversion, the problem is how to compare the impacts, e.g., land use, water use, emissions, etc. Many LCA methods have their own database associated with the method. Only a few methods allow you to integrate your own 'field' data, i.e., primary data, and thus the results stay on a general level.

5.2.3 I/O models

I/O analysis is particularly useful to get an overview of an industry, sector, region, or country as it provides good aggregate data and helps identify industry hotspots. To identify key consumption sectors[59] and link consumption patterns to biodiversity, impacts[58] are seen as the focus of current I/O studies under the field of biodiversity footprint. There have also been studies exploring the possibilities to develop a so-called hybrid LCA-MRIO approach for product-based biodiversity footprints[59], combining the I/O analysis and LCA models. There are no specific methods identified as biodiversity footprint methods under I/O. Hence, 5 different articles using different I/O databases and methods for quantifying the biodiversity impacts were selected to provide an overview of what kind of aspects are covered when an I/O method is used for biodiversity footprint and how it is done.

An interesting aspect recognized during this review process is that I/O databases cannot independently quantify the biodiversity impact. There is one exception to this: EXIOBASE, which does generate biodiversity footprint metrics because it includes pre-calculated state impacts (though it only covers a few impact drivers/pressures). The I/O models can calculate the pressure footprints, but for biodiversity footprinting, it must be incorporated together with other models e.g., PDF methods, MSA methods, etc. This is also evident from the methods reviewed. In addition, to increase the outreach and depth of data coverage of I/O models, which would allow to break down the aggregated industry or sector data into smaller, more detailed, disaggregated products and provide better accuracy of the results, I/O databases are incorporated with LCA databases, and these incorporated versions are called hybrid models. Various names are used for these hybrid models in different research e.g., hybrid LCA, hybrid MRIO, etc.

Table 6. Summary of findings from NCA, LCA and I/O methods' mapping.

	NCA	LCA	I/O
Typical use	A performance assessment in a geographical area, e.g., country, region or production site	A risk assessment focusing on product and/or value chain	A risk assessment based on supply chain/sector/industry/region/country
Data	Primary data from own data collection	Process based average data	Industry/sector based average data
Strengths	Exact and precise, cover species, ecosystem extent and ecosystem condition	Well-developed models for land-use driven biodiversity loss in terrestrial ecosystems, for assessments on products/value-chains	Provides a good overview of overall sector/industry, is thus suitable for quick, low-cost initial screening of economic activities and their impacts on the environment/biodiversity through environmental extensions
Weaknesses	Difficult to apply for a product and/or value chain	Other pressures than land use (and land use change) is only covered in a few methods	Aggregation error, tends to miss some important aspects in the analysis due to the aggregation of the data, uncertainty of results due to missing details
Opportunities	Possible to identify biodiversity hot spots for more detailed assessment	There are promising methods than can be further developed, e.g. through developing indicators for all impact drivers, filling data gaps etc; possible to identify biodiversity hot spots for more detailed assessment	widening the scope of analysis, I/O analysis of product-based biodiversity footprint is good possibility; possible to identify biodiversity hot spots for more detailed assessment
Risks	Compromising data requirements for decreasing the workload, might result in unreliable results	Setting system boundaries, defining of reference situations, and quality of input data influence strongly on results, which should be interpreted with care	Uncertainty or inaccuracy of results due to missing details in the aggregation

5.3 Implementing the methods for business applications

Results from method mapping were used to create a business application table (Annex 1), which gives detailed information about the scope of the methods when implemented for business applications. The scope includes product/service, site/project, value chain, supply chain, corporate, portfolio/sector and country/region. The methods column includes all the NCA, LCA and I/O methods that have been mapped in our review work. The methods are arranged based on the assessment approach (NCA or LCA) and the date of their publication so from the oldest to the newest. The first 10 methods are the NCA methods and last 5 are the I/O methods while in between are all LCA methods. This business application review depicts that among the reviewed NCA methods, Natural Capital Protocol (NCP) provides the full coverage of all the defined scopes. In addition, among LCA methods too, Ecological Scarcity, Recipe 2016, LUCI-LCA, LC-Impact, BIM and GBSFI include all the defined scopes. The review shows that the coverage of the methods reviewed is mainly between value chain to portfolio/sector. While on the other project/site and country/region are the least covered scopes.

The business application table (Annex 1) provides a concise overview of different methods based on the scope of the business application. The work continues in Task 2.2 and the methods will be analyzed more in detail also regarding other aspects e.g., coverage regarding impacts on biodiversity (Fig. 4) and the impact drivers for biodiversity loss. So far mainly "species global extinction rate" regarding impacts and "land use/land use change" regarding impact drivers are covered well in the reviewed methods and the other aspects have gained less attention.

6 Tool screening

The rapidly evolving landscape of methods, tools, indicators, and metrics to measure and value the risks, impacts and dependencies of businesses on biodiversity illustrates how biodiversity measurement is gaining traction among the business community. For instance, the latest update on the report "Assessment of Biodiversity Measurement Approaches for Businesses and Financial Institutions" from the EU Business and Biodiversity Platform (2022)[62] describes 29 approaches, with various maturity levels ranging from pilots to operational approaches. Another example is the tool database, provided by The Science Based Targets Network (SBTN)[63] of which over 40 tools include biodiversity. Additionally, several companies have

[62] Lammerant, J., Driesen, K., Verhelst, J., De Ryck, J. (2022). Assessment of Biodiversity Measurement Approaches for Businesses and Financial Institutions – Update 4. EU Business @ Biodiversity Platform. Available at: https://green-business.ec.europa.eu/business-and-biodiversity/our-activities/workstreams/measuring-your-impacts-and-dependencies-biodiversity_en
[63] https://sciencebasedtargetsnetwork.org/

started to develop their own tools/biodiversity modules, to e.g., collect data from primary producers, set targets and communication purposes, adding to the variety of tools.

The increasing number of tools opens opportunities for businesses to start their biodiversity footprinting journey, while at the same time the fast increase of number of tools and their variety can lead to confusion in the business world as well as among NGOs and other experts.

6.1 The screening procedure

The primary focus for this report was to review methods, rather than tools. However, due to the increasing number of tools, and because tools are closely connected to methods and often more used by the business community than the methods themselves, we decided to complement the work with a tool screening, limited to 19 different tools (Annex 2). The selection aimed to reflect the diversity of tools and its application areas. This was limited to open-access tools, with some exceptions. Inspired by the SBTN tool database, we created a table with parameters to summarize our findings (Table 7).

Table 7. Table used for the tool screening, modified from the SBTN tool database[63].[63]

Tool – overview							Data		Scope	
Tool	Tool class	Description	Tool type	Open-access (Y/N)	Methods	Skills required (high, medium, low)	Input data	Output data	Scope (geographic and sector)	Spatial resolution

6.2 Tool classes

Since different levels of decision making (and action) related to biodiversity require different types of tools, the tools were grouped into two classes: (1) *biodiversity risk assessment tools*, (2) *biodiversity impact assessment / monitoring tools.*

(1) <u>Assessing risks for biodiversity:</u> In the phase of planning supply chains, designing new products, selecting sourcing regions, etc., risk assessment tools help detecting potential negative impacts on material biodiversity and ecosystems (services) beforehand. Examples for risk assessment tools are the WWF Biodiversity Risk Filter, the Nature Risk Profile methodology (UNEP 2023), the Integrated Biodiversity Assessment Tool / IBAT (IUCN, Bird Life International, UN-WCMC) and others.

(2) <u>Measuring impacts on biodiversity and the associated business performance:</u> Many tools focus on assessing the changes in the state of biodiversity (i.e., impacts), while some offer additional features, such as performance assessment or progress monitoring.

For example, in food supply chains tools, such as the Cool Farm Tool (Cool Farm Alliance), the Biodiversity Performance Tool and the Farm Sustainability Assessment / FSA (SAI Platform), support biodiversity impact assessment undertaken at the farm level. Most of the tools to determine the level of sustainability – including biodiversity – have been developed for the food sector with agriculture as the main provider of raw material, e.g., the SMART Tool (Fibl) or the RISE Tool (Berner Fachhochschule). New tools such as the Regionalwert-Leistungsrechner (Regional Agricultural Performance Calculator)[64] aim to make sustainability in agriculture visible and give it a monetary value to reward practices in agriculture which contribute to the common good, improve the environment and strengthen the local economy.

In addition, some tools offer monitoring solutions to help companies track biodiversity performance across various scopes, such as a supply chain – e.g., the contribution to biodiversity loss as well as the (potential) improvement of biodiversity state. Examples of such tools include The Biodiversity Monitoring System (BMS) of Food for Biodiversity that collects data on habitats, ecological structures etc. on the farm and on agricultural practices affecting biodiversity.

The tool screening is presented in Annex 2 under which 8 tools belonged to the first category, *assessing risk for biodiversity* while 10 to the second category, *measuring impacts on biodiversity and the associated business performance*. Referring to the ease of use of the tool, only one tool required high level skills/training, 11 required medium level skills while 6 required low/basic level skills. 14 tools among the reviewed have global coverage while at least 7 include agriculture and food sectors.

However, the performed tool screening is not a complete list of tools but rather provides examples on types of tools and how they can be used as a complement to the method mapping.

7 Results based on case study survey and interviews

CircHive-project started by designing and conducting a survey for case study partners (CSP). All eleven CSP answered, including nine private and two public organizations. The respondents represent all five case study hubs of CircHive i.e., *food and agriculture*, *biomaterials*, *retailers*, *financial sector,* and *cities*. The objective of the survey was to understand what CSPs are currently doing/have done to evaluate, report and reduce their environmental impacts; and to learn their understanding of biodiversity aspects in relation to other environmental aspects. In addition to the survey, interviews were conducted with each CSP (except cities, which will be interviewed later) to get an in-depth understanding on their needs and support required/expected from CircHive, to create a common ground of understanding on topics

[64] https://www.regionalwert-leistungen.de/about-us/

related to biodiversity footprint (BF) and natural capital accounting (NCA) and further develop planned pilots accordingly. Based on the results from the survey and analysis of the interviews conducted, the overview of results is presented below.

7.1 Focus on business impacts and/or dependencies

All CSP responded that they are aware of their organization's impacts on the environment and most of them also on biodiversity. They further state that they are trying to make a positive impact and reduce negative impacts on the environment and biodiversity, e.g., by reducing resource use and by preventing any harmful impact. Despite not having any monitoring or measurement of natural capital, CSP responded that they are today – to various degrees, e.g., dependent on the sector – able to recognize their dependence on natural capital e.g., land and water use.

7.2 Data collection and needs

The primary focus for the CSP on data collection is product or supply chain. A few responders also include the farm or site level. The organizations collect a lot of primary data from their own operations, the supply chains, and the suppliers, often with the aim of ensuring the quality and transparency of their products. When required, the gaps are filled with data from national and global databases. The CSP highlighted that harmonization of available biodiversity data is a key need. Another bottleneck is the difficulty in accessing biodiversity related data – not due to not being available, but because of the complexity and vagueness of the data requirements for assessing the impacts. Furthermore, the CSPs expect to see the development of methodologies for biodiversity impacts at the same level as the environmental impact methodologies.

7.3 Current uses and needs for BF and NCA for private and public actors

The surveys and interviews showed that most of the CSP claim that they are involved in biodiversity related activities. However, the levels of involvement and the content vary a lot – some are in the very beginning of their biodiversity journey, while some are well familiar with the concept of dependencies and impacts on biodiversity and already initiated the assessment process and/or even created their own measurement tool. Overall, the CSP state that they are aware of the importance of biodiversity, their role in the conservation of nature and have a great interest in assessing their impacts.

Overall expectations either towards BF or NCA was a solution for how to measure your target of "being net positive on biodiversity" or that you have "improved the key indicator species by 10%". LCA as a methodology for BF was quite well known among the CSP, but only few had used it for climate impact assessment only. BF was seen as a potentially useful tool for internal use, but also towards the consumers to be able to compare products, if there were some harmonized approaches.

From a NCA perspective, the survey and interviews showed that the organizations had limited to no knowledge exactly about NCA directly as a concept but were able to relate to the idea of NCA e.g., through the understanding what natural capital is and the impacts on nature they need to be aware of. Furthermore, CSPs linked to primary production even had some pilot studies like counting species, but more to study the effort of some management practices on biodiversity rather than from NCA perspective. On a larger scale, the NCA approach was seen difficult to implement as measuring everything on every farm or forest site would require too many resources. The CSP also highlighted a need for a 'one-for-all-kind' method, that could assess positive and negative impacts on all environmental aspects, including biodiversity. While this need may be understandable, our research shows that different methods and tools answer different questions and respond to different business needs (e.g., site performance management vs risk screening in a supply chain). Besides, biodiversity cannot be represented by a single or couple of metrics but rather by a complex set of metrics applicable to specific business applications and scopes, and hence not readily produced by a single method or tool.

8 Conclusions

The frontrunner companies developing more sustainable products with renewable or recycled raw materials and using renewable energy and/or nature-based solutions, have long struggled with economic feasibility of the business, due to the lower cost of linear economy models and fossil resources. The green transition took a big leap forward, when in January 2023, the EU Corporate Sustainability Reporting Directive (CSRD) entered into force, requiring all large companies operating in the EU and all listed companies (except for micro-enterprises) to disclose information on a range of ESG topics, including biodiversity. Standardized biodiversity footprinting methods would enable even better comparisons between products and companies.

While this renewal brings opportunities, it also raises concerns within the industry. Do we have all the data needed or do we get it from the suppliers? Do we have the knowledge and resources to carry out the required data collections, assessments, and reporting? All in all, there is a strong need for simplified and standardized methods and procedures, and harmonized data sets.

Task 2.1 in CircHive-project focused on: reviewing on existing academic approaches and gaps for NCA and BF; understanding business viewpoints on current uses of and needs for NCA and BF through survey and interviews of case-study partners; and summarizing possibilities and restrictions of different NCA and BF methods.

Method's review included NCA (10), LCA (31), and I/O (5) based methods. The three different approaches had their own typical uses, strengths, and weaknesses. NCA-based methods were mostly used for valuing ecosystem assets, extent, and condition of some geographical area, e.g., country, region or production site. LCA-based methods were mostly focusing on product or production process. I/O-models were able to assess the impact on the whole value-chain or business portfolio, although not alone but with the help of a LCA method.

On the other hand, NCA-based methods are difficult to apply for a product and/or value chain; current LCA-based methods have not covered other impact drivers than land use (and land use change) in biodiversity, and there is some uncertainty with I/O-results due to missing details and aggregation of the data. It would be difficult or even impossible to develop one method that would fit all the users. On the other way round, the gaps in one method could be covered with another method. Based on the findings, the synergies and differences between assessments and accounting methods need to be further explored (Task 2.2). For instance, would accounting approaches be useful and possible for all business applications?

As a result from tool screening, the several types of supporting tools were divided into two main classes: (1) biodiversity risk assessment tools and (2) biodiversity impact assessment / monitoring tools. Tools are always based on some method. They lower the threshold of using a method by providing step-by-step guidance for the user. However, they might lower the transparency if all the background values and models are not described in detail.

The survey and interviews of case-study partners (CSP) focused on data and methods. The data quality directly links to the results of the biodiversity impact assessment. Access to good, harmonized data throughout the value chain is challenging. But it is even more difficult to know what kind of data is needed when measuring impacts on biodiversity.

Overall expectations towards BF or NCA was a solution how to measure your target of "being net positive on biodiversity" or to reach the statement that you have "improved the key indicator species by 10%". LCA as a methodology for BF was quite well known among the CSPs, but it had been used mainly for assessing climate change related impacts. NCA was not so well known, although some CSPs had been collecting biodiversity data in a similar manner than in NCA. At first impression, the NCA approach was seen difficult to implement as measuring everything on every farm or forest site would require a lot of resources.

The key for businesses to contribute to safeguarding biodiversity (and their businesses of which nature depends on), and to survive the upcoming regulatory transformations and economic changes, is to gain good knowledge of their own impacts and dependencies on natural capital. But it is not only that – sustainable natural capital management is also critical to manage risks, seize opportunities and to find balance between business and biodiversity.

9 Annexes

Annex 1. Examples of Methods for Business applications.

Annex 2. Tool screening output.

Annex 3. Mapping existing Methods with classification criteria.

Annex 1. Examples of Methods for Business applications (Yes= green; No = White)

Chapter number	Name of the method	Product/service	Site/project	Value chain	Supply chain	Corporate	Portfolio/Sector	Country/Region
1.1	LIFE Methodology		Yes			Yes		
1.2	Environmental profit and loss (EP&L)	Yes	Yes	Yes	Yes	Yes	Yes	
1.3	Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)		Yes		Yes	Yes	Yes	Yes
1.4	Natural Capital Protocol	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1.5	Site-based direct biodiversity state measurement		Yes		Yes	Yes		Yes
1.6	Biological Diversity Protocol		Yes		Yes	Yes		Yes
1.7	Comprehensive Accounting in Respect of Ecology (CARE)					Yes		
1.8	Double-entry bookkeeping applied to natural capital		Yes		Yes	Yes		Yes
1.9	SEEA EA		Yes			Yes		Yes
1.10	British Standard BS 8632:2021		Yes			Yes		
2.1	Stepwise 2006	Yes	Yes				Yes	
2.2	Ecological scarcity	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2.3	Land use impacts on biodiversity in LCA: a global approach	Yes	Yes	Yes				Yes
2.4	ReCiPe 2016	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2.5	Biodiversity impacts from water consumption on a global scale for use in LCA	Yes		Yes	Yes	Yes	Yes	
2.6	Biodiversity Damage Potential (BDP)	Yes	Yes					
2.7	Land Use Change Improved LCA (LUCI-LCA)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2.8	Land use intensity specific biodiversity footprint (LUIS)	Yes			Yes			
2.9	Forest Fragmentation Potential						Yes	
2.10	IMPACT World+	Yes		Yes	Yes	Yes	Yes	
2.11	MariLCA - An effect factor approach for quantifying the entanglement impact on marine species of macroplastic debris within LCIA	Yes		Yes	Yes	Yes	Yes	

2.12	Valuing Biodiversity in Life Cycle Impact Assessment							
2.13	BioImpact							
2.14	Global Biodiversity Score (GBS)							
2.15	LC-Impact							
2.16	Product Biodiversity Footprint (PBF)							
2.17	Land use Impacts on Functional Plant Diversity (FPD)							
2.18	Biodiversity Impact Metric (BIM)							
2.19	Biodiversity Indicators for Site-based Impacts (BISI)							
2.20	Empirical characterization factors to be used in LCA and assessing the effects of hydropower on fish richness							
2.21	Global Biodiversity Score for Financial Institutions (GBSFI)							
2.21	Biodiversity Footprint for Financial Institutions (BFFI)							
2.23	Biodiversity Metric 4.0							
2.24	Moving beyond land use intensity types: assessing biodiversity impacts using fuzzy thinking							
2.25	Considering habitat conversion and fragmentation in characterization factors for land-use impacts on vertebrate species richness							
2.26	Corporate Biodiversity Footprint (CBF)							
2.27	MariLCA - Development of simplified characterization factors for the assessment of expanded polystyrene and tire wear microplastic emissions applied in a food container life cycle assessment							
2.28	MariLCA - An effect factor approach for quantifying the impact of plastic additives on aquatic biota in LCA							
2.29	Global Extinction Probability (GEP)							
2.30	MariLCA - Characterization factors for microplastic impacts in life cycle assessment: Physical effects on biota from emissions to aquatic environments							
2.31	The LANCA® method including BioMAPS							

3.1	On the suitability of input-output analysis for calculating product-specific biodiversity footprints							
3.2	Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis							
3.3	Increasing Impacts of land-use on biodiversity and carbon-sequestration driven by population and economic growth							
3.4	Consumption-based biodiversity footprints – Do different indicators yield different results?							
3.5	Biodiversity footprint assessment for corporations							

Annex 2. Tool screening output.

Tool – overview						Input / Output		Scope	
Tool	**Description**	**Type**	**Open access**	**Method**	**Skills required**	**Input data**	**Output data**	**Geographic and sector**	**Spatial resolution**
Assessing biodiversity risks									
WWF Biodiversity Risk Filter[65]	The WWF Biodiversity Risk Filter supports companies and financial institutions to explore and assess biodiversity risks related to the sourcing country or region of raw material. Biodiversity Risk Filter follows a four-level hierarchy: 1) risk type, 2) risk category, 3) indicator and 4) metric.	Web-application	Yes	Classification of risks aligns with TNFD	Low	Industry sector, supply chain data, business importance, location, commodity	Scape risk scores for physical risks and reputational risks, top ten risk indicators	Global, 25 industrial sectors	
Nature Risk Profile[66]	A tool for Profiling Nature Related Dependencies and Impacts guideline aims to enable the financial sector to measure and address nature-related risk by providing scientifically robust and actionable sustainability analytics on nature impacts and dependencies.	Guide-book	Yes	Exploring NC Opportunities, Risks, and Exposure	Medium	Geospatial biodiversity datasets, S&P Global's information on local business activities	Global geographic scope, can be applied in various regions and sectors	Global, financial sector	
Integrated Biodiversity Assessment Tool (IBAT)	A subscription-based service that provides users with access to authoritative global biodiversity data. The tool is underpinned by three of the world's most comprehensive biodiversity datasets: the IUCN Red List of Threatened Species, the World Database on Protected Areas, and the World Database of Key Biodiversity Areas. IBAT allows users to visualize and analyze this data, making it a valuable resource for conservation planning, policy development, and environmental impact assessments.	Web-application	Yes and No. IBAT can be used for free, but businesses pay	Biodiversity: IUCN Red List, World Database on Protected Areas and KBAs.	Low	Polygons are required to develop reports but can be drawn within the tool if no spatial data are available.	E.g. fresh water analysis, proximity analysis and STAR. Can generate maps of KBAs and other areas and link these with the Red List.	Geographic (spatial models)	Multi-level applications

[65] https://riskfilter.org/biodiversity/home
[66] https://www.spglobal.com/esg/solutions/nature-risk-profile-methodology.pdf

Toolkit for Ecosystem Service Site Based Assessment (TESSA)[67]	A guidebook-based toolkit aimed at providing a series of methodologies to quickly assess the importance of a series of ecosystem services based on field observations, interviews, and simple models. Particularly adapted to data-scarce environments and will give the evaluator a qualitative understanding of the relative importance of different ecosystem services.	Guide-book	No	NCA	Medium		Qualitative and quantitative	Global	Project-level
Resource Watch[68]	A tool consisting of a collection of hundreds of global datasets covering information about resources and human geography worldwide. It aims to visualize current global challenges, e.g., climate change, poverty, water risk, state instability, air pollution.	Data Repository	Yes		Low	N/A	Quantitative (format depends on the source data e.g. maps, xlxs)	Global and region specific, cross sector	Global maps (possibility with certain maps to enlarge to country-level)
Species Threat Abatement and Restoration (STAR)	A conservation tool that assesses the potential impact of conservation actions on the extinction risk of threatened species. The STAR metric considers both the current threats (Threat Abatement Metric) facing species and the potential for habitat restoration (Restoration Metric) to improve their populations. The STAR metric can be used to identify priority areas for conservation and restoration action and enables actors to add up their total contributions to preventing biodiversity loss.	Web-application, but linked with field assessments for calibration	Limited number of free runs, then it becomes a paid tool	The STAR value of a pixel is calculated using the number of threatened species.	Medium	IUCN Red List of species that are in the different threat categories, their distribution and level of threat. Local field data for calibration.	An assessment report and several csv files containing scores for each threat type, and a csv file with the spatial location of each pixel.	Global (terrestrial)	5 km by 5 km
Global Safety Net[69]	The aim of the tool is to provide information regarding terrestrial areas globally that are essential for biodiversity as well as climate resilience and visualize the impact that	Dataset	Yes		Low	N/A	Quantitative (visualization of quantitative data)	Global, cross-sector	Country boundaries with possibility to

[67] https://www.birdlife.org/tessa-tools/
[68] https://resourcewatch.org/about
[69] https://www.globalsafetynet.app/

	preservation of land in these areas would have on climate change and biodiversity.								aggregate on US states
NatureMap/ Explorer[70]	Provides a set of global maps on biodiversity and ecosystems on a global scale aimed to provide information regarding biodiversity loss and net GHG from land use.	Data Repository	Yes		Low	N/A	Quantitative (maps, spatial data)	Global, cross-sector	
Tool	**Description**	**Type**	**Open access**	**Method**	**Skills required**	**Input data**	**Output data**	**Geographic and sector**	**Spatial resolution**
Measuring biodiversity impacts and monitoring the associated performance									
Cool Farm Tool[71]	The Cool Farm Tool is a greenhouse gas calculator intended for product-level calculations of outputting emissions for individual products produced on-farm. It can also be used for determining and assessing the state of biodiversity performance (on farm-level). The Cool Farm Tool's (CFT) main feature is a greenhouse gas (GHG) calculator.	Web-application	Yes	For biodiversity: action-based approach, where points are given for efforts made	Medium	For biodiversity: expert judgement as collected in "Conservation evidence database"	Quantitative visualization of a biodiversity score that updates as farmers input their actions	Global, agriculture	Farm-level
Biodiversity Performance Tool (BPT)[72]	BPT facilitates the assessment of the potential for functional biodiversity at farm level by collecting data on biodiversity management and agricultural practices for 79 keydata/indicators. The BPT supports farmers and farm assessors to identify the current situation regarding biodiversity on the farm, to evaluate basic indicators (traffic-light system) and to select effective measures for a Biodiversity Action Plan (BAP).	Web-application	Yes	Three categories of thresholds (green/yellow/ red) have been selected for the basic indicators	Medium	Agricultural practices with relevance for biodiversity: pesticide and fertilizer management, soil, crop rotation, water, GMO plants and breeds	Evaluation of 79 basic indicators according to a traffic-light system, links to the description of measures to improve biodiversity	Europe, Agriculture	Farm-level
Farm Sustainability	Flexible sustainable sourcing model for users, as it enables buyers to understand the sustainability levels of the crops that they are	Web-application	Yes		Medium	Farm-level questionnaire, self-	Self-assessment report, levels	Global, agriculture	Single farm or group of farms

[70] https://explorer.naturemap.earth/about
[71] https://app.coolfarmtool.org/account/login/?next=/
[72] https://www.biodiversity-performance.org/

Assessment (FSA)[73]	sourcing, either through farmers directly applying the FSA, or through the benchmarking of pre-existing farm-level sustainable agriculture programmes.					assessment, answer ‘yes’ or ‘no’ to 109 questions	FSA gold, silver, or bronze		
Sustainability Monitoring and Assessment RouTine (SMART)[74]	Holistic sustainability analysis and evaluation of agricultural and food companies. Based on the globally valid SAFA guidelines. It consists of an own database as well as a scientifically sound evaluation methodology including an extensive indicator pool. The assessment method involves a weighting of the indicators according to the level of impact on the various SAFA subthemes.	Web-application	No	Own method based on the Sustainability Assessment of Food and Agriculture systems (SAFA)[75]	High	The SMART tool requests information on governance/management, environmental and economic resilience, social integrity	Graph and report regarding 21 sustainability topics according to the SAFA Guidelines	Global, food sector	Farm-level, company-level
RISE tool[76]	“Response-Inducing Sustainability Evaluation” (RISE), which allows an easy assessment at the farm level. It is system-oriented and offers a holistic approach for advice, education, and planning.	Model	Yes	Computer-supported indicator-based method	Medium	RISE is based on twelve indicators of economic, ecological, and social situation	The results identify weak aspects of the farm and help induce steps to improve	Local, agriculture	Farm-level
Biodiversity Monitoring System (BMS)[77]	The BMS allows standards, food companies and cooperatives to monitor the biodiversity performance of certified farms/supplying farmers/members. The monitoring is based on 60 indicators with high relevance for the protection and creation of potential for biodiversity and the reduction of negative impacts.	Web-application	No, needs registration	BMS describes the development over time of the main indicators	Medium	109 data /information covering nine clusters	Report on the current state of performance of a group of farmers	Europe, agriculture	Group of farmers

[73] https://saiplatform.org/fsa/
[74] https://organic-farmknowledge.org/tool/39608
[75] https://www.fao.org/nr/sustainability/sustainability-assessments-safa/en/
[76] https://www.bfh.ch/dam/jcr:0540a777-ab97-4555-b7ca-bb71904ae97c/what-is-rise.pdf
[77] https://bms.biodiversity-monitoring.info/

Local Ecological Footprinting Tool (LEFT)[78]	A land-use impact assessment tools aimed for companies with site-based impacts. The tool produces maps of land cover classes and data on biodiversity parameters (e.g. number of threatened species, habitat fragmentation, habitat connectivity).	Web-application	Yes		Medium	Spatial data	Quantitative/GIS data	Global, cross-sector	Up to 0.5 x 0.5 decimal degree. Minimum long/lat degree 0.1.
GloBio(web)[79]	The tool calculates terrestrial biodiversity impact as a function of six pressures: land use, road disturbance, fragmentation, hunting, atmospheric nitrogen deposition and climate change. It is expressed by the mean species abundance (MSA) indicator. There are three specified versions of the tool: GLOBIO-aquatic, GLOBIO-Species, GLOBIO-Ecosystem Services.	Dataset	Yes		Low	N/A	Quantitative (MSA indicator)	Global, cross-sector	10 arcsecond spatial resolution
FABLE Calculator[80]	An excel based accounting tool for decision support on a country-level. Focusing on the agricultural sector and used to estimate the impact that different land-use systems have on biodiversity from 2000-2050. Includes 88 products in the food sector and it is possible through estimation of consumer demand combined with agricultural activities to estimate the impact and compare between systems.	Model	Yes		Medium	By default in tool	Quantitative (xlsx)	Global, food and agriculture sector	Country-level
BioScope[81]	Biodiversity impact tool for supply chains assessing multiple drivers (e.g., land use, climate change, acidification) of businesses and financial institutions. The obtained results are visulized on a world map or retrieved as a table.	Web-application	Yes	ReCiPe	Medium	Countries of suppliers, commodities, map of value chain	Quantitative (number of species lost over times, species.yr)	Global, cross-sector	Country-level

[78] https://www.left.ox.ac.uk/
[79] https://www.globio.info/
[80] https://www.abstract-landscapes.com/fable-calculator
[81] https://www.bioscope.info/

Annex 3. Mapping existing Methods with classification criteria

1 Methods based on NCA

1.1 LIFE Methodology

	https://institutolife.org/o-que-fazemos/desenvolvimento-de-metodologias/como-surgiu-a-metodologia-life/ https://institutolife.org/o-que-fazemos/desenvolvimento-de-metodologias/				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA based method	Performance assessment	LIFE institute developed the Biodiversity Pressure Index to assess the impact of organizations to biodiversity and ecosystem services	Impact	Production site / Company	Quantitative

Short description

The LIFE Methodology works with the Biodiversity Pressure Index (BPI). It has been created to compare and monitor impact of any organization/producer to biodiversity and ecosystem services. There are 5 environmental aspects measured and assessed to calculate the BPI: waste generation, water usage, energy consumption, land use, greenhouse gas emission. The BPI is obtained through information relative to the quantity and severity relating to these 5 selected environmental aspects. Information on the quantity value refers to a direct relationship between the data of the organization/producer compared to an official data for this aspect in the EU.

This generates a quantity value of impact for each environmental aspect referring to its contribution to the regional total. Information on severity, considers information to define the criticality: water availability in the region, potential for global warming from gases emitted, impact of the energy sources used, hazard and disposal of waste generated by, and fragility of the ecoregion occupied.

This information, although qualitative, is quantitatively represented with severity values ranging between 0 and 1. By multiplying the quantity values of impact by their severity factors, "Pressure Values" (PV) are generated for each environmental aspect. For comparison purposes, these pressure values are transformed into "Pressure Indexes" (PI), with the purpose of being mathematically distributed on the same scale, from zero to one thousand. This distribution has as reference the value of greatest impact known in the region for each environmental aspect.

The minimum performance in biodiversity conservation for the LIFE Methodology is determined by two factors: the Biodiversity Pressure Index (BPI) and the company's turnover.

Implementation example

Not available.

Summary of the implementation example:

Risk assessment: impact assessment on values from organization/producer related to severity for each environmental aspect.

Evaluation target: Evaluation of pressure values transformed into pressure indexes (PI) of the five environmental aspects assessed.

Input data: quantity value and severity value of data from the organization/producer and regional values of 5 environmental aspects. For land use it is used the number of hectares, according to occupancy classes in accordance with MSA (Mean Species Abundance).

Spatial scale: Europe or Brazil

Possibilities and restrictions how to use the method

Advantages of this methodology include that the quantity values for impacts created by companies are aggregated with regional severity values taking into account the thresholds and pressures present in a territory.

One of the limitations are the data sources, whenever there is not enough information, assumptions on severity values can be limited. For instance, for land use it is used the MSA which can be a useful indicator but can have limitations taking into account biodiversity features in a certain territory.

Even so, the LIFE Biodiversity Positive Performance tool assesses values of conservation investments, in terms of the importance of the habitat or influencing policy and management. The assigned value of Biodiversity Positive Performance is compared to an index called Biodiversity Minimum Performance.

This is calculated from the Biodiversity Pressure Index as a function of the turnover of the business. This calculation allows to assess whether negative impacts are offset by biodiversity positive actions.

This methodology includes interactions with socio-economic factors including mitigative actions that can be important to compensate impacts.

1.2 Environmental Profit and Loss (EP&L)

Environmental Profit and Loss (EP&L)	https://keringcorporate.dam.kering.com/m/788c4d5588730055/original/Kering-EP-L-report-2019.pdf https://www.kering.com/en/sustainability/measuring-our-impact/our-ep-l/methodology/				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
NCA	Performance assessment	To show the net monetary impacts on society of environmental externalities	Impact driver	Company/Production site	Monetary

Short description

An Environmental Profit and Loss (EP&L) account is a business management method and tool providing an in depth analysis of the resulting impacts a company's activities have on the environment, which also helps decision makers consider this valuable information alongside traditional financial metrics. Kering's pioneering EP&L measures and values in economic terms the environmental impacts across its own operations and entire supply chain.

Implementation example

The EP&L values in monetary terms various impact drivers (e.g., air emissions, GHGs, land use, waste, water consumption, water pollution).

Kering's 2021 Group EP&L is estimated to be € 562M. This includes the impact of consumer product use and end of life, which represents € 40M.

On a comparable basis, Kering's 2021 Group EP&L amounted to € 522M (excluding impacts related to consumer product use and end of life), decreasing it by 11% in absolute terms compared to 2019. This result is argued to reflect the efficacy of the Group's sustainability efforts, which has a key focus on responsible sourcing policies and improving manufacturing and processing efficiencies, while also seeking optimum sustainable management of sites and activities, such as using green energy. Looking at the bigger picture of the Group EP&L results and achievements, the EP&L intensity has decreased by -41% between 2015 and 2021, attaining Kering's EP&L target 4 years ahead of time."

Looking at its impact across its value chain, the impacts related to its direct operations (Tier 0 – stores, warehouses, offices) are still limited, making up 14% of the total impact. The biggest part of its impacts is related to its supply chain (Tier 1 to 4 assembly, manufacturing, sourcing) representing 79% of its total impacts. The impacts associated with the consumer use phase and end of life for products are quite limited, accounting for 7% of total impacts and almost exclusively concentrated in the product use phase. 2021 EP&L REPORT 6 GHG emissions and land use represent its biggest environmental impacts and are respectively responsible for 37% and 31% of its EP&L footprint. In 2021 and in absolute figures, they correspond to 2,381,991 tons of CO_2 and 299,673 hectares, driven primarily by leather use.

Summary of the implementation example:

Risk assessment: environmental externalities of all their products and activities for direct operations and supply chains, broken down per commodity and impact driver (not actual impact)

Evaluation target: group level impacts on society

Input data: Both impact drivers and monetary values (value transfer techniques)

Spatial scale: Global (supply chains).

Possibilities and restrictions how to use the method

Limits:

- No information on quantitative metrics
- No information on monetary valuation techniques (e.g., value transfers)
- Unclear the extent to which biodiversity is included in the "land use" impact driver
- Not an accounting framework:
    - only statement of performance, no asset / liability (no balance sheet)
    - inappropriate comparison with financial P&L (externality monetary values are not comparable with financial values)

1.3 Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)

ENCORE	https://encorenature.org/en				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
NCA	Risk assessment	The aim is to help financial institutions and corporates to better understand their impacts and dependencies related to biodiversity	Impact and dependencies	Business sector / Investor portfolio	Qualitative

Short description

ENCORE was developed by the Natural Capital Finance Alliance in partnership with UNEP-WCMC. It was launched in 2018, originally for the finance sector but this tool can also be used by other sectors.

ENCORE was developed to help organizations understanding their impacts and dependencies on nature, and thus to analyze how these impacts and dependencies might represent a business risk if environmental degradation disrupts them. This tool is supposed to give them clues to account for biodiversity in their risk management processes. For example, the investors can know whether their investments influence biodiversity and impact it badly, and whether their portfolio aligns with biodiversity targets. To simplify analysis of exposure, the 21 ecosystem services detailed by ENCORE are consolidated into the five ecosystem services defined in CISL's taxonomy. ENCORE details the dependencies of the 21 ecosystem services for 86 business processes.

Implementation example

In June 2020, a study has been conducted by the Dutch bank to assess biodiversity risks for the Dutch financial sector.

To assess for physical risks, ENCORE was used. The 86 business processes are first linked to economic sectors, and then the exposure of Dutch financial institutions to those sectors is determined by analyzing bonds, shares and loans. Finally, the dependency of the Dutch institutions was assessed.

The results show that 510 billion€ is highly or very highly dependent on one or more ecosystem services, which represents 36% of the portfolio analyzed. It means that the loss of ecosystem services would lead to substantial disruption of business processes and financial losses. Also, one quarter of the euros invested are dependent on biodiversity.

This analysis shows that the Dutch financial sector is highly dependent on biodiversity, and it is therefore a call to action.

<u>Summary of the implementation example:</u>

Risk assessment: Assessment of the biodiversity dependency of the Dutch financial sector

Evaluation target: Evaluation of the dependency of more than 1400 billion€ invested in the Netherlands

Input data: Type of investment (loans, shares and bonds), value of these investment and business process related

Spatial scale: Portfolio investments of the whole country

Possibilities and restrictions how to use the method

Advantages :

- ENCORE synthetizes large body of literature on natural capital dependencies and impacts of all economic activities
- ENCORE is based on recognized classifications and expert interviews were conducted with sector specialists to validate information when there was a lack in the literature review
- It is internationally recognized: The taskforce on Nature-related Financial Disclosures (TNFD) framework, SBTN & CRSD recommend using ENCORE for dependencies

Limits :

- ENCORE does not account for location-specific information
- Only potential impacts, dependencies and hence material issues are assessed

1.4 Natural Capital Protocol

Natural Capital Protocol	https://capitalscoalition.org/capitals-approach/natural-capital-protocol/?fwp_filter_tabs=guide_supplement				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
NCA	Performance assessment	To measure and value natural capital impacts and dependencies	Dependency, Impact	Any level (portfolio, organisation, product, landscape)	Qualitative, Quantitative, Monetary

Short description

The Natural Capital Protocol is a framework designed to help generate trusted, credible, and actionable information that business managers need to inform decisions. The Protocol responds by offering a standardized framework to identify, measure and value impacts and dependencies on natural capital. The Framework guides the user through four logical Stages and nine Steps. Once you reach the end, the results may lead you to reconsider one or more of the Steps, or to ask another question.

The Protocol builds on a number of approaches that already exist to help business measure and value natural capital, including the Corporate Ecosystem Services Review (WRI, WBCSD and the Meridian Institute. 2012.), and the Guide to Corporate Ecosystem Valuation (WBCSD, IUCN, ERM, and PwC. 2011). These references and resources are listed at the back of the document and provide useful guidance to help complete the Stages and Steps of the Protocol. The Protocol does not, however, explicitly list or recommend specific tools or methodologies.

The Protocol focuses on improving internal decision making. It is not a formal reporting framework and does not assume or require that assessment results are reported or disclosed externally. It is important to note that while the Protocol does provide a standardized process, it also remains flexible in the choice of measurement and valuation approaches used, which means that results may not be comparable within or between different businesses and applications. Nevertheless, the Protocol does provide the foundation for future work around comparability in natural capital reporting and standard setting.

The Protocol is purposely a broad and flexible framework that is applicable to any business sector, operating in any geography, at any organizational level. It allows you to adapt, leverage, and integrate your existing business processes into the framework if needed, and encourages experimentation with different approaches and methods depending on the decisions you are looking to inform. The Protocol provides guidance on all types of valuation, whether qualitative, quantitative, or monetary, depending on which is most appropriate for the decision you are attempting to inform.

The Natural Capital Protocol includes 4 stages:

FRAME

- *Consider a wide range of impacts and dependencies that your business has perhaps not considered before, but which may be relevant to your business and stakeholders.*
- *Think about how better information on natural capital could be relevant to your company's decision-making process. What kinds of decisions would benefit and on what timescale?*
- *Observe replicability by recording engagement with internal or external stakeholders.*

SCOPE

- *The Scope Stage confirms your most relevant natural capital impacts and/or dependencies through a materiality process (Step 04), from the perspective of both your business and your stakeholders.*
- *Engaging stakeholders should be done with care and rigor.*
- *Having defined your scope in this Stage, it is critical that you remain consistent and work within this scope throughout the following Stages and Steps. This will ensure that your results remain relevant to your original objective.*

MEASURE AND VALUE

- *Rigor is especially important in the Measure and Value Stage, and involves ensuring your data and methods are technically correct, scientifically accurate, and consistent with economic theory.*
- *Measurement and valuation should cover the impacts and/or dependencies you have identified as relevant or material.*
- *It is critical to record all of your measurements, valuations, and assumptions, to allow replicability, monitoring, and comparison in the future.*
- *Throughout the measurement and valuation process, keep checking that your scope remains consistent. Do not drift beyond what is productive and manageable.*

APPLY

- *The Apply Stage benefits from replicability and transparency. Documenting and recording all previous decisions, methods, caveats, and assumptions will help with validation and verification.*
- *Use rigor when interpreting your results; it is important to test your assumptions and identify strengths and weaknesses sufficiently enough to ensure your results are decision appropriate. This includes checking that your results are relevant to your original objective.*
- *If you wish to compare results between assessments, then consistency between approaches will be essential.*

Implementation example

Many companies have applied The Natural Capital Protocol.[1]

<u>Summary of the implementation example:</u>

Risk assessment: Identification of which natural capital impacts and dependencies are material, critical or at risk for the business and its stakeholders

[1] https://capitalscoalition.org/impact/case-studies/?fwp_filter_tabs=case_study

Evaluation target: Flexible

Input data: Broad, any impact and dependency input data

Spatial scale: Flexible

Possibilities and restrictions how to use the method

No restriction. Freely available online with many supporting resources and case studies.

1.5 Site-based direct biodiversity state measurement

Site-based direct biodiversity state measurement	Houdet, J & Teren, G. (2022). Quality Biodiversity Footprint Assessments in Practice: Why Organisational Biodiversity Accounting Matters. A Position Paper of the Biodiversity Disclosure Project (BDP). National Biodiversity and Business Network, Endangered Wildlife Trust, South Africa. https://407264.p3cdn1.secureserver.net/wp-content/uploads/2022/11/BDP-Quality-Biodiversity-Footprints.pdf Case study for species: https://407264.p3cdn1.secureserver.net/wp-content/uploads/2022/05/eskoms_biodiversity_footprint_-_bd_protocol_pilot_study.pdf				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
Organisational biodiversity accounting (draws from environmental impact assessment)	Organisational level (company, municipality, etc.)	To help organizations identify, measure, record, consolidate and report on the periodic and accumulated changes in the state of biodiversity (ecosystems and material species)	State of ecosystems (surface area adjusted for condition / integrity), state of material species (population or habitat)	Supply chains, direct operations, clients	Total, Positive and Negative Biodiversity Footprints, statements of position and performance

Short description

There are two core methods for assessing the 'footprint' of a business on ecosystem condition (impact expressed in condition adjusted area) (ALIGN)[2]:

[2] UNEP-WCMC, Capitals Coalition, Arcadis, ICF, WCMC Europe 2022. Recommendations for a standard on corporate biodiversity measurement and valuation, Aligning accounting approaches for nature. https://knowledge4policy.ec.europa.eu/publication/align-project-recommendations-standard-corporate-biodiversity-measurement-valuation_en

- Using model-based approaches to infer changes in condition resulting from either specific company pressures or generic sector pressures. These typically use land use type (land cover and land use intensity) and other pressures (such as fragmentation or terrestrial acidification) as a 'package' of pressures to estimate ecosystem condition and use realm level metrics. Life Cycle Analysis that includes an ecosystem quality endpoint metric also applies this approach.
- Directly measuring change in the condition of ecosystems on the ground using field surveys or remote sensing, using an appropriate condition rating system. For many biomes or specific ecosystem types, there may be established, commonly applied methodologies for assessing their condition, based on tailored indicators.

Site-based direct impact measurements (satellite imagery, site surveys) can be used in organizational biodiversity accounting if specific accounting rules are adhered to.

There is a common myth in the biodiversity footprint space that a single metric measuring biodiversity state is required for consolidation, for instance at the corporate level. While a single unit is indeed required to consolidate ecosystem impact data, conversion tables allow for different biodiversity state metrics to be translated into a surface area adjusted for condition / integrity metric (i.e. surface area equivalents). Consolidating separate, but ecologically-appropriate measurement metrics is superior to trying to use one metric to measure all ecosystems in a one-size fits all approach. Best practice in biodiversity footprint / impact measurement should involve:

- Undertaking separate assessments of impacts on ecosystems and impacts on material species,
- Consolidating impact information only for ecosystem accounts,
- Using ecosystem condition /integrity assessment methods that are most appropriate to the ecosystem type (i.e. most generally accepted /recognized method in the region where the impact occurs), at the finest possible spatial scale;
- Using the same ecosystem condition /integrity method for ecologically equivalent, ecosystem assets (e.g., the same method for all similar grassland ecosystems)

These principles aim to ensure ecological equivalency is used at the finest scale possible, in recognition of the incommensurability of biodiversity (no two sites hold exactly the same biodiversity features).

Not following these principles presents risks of greenwashing as companies may underreport losses of biodiversity assets or claim reaching targets (e.g., net gains / net positive impacts or no-net-loss) without any evidence.

For species, site surveys can also be used to produce Total, Negative and Positive Footprints. See case study below.

Implementation example

For species[3]:

Detailed species lists (mammals, avifauna, herpetofauna, butterflies, plants) have been compiled during past environmental impact assessments for both Ingula and Sere. There are updated regularly through on-site monitoring. As per the BD Protocol[4], not all species should be included in the impact inventory, only priority species. To determine the later, a species materiality assessment was carried out. It involved rating the species as per four criteria, conservation status, population assessment / monitoring (capacity to do both), likelihood of impacts and severity of impacts. The sum of individual species scores determines the importance of the species in the context of each Eskom site[5]. The threshold for species inclusion in the impact inventory was a minimum of 8 for Ingula and a minimum 10 for Sere. At Sere, due to the lack of detailed site knowledge, additional field surveys aimed to identify all plant species of conservation concern during the rainy season. Two days were spent walking throughout study site (not performing transects), identifying species not seen during the transects. Over 20kms were covered during this time.

<u>Summary of the implementation example:</u>

Risk assessment: impacts on species survival at two sites

Evaluation target: species population for accounting purposes

Input data: habitat and population sizes

Spatial scale: species dependent

Possibilities and restrictions how to use the method

The biggest challenge here is that many ecosystems do not have direct condition assessment methods. Engaging with local researchers to design rating systems for ecosystem types where these are not developed can aid in filling method gaps.

Same situation would apply to species.

[3] https://407264.p3cdn1.secureserver.net/wp-content/uploads/2022/05/eskoms_biodiversity_footprint_-_bd_protocol_pilot_study.pdf

[4] Any example from the BD Protocol website for impacts on ecosystems: https://nbbnbdp.org/bd-protocol/ (see under BD Protocol for the Sibanye-Stillwater example).

[5] Houdet et al. (2021). Eskom's Biodiversity Footprint - BD Protocol pilot study. DOI: 10.13140/RG.2.2.29037.51685.

1.6 Biological Diversity Protocol (BD Protocol)

<table>
<tr><td>Biological Diversity Protocol (BD Protocol)</td><td colspan="5">Main page: https://nbbnbdp.org/bd-protocol/
BD Protocol document: Endangered Wildlife Trust (2020). The Biological Diversity Protocol (BD Protocol) (2020). National Biodiversity and Business Network - South Africa, 123p. https://407264.p3cdn1.secureserver.net/wp-content/uploads/2022/05/bdp_final_080321.pdf</td></tr>
<tr><td>Assessment approach</td><td>Assessment type</td><td>Main objective</td><td>Assessment focus</td><td>Scope</td><td>Output type</td></tr>
<tr><td>NCA</td><td>Performance assessment</td><td>Accounting framework that helps organizations identify, measure, record, consolidate and report on the periodic and accumulated changes in the state of biodiversity, through double-entry bookkeeping (DEBK)</td><td>State of ecosystems (surface area adjusted for condition / integrity), state of material species (population or habitat)</td><td>Organisational level (company, municipality, etc.)</td><td>Total, Positive and Negative Biodiversity Footprints, statements of position and performance</td></tr>
</table>

Short description

The Biological Diversity Protocol (BD Protocol) constitutes the first accounting framework that helps organizations identify, measure, record, consolidate and report on the periodic and accumulated changes in the state of biodiversity, through double-entry bookkeeping (DEBK). The goal is to enhance the completeness, accuracy and comparability of biodiversity impact information, for internal reporting and external disclosure.

The BD Protocol adopts a specific definition of organizational biodiversity accounting, which follows accounting rules:

- An asset inventory or register of affected ecosystems and material species, organised in line with relevant international (e.g. IUCN Global Ecosystem Typology) and national classification systems (e.g., EUNIS Habitat Classification in Europe, South African ecosystem types, Terrestrial Ecological Systems of the United States),
- Measurement techniques that use spatially explicit data, suitable to each asset category,
- The assessment of net impacts for gains and losses of like-for-like assets (ecological equivalency principle) in line with the mitigation hierarchy,
- Use of recording rules based on double-entry bookkeeping (DEBK) from financial accounting,
- Compilation of asset-specific statements of performance and position, which can be aggregated for ecosystems but need to be kept separate for material species,
- Time period assumption, and

- The segregation of biodiversity state data per value chain boundary, as well as per type of impact (direct, indirect, future).

Implementation example [6,7]

Sibanye-Stillwater undertook an initial biodiversity footprint assessment aligned with the Biological Diversity Protocol (BD Protocol) in 2021. The aim was to complete a desktop assessment with the existing information as well as identifying the gaps that need to be addressed going forward.

This assessment included the direct biodiversity impacts of Sibanye-Stillwater for its direct operations:

- South African (SA) operations: Beatrix, Blue Ridge, Burnstone, Driefontein, Ezulwini, Kloof, Kroondal, Marikana (incl. ex Aquarius), Rand Uranium and Rustenburg Platinum Mines (RPM);
- United States of America (USA) operations: East Boulder Mine (EBM) and Stillwater Mine (SWM).

As per the BD Protocol, business impacts on biodiversity includes impacts on ecosystems and material species. While this report compiles the net ecosystem impacts of both SA and USA operations, it does not yet cover impacts on material species for SA operations. Due to the lack of appropriate data for these sites, impacts on material species will be evaluated at a later stage, considering the complex nature of these assessments an integrated plan will be developed to find feasible measurement methods in future.

Sibanye-Stillwater's ecosystem asset:

Sibanye-Stillwater's ecosystem asset register or inventory holds 38 ecosystem types, 24 for SA operations and 13 for USA operations. Overall, the Total Biodiversity Footprint of Sibanye-Stillwater was 49 897,41 Ha at date of acquisition of various assets, with around 86% of Negative Biodiversity Footprint (42 998,47 Ha eq.) and 14% of Positive Biodiversity Footprint (6 745,78 Ha eq.).

At the time of assessment (current state in 2020 / 2021), the Total Biodiversity Footprint increased to 49 912,01 Ha, with around 87% of Negative Biodiversity Footprint (43 489,32 Ha eq.) and 13% of Positive Biodiversity Footprint (6 422,68 Ha eq.).

Summary of the implementation example:

Risk assessment: All single, double and societal material biodiversity impacts assessed. Dynamic materiality captured through the ongoing accounting process (DEBK).

Evaluation target: Biodiversity Footprint of the group (direct operations and direct impacts only)

Input data: ecosystem extent and condition (for all sites), population / habitat sizes for material species (only for USA sites)

[6] Houdet, J., Teren, G., (2022). Sibanye-Stillwater's consolidated biodiversity footprint. Pilot assessment as per the Biological Diversity Protocol – Group level consolidated report. National Biodiversity & Business Network – Endangered Wildlife Trust / Sibanye-Stillwater

[7] Houdet, J., Teren, G., Nelson, B., (2023). Sibanye-Stillwater's consolidated biodiversity footprint. Update assessment as per the Biological Diversity protocol – Group level consolidated report. National Biodiversity & Business Network – Endangered Wildlife Trust / Sibanye-Stillwater.

Spatial scale: Down to the hectare / acre scale. The use of the ecological equivalency principle implies that national vegetation / ecosystem classifications are used.

Possibilities and restrictions how to use the method

It can apply to any type of organization (any industry).

Exclusions: genetic diversity, assessment for a service, product or portfolio of financial assets (e.g., bonds).

Changes in the state of biodiversity which are modelled (i.e. potential changes in the state of biodiversity) cannot be used for biodiversity accounting. Some biodiversity footprint measurement approaches rely on impact driver data and so cannot satisfy the requirements of biodiversity accounting. For instance, they do not identify biodiversity assets, do not have spatial information for each asset category, and cannot apply ecological equivalency at any meaningful scale (i.e. not useful for on the ground management and accountability).

1.7 Comprehensive Accounting in Respect of Ecology (CARE)

CARE	https://www.chaire-comptabilite-ecologique.fr/projets?lang=fr https://capitalscoalition.org/publication/improving-na				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
Extension of financial accounting to natural and social capital issues	Company	To provide more complete information on the costs associated with a sustainable business model, by distinguishing between preservation costs and operating costs	Natural and social capital "metrics" which are not specified (hidden behind monetary values)	Direct operations	An adjusted balance sheet in monetary values

Short description

A direct extension of historical cost accounting specifically extending the principle of protection of produced/financial capital to natural and human capitals. This is implemented through inclusion of social and environmental issues in the balance sheet and income statement, and extension of financial solvency to environmental, human and social solvency. Social and environmental issues are:

- Addressed through the preservation of "capital" "entities" (climate, biodiversity, soils, human beings employed, etc.)
- Reflected in the balance sheet and income statement by the recognition of social and environmental liabilities (debts)

Natural and human capitals, conceived as liabilities, are valued at their preservation costs (prevention or restoration – not compensation – costs).

Assets are uses of capitals (financial, natural, and human). The income is the surplus of revenues after all the capitals have been preserved. To be fully operational, CARE ultimately needs to be articulated with the "accounting for the management of ecosystems" model that accounts for the ecological performances reached at the level of the collective management of a given natural capital entity.

Implementation example

An example of the application of the CARE method involves a hypothetical apple and wheat farm. The soil is the natural capital that needs to be preserved in this case. An income statement of the farm for a specific year was developed, providing better visibility to natural capital by inclusion of: (i) natural capital operating expenses and (ii) preservation of soil expenses.

A balance sheet of this farm was also produced with the new additions of the CARE model, including: (i) explicit information about amortization and depreciation of assets and (ii) an explicit distinction of different types of issues (financial and natural) and (iii) the articulation between natural and financial capitals (liabilities) and assets (financial, natural, and mixed) and (iii) the preservation of capitals.

<u>Summary of the implementation example:</u>

Risk assessment: Quantification of restoration / preservation expenses to reach sustainability targets.

Evaluation target: Adjusted financial statements for the company.

Input data: Unclear. No complete case study could be found.

Spatial scale: Unclear, assumed to be site specific.

Possibilities and restrictions how to use the method

The main problems include:

- Relies on other measurement tools (no guideline on how to measure anything);
- Final output reduces all ecological phenomena to monetary values (without providing evidence any natural capital performance / improvement, which could theoretically be found in other assessments).
- No clear guidance of what constitutes "natural capital" (e.g., apples and tree plantations).

1.8 Double-entry bookkeeping applied to natural capital

Double entry bookkeeping applied to natural capital accounting	Joël Houdet et al. (2020). Adapting double-entry bookkeeping to renewable natural capital: An application to corporate net biodiversity impact accounting and disclosure, Ecosystem Services, Volume 45, 101104. https://doi.org/10.1016/j.ecoser.2020.101104 GHG emissions and removals: https://www.researchgate.net/publication/358084006_GREENHOUSE_GAS_ACCOUNTING_AND_NET-ZERO_TARGET_SETTING_-_THE_CASE_FOR_ORGANISATIONAL_GHG_D Applied in BD Protocol				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
Adaptations of double entry bookkeeping to natural capital	Organisation al level	To account for both changes in stocks and flows (gains / losses) in bio-physical terms. To enable a full audit trail from consolidated statement to specific natural capital change.	Any natural capital stock / asset (e.g., ecosystem, GHG emissions / removals)	Direct operations, supply chain, clients	Quantita-tive state-ments of position and perfor-mance for natural capital themes

Short description

DEBK allows companies to account and disclose both periodic performance, through the Statement of Financial Performance, and the net (or accumulated) result of past periodic performances via the Statement of Financial Position. New conventions to double-entry bookkeeping are thus proposed to facilitate natural capital accounting and disclosure for both periodic and accumulated changes. To date this has been applied to biodiversity (ecosystems, material species) and GHG emissions and removals.

Rationale: Sustainably managing and conserving renewable natural capital involve complementary factors, including their ability to sustain (renew) themselves (e.g., sufficient space and time to do so) and the implementation of cost-effective management systems. To support this, reliable and regular assessments of changes in stocks and flows (e.g., amounts of extracted resources), in both space and time, as well as in terms of integrity, are required. In other words, to understand whether a business sustainably manages a specific renewable natural capital stock, it needs to go beyond monitoring natural capital flows and be able to understand the status (amount, condition, location) of the stock it interacts with and track the changes in stocks due to its activities and, potentially, those of other economic agents that may also rely on these stocks. In doing so, the company would be expected to be in a position to understand the level/extent of its impacts and dependencies and whether management activities are effective in sustainably managing or conserving renewal natural capital. This is the type of information that both internal and external stakeholders require in order to make informed decisions (e.g., resource management and investment choices, share purchase/sale, social licence to operate).

However, the underlying changes in natural capital stocks (e.g., stocks of renewable resources, air or water quality) are typically not accounted for by business. For instance, disclosures do not explicitly refer to a baseline year but are valid only for the reporting period, typically for a timeframe of a year preceding the disclosure (e.g., amount of materials used over the financial reporting period). This leads to a series of annual disclosures with no information on net impacts or changes since a relevant baseline year (e.g., starting date of resource exploitation or emission generated).

Implementation example

The case study is a 'habitat banking' project in the Cossure plain of southern France (the "Cossure offset project") where 12.5 M€ were invested to restore and manage previously-farmed land for a period of at least 30 years so as to sell biodiversity offset credits to project developers who are required to offset their impacts as a condition of their environmental permit.[8] In 2008, 357.00 ha of irrigated orchards were purchased (condition score of 0 for the whole surface area since it was intensively cultivated), located on properties mostly adjacent to an existing nature reserve holding the original ecosystem identified as the Coussoul steppe (i.e. 357.00 ha of "natural" or reference state ecosystem with a rating of 5 out of 5). While basic restoration activities (e.g., exotic tree species and infrastructure removal) were undertaken over the whole 357.00 ha to generate a grassland fallow favourable to targeted bird species, three additional measures were tested to further accelerate the return of the Coussoul steppe on a portion of the site[9]:

- The seeding of various species (60.00 Ha);
- The spreading of hay obtained from other Coussoul properties (24.00 Ha);
- The addition of mycorrhizae and vegetative parts to seed mixes (3.00 Ha).

Summary of the implementation example:

Risk assessment: Accounting for net impact of a biodiversity offset site

Evaluation target: Natural Capital Statements of Performance and Position

Input data: Extent and condition of ecosystems

Spatial scale: Site specific.

Possibilities and restrictions how to use the method

This approach needs to be expanded to all forms of natural capital (different DEBK equations for each NC asset).

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[8] Dutoit, F., Jaunatre, R., Alignan, J.-F., Bulot, A., Buisson, E., Calvet, C., Wolff, A., Sauguet, F., Debras, J.-F., Provost, E., & Napoleone, C. (2015). Première expérimentation de compensation par l'offre: bilan et perspective. *Sci. Eaux Territ*., 16, 64–69.

[9] Rouvière, L., & Thiévent, P. (2016). Restaurer un écosystème unique en Europe : le secteur privé comme levier de développement d'un projet de territoire fondé sur la restauration de la biodiversité : Retour d'expérience sur l'opération Cossure, première expérimentation d'un dispositif de compensation par l'offre en France. CDC Biodiversité. In Mulongoy, M.J., & Fry, J. (eds.), Restoring life on earth: Private-sector experiences in land reclamation and ecosystem recovery. Technical Series No. 88, 47-58. Secretariat of the Convention on Biological Diversity, Montreal 2016.

It exclusively work at the scale of a legal entity / organisation, not a product / service; just like financial accounting does.

1.9 Measuring NC consistent with SEEA

SEEA EA	United Nations et al. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available at: https://seea.un.org/ecosystem-accounting.				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
NCA	Performance assessment	To organize and present data on the environment and its relationship with the economy	Dependency, Impact driver	Country, region (same principles can be implemented at other scales and for different actors, such as businesses)	Quantitative, Monetary

Short description

The System of Environmental-Economic Accounting (SEEA) is the globally accepted international environmental-economic accounting standard offering a framework for organizing and presenting data on the environment and its interactions with the economy. The scale of such accounts typically ranges from national to regional. However, the same principles can be implemented at other scales and for different actors, such as businesses.

The SEEA brings together environmental and economic information in an internationally agreed set of standard concepts, definitions, classifications, accounting rules and tables to produce internationally comparable statistics. The SEEA consists of two main frameworks:

The SEEA Central Framework (SEEA CF) was adopted by the UN Statistical Commission as the first international standard for environmental-economic accounting in 2012[10]. The Central Framework provides a statistical standard to measure environmental flows, i.e., the flows of natural inputs, products and residuals between the environment and the economy, and within the economy; stocks of environmental assets, i.e., the stocks of individual assets, such as water or energy assets; and economic activity related to the environment, i.e., monetary flows associated with economic activities related to the environment, including spending on environmental protection and resource management, and the production of 'environmental goods and services'.

[10] UN (2014) System of Environmental-Economic Accounting 2012: Central Framework. United Nations, European Commission, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation Development, World Bank, New York.

The SEEA Ecosystem Accounting (SEEA EA) complements the Central Framework and was adopted by the UN Statistical Commission in 2021 (United Nations et al. 2021). It takes the perspective of ecosystems and considers how individual environmental assets interact as part of natural processes within a given spatial area. The SEEA EA comprises a scientifically robust and comprehensive framework for measuring ecosystems and their linkages to economy and human wellbeing, including ecosystem services and their economic value. Conceptually, SEEA EA views ecosystems as natural capital assets, characterizing them by their extent and condition and linking them to society through the provision of ecosystem services. SEEA EA constitutes a set of standards, principles, and recommendations to measure ecosystems extent, condition, and ecosystem services in physical and monetary terms. Importantly, SEEA EA constructs both physical (extent and condition of ecosystems, amount of ecosystem services) and monetary (economic value of ecosystem services and ecosystem assets) measures of ecosystems and their contributions to the economy and human wellbeing.

The SEEA EA is built on five interlinked accounts:

1) Ecosystem extent (physical);
2) Ecosystem condition (physical);
3) Ecosystem services flow (physical)
4) Ecosystem services flow (monetary); and
5) Monetary ecosystem asset account.

These accounts are compiled using spatial data and information about the functions of ecosystem assets and the ecosystem services they produce (United Nations et al. 2021.)

Implementation example

Forico, an australian company producing wood fibre, applied SEEA EA to recognize, record and value environmental benefits from their forest estate called Surrey Hills estate.[11]

Ecosystem assets: To identify different types of ecosystem assets at the Surrey Hills estate, each individual spatial area in Surrey Hills was mapped to a management zone classification that includes the following classes: plantation forest, natural forest, infrastructure and non-forest. The management zone classification was developed for Forico’s purposes to enable them to expand their reporting to include ecosystem assets and to link them with their management and financial accounting processes. For these assets they have produced accounts for ecosystem extent, ecosystem condition, and ecosystem services.

Ecosystem extent: The company has produced a map on the Surrey Hills estate showing the extent of different ecosystem assets (according to the management zone classification). According to the company, largest of the assets are the planation forest and the natural forest.

Ecosystem condition: To measure the condition of the ecosystem assets, Forico completed vegetation assessments across natural forest ecosystem assets.

[11] https://ideeagroup.com/wp-content/uploads/IDEEA_Forico-Forest-Ecosystem-Accounting-Nov-2018.pdf

Ecosystem services: The accounting concentrated on measuring the flows of the following ecosystem services: wood fiber provisioning, carbon sequestration, water provisioning, and habitat services. For some of the ecosystem services, also monetary value was assessed (not specified that for which).

Summary of the implementation example:

Risk assessment: Accounts that record and present Forico's ecosystem assets, their extent and condition as well as ecosystem services they provide in accordance with the SEEA EA framework.

Evaluation target: Testing the use of the SEEA in a corporate setting

Input data: No information provided

Spatial scale: A site called Surrey Hills estate

Possibilities and restrictions how to use the method

Lack of sufficiently detailed data and data collection being an expensive activity for companies may hinder companies to apply SEEA EA. Therefore, data sharing and open-source databases are found important.[12] On the other hand, companies already applying tools for measuring biodiversity at site level regularly, can easily integrate this data into extent and condition accounts.

1.10 British Standard BS 8632:2021

British Standard BS 8632:2021	BS 8632:2021 Natural Capital Accounting https://www.bsigroup.com/en-GB/standards/bs-86322021/				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
BS 8632:2021 Natural Capital Accounting for Organizations — Specification	Performance assessment	To account for both changes in stocks and flows (gains / losses) in monetary terms	Any natural capital stock / asset and flow	Direct operations, supply chains	Natural Capital Balance Sheet & Natural Capital Income Statement in monetary terms

Short description

The British Standard provides specifications and guidance for the process of preparing natural capital accounts for organizations. By combining financial, environmental and socio-economic information, natural capital accounting reveals the value of nature to organizations, and the rest of society, and the value of organizations' (positive and negative) impacts on nature. The purpose is to better integrate natural capital considerations into financial and other business analyses.

[12] United Nations, 2022. SEEA Ecosystem Accounting for Business
A quick introduction. https://seea.un.org/content/seea-ecosystem-accounting-business-quick-introduction

The British Standard presents the terminology, principles, steps and outputs of natural capital accounting with the aim that the process is transparent, repeatable and generates information that is useful for decision making. This process of providing comprehensive and transparent information can help an organization:

- identify its impacts and dependencies, and that of its value chain, on natural capital assets, and associated risks and opportunities;
- communicate information and implications within the organization and with external stakeholders;
- make more informed business strategies and operational decisions by integrating natural capital accounts with assessment of other capitals and by testing different scenarios about the future conditions and management or investment options; and
- monitor changes over the accounting period due to internal and external factors and evaluate effectiveness of the decisions by the organization in addressing such change.

There are two key outputs from natural capital accounting – each with supporting schedules: (i) the Natural Capital Balance Sheet and (ii) the Natural Capital Income Statement. These are inspired by the financial balance sheet and income statement (or profit and loss account) to improve consistency with financial accounts even though some details differ. The information used to create a natural capital account may come from financial accounting, management accounting, environmental, social and governance (ESG) analysis and other economic, social and environmental analyses undertaken by the organization, or available in academic or official publications or grey literature.

The British Standard is applicable to organizations of all types (public, third sector and listed and unlisted private) across all sectors, and of any size (such as SMEs and larger businesses) and to one or more sites in which they operate. A group of organizations dependent on the same natural capital assets, or considering collaborating to change their impacts, may produce joint natural capital accounts.

Implementation example

Several companies have applied, including Northumbrian Water Group and OFI. No report could be accessed though.

<u>Summary of the implementation example:</u>

Risk assessment: Identification of which natural capital impacts and dependencies are material, critical or at risk for the business and its stakeholders.

Evaluation target: The value of natural capital assets owned / controlled by the business.

Input data: Unclear the exact type of input quantitative data, besides ecosystem extent and condition variables.

Spatial scale: Local information, typically within a landscape.

Possibilities and restrictions how to use the method

The method is described in a book without having a web-application.

2 Methods based on LCA

2.1 Stepwise2006

Stepwise2006	Weidema et al. (2008). Environmental Improvement Potentials of Meat and Dairy Products. European Commission–Joint Research Centre–Institute for Prospective Technological Studies, Luxembourg: Office for Official Publications of the European Communities.				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Risk assessment	To apply approach to monetarization that avoids some of the problems of earlier cost-benefit assessments	Impact drivers	Product	Monetary

Short description

Impact drivers:

- global warming (fossil / nonfossil)
- photochemical ozone - vegetation
- terrestrial acidification
- terrestrial and aquatic eutrophication
- terrestrial and aquatic ecotoxicity
- nature occupation

Stepwise2006 is an endpoint impact assessment method which avoids weighting in its strict sense. It applies approach to monetarization that avoids some of the problems of earlier cost-benefit assessments. The method carries all impacts to a single score either in in Quality Adjusted Life Years (QALY) or in monetary units.

Implementation example

Comparing environmental burdens, economic costs and thermal resistance of different materials for exterior building walls (scientific article)[13]

In the example article, the environmental impacts and economic costs of different exterior walls were explored using LCA and LCCA approaches. In addition, the indoor energy consumption and live ability in relation to the R-value were investigated.

Environmental and cost analyzes were performed for a total of six wall designs: a single-layer setup for both AAC and brick walls, a double-layer air gap setup for both AAC and brick walls, and an EPS-insulated double-layer setup for both AAC and brick walls. The scope of the environmental impact

[13] Talang and Sirivithayapakorn (2018). Comparing environmental burdens, economic costs and thermal resistance of different materials for exterior building walls. Journal of Cleaner Production, Volume 197, Part 1, Pages 1508-1520. https://doi.org/10.1016/j.jclepro.2018.06.255

assessment was from the cradle to the gate, including the production of raw materials, the transportation of raw materials to the construction site and the construction of walls. The functional unit is 1 m^2 of wall with a thickness of 10 cm or 20 cm for single- and double-layer walls excluding paint. LCIA was performed using the Stepwise2006 method, which combines the IMPACT2002+ v. 2.1 characterization model and the EDIP2003 methods (Weidema et al., 2008), and the ecoinvent[14] database was used for consequential modeling. The study determined only eight environmental impact categories (from 15 impact categories) for global warming, respiratory inorganics, respiratory organics, occupation, acidification, aquatic eutrophication, terrestrial eutrophication, and mineral extraction.

Through environmental cost analyses, this study illustrated the connection between the environmental impacts and economic benefits of LCA, which has not been considered by others for wall construction. In addition, the study showed that significant factors in building construction were the environment and economy, as well as the building's R-values.

Summary of the implementation example:

Risk assessment: the environmental impacts and economic costs of different exterior walls

Evaluation target: Product

Input data: Secondary

Spatial scale: Global

Possibilities and restrictions how to use the method

The Stepwise method applies new approaches to monetarization that partly avoid the problems of previous cost-benefit assessments, which have been considered incomplete and high uncertainty in the monetarization of environmental impacts. The Stepwise2006 method combines the best characterization models from the two recent impact assessment methods, the IMPACT2002+ v. 2.1 and EDIP2003 methods.

Because the method is based on the correspondence between QALY and monetary units, it can seamlessly integrate new impact categories, e.g., for social and economic impacts, which allows for a continuous increase in the coverage of the assessment.

[14] Wernet et al. (2016). The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, 21, 1218-1230. https://doi.org/10.1007/s11367-016-1087-8.

2.2 Ecological Scarcity 2013

EcoScarcity 2013	https://esu-services.ch/projects/ubp06/ Frischknecht et al. (2006). Swiss Ecological Scarcity Method: The New Version 2006. Berne, Switzerland.				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Risk assessment	Measure the current environmental situation based on politically determined environmental targets and makes it possible to assess relevant environmental pressures on the widest possible basis	Impact drivers	Product	Quantitative

Short description

Impact drivers: biodiversity damage potential through land use

The Ecological Scarcity method was developed in Switzerland. It weights environmental impacts (pollution emissions and resource consumption) by applying eco-factors. The eco-factor of the substance is derived from environmental legislation or similar political goals. The eco-factor is derived from three elements [15]: characterization, normalization, and weighting.

Implementation example

Micropollutant abatement with UV/H2O2 oxidation or low-pressure reverse osmosis? A comparative life cycle assessment for drinking water production (scientific article)[16]

The study compares the environmental effects of two treatment scenarios as an additional barrier to reducing micropollutants (MP) in the drinking water production of a certain drinking water supplier located in Basel.

LCA provided a methodological approach to achieve the defined treatment goal. The functional unit is 1 m^3 water production before managed aquifer recharge (MAR). In the study, Ecological Scarcity was chosen as the impact assessment method. The assessment of the LCA inventory was carried out according to the ISO 14044[11] methodology with characterization, normalization, and weighting steps (ISO, 2006a; 2006b).

The results of all impact categories were weighted and summed up completely into a single score. The system boundaries included only the processes necessary for the respective treatment scenario, i.e., raw

[15] ISO. Environmental Management - Life Cycle Assessment - Principles and Framework. International Standard ISO 14044; International Organisation for Standardisation: Geneva, Switzerland, 2006.
[16] Roth et al. (2022). Micropollutant abatement with UV/H2O2 oxidation or low-pressure reverse osmosis? A comparative life cycle assessment for drinking water production. Journal of Cleaner Production, Volume 336, 130227. https://doi.org/10.1016/j.jclepro.2021.130227

materials, principal infrastructure, chemicals, energy consumption, construction, transportation, and end-of-life treatment.

Summary of the implementation example:

Risk assessment: Environmental impacts of micropollutant treatment scenarios

Evaluation target: Product

Input data: secondary (Ecoinvent 3.3)[14]

Spatial scale: Country (Switzerland) / EU

Possibilities and restrictions how to use the method

The method can be used for product comparisons, process and product improvements, assessment of the total environmental impacts of production sites or the country's final consumption. The results are useful for political or business decision-makers to improve the management of environmental issues. The method helps environmental management and decision-making.

2.3 Land use impacts on biodiversity in LCA: a global approach

	de Baan et al. (2013). Land use impacts on biodiversity in LCA: a global approach. The International Journal of Life Cycle Assessment, 18(6), 1216–1230. https://doi.org/10.1007/s11367-012-0412				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Biodiversity impact from land use	Quantifying biodiversity impact from land use (occupation) (forestry and agriculture primarily)	Impact (occupation impacts on biodiversity)	Product (but focused on primary production)	BDP (biodiversity damage potential)

Short description

The methodology developed by de Baan et al. (2012) can be used to assess the biodiversity damage potential (BDP) from land use on a global scale. It is based on the UNEP/SETAC land use assessment framework and focuses on biodiversity impacts resulting from land occupation. It differentiates species richness (multiple taxa; plants, mammals, between different land use types based on (1) hectares of land occupied, (2) land type classification (annual or permanent crops, pastures, and meadows) and (3) biome ((semi-)natural vegetation type in the given area, e.g., tropical savannah). The method is built upon biodiversity monitoring data as well as a global quantitative literature review. The output is a biodiversity damage potential (BDP) score which reflects the relative changes in species richness between agricultural and (semi-)natural land use of the biome.

Implementation example

Röös et al. (2015)[17] used the method for assessing three dietary scenarios regarding biodiversity and land use, as well as climate impact. The diets assessed were (1) average Swedish diet (SNÖ), (2) a diet corresponding to Nordic nutrition recommendation (RIKSMATEN), and (3) a low carbohydrate high fat diet (LCHF). Using de Baan provided BDP values per kg of the assessed food items, as well as an assessment of the different diets.

The study showed that climate impact had a similar pattern as biodiversity impact, where the impact was higher for animal-based foods (65-85% of the total impact), whereas fruits and vegetables (8-16%) and grains and potato (0-12%) had a smaller negative impact.

Summary of the implementation example:

Risk assessment: Quantification of biodiversity impact from land occupation

Evaluation target: Product

Input data: Land use (m^2) and origin of product (land use type)

Spatial scale: Global

Possibilities and restrictions how to use the method

Advantages**:**

There are some data limitations resulting in that assessments cannot be done for all world regions. The characterization factors should also be used with caution as there are uncertainties. Impacts on transformation (land use change) is not considered either. It is applicable for forestry and agriculture, but not to other important land use activities such as construction, mining, agri- and silviculture.

Limits**:**

The method has many possibilities and has 'paved the way' for many LCA-based biodiversity assessment methods, that have been developed based on de Baan et al. (2012), such as Chaudhary and Brooks (2018)[26]. Thus, the method is not anymore in the forefront.

[17] Röös et al. (2015). Evaluating the sustainability of diets–combining environmental and nutritional aspects. Environmental Science & Policy, 47, 157–166. https://doi.org/10.1016/j.envsci.2014.12.001

2.4 ReCiPe 2016

ReCiPe 2016	https://pre-sustainability.com/articles/recipe/ Huijbregts et al. (2017). ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. Int J Life Cycle Assess, 22, 138–147. https://doi.org/10.1007/s11367-016-1246-y				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Risk assessment	To summarize and simplify the extensive environmental indicators	Impact driver	Product	Quantitative

Short description

Impact drivers:

- Climate Change (Terrestrial and freshwater ecosystem);
- Freshwater, Marine and Terrestrial ecotoxicity
- Land use and transformation
- Freshwater/Marine eutrophication
- Water use (terrestrial and freshwater ecosystem)
- Terrestrial acidification
- Photochemical ozone formation

ReCiPe is a method for the life cycle impact assessment (LCIA). Its first version was developed in collaboration between RIVM, Radboud University Nijmegen, Leiden University and PRé Sustainability in 2008. In ReCiPe the results of the life cycle inventory are converted into a limited number of indicator points. They are defined on two levels, 18 midpoint indicators and 3 endpoint indicators.

Implementation example

Prospective life cycle assessment of a bioprocess design for cultured meat production in hollow fiber bioreactors (scientific article)[18]

The article compares process design scenarios to each other to improve information on the environmental effects of cultured meat production and to reduce them through the design of a more advanced bioprocess system.

LCA was used to assess the environmental impact of cultured meat produced in a bioprocess. Functional unit (FU) was 1 kg of cultured meat consisting of skeletal muscle cells. LCA was implemented using the OpenLCA 1.10.12 program and ReCiPe 2016 (H) midpoint method and Cumulative Energy Demand (CED) for the impact assessment. The environmental impact categories were selected based on the relevance to the product systems, including cumulative energy demand, water consumption, terrestrial acidification, ozone formation, land use, freshwater eutrophication, fossil resource scarcity and fine

[18] Tuomisto et al. (2022). Prospective life cycle assessment of a bioprocess design for cultured meat production in hollow fiber bioreactors. Science of The Total Environment, Volume 851, Part 1, 158051. https://doi.org/10.1016/j.scitotenv.2022.158051

particulate matter formation. This analysis uses cradle to gate (raw material extraction to factory gate) as a system boundary.

The findings are intended as a reference framework for research and development work towards improving the environmental protection of cultured meat production systems. The research offers an opportunity to compare the design scenarios of different bioprocesses based on environmental effects. Based on the LCA results of the article, it is recommended that R&D activities to improve the environmental protection of cultured meat production systems focus on five areas.

Summary of the implementation example:

Risk assessment: the environmental impact of cultured meat produced in a bioprocess

Evaluation target: Product- cultured meat

Input data: Both primary and secondary data are used. Data was collected from Ecoinvent 3.6.[14] database, Agri-footprint database, and scientific articles.

Spatial scale: City / country (Wales, UK)

Possibilities and restrictions how to use the method

It provides a state-of-the-art method of converting life cycle inventory into a limited number of life cycle impact scores at the midpoint and endpoint level. The endpoint and midpoint categories represent a global scale, in line with the global nature of many products' life cycles. Although the method has been developed a lot, there is still room for improvement in, for example, considering the marine environment, the average scarcity of fossil resources, and the impact of climate change on the spread of infectious diseases.

2.5 Biodiversity impacts from water consumption on a global scale for use in LCA

	Verones et al. (2017). Biodiversity impacts from water consumption on a global scale for use in life cycle assessment. The International Journal of Life Cycle Assessment, 22, 1247-1256. https://doi.org/10.1007/s11367-016-1236-0				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	A spatially differentiated approach, accounting for impacts from water consumption on biodiversity loss on a global level	Impact	Global	Quantitative

Short description

A spatially differentiated approach, accounting for impacts from water consumption on biodiversity loss on a global level. The aim of the method is to build on a previous method to enhance the spatial coverage as well as on species. Its functionality was demonstrated via an application to a global case study of four different crops.

Comprehensive global impact assessment methodologies are required to assess impacts from water consumption on biodiversity, as agriculture have a big part in the global water-use which could have the potential of depriving many ecosystems of water.

Main variables: Scarcity of water; Species richness

Main goal:

To assess biodiversity loss from **water consumption** in

(a) wetlands and (b) terrestrial ecosystems

(i) on a worldwide level,

(ii) for five taxonomic groups (birds, amphibians, reptiles, mammals, and vascular plants),

(iii) for two impact pathways (water deprivation of wetland ecosystems and water deprivation of plants in terrestrial ecosystems)

Methods: Characterization factors (CFs) were made for: Animal taxa, Plant taxa[19,20,21]

CFs are expressed as global fractions of potential species extinctions (PDF) per cubic meter of water consumed annually and are developed with a spatial resolution of 0.05 arc degrees. Species geographic ranges + threat level (IUCN) were used to create a vulnerability indicator which is included in the CF.

Study results:

The amount of water consumption alone is not sufficient to indicate the places of largest impacts but that species richness and vulnerability of species are indeed important factors to consider.

Largest impacts are calculated for vascular plants in Madagascar, for maize, and for animal taxa; in Australia and the USA for surface water consumption (cotton); and in Algeria and Tunisia for groundwater consumption (cotton).[22]

Implementation example

One case study conducted with the method was to determine the impact globally of cultivation of four crops (i.e. wheat, rice, maize and cotton) which concluded that maize had the largest impact.

Summary of the implementation example:

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[19] Spatial data for the geographic bird range sizes: BirdLife International; Nature Serve (2012)
[20] Spatial data for the geographic range sizes of other taxa: IUCN (2014)
[21] Animal species occurrences are based on the geographical range data from IUCN.
[22] Kreft and Jetz (2007). Global patterns and determinants of vascular plant diversity. Proceedings of the National Academy of Sciences, 104(14), 5925-5930. https://doi.org/10.1073/pnas.0608361104

Risk assessment: Species richness (PDF)

Evaluation target: The effect of water scarcity on species richness (main focus on wetlands)

Input data: Primary, Secondary

Spatial scale: Global

Possibilities and restrictions how to use the method

The presented CFs are included in the LC-Impact methodology for life cycle impact assessment (Verones et al. 2017). The spatially differentiated CFs are available as Google Earth files and shapefiles for use in geographic information systems. Regionalized inventories for agricultural water consumption are for example available from Pfister et al. (2011)[23] and spatial information is also available for datasets in ecoinvent[14].

The method is holistic in the sense that it is including the current threat level, geographic range of species as well as CF for both aquatic and terrestrial ecosystems.

The CF for animal taxa contains a considerable degree of uncertainty, due to the simplifications and assumptions necessary for modeling wetlands on a global scale.

2.6 Biodiversity Damage Potential (BDP)

Biodiversity Damage Potential	Knudsen et al. (2017). Characterization factors for land use impacts on biodiversity in life cycle assessment based on direct measures of plant species richness in European farmland in the 'Temperate Broadleaf and Mixed Forest' biome. Science of The Total Environment, Volume 580, Pages 358-366. https://doi.org/10.1016/j.scitotenv.2016.11.172				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Risk assessment	Provide Characterization Factors (CF) for LCA of agricultural products regarding biodiversity impact of land use	Impact drivers (land use)	Product	Quantitative

Short description

Biodiversity damage potential is a LCA method for land use that aims at incorporating the impacts of management practices (i.e., organic versus conventional) and land uses (pasture, arable land, hedges) into characterization factors (CF) for agricultural products (Knudsen et al., 2017). The applies plant species richness (expressed as PDF) as indicator for the biodiversity impact. This is used to calculate the output value i.e., biodiversity damage potential (BDP), as follows:

$$BDP = CF \times t \times A$$

[23] Pfister et al. 2011. Projected water consumption in future global agriculture: scenarios and related impacts. Science of The Total Environment, Volume 409, Issue 20, Pages 4206-4216. https://doi.org/10.1016/j.scitotenv.2011.07.019

The CF is the specific PDF for a certain land use class compared with a reference state, *t* is time and *A* is the area affected by the certain land use class. The reference state that is chosen for the method is semi natural woodland. Furthermore, the method is based on case studies within the Temperate Broadleaf and Mixed Forest biome in Europe and the method has currently only been tested within this biome (Knudsen et al., 2017).

Implementation example

The method has thus far been tested on six case study sites within the Temperate Broadleaf and Mixed Forest biome. The case study sites including Austria (pannonian climate), Germany (continental climate), France (sub-mediterranean climate), Hungary (pannonian climate), Switzerland (alpine climate) and Wales (Atlantic climate) (Knudsen et al., 2017). The conclusion that was drawn from the results was that the CF is highest in arable land, since it has almost exclusively positive values (indicating lower biodiversity quality than the reference state) This is in contrast with the other management systems which mainly have negative CF (indicating higher biodiversity quality than reference state) (Knudsen et al., 2017).

<u>Summary of the implementation example:</u>

Risk assessment: Biodiversity impact (expressed as PDF in terms of species richness) from land use within six European countries in the Temperate Broadleaf and Mixed Forest biome.

Evaluation target: Agricultural products

Input data: Secondary data[24,25]

Spatial scale: Biome

Possibilities and restrictions how to use the methods:

Advantages:

- Method based on dataset which has used the same sampling method in each country for biodiversity data which provides coherent data.
- Incorporates the positive impact of organic farming on specifically biodiversity into LCA.
- Covers the majority of EU as the region mainly is within the 'Temperate Broadleaf and Mixed Forest' biome.

Limits:

- Currently restricted to Temperate Broadleaf and Mixed Forest biome and thus falls short for global comparison.
- The reference state was chosen based on similarity to natural habitat without anthropogenic interference, thus it is indcated that the more « natural » a land is the higher biodiversity

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[24] Arndorfer et al. (2010). Delimitation of BIOBIO Case Study Regions and the Selection of Case Study Farms. BOKU. 65 p. Online at. http://www.biobio-indicator.org/deliverables/D31.pdf

[25] Herzog et al. (2012). Biodiversity indicators for european farming systems. A Guidebook. Zurich, Agroscope Reckenholz-Tanikon Research Station, p. 101. https://www.cabdirect.org/cabdirect/abstract/20123402699

quality there is which is not always the case. Reference state is crucial for the validity of the results.

2.7 Land Use Change Improved LCA (LUCI-LCA)

LUCI-LCA	Chaplin-Kramer et al. (2017). Life cycle assessment needs predictive spatial modelling for biodiversity and ecosystem services. Nature Communications, 8, 15065. https://doi.org/10.1038/ncomms15065				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Spatially explicit modelling of commodity production expansion on biodiversity and ecosystem services	Impacts and dependencies	Product (Commodities)	Quantitative

Short description

LUCI-LCA can be used to estimate the impact of production shifts on biodiversity and ecosystem services. The method uses statistical information to link commodity production with land use extent. By extrapolating from historical data, the potential land use change associated with additional commodity production can be estimated. Spatially explicit models for estimating land use change impacts are then applied.

Implementation example

Not available

Summary of the implementation example:

Chaplin-Kramer et al. (2017) provide a case-study example where they estimate the impact of bio-based plastic feedstock (maize and sugarcane) production expansion on Mean Species Abundance (MSA).

Risk assessment: Biodiversity impact of the production expansion of two commodities

Evaluation target: Maize and sugarcane used for BIO-HDPE production

Input data: National FAO data is used to relate production to the area of a particular crop over a time series (production in each year is compared against harvest area in each year). InVEST (v 3.2) GLOBIO model is used to estimate biodiversity impacts.

Spatial scale: Country

Possibilities and restrictions how to use the method

The method demonstrates that publicly available, spatial data can be applied to predictive modelling of large-scale changes in land systems through LCA.

Advantages:

Can only be applied on the large-scale, for individual sectors and regions/countries for which production statistics and land use data is available.

Possibilities:

The straightforward approach is easy to understand and uses data that is publicly available.

2.8 Land use intensity specific biodiversity footprint (LUIS)

LUIS	Chaudhary and Brooks (2018). Land Use Intensity-Specific Global Characterization Factors to Assess Product Biodiversity Footprints. Environmental Science & Technology, 52, 9, 5094-5104. https://doi.org/10.1021/acs.est.7b05570				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Risk assessment	To assess biodiversity footprint of products (using the characterization factors presented in the paper)	Impact	Product / Value Chain	Quantitative

Short description

The LUIS method provides characterization factors (CFs) for potential biodiversity loss in 804 different ecoregions for five different taxonomic groups (mammals, birds, amphibians, reptiles and plants), and a taxa-aggregated unit resulting from different types of anthropogenic land use. The method covers cropland, pasture, forestry, and urban land use, at three different levels of land use intensity (minimal, light and intense), for the five taxons the unit is potential species loss (PSL), however, for the aggregated it is potential disappeared fraction (PDF). The CFs are developed based on vulnerability scores and countryside SAR, which are developed by using e.g., data on global land use intensity maps, WWF Wildfinder database and IUCN red list habitat classification scheme. The method provides CFs for land transformation (e.g., for deforestation situations) and land occupation, and these reflect the potential biodiversity loss of human disturbance as in comparison to natural (primary) vegetation in the chosen ecoregion. The LCA framework can be viewed in Fig. 1.

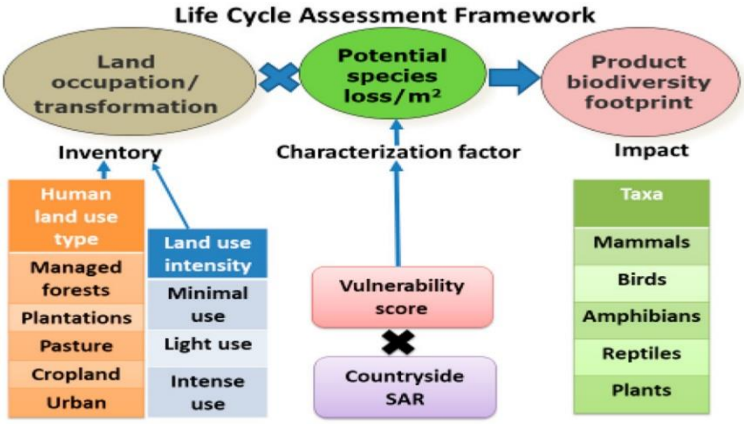

Fig. 1. Life Cycle Assessment framework. Reprinted from Chaudhary and Brooks (2018).[26]

Implementation example

Tidåker et al. (2021) used the CFs from Chaudhary and Brooks (2018) to evaluate the biodiversity impact of pulses consumed in Sweden. The evaluation of production encompassed and compared pulse crops cultivated in Sweden as well as pulses produced abroad (China, Italy, Canada, and Turkey), grown in both conventional and organic production systems. A comparison of the pulses is visualized in Figure 2.

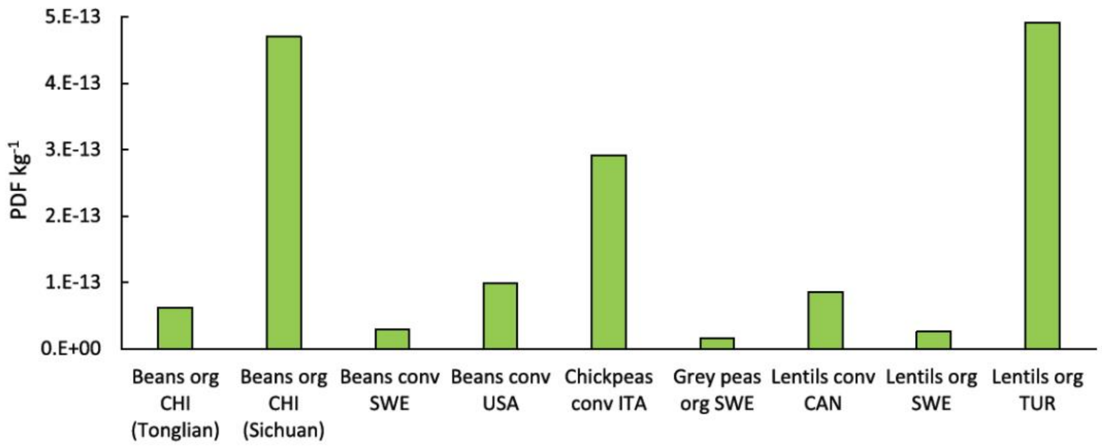

Fig. 2. Biodiversity impact (potential disappeared fraction; PDF) per kg cooked pulses originating from conventional (conv) or organic (org) production in two regions in China (CHI), Sweden (SWE), USA, Italy (ITA), Canada (CAN) and Turkey (TUR). Reprinted from Tidåker et al. (2021).[27]

Summary of the implementation example:

[26] Chaudhary and Brooks (2018). Land Use Intensity-Specific Global Characterization Factors to Assess Product Biodiversity Footprints. *Environmental. Science & Technology,* 52, 9, 5094–5104. https://doi.org/10.1021/acs.est.7b05570

[27] Tidåker et al. (2021). Towards sustainable consumption of legumes: How origin, processing and transport affect the environmental impact of pulses. Sustainable Production and Consumption, Volume 27, Pages 496-508. https://doi.org/10.1016/j.spc.2021.01.017

Risk assessment. evaluating the biodiversity impact of pulses

Evaluation target: product

Input data: primary and secondary. FAO stat, data from industry, literature, and scientific articles.

Spatial scale: country

Possibilities and restrictions how to use the methods

Advantages:

- easy/hands-on
- compatible with global database sets, e.g., FAO stat (need area of the given land use type in m^2)
- global application
- shows results on ecoregional scale (finer scale than country)

Limits:

- intensity levels roughly divided, and the results between e.g. conventional and organic farming is very similar due to the reference situation (i.e. a world without humans)
- insects and other arthropods are excluded
- PDF-Unit may be converted to be useful, only includes the impact driver of land use and land use change

2.9 Forest Fragmentation Potential (FFP)

FFP	Larrey-Lassalle et al. (2018). A methodology to assess habitat fragmentation effects through regional indexes: Illustration with forest biodiversity hotspots. Ecological Indicators, Volume 89, Pages 543-551. https://doi.org/10.1016/j.ecolind.2018.01.068				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Illustration with forest biodiversity hotspots	Impact	Global	Quantitative

Short description

In the context of Forest Fragmentation Potential (FFP), the metapopulation capacity λ is employed to assess and compare the ability of various fragmented landscapes to sustain viable metapopulations.

Implementation example

The assessment focused on biodiversity hotspots so that it could be implemented globally. A region had to meet two criteria to be classified as a biodiversity hotspot: 1) the area must have many endemic vascular plants and 2) have 30% or less of its original vegetation, which corresponds to the fragmentation threshold below which it is important to consider fragmentation.

The study considered all ecoregions that belong to biodiversity hotspots, focusing on the most important habitat types of forests. To illustrate the applicability and interest of the methodology, all forest ecoregions included in the biodiversity load areas were provided with global spatial fragmentation indices calculated at a dispersal distance of 1 km valid for multiple species. Ecoregions were divided by a virtual grid and statistical analysis was performed on metapopulation capacity values calculated at the grid square scale to obtain forest fragmentation potential FFP at three spatial aggregation levels within the ecoregion (highly converted forest and whole forest ecoregion).

<u>Summary of the implementation example:</u>

Risk assessment: Species richness

Evaluation target: Forest – species richness

Input data: Primary, Secondary

Spatial scale: Global

Possibilities and restrictions how to use the method

Advantages:

- Suitable for 300 ecoregions around the world
- Has been developed to fit most species
- Specialized in forests
- Suitable for a large number of species, scales and regions
- consider habitat fragmentation

Limits:

- Covers land use change only
- includes only one land use class (forest)
- Methodological and practical limitations

2.10 IMPACT World+

IMPACT World+	Bulle et al. (2019). IMPACT World+: a globally regionalized life cycle impact assessment method. Int J Life Cycle Assess 24, 1653–1674. https://doi.org/10.1007/s11367-019-01583-0				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Assessing emissions and resource consumption from any location worldwide through characterization factors at four hierarchical levels of resolution	Impact	Product	Quantitative

Short description

Methods with IMPACT World+, uses a midpoint-damage framework with four distinct complementary viewpoints to present an LCIA profile. A total of nine different characterization factors are used: Global warming, marine acidification, mineral resource depletion, terrestrial and freshwater acidification, freshwater eutrophication, ecotoxicity and human toxicity, impacts on human health, water consumption and ecosystem quality.

The study follows the following structure.

Emissions/extraction -> Midpoint level impacts/indicators -> Damage level impacts/indicators -> Damage on areas of protection-> Damage on areas of concern

Method

The long-term impact categories have been subdivided between shorter-term damages (over the 100 years after the emission) and long-term damages.

The IMPACT World+ method integrates developments in the following categories, all structured according to fate (or competition/scarcity), exposure, exposure response, and severity:

- climate change (ecosystem quality)
- freshwater and terrestrial acidification
- freshwater and marine eutrophication
- land transformation and occupation for biodiversity
- water availability
- freshwater ecotoxicity interim
- photochemical ozone formation
- terrestrial and marine ecotoxicity
- ionizing radiations

Results:

(a) climate change and impacts of particulate matter formation have a dominant contribution to global human health impacts whereas ionizing radiation, ozone layer depletion, and photochemical oxidant formation have a low contribution and

(b) climate change and land use have a dominant contribution to global ecosystem quality impact.

(c) New impact indicators introduced in IMPACT World+, and not considered in ReCiPe or IMPACT 2002+[28], in particular water consumption impacts on human health and the long-term impacts of marine acidification on ecosystem quality, are significant contributors to the overall global potential damage.

Implementation example[29,30,31,32]

Not available.

Summary of the implementation example:

Risk assessment: potentially disappeared fraction of species, PDF; Charactarization factors; DALY

Evaluation target: product

Input data: Primary, Secondary

Spatial scale: *Global*

Possibilities and restrictions how to use the method

The IMPACT World+ method builds on a midpoint-damage LCIA framework that ensures consistency of modeling assumptions and choices across impact categories. It allows assessing emissions and resource consumption from any location worldwide through characterization factors at four hierarchical levels of resolution: global default, continental default, country default, and native resolutions for all regional impact indicators with the associated uncertainty due to spatial variability. For most of impact indicators, spatial variability of elementary flow-specific CFs is larger than the variability among elementary flows.

[28] Jolliet et al. (2003). IMPACT 2002+: A new life cycle impact assessment methodology. Int J LCA 8, 324–330. https://doi.org/10.1007/BF02978505

[29] Hauschild and Wenzel (1998). Environmental Assessment of Products. ISBN: 978-0-412-80810-4. https://link.springer.com/book/9780412808104

[30] Toffoletto et al. (2007). LUCAS - A New LCIA Method Used for a Canadian-Specific Context. Int J Life Cycle Assessment 12, 93–102. https://doi.org/10.1065/lca2005.12.242

[31] Verones et al (2017). LCIA framework and cross-cutting issues guidance within the UNEP-SETAC Life Cycle Initiative, Journal of Cleaner Production, Volume 161, Pages 957-967. https://doi.org/10.1016/j.jclepro.2017.05.206

[32] Margni M et al. (2008) Guidance on how to move from current practice to recommended practice in life cycle impact assessment. UNEPSETAC Life Cycle Initiative. https://www.lifecycleinitiative.org/wp-content/uploads/2012/12/2008%20-%20Guidance%20to%20move%20to%20LCA.pdf

2.11 MariLCA - An effect factor approach for quantifying the entanglement impact on marine species of macroplastic debris within LCIA

MariLCA	Woods et al. (2019). An effect factor approach for quantifying the entanglement impact on marine species of macroplastic debris within life cycle impact assessment. Ecological Indicators, Volume 99, Pages 61-66. https://doi.org/10.1016/j.ecolind.2018.12.018, https://ars.els-cdn.com/content/image/1-s2.0-S1470160X18309518-mmc1.docx				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	The impact of plastic entanglement on marine species	Impact	Product	Quantitative

Short description:

A preliminary effect factor (EF) for working towards including the impacts of entanglement in plastic waste on marine biodiversity in life cycle assessment (LCA).

Main goal:

The impact of plastic entanglement on marine species.

Methods:

EF modelling approach couples spatially-differentiated and taxon-specific estimates of the current fraction of species affected by entanglement with spatially-differentiated floating macroplastic density estimates.

Results:

Results indicate that the effect of macroplastic density on the fraction of species potential affected by entanglement is highest in areas with low estimated plastic density, most prominently the Southern Ocean and equatorial Pacific.

Data sources:

The effect factor (EF) follows an average LCIA approach, meaning that the EF reflects the average distance between the current state and preferred state of the environment per unit of pressure increase.[33]

Implementation example:

Not available.

[33] Huijbregts et al. (2011). Do we need a paradigm shift in life cycle impact assessment? Environ. Sci. Technol. 45 (9), 3833–3834. https://doi.org/10.1021/es200918b

Summary of the implementation example:

Risk assessment: potentially disappeared fraction of species (PDF)

Evaluation target: product

Input data: secondary

Spatial scale: global

Possibilities and restrictions how to use the method

discovered trade-offs between data source options, e.g. species coverage versus range extent accuracy. In addition, we identify knowledge gaps, e.g. defining species sensitivity effect thresholds to enable statistically relating pressure (density of floating marine macroplastic) with effect (the potentially affected fraction of species), and set out options for future methodological development for achieving quantification of an effect factor ready for incorporation in to a life cycle impact assessment modelling approach.

2.12 Valuing Biodiversity in Life Cycle Impact Assessment

	Lindner et al. (2019). Valuing Biodiversity in Life Cycle Impact Assessment. Sustainability, 11 (20), 5628. https://doi.org/10.3390/su11205628				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA-based method	Performance assessment	To quantify potential biodiversity impacts of land use	Impact	Product	Quantitative

Short description

The method allows the integration of the impacts for land using processes on biodiversity into LCA assessment.

The method proposed by Lindner et al. (2019) is a land-use focused impact assessment method applicable to established LCA principles. The aim of the method is to provide a biodiversity value (BV_{LU}) for a specific patch of land that is used for evaluation of biodiversity based regarding naturalness. Several criterions are aggregated into a land-use specific biodiversity value BV_{LU}. To differentiate between different land use classes, each class is assigned a land use specific biodiversity value which ranges from a minimum to a maximum. If all parameters within a class have the highest biodiversity quality, the BV_{LU} reaches its maximum. The maximum and minimum level as well as how large the interval is depending on the specific land use class. The BV_{LU} is then transformed into a local biodiversity value BV_{LOC} and this value is multiplied by an ecoregion factor (EF) that provides a comparable global biodiversity value BV_{GLO}. This is used as a quality indicator (Q). The difference in Q between BV_{GLO} and the reference state (without interference) is used as indicators in LCIA and further LCA calculations.

Implementation example

Hemeroby as an impact category indicator for the integration of land use into life cycle (impact) assessment (Scientific article)[34]

To illustrate the application of the method, the authors give an example using a common consumer product that combines various components of land use – a pizza which consists of wheat dough, tomatoes, pork salami and dairy cheese (Table 1). The pizza is baked in a traditional wood-fired oven fed with beech logs.

A BV_{LOC} is calculated using the mathematical formula in the method. The EF for the place where the ingredient is grown is noted. As can be seen in Table 2, the EF differs significantly for soy compared to the other ingredients. The EF and BV_{LOC} are then aggregated to the BV_{GLO} which is the Q. From the Q the difference (deltaQ) to the "natural state" is calculated, from which the impact per functional unit for the pizza can be derived (Lindner et al., 2019).

Table 1. Basic data for ingredients used in the example. Adapted Lindner et al. (2019).

Ingredient	**Quantity per FU**	**Land Use Class**	**Ecoregion**	**Land Use per Ingredient** [m^2a/kg]	**Land Use per FU** [m^2a/FU]
wheat flour	200 g/FU	agricultural land, typical intensive cultivation	PA0445 [(a)]	1.5	0.3
cheese	200 g/FU	agricultural land, monoculture soybean	NT0704 [(b)]	4.5	0.9
salami	100 g/FU	agricultural land, monoculture soybean	NT0704 [(b)]	8.0	0.8
tomatoes	100 g/FU	greenhouse plantation, highly intensified	PA1219 ©	0.05	0.005
firewood	0.002 m^3/FU	forest, beech	PA0445 [(a)]	1000	2.0

Table 2. Aggregation of the specific biodiversity value (BVLU) of the ingredients to the complete product and considering the ecoregion factor (EF). Adapted Lindner et al. (2019).

Ingredient	**BV_{local}**	**EF**	**BV_{global} = Q**	**ΔQ**	**Land Use per FU** [m^2a/FU]	**Impact per FU = Land Use * ΔQ** [BVI m^2a]
wheat	0.373	0.127	0.045	0.081	0.3	0.025
soy/cheese	0.329	0.427	0.141	0.285	0.9	0.257
soy/salami	0.329	0.427	0.141	0.285	0.8	0.228
tomatoes	0.000	0.110	0.000	0.110	0.005	0.001
firewood	0.821	0.127	0.112	0.015	2.0	0.030
total						0.540

Summary of the implementation example:

Risk assessment: The biodiversity impacts of the commodities needed for producing a pizza.

[34] Fehrenbach et al. (2015). Hemeroby as an impact category indicator for the integration of land use into life cycle (impact) assessment. The International Journal of Life Cycle Assessment, 20, 1511–1527. https://doi.org/10.1007/s11367-015-0955-y

Evaluation target: Product

Input data: Primary and secondary data

Spatial scale: Land use category, biome

Possibilities and restrictions how to use the method

Currently wider adoption of method could allow moving from using naturalness to other references that reflect societal values.

Advantages:

- The method facilitates the differentiation in impact on biodiversity between biomes and ecoregion as these are accounted for in addition to differentiation between practices (land use classes and management classes).
- The differentiation between ecoregions is particularly useful to understand how the biodiversity impact of a specific land-use can vary significantly depending on the ecoregion. Lindner et al. (2019) describes that this can help to answer questions such as "How much worse is it to destroy half the biodiversity on a [square kilometer] the Peruvian Yunga versus half the biodiversity on another [square kilometer] in the Siberian tundra". This makes it globally comparable.
- On a product base, the method is easy to comprehend.

Limits:

- The working assumption of the method is that the more "natural" a patch of land is, the better for biodiversity it is. However, this does not have to be the case in all scenarios e.g., if the anthropogenic involvement aimed to implement elements to elevate or protect biodiversity. This limits the use of the method to areas where the natural state is with a certainty the better option.
- The method is a top-down approach as biodiversity is interfered by a use of indicators and not by measuring on-site the biodiversity. Thus, certain generalizations can occur.
- Unclear if the method would be applicable to other targets than products.

2.13 BioImpact

BioImpact	Turner et al. (2019). Accounting for biodiversity in life cycle impact assessments of forestry and agricultural systems—the BioImpact metric. The International Journal of Life Cycle Assessment, 24, 1985–2007. https://doi.org/10.1007/s11367-019-01627-5				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Risk assessment	Accounting the biodiversity impact of different sites/systems, by consideration of multiple aspects of biodiversity	Impact	Site/region	Quantitative (BioImpact Score)

Short description

BioImpact is a method where a quantitative value for biodiversity impact is derived from semi-quantitative questions, which are incorporated into LCA (Turner et al. 2019). The aim of the method is to develop a LCA method that considers more aspects of biodiversity than species diversity i.e., species composition, structure, function, genetic diversity and organizations, connectivity and fragmentation, disturbance, threatened species, invasive species, population, as well as community diversity. The semi-quantitative questions are each answered with numbers ranging from -10 to +10 where the negative values indicate biodiversity improvement, the positive values indicate biodiversity loss whereas 0 indicates no change in biodiversity. There is an optional weighing of the scores depending on varying importance of the different ecological concepts included in the survey. The recommendation from the developers, is to supplement BioImpact with scientific literature primarily and expert elicitation processes secondarily. The time frame for using the BioImpact method for a given project is estimated to take 5-8 weeks including literature review, scoring questions and advisory through expert elicitation.

Implementation example

Turner et al. (2019) implements BioImpact on land uses in Australia. It focuses on four production systems, two forestry systems (native forestry and pine plantation) and two agricultural systems (cropping/pasture and rangeland grazing), to allow for comparison both between and within systems. In this implementation of BioImpact, both literature reviews and expert elicitation were conducted. Some key biodiversity concepts were valued higher than some others, thus points in each question were weighted before the final BioImpact score. The result of the BioImpact scores showed higher values, meaning greater biodiversity loss, for cropping/pastures, rangeland grazing and pine plantation than native forestry[39].

<u>Summary of the implementation example:</u>

Risk assessment: The biodiversity impact of different land uses in Australia

Evaluation target: Production site

Input data: Both primary (survey) and secondary (e.g., hardwood and softwood data: Forest and Wood Products Australia; Paper data: Australian paper industry statistics)

Spatial scale: Sites (two agricultural systems and two forestry systems)

Possibilities and restrictions how to use the method

Advantages:

- BioImpact considers a broad spectrum of key biodiversity concepts, which can be beneficial to use in a disturbance framework.
- The method is applicable for agricultural and forestry systems.
- The use of BioImpact is not dependent upon software (e.g., GIS) or complex modelling.

Limits:

- For optimal application, BioImpact requires extensive literature and access to ecological experts. Consequently, lack of this input can have a large impact on the output and its accuracy.
- The weighing of the key concepts can be subjected to biases and needs to carried out in a consistent manner to allow for correct comparison and further utilization in LCA.
- It is not clear if the method is applicable to other countries/regions, or if adjustments are needed to adapt to the given local conditions.

2.14 Global Biodiversity Score (GBS)

Global Biodiversity Score (GBS)	https://www.cdc-biodiversite.fr/documentation-gbs/ Report: The Global Biodiversity score, *GBS Review: Core concepts,* May 2020. Accessible here: https://www.cdc-biodiversite.fr/wp-content/uploads/2023/01/20200518_GBS-review_Core-concepts_final-version_no-track-changes.pdf				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA + I/O	Performance assessment	To quantify the company's contributions to the direct drivers & to reflect the state of the biodiversity, that covers the entire value chain.	Dependency, Impact, Impact drivers	• Product • Production site / Company • Business sector / Investor Portfolio	Quantitative ($MSA.km^2$)

Short description

The Global Biodiversity Score (GBS) uses company data (purchases, turnover, inventory data and pressure data) to model the impacts in $MSA.km^2$. When the data on impact drivers/pressures from the company is available, the GBS converts those impact drivers/pressures into impacts using the GLOBIO model's pressure impact relationships. When the data on impact drivers/pressures is not available, it can convert inventory data into pressure data. If the inventory data from the company is not detailed enough, it can use LCA methods to convert quantities of products into inventory data. Finally, if there is no physical data, it can use financial data to compute impacts by using an I-O model (EXIOBASE).

Terrestrial Impact drivers:

- Land / sea use change: Land use, Fragmentation and Encroachment
- Direct exploitation is not directly associated to specific impact drivers/pressures in GLOBIO Terrestrial. The GBS however includes the impacts of extraction of living biomass (crops, wood logs) and non-living materials (metal ores, fossil fuels). The impact driver/pressures associated to unsustainable hunting (and fishing for aquatic pressures) are not yet covered
- Climate change
- Pollution: Atmospheric nitrogen deposition, and on-site pollution is partly accounted for in the impact driver/pressure Land use. Pollution related to pesticides and ecotoxicity will be covered in another document as it will not rely on GLOBIO Terrestrial (CDC Biodiversité 2020b). Other sources of pollution such as plastic pollution are not covered yet
- Invasive alien species: not yet covered

Freshwater Impact drivers:

- Land / sea use change: Land use in catchment of rivers and wetlands, Wetland conversion
- Direct exploitation: Hydrological disturbance since the impacts of over-withdrawal of water beyond the capacity of natural ecosystems is taken into account. The impact drivers/pressures associated to unsustainable freshwater fishing are not yet covered
- Climate change: Hydrological disturbance, as it also includes the impact of climate change on rivers and floodplain wetlands and swamps
- Pollution: Nutrient emissions. Pollution related to pesticides and ecotoxicity is covered in the Ecotoxicity review document (CDC Biodiversité 2020b). Other pollution sources such as plastic pollution are not covered yet

Marine impact drivers :

- Overfishing : the Depletion Index linked to fishing activities can be measured

Implementation example

GBS[35] used for Schneider Electric: The biodiversity footprint of the whole Schneider group was assessed in 2019 to report impacts. It is made at corporate level, to quantify biodiversity hotspots and opportunities all along Schneider Electric's value chain. The impacts are assessed for activities in scope 1 and 2 as well as upstream activities in scope 3 For the scope 3 downstream activities, only the climate change impacts have been assessed.

The customer part of the value chain is the most impactful (85% of total impact). It represents the use phase of products. The operations are only responsible for 0,6% of total impact with the scopes 1 and 2 GHG emissions. The supply chain is responsible for 13% of total impact, and the impact is mainly composed of GHG emissions impacts and wood impacts.

[35] Case study Summary sheet Schneider Electric. Accessible here: https://www.cdc-biodiversite.fr/wp-content/uploads/2022/05/Etude-de-cas-Schneider-Electric.pdf

Summary of the implementation example:

Performance assessment: Biodiversity footprint of Schneider Electric corporate, to quantify the impacts of the whole value chain of Schneider.

Evaluation target: Organization: Schneider Electric group: scope 1, 2 and upstream activities for scope 3 (and also downstream climate change impacts)

*Input data: Primary (*scope 1 surface area occupied, volumes of water consumed, GHG emissions*) & Secondary (purchases, turnover)*

Spatial scale: Country / EU

Possibilities and restrictions how to use the method

Advantages:

- The GBS covers the impacts related to the whole value chain
- It takes into account different pressures on biodiversity
- By default, the GBS can be calculated with secondary data already stored in the tool, that can be completed by primary data when they are available
- Different types of primary data can be used by the tool

Limits:

- In GLOBIO, the pressure-impact relationships are based on limited and fragmented scientific data (there is a lack of taxon and ecosystems)
- The GBS does not consider a few pressures on biodiversity (some chemical pollutions, resources overexploitation, invasive species)
- The GBS does not consider marine biodiversity impacts (except overfishing)
- The default approach gives a vague result of the biodiversity footprint, unless completed by using additional data for better results

2.15 LC-IMPACT

LC-IMPACT	https://lc-impact.eu/ Verones et al. (2020). LC-IMPACT: A Regionalized Life Cycle Damage Assessment Method." Journal of Industrial Ecology 24 (6): 1201–19. https://doi.org/10.1002/crossmark_policy				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Ecoconception tool to compare the biodiversity impact of a product against a reference product	Impact	Product	Quantitative

Short description

The LC-IMPACT methodology has been developed in the three and half year long EU-FP7 project in 2009-2013. It is an LCIA method that covers three areas of protection: human health, ecosystem quality and natural resources. Currently, LC-IMPACT includes 11 broad impact categories, all of which affect one or two areas of protection. Three ecosystem types are distinguished within the "ecosystem quality" areas of protection (see below). End point ecosystem qualities results are expressed in Potential Disappeared Fraction of Species per year (PDF / yr).

Impact categories composing each ecosystem quality assessment are:

Terrestrial:
- Climate change
- Photochemical ozone formation
- Acidification
- Land stress
- Toxicity

Freshwater:
- Climate change
- Toxicity
- Eutrophication
- Water stress

Marine:
- Toxicity
- Eutrophication

Implementation example

LC-IMPACT: A regionalized life cycle damage assessment method (scientific article)[36]

The example compares the effects of different fuel options. The functional unit was defined as driving one passenger kilometer with a Euro 5 car in Europe using petrol and biofuel. The comparison included low sulfur petrol in Europe, E85 fuel with bioethanol produced from sugarcane in Brazil, and E85 fuel with bioethanol produced from maize in the United States. The information on petrol transportation was taken from Ecoinvent[14]. Ethanol was supposed to substitute petrol 1:1 energetically in modern fuel-injected cars.

Climate change, land use, water stress and particle formation were chosen as the illustrative impact categories of the case study. The CF values used were downloaded from www.lc-impact.eu. Ecoinvent 3.5[14] with the cutoff allocation method was used as background database. Calculations were made with Brightway 2 LCA software.

Ecosystem terrestrial quality

A strong contribution of climate change was observed in this area of protection (for each 3 scenarios). The remaining impact is due to land occupation.

[36] Verones et al. (2020). LC-IMPACT: A Regionalized Life Cycle Damage Assessment Method." Journal of Industrial Ecology 24 (6): 1201–19. https://doi.org/10.1002/crossmark_policy

However, for this indicator results vary greatly between site-dependent and site-generic assessment (factor 80). Contribution of midpoint impact categories vary according to the timeframe and evidence level chosen ("all effects and infinite time horizon" vs "certain effects and 100 years' time horizon") but order of importance remains the same (but for sugarcane ethanol where land occupation becomes the first driver of species lost when considering certain impact 100 years).

Freshwater ecosystem quality

Under certain impact 100 years, water stress is fully responsible of species loss for all products considered. When assessing all impacts long term, climate change becomes the main driver for petrol fueled car and respectively counts for 30% and 20% for sugarcane ethanol and maize ethanol.

The impact of water consumption varies from a factor 3 between site-generic and site-dependent assessment.

Summary of the implementation example:

Performance assessment: Impact on human health, terrestrial and aquatic ecosystems of three different fuel options for a Euro 5 car powering

Evaluation target: 3 products: low sulfur petrol in Europe, E85 with bioethanol from sugarcane producted in Brazil, E85 with bioethanola from US cultured maize

Input data: Primary and secondary Ecoinvent 3.5[14] cut off, Characterization factors (CF) from LC Impact database

Spatial scale: *Country / EU*

Possibilities and restrictions how to use the methods

Advantages:

- Characterization factors with spatial detail (going beyond country scale data)
- Opportunity to analyze data with different time horizons and confidence levels
- LC-impact uses vulnerability factors which enable to consistently address the global extinction of species
- Use of global PDF metric

Limits:

- LCA software tools and Lifecycle inventory databases do not handle spatially differentiated data well preventing from a greater diffusion of the LC-Impact method
- Inventory data at native scale should be ideally used to determinate accurate normalization references and enable a more faithful normalization
- Uncertainty data only discussed qualitatively and not quantitatively
- No midpoint characterization factors because they are not consistently available yet across considered impact categories. Regionalization can lead to different results in midpoint and endpoint (if some regional mechanisms are not included in the midpoint calculation). Debate

of which indicators should be the best midpoint indicators based on the localization of the impact in the cause-effect chain.

2.16 Product Biodiversity Footprint (PBF)

	Product Biodiversity Footprint http://www.productbiodiversityfootprint.com/				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA-based method	Performance assessment	The method aims to compare the biodiversity impact of a product/service against a reference product	Impact driver (IPBES drivers of change) and subdivision in 9 targets	Product	Quantitative

Short description

The Product Biodiversity Footprint (PBF) is a design tool enabling to compare the contribution to biodiversity pressure between a reference product and an alternative on nine dimensions (Table 3).

Table 3. Impact drivers and corresponding IPBES drivers of change. Adapted from Asselin et al. (2020).[37]

PBF Impact drivers		IPBES direct drivers
Climate change (LCA result under LC-impact method)		Climate Change
Photochemical Ozone (LCA result under LC-impact method)		Pollution
Eutrophication (LCA result under LC-impact method)		
Acidification (LCA result under LC-impact method)		
Water stress (LCA result under LC-impact method)		Habitat Change
Land occupation (LCA indicator modified)		
Land transformation (LCA indicator modified)		
Species management (from qualitative data)		Species management
Invasive Species (from qualitative data)		Invasive Species

Implementation example

[37] Asselin et al. (2020). Product Biodiversity Footprint – A novel approach to compare the impact of products on biodiversity combining Life Cycle Assessment and Ecology. Journal of Cleaner Production, Volume 248, 119262. https://doi.org/10.1016/j.jclepro.2019.119262

PBF was used in partnership with L'Oréal to compare the biodiversity impact of two shower gels made with palm oil derivative from Malaysia.[38] The reference product is sourced from conventional palm oil while the variant product is sourced from palm oil meeting the Round table on Sustainable Palm Oil (RSPO) criteria. A cradle-to-gate approach was taken, encompassing the following steps: raw material production (including bio-based chemicals for agricultural processes), raw material transformation into chemical derivatives, packaging, and transportation to bottling plant, shower gel component and transportation to plant and shower gel manufacturing and bottling.

The functional unit was defined as: "Provide shower gel enabling 15 body washes".

PBF follows a three steps approach:

1. Collecting inventory data to perform a LCA under LC- Impact methodology (using country-level spatialized characterization factors).
2. Modelling of Practice Adjustment Coefficient (PAC) indicators and Characterization factors adjustments. This was done thanks to RSPO data and scientific literature on the impact of palm oil practices on bird species richness[39].
3. Estimation of the qualitative impact of reference and variant product on species management and invasive species. Implemented practices for species management and conservation at palm agricultural phase were valued for species management while the risk of diffusion of invasive alien species in transport phase was assess for invasive species.

The analysis presented results per MEA drivers and sub indicators. Variant shower gel was shown less impacting in:

- habitat change (due to the absence of land transformation)
- climate change (due to land transformation)
- invasive alien species (76 vs 100) and species management (63 vs 100)

No significant difference in pollution were observed between the variant and reference product.

Summary of the implementation example:

Performance assessment: Impact on biodiversity of sustainable sourced palm oil shower gel (RSPO compliant) compared to a conventionally sourced shower gel

Evaluation target: Sustainably sourced and conventional sourced palm oil-based shower gel comparison regarding nine indicators linked to biodiversity

Input data:

- Primary data: on agricultural data, gel composition, bottling site manufacturing

[38] Panorama des méthodes d'évaluation environnementale - Product Biodiversity footprint », Chair Elsa Pact (2021). https://www.elsa-pact.fr/content/download/3825/37219/version/1/file/M09_ProductBiodiversityFootprint_V01.pdf
[39] Fitzherbert et al. (2008). How will oil palm expansion affect biodiversity?. Trends in ecology & evolution, 23(10), 538-545. https://doi.org/10.1016/j.tree.2008.06.012

- Secondary data: Databases (Ecoinvent[14], Ademe), inventory data from Ecoinvent 3.3, core Characterization factor from LC-Impact

Spatial scale: Country

Possibilities and restrictions how to use the methods

Advantages:

- PBF distinguish between agricultural practices when current LCA methods cannot
- Instinctive results visualization (except for the multi-criteria results, see below)
- Cover all five Millenium Ecosystem Assessment (MEA) pressures
- Elaborates on life cycle assessment scientific community
- Powerful decision-making tool appreciated by companies

Limits:

- Impact on aspects such as marine biodiversity, ecotoxicity and land use change are not covered.
- Impact drivers are not classified by realms (terrestrial / freshwater / marine)
- Qualitative assessment of invasive species and species management. Goal is to lean toward a semi-quantitative assessment.
- Multi-criteria results are not easily communicable. The unit is consistent for habitat change, pollution, and climate change (PDF.yr) but invasive species and species management are not expressed in this unit.
- Use of Potential Disappeared Fraction (PDF) is controversial and does not speak to beyond the LCA community. Ecologists are not at ease with this unit.

2.17 Land use Impacts on Functional Plant Diversity (FPD)

FPD	Scherer et al. (2020). Characterizing Land Use Impacts on Functional Plant Diversity for Life Cycle Assessments. Environmental Science & Technology, 54 (11), 6486-6495. https://doi.org/10.1021/acs.est.9b07228				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	A framework for developing characterization factors for functional diversity as affected by land use	Impact	Country / Region	Quantitative

Short description

A framework for developing characterization factors for functional diversity as affected by land use. It exploits the large databases on plant traits and species composition that have recently become available and allow bringing biodiversity impact assessment to the next level. Three functional diversity indices therein describe different aspects of functional diversity, namely richness, evenness, and divergence.

Implementation example

Not available.

Summary of the implementation example:

Risk assessment: Plant functional diversity

Evaluation target: Organisation (Land use change)

Input data: Primary + secondary

Spatial scale: Local – Land use

Possibilities and restrictions how to use the method

Characterization factors were derived for functional plant diversity loss caused by marginal land occupation of former forests with agricultural land, taking into account confounding environmental covariates.

Three functional diversity indices describe different aspects of functional diversity:

Richness, Evenness, Divergence

Richness, evenness, and divergence were modelled based on plant traits obtained from the most comprehensive trait database for Northwest Europe, including Germany - the LEDA Traitbase. LEDA provides 26 traits for up to 3345 species.

The authors include in the final study uncorrelated traits only (Spearman rank correlation < 0.5), leading to 4 final traits, representing different plant organs – canopy height, specific leaf area, seed number, and seed mass.[40]

1. Functional Plant Diversity. Functional diversity metrics express the diversity in (functional) traits, often weighing contributions of traits of individual species by their abundance. Traits were obtained from the most comprehensive trait database for Northwest Europe, including Germany, the LEDA Traitbase.18,19 LEDA provides 26 traits for up to 3345 species.

2. Land Use. The land use of vegetation plots was retrieved from the CORINE Land Cover (CLC) data sets.30 CLC is coordinated by the European Environment Agency, and their maps cover Europe.

3. Natural Experiment. Natural experiments are observational studies designed as quasi experiments which, like controlled experiments, compare treatment and control groups. In this study, the treatment groups are the vegetation plots with agricultural (anthropogenic) land uses, and the control groups are the plots with forest (natural) land uses.

4. Characterization Factors (CFs) were derived based on the median functional diversities of matched sample pairs for each of nine land use combinations.

Input data requires

[40] https://pubs.acs.org/doi/suppl/10.1021/acs.est.9b07228/suppl_file/es9b07228_si_001.pdf

- Difficulties:
  - Processing and categorization
  - Formation of charaterization factors relative to the study area
- Readily available databases:
  - Corine land cover vegetation plots seem easy to acquire
  - LEDA plant function diversity traits seem easy to acquire

Result is a robust and comprehensive result displaying the effect of land use change on plant communities. Results highlighting the differences in plant functional diversity in Broad-leaved forests, non-irrigated arable land, pastures, complex cultivation patterns as a result of land use change.

2.18 Biodiversity Impact Metric (BIM)

BIM	CISL (2020). Measuring Business Impacts on Nature: A Framework to Support Better Stewardships of Biodiversity in Global Supply Chains. University of Cambridge Institute for Sustainability Leadership. https://www.cisl.cam.ac.uk/system/files/documents/measuring-business-impacts-on-nature.pdf				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA-based methodology	Risk assessment	Used to assess and track how a business's sourcing affects biodiversity, with regards to land use and land use change linked to agricultural production	Impact	Commodity/ Production site/Company/Region	Quantitative

Short description

The Biodiversity Impact Metric (BIM), developed by The University of Cambridge Institute for Sustainability Leadership (CISL), aims to assess impacts on biodiversity from various commodities. The method used assesses impact based on e.g. geo-spatial data (sourcing country), land area needed for producing the commodity, proportion of biodiversity lost when the land is transformed, type of land use and its intensity, as well as the relative global importance of biodiversity present on the given site. The input data needed from businesses is commodity type, sourcing country and quantity purchased. The variables (1) land area, (2) proportion of biodiversity lost and (3) biodiversity importance (range rarity) are multiplicated. The unit of output is 'weighted hectares and the result can be divided by the total amount of commodity purchased to indicate impact per unit sourced (e.g. per kg).

The method can work at any scale. The geographic area (e.g. farm, sub-region, country) at which a business chooses to focus their impact assessment on is dictated only by the availability of the underlying data.

The outputs from the method are most easily interpretable in relative terms, for example, by examining whether the sourcing of a commodity is having a higher or lower impact on biodiversity per tonne sourced compared to other sourcing locations or the global average. By examining the total weighted hectares, a company can identify potential hotspots of their sourcing risk.

Implementation example

Not available.

<u>Summary of the implementation example:</u>

Risk assessment: Assessment of the three variables of different sourcing cocoa locations, evaluation of risk and opportunities of sites and yields.

Evaluation target: Evaluation of impact-weighted hectares thanks to the yields, land area, proportion of biodiversity loss and biodiversity importance.

Input data: Tonnes sourced: Business data.

Yield (kg/ha): From credible sources including a business's own data, otherwise FAO country-level yield estimates used.

Land area (ha): Estimated using the volume of raw material purchased (tonnes)/agricultural yield (tonnes per hectare).

Proportion of biodiversity lost: Global Mean Species Abundance (MSA) values for different land use types and intensities.

Intense (0.90) used for the global average as detailed intensity and land use information is unknown.

Biodiversity importance: Range rarity for cocoa-producing regions (an average that is weighted according to the land area used for production in each region).

Spatial scale: Site (National) or commodity/product

Possibilities and restrictions how to use the method

BIM is a flexible framework that can be applied in a wide range of contexts. The method aligns with the principles of site-based measurement approaches but adapts these to the context of the value chain. It is a practical risk-screening tool for supply chain businesses that source agricultural commodities. The approach allows businesses to proactively manage risks relating to the degradation of biodiversity and its wider societal impacts. By highlighting potential high-risk commodities, contexts or practices, businesses can prioritise where they would benefit from better visibility of their supply chain and collection of more accurate data on their operating practices.

This method reflects the level of biodiversity that persists in a productive landscape relative to the biodiversity that would be there if the original habitat remains intact. BIM does not assess when land transformation took place. It assesses an ongoing occupancy impact or opportunity cost for biodiversity of maintaining the transformed land in commodity production. It is not focused on individual species that should be taken into account, neither overlapping of sites with protected areas.

The method weights three variables equally, which means that the score tends to be more heavily driven by the 'area' variable than 'quantity impacted' and 'biodiversity importance'. Further, it is a relative measure, which is appropriate for examining differences between different sourcing areas using data collected with a similar level of accuracy or company level scores. It needs to be stressed that while comparing commodities, comparing different systems with yields hard to calculate can decrease accuracy.

The method is not suitable for comparing the trade-offs between the three variables. The method does not assess the broader landscape context, for example, a producer may manage their production areas in an intensive way but provide and protect natural habitat in the surrounding landscape.

BIM would only account for the production area impacts. Finally, the method does only consider land use (change) as a driver for biodiversity loss, and excludes other drivers such as climate change and ecotoxicity.

2.19 Biodiversity Indicators for Site-based impacts (BISI)

BISI	UNEP-WCMC, Conservational International and Fauna & Flora International (2020). Biodiversity Indicators for Sitebased Impacts. Cambridge, UK. Biodiversity Indicators for Site-based Impacts Methodology V3.2 (1).pdf (unep-wcmc.org)				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
State-Pressure-Response (SPR) framework	Risk Assesment	Aggregate site-level data on biodiversity impact, benefits, and performance to provide indicators of biodiversity management to companies with site-based impacts	Impact	Company/site	Indicators and scores of biodiversity performance

Short description

The Biodiversity Indicators for Site Based Impacts (BISI) is a method aimed at providing biodiversity performance indicators for companies with site-based impacts (UNEP-WCMC, 2020). Initially, the method was implemented for the mining and energy sectors but is now applicable to most sectors with site-based impacts. Within the general framework there are three stages to follow:

Stage1: Biodiversity significance screening
The first stage starts with an analysis of the company's operations to identify sites where there potentially could be high biodiversity impact and compare this with available data for the site. The places are validated through site visits and discussions with site managers (UNEP-WCMC, 2020).

Stage2: Site-level indicator framework
The State-Pressure-Response (SPR) framework is used to define biodiversity indicators specific to the company. The SPR is based primarily on globally and locally available datasets and secondly on discussions with site-level personnel operating in the high biodiversity significance areas (UNEP-WCMC, 2020).

Stage 3: Aggregating indicators to corporate level
Finally, the SPR scores of all levels (from site up to business, division, and corporate level) are aggregated to provide indicators on the corporate level (UNEP-WCMC, 2020).

Implementation example

A pilot study was conducted on the Kolomea open cast iron ore mine in South Africa operated by the company Anglo American. The aim of the assessment was to evaluate the biodiversity performance of the company, track the progress towards net positive impact of the mining sites as well as provide a biodiversity risk analysis of the sites. The study passed through stage 1 and 2, as stage 3 has not yet been ready for pilot studies.

Initially, information from the site was obtained mainly from a BAP as well as other documents (BISI lists documents accepted for establishing a baseline state) of the sites to establish a pre-project state for the various biodiversity features. The overall *Site Biodiversity Significance* score was deemed a medium level due to the presence of a protected area and the number of threatened species present (EU Business, 2021)[41].

In the second stage there was different results in state, pressure respective response. The State has varied outcomes, with the BMUs directly impacted having a larger decline than BMUs not within the area of direct impact. Pressures are highest in the direct impacted habitats, but the specific animal groups where there's occurring project-induced pressures have low to medium levels on pressures. Response is overall medium as there are responsive measures for all categories in plan, but all are not yet effective (EU Business, 2021)[40].

Summary of the implementation example:

Risk assessment: Habitat and species (SPR assessment)

Evaluation target: Operating sites

Input data: Primary data

Spatial scale: Site and adjacent impacted areas.

Possibilities and restrictions how to use the method

Advantages:

- Provides standardized indicators that can be used for multiple reporting purposes.
- With the required data provided, it gives tools for prioritizing management responses to sites with high biodiversity impacts.
- Besides the risk assessment, the method also includes biodiversity positive impacts.
- Includes multiple biodiversity features related to habitat and species e.g., protected areas, critical habitats, IUCN Red List Threatened Species.

Limits:

- Assessment from expert auditor is needed.
- The method is reliant upon already existing biodiversity management systems. For companies where this is in place, providing indicators is easy. Where this is not in place, the method requires additional work and may thus limit the use.

[41] EU Business 2021. ASSESSMENT OF BIODIVERSITY MEASUREMENT APPROACHES FOR BUSINESSES AND FINANCIAL INSTITUTIONS. Critical assessment of biodiversity accounting approaches for businesses (europa.eu)

- The qualitative criteria for selection of focal biodiversity features might create variability in biodiversity features deemed to meet these criteria depending on who is conducting the selection.

2.20 Empirical characterization factors to be used in LCA and assessing the effects of hydropower on fish richness

	Turgeon et al. (2021). Empirical characterization factors to be used in LCA and assessing the effects of hydropower on fish richness. Ecological Indicators, Volume 121, 107047. https://doi.org/10.1016/j.ecolind.2020.107047				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Measure the of change in fish species richness following impoundment to develop **ecological indicators**	Impact	Local	Quantitative

Short description

Direct empirical data was used to measure the change in fish species richness following impoundment to develop ecological indicators to be used in LCA, and accounting for hydropower impacts on aquatic ecosystems.

1) develop robust empirical Characterization Factors (CFs) and impact scores (IS), based on potentially disappeared fraction of species PDF, across three spatial scales (sampling station, reservoir, and biome).

2) calculate the impact score of impoundments, i.e., transforming a river into a reservoir and its subsequent occupation by the reservoir (ISR; PDF·m^2·year of affected area, accounting for the affected surface and time of occupation), and relate the Impact Score to hydropower generation (IS; PDF·m^2·year of affected area/kWh).

3) to test the need for regionalization by examining if the observed patterns were consistent across the three biomes.

Implementation example

Not available.

<u>Summary of the implementation example:</u>

Risk assessment: Species richness

Evaluation target: River affected by dam impoundment

Input data: Primary, Secondary

Spatial scale: Local

Possibilities and restrictions how to use the methods

Advantages:

First empirically based characterization factors for fish biodiversity in LCA[42];

Extensive literature search to extract rate of change in fish richness;

Development of characterization factors for hydropower from three biomes: tropical, temperate, boreal;

High impact of hydropower in the tropics, lower impacts in temperate & boreal regions;

- Significant change in species richness in tropics
- Moderate change in species richness in temperate regions
- Minimal change in species richness in boreal regions

Hydropower can decarbonize our economy but at higher ecological cost in the tropics.

Limits:

Indicators are sensitive to the duration of the study (the period over which data have been collected after impoundment), which can underestimate the impacts. This result highlights the need to account for the duration of the transient dynamics to reach a steady state (rate of change in species richness = 0) before developing ecological indicators. Does not take into consideration the effect of mitigation measures such as fish ladders or the effect of hydro-turbine type on fish mortality.

2.21 Global Biodiversity Score for Financial Institutions (GBSFI)

GBSFI	Finance for Biodiversity : Guide on biodiversity measurement approaches, Finance for Biodiversity Pledge, 2022 : https://www.financeforbiodiversity.org/wp-content/uploads/Finance-for-Biodiversity_Guide-on-biodiversity-measurement-approaches_2nd-edition.pdf				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Quantitative tool to reflect the state of biodiversity of financial institutions' non-listed assets (i.e: real estate, infrastructure, PE)	Impact driver (IPBES drivers of change), Impact	Business sector / Investor Portfolio, Company with value chain	Quantitative

Short description

The Global Biodiversity Score for Financial Institutions (GBSFI) is based on the GBS. The operational frameworks differ considering differences in terms of coverage (one company vs multiple financial assets) and data availability (comprehensive company data versus scarce publicly available data).

[42] https://ars.els-cdn.com/content/image/1-s2.0-S1470160X20309869-mmc1.docx

As for the GBS, the pressures are first quantified thanks to LCA methods (if collected data is economic activity data, the EXIOBASE database is used to quantify pressures), then the GLOBIO tool links the pressures into impacts on biodiversity that are given in MSA.km^2.

Input data required from financial institutions can be either its own data, data purchased from third-party data providers or a mix of both. The GBSFI can work with different datasets, by increasing order of precision:

1. Economic activity data: turnover and purchases by country and industry. In that case, the EXIOBASE database is used.
2. Pressures, resources and emissions data (Table 4):
    - commodities, services or refined products extracted or consumed
    - Carbon emissions on Scopes 1, 2, 3
    - Land use changes
    - Water withdrawal and consumption by Scope
    - Nitrogen and phosphorous emissions by Scope
3. Biodiversity direct data: when detailed ecological monitoring data are available, the Mean Species Abundance can be directly calculated.

Table 4. The drivers covered are the following. Adapted from CDC Biodiversity (2021).[43]

Hydrological disturbance due to climate change	Climate Change
Effects of climate change on terrestrial ecosystems	
Noise, light and disturbance	Pollution
Terrestrial eutrophication	
Freshwater eutrophication	
Land use change / land transformation	Land / sea use change
Land occupation	
Land use change in river and wetland catchments	
Encroachment	
Fragmentation	
Wetland conversion	
Water use	Direct exploitation

The asset categories covered are the following (emerging – 1-4 times applied):

- Listed equity
- Private equity
- Mortgages and real estate
- Impact funds

Coverage: the method covers the Scope 1, Scope 2 and Scope 3 upstream.

The only Business/finance application to date is the assessment of current performance.

43 CDC Biodiversity 2021. https://www.cdc-biodiversite.fr/wp-content/uploads/2022/05/Etude-de-cas-Mirova.pdf.

Implementation example

Mirova is an asset management company dedicated to responsible investment and has conducted a biodiversity footprint analysis of one of its portfolio companies, Bonduelle, using the GBS-FI method based on 2017 data.

The assessment was conducted in 3 data collection steps:

1. Step 1: financial data

Collection of turnover for the different geographic zones and application of the input-output GBS module with the "Processing of food products n.e.c" sector.

The dynamic impact is 23 MSA.km², the static impact is 5 000 MSA.km².

2. Step 2: Refined assessment based on pressure and inventory data estimated by Mirova

Refinement of data: land use, water consumption and GHG emissions. This refinement is based on publicly available data (Bonduelle CSR report, Carbone 4).

The results show that the default approach (step 1) overestimates cultivated land and underestimates water consumption.

3. Step 3: Refined assessment with non-published Bonduelle data

Refinement of Step 2's data by Bonduelle : spatial allocation of land use, water consumption. Bonduelle has corrected the spatial allocation of Mirova for land use and its global water consumption.

<u>Summary of the implementation example:</u>

Performance assessment: Terrestrial and aquatic static and dynamic impact of Bonduelle in MSA.km²

Evaluation target: 3 steps corresponding to different data collection and estimation methodologies are compared:

- Step 1: default approach (based on financial data)
- Step 2: integration of data of Mirova's analysts specialized in food industry
- Step 3: collection of Bonduelle's data

Input data: Turnover, cultivated area, supply system, water consumption (Bonduelle)

Proxies for spatialization of land use and water consumption (Mirova)

GHG emissions (Carbone 4)

Spatial scale: Company with value chain

Possibilities and restrictions how to use the method

Advantages:

- Scientifically well underpinned (best available knowledge and tools e.g., GLOBIO, EXIOBASE)

- Quantitative scientifically robust link between pressures and impacts
- Covers terrestrial and aquatic biodiversity
- Differentiates past and new impacts
- Spatially explicit
- Covers most drivers for biodiversity loss
- Covers all industry sectors and all countries
- Compatible with site-level data (micro) and international objectives (macro)
- Will allow for introducing weight factors differentiating ecosystem condition based on protection regime, protected species, etc.

Limits :

- Only applicable to non-listed assets
- Pressure-impact relationships in the GLOBIO model are biased towards the most studied species and ecosystems
- Marine biodiversity is not factored in
- Invasive species and soil degradation are not factored in yet; overexploitation is factored in only partially
- Remaining shortcomings in reallocation rules (i.e., linking pressures to economic activities)

2.22 Biodiversity Footprint for Financial Institutions (BFFI)

BFFI	Finance for Biodiversity : Guide on biodiversity measurement approaches, Finance for Biodiversity Pledge, 2022 : https://www.financeforbiodiversity.org/wp-content/uploads/Finance-for-Biodiversity_Guide-on-biodiversity-measurement-approaches_2nd-edition.pdf				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Provide a biodiversity footprint of the economic activities in which a financial institution invests, expressing the impact in PDF.ha.yr and m^2/€ invested	Impact driver (IPBES drivers of change), Impact	Business sector / Investor Portfolio, Portfolio company with value chain	Quantitative, Monetary

Short description

The Biodiversity Footprint Financial Institutions (BFFI) provides a biodiversity footprint of the economic activities in which a financial institution (FI) invests. The methodology allows calculation of the environmental pressures and the biodiversity impact of investments within an investment portfolio, at the level of a portfolio, an asset class, a company, or a project. Table 5 shows the impact drivers of the method.

Table 5. Impact drivers and corresponding IPBES drivers of change. Adapted from Finance for Biodiversity (2022).

Effects of climate change on freshwater ecosystems	Climate Change

Effects of climate change on terrestrial ecosystems	
Terrestrial acidification	Pollution
Terrestrial eutrophication	
Freshwater eutrophication	
Marine eutrophication	
Terrestrial ecotoxicity	
Freshwater ecotoxicity	
Marine ecotoxicity	
Photochemical ozone formation	
Land use change / land transformation	Land / sea use change
Land occupation	
Water use	Direct exploitation

The asset categories covered are the following (mature - >5 times applied):

- Corporate loans
- Listed equity
- Private equity
- Corporate bonds
- Sovereign bonds
- Mortgages and real estate
- Impact funds
- Green bonds
- Project finance

Business/finance applications:

- Assessment of current performance
- Assessment of future performance (emerging)
- Tracking progress to targets
- Comparing options/benchmarking
- Assessment / rating of 3rd parties (emerging)
- Screening and assessment of opportunities
- Biodiversity accounting
- ESG screening and engagement (emerging)

Coverage: the method covers the Scope 1, Scope 2, and Scope 3 upstream.

The BFFI consists of 4 steps:

1. Scope and system boundary

This step creates an overview of the economic activities in which the financial institution (FI) invests. It includes a definition of the activities of a company as well as a selection of the major investments included in the assessment.

2. Assess environmental inputs and outputs

The environmental data in the EXIOBASE input/output-database is used to assess what pressures are linked to the economic activities unless more accurate data (like company data) is available. The environmental pressures are attributed to the investor based on attribution rules, like the share of the investment in the total value of the investment object.

It is also possible to use other input data, such as other input/output-tables (e.g., EORA), LCA databases (e.g., Ecoinvent[14], World Food Database, Agrifootprint Database), or specific on-site data (currently done for assessing specific projects for impact investors).

3. Assess environmental pressures and the impact on biodiversity

The ReCiPe model is used to calculate the environmental pressures on a midpoint level and to calculate the resulting impact on ecosystem quality or biodiversity (endpoint level). This results in an impact on terrestrial, freshwater, and marine biodiversity. The unit used to express the impact on biodiversity is PDF.ha.yr, the Potentially Disappeared Fraction of species multiplied with the area (in hectare for terrestrial, or cubic meter for aquatic biodiversity) and duration of the loss (in year).

The result is then used to calculate the biodiversity footprint in m2 per € invested (for each investment category) and the total footprint in m2 for all investments. In this process, ReCiPe covers the following midpoints:

- For terrestrial ecosystem quality: Climate change, Photochemical ozone formation, Acidification, Ecotoxicity, Water scarcity, Land use occupation, Land use change
- For freshwater ecosystem quality: Climate change, Eutrophication, Ecotoxicity, Water scarcity
- For marine ecosystem quality: Ecotoxicity, Eutrophication

4. Qualitative analysis : interpret results and take action

A qualitative analysis is used to guide the interpretation and the use of the footprint results, looking at the limitations of the data and the footprinting methodology and their potential influence on the footprint results. The combined quantitative and qualitative analyses are used to decide on follow-up actions, like zooming in on impact hotspots, engagement with companies, and/or establishing/changing investment criteria.

Implementation example

FMO (Dutch Entrepreneurial Development Bank) invests in Agro Vision Peru SAC ('Agrovision'), a fruit farming company with land and water assets and operations based in Northern Peru. The BFFI is applied to FMO's portfolio company Agrovision. [44]

1. Scope and system boundary

Activities included :

- Direct land use and land use change from planting of crops and reforestation
- Production of seedlings
- Production of fertilizers and pesticides
- Emissions resulting from application of fertilizers and pesticides
- Drip irrigation
- Tillage operations
- Electricity, heat, and water use
- Housing and transport of employees

2. Assess environmental inputs and outputs

The total biodiverstity loss due to the crops, housing and transport of employees and ancillary activities is 1 168 ha. On an area of 1 978 ha, a resforestation project converts dry forest land into a forest cover (nature restauration). The net positive impact of the project is 117 ha.

3. Assess environmental pressures and the impact on biodiversity

Impacts are split by driver of biodiversity loss. The main drivers are the transportation of employees (global warming impact caused by GHG emissions from buses) and direct land use impacts for the crop production (caused using fertilizer and pesticides). The highest contribution is from the blueberry crops.

Summary of the implementation example:

Performance assessment: Evaluation of the biodiversity loss in hectares (derived from the PDF.m^2.year) due to different processes involved in the production of crops of a company invested

Evaluation target: Processes included: Crops (blueberry, asparagus, grapes, avocado), Transport of employees, Housing of employees, Ancillary activities, Nature restoration

Input data: Financial data, Physical data (if available)

Spatial scale: Company with value chain

Possibilities and restrictions how to use the method

[44] Biodiversity Footprint for Financial Insitutions, Exploring Biodiversity Assessment, Netherlands Enterprise Agency, 2021 : https://www.government.nl/binaries/government/documenten/reports/2021/07/29/biodiversity-footprint-for-financial-institutions/Biodiversity+Footprint+for+Financial+Institutions+-+exploring+biodiversity+assessment.pdf

Advantages:

- Use of open-source database and methodologies (no black box calculations)
- The EXIOBASE allows for a geographical identification of impact hotspots on a country level
- Location/region-specific data can be used when available
- Covers most drivers for biodiversity loss, including pollution
- Scalable to be used by other banks
- The complementary qualitative analysis guides correct interpretation and use

Limits:

- Approach based on sector averages, revenue and models: it currently represents potential rather than actual biodiversity footprint.
- EXIOBASE data is based on sector averages, and thus not company specific. This weakness can be addressed by using other LCA databases or by collecting additional data.
- Land-use related impacts are biased to temperate regions which means that land-use related impacts will be less accurate for tropical regions.
- Inclusion of location-specific characteristics is limited, limiting the methodology's fitness for use on a project level. On a portfolio level, with the aim of identifying biodiversity impact hotspots, this limitation is acceptable.
- Not all drivers of biodiversity loss are covered by the ReCiPe methodology: introduction of invasive species is not yet covered, overexploitation is not yet fully covered.

2.23 Biodiversity Metric 4.0

	(Natural England, 2023) https://publications.naturalengland.org.uk/publication/6049804846366720				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
Biodiversity accounting	Risk and performance assessment	Assessing and forecast nature losses and gains resulting from land use changes	Biodiversity impact (positive and negative)	Site proposed for development (e.g. residential areas, cities, wind power plants, mines)	Quantitative

Short description

Biodiversity Metric (BM) 4.0[45] provides a way to measure, account for and forecast nature losses and gains resulting from development, or other land use changes.[46] It can be used by various sectors and in different nature types, primarily to inform decision making in planning processes involving physical

[45] Original version, released 2019, is Defra biodiversity metric

[46] Natural England. (2023). The Biodiversity Metric 4.0 - User Guide. Natural England Joint Publication JP039.

interventions and to achieve a better state of nature than beforehand, i.e. achieving Biodiversity Net Gain.

In short, BM 4.0 calculates the baseline nature value of a site and predicts the future biodiversity value (after an intervention, including e.g. habitat creation or other biodiversity offsets). The method uses habitats and 'biodiversity units' as a proxy to describe the relative biodiversity value of a site. There are three types of biodiversity units, which are calculated in three separate 'modules' of the method: (1) area units, (2) hedgerow units and (3) watercourse units. The biodiversity unit is primarily assessed through a given habitat's conservation value (e.g. distinctiveness), condition and area.

BM 4.0 is created in, and thus adapted to, United Kingdom conditions. However, other countries have used the method as a base and an inspiration for developing similar methods. An example is the Swedish method CLImB[47], which has adapted BM 4.0 to the Swedish and Nordic nature conditions.

Implementation example

The implementation example was downloaded from Natural England, the developer of BM 4.0. The example shows how the method can be used within a hypothetical residential development, an edge of a town in north-west England. Here, the method is applied in the early design process, in order to achieve biodiversity net gain requirements.

Data are assumed to be collected about the site conditions. The habitats on-site are scrubs, woodland, hedgerows, and tree lines, but predominantly 'modified grassland' (Table 6). This is the baseline, which any expected losses and gains are measured against, to calculate the net changes due to the up-coming exploitation.

The output is presented in Table 7. BM metric 4.0 inform the decision makers that the focus for the development may be focused on the 'modified grassland', due to its low distinctness in comparison to the other habitats. This will reduce the loss of biodiversity units, but the project will still have losses. The developers can offset these losses by e.g. enhancing the existing medium distinctiveness habitats.

[47] https://climb.ecogain.se/method

Table 6. Summary of the biodiversity units for the site, divided into habitat area and hedgerows. Reprinted from Natural England, 2023. (Contains public sector information licensed under the Open Government Licence v3.0).

Habitat type	Area (ha) / length (km)	Habitat Distinctiveness	Habitat Condition	Strategic Significance	Baseline biodiversity units
Modified grassland	2.6	Low	Poor	Low	5.20
Other woodland; broadleaved	0.53	Medium	Poor	High	2.44
Other neutral grassland	0.52	Medium	Poor	Low	2.08
Other woodland; broadleaved	0.19	Medium	Moderate	High	1.75
Bramble scrub	0.16	Medium	Condition Assessment N/A	Low	0.64
Total habitat area	**4 ha**	**Total area habitat biodiversity units**			**12.11**
Species-rich native hedgerow	0.14	Medium	Moderate	High	1.29
Species-rich native hedgerow with trees	0.04	High	Moderate	High	0.55
Line of trees	0.01	Low	Good	High	0.07
Total hedgerow length	**0.19 km**	**Total hedgerow biodiversity units**			**1.91**

Table 7. Losses and gains of biodiversity units. Reprinted from Natural England, 2023. (Contains public sector information licensed under the Open Government Licence v3.0).

Biodiversity unit type	Description	Losses and gains of biodiversity units
Area habitat	Baseline area habitat biodiversity units	12.11
Area habitat	Net on-site enhancement and creation of habitats Habitat enhancement: - 0.42 ha of 'other neutral grassland' from poor to good condition, low strategic significance - 0.16 ha of 'bramble scrub' to 'mixed scrub' from 'Condition Assessment N/A' to good condition, low strategic significance - 0.19 ha of 'other woodland; broadleaved' from moderate to good condition, high strategic significance - 0.53 ha of 'other woodland; broadleaved' from poor to moderate condition, high strategic significance Habitat creation – all low strategic significance: - 0.81 ha of 'vegetated gardens' – 'Condition Assessment N/A' - 1.79 ha of 'developed land; sealed surface' – condition 'N/A – Other' - 0.1 ha 'intensive green roof' in good condition	+13.15
	Total net gain in area habitat biodiversity units	**+1.59**
Hedgerow	Baseline hedgerow biodiversity units	1.91
Hedgerow	Net on-site retention, creation, and enhancement of hedgerows Hedgerow enhancement – high strategic significance: - 0.05 km of 'species-rich native hedgerow' in moderate condition enhanced to good condition Hedgerow creation: - 0.07 km of 'species-rich native hedgerow with trees' in good condition - 0.08 km of 'species-rich native hedgerow' in good condition 0.02 km 'line of trees' in moderate condition	+2.15
	Total net gain in hedgerow biodiversity units	**+0.24**

Area habitat	**Overall percentage net change in area habitat biodiversity units**	**+13.15%**
Hedgerow	**Overall percentage net change in hedgerow biodiversity units**	**+12.62%**

<u>Summary of the implementation example:</u>

Risk assessment: assessment of biodiversity values before and after a physical intervention, to enable planning that consider nature values

Evaluation target: identify the best alternative(s) for a development or other land use changes, achieving biodiversity net gain

Input data: habitat type; size (hectares/kilometers); condition and target condition; strategic significance; timing of habitat intervention relative to biodiversity loss; spatial risk; extent of interventions

Spatial scale: site (hypothetical residential development)

Possibilities and restrictions how to use the method

- Cross-sectoral method and applicable for various habitat types
- The method is adapted to UK conditions, and will probably need adjustments to be fully applicable/relevant to other countries or regions
- The quality and reliability of the output is highly dependent of the quality of the data inputs
- The method provides objective assessments of potential biodiversity changes, but e.g. as the values are a proxy for the relative nature values (rather than absolute) it should be regarded as a support, and be used alongside ecological expertise
- It should not be used for irreplaceable or very high distinctiveness habitat

2.24 Moving beyond land use intensity types: assessing biodiversity impacts using fuzzy thinking

	Lindner et al. (2021). Moving beyond land use intensity types: assessing biodiversity impacts using fuzzy thinking. The International Journal of Life Cycle Assessment, 26, 1338–1356. https://doi.org/10.1007/s11367-021-01899-w				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA-based method	Performance assessment	To quantify potential biodiversity impacts of land use	Impact	Product	Quantitative

Short description

The method captures the impact of management practices on biodiversity, as a decrease in Biodiversity Potential (BP). It uses mathematical functions representing the impact of land uses to support improved management. Differences in biodiversity which are specific to the location are accounted for using, for example, an ecoregion specific factor.

Implementation example

The article gives an example of the biodiversity impacts linked to paper production in Finland. The method was applied to two scenarios, one representing an intensive forestry practice, and another representing lower intensity forestry management. Both scenarios take place in the same ecoregion. The Biodiversity Potential (BP) was calculated using weighting factors, which assign different weights to the various biodiversity contributions.

Summary of the implementation example:

Risk assessment: The biodiversity impacts of the commodities needed for producing paper

Evaluation target: Product

Input data: Primary and secondary data (e.g. WildFinder database, GIS layers from governmental bodies or nature conservation NGOs)

Spatial scale: Land use category, biome, ecoregion

Possibilities and restrictions how to use the method

Wider adoption of method could allow moving from using naturalness to other counterfactuals (references/baselines) that reflect societal values. The method is only applicable to specific management types and does not cover land use change.

Advantages:

- The method enables land use management practices to be accounted for LCA without requiring sub-categories for different intensities to be explicitly established
- The biodiversity potential is weighted across ecoregions
- There are multiple reference states – makes it more dynamic and specific to each case

Limits:

- It is a risk that the expert-based fuzzy method unconsciously hides knowledge gaps, leading to the exclusion of relevant parameters
- There are multiple reference states – makes the results harder to benchmark

2.25 Considering habitat conversion and fragmentation in characterization factors for land-use impacts on vertebrate species richness

	Kuipers et al. (2021). Considering habitat conversion and fragmentation in characterisation factors for land-use impacts on vertebrate species richness. Science of The Total Environment, Volume 801, 149737. https://doi.org/10.1016/j.scitotenv.2021.149737				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Risk assessment	To assess biodiversity footprint of products (using the characterization factors presented in the paper)	Impact	Product / Value Chain	Quantitative

Short description

The method uses the species-habitat relationship (SHR), which is a modification of the countryside species-area relationship (c-SAR). The SHR considers impacts from habitat conversion on species richness, but also effects from fragmentation. This is used to develop new characterization factors for each of the four taxonomic groups of vertebrate species; amphibians, birds, non-flying mammals, and reptiles. The CFs are created for both land use (occupation) and land use change (transformation), and for 702 terrestrial ecoregions.

Implementation example

The article Kyttä et al. (2023) [48], compares the method by Chaudhary and Brooks (2018) [26] and the method by Kuipers et al. (2021), for measuring impacts related to land use and land use change from diets of 90 different food groups.

To measure the impacts, the land use and land use change from the food groups were assessed. Average of five-year yield data, as well as the area of land use change was assessed from FAOSTAT. For land use change the recommendations by UNEP-SETAC[49] of allocating the impact over the sequent 20 years was applied. The area of land use and land use change where multiplied with the characterization factors from the two methods to estimate the impact.

The impacts from the diets and food groups, using the CFs develop by Kuipers et al. (2021), are visualized in Fig. 3 below. Figure and figure text is retrieved from Kyttä et al. (2023)[46].

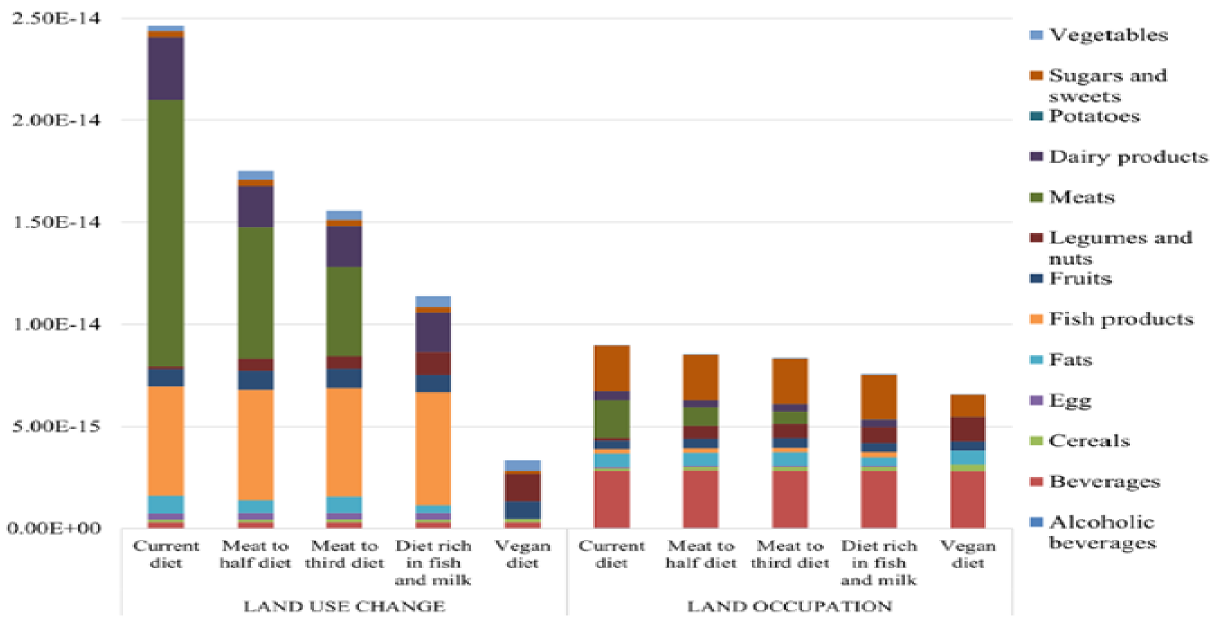

Fig. 3. Disaggregated biodiversity impacts (PDF/person/day) arising from land occupation and land transformation, assessed using the method of Kuipers et al. (2021) for the current Finnish diet and four alternative diets.

[48] Kyttä et al. 2023. Land-use-driven biodiversity impacts of diets—a comparison of two assessment methods in a Finnish case study. Int J Life Cycle Assess 28, 1104–1116. https://doi.org/10.1007/s11367-023-02201-w.
[49] Koellner et al. (2013). UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA. The International Journal of Life Cycle Assessment, 18, 1188-1202. https://doi.org/10.1007/s11367-013-0579-z.

Summary of the implementation example:

Risk assessment: evaluating the biodiversity impact of current, and alternative, Finish diets.

Evaluation target: product.

Input data: primary and secondary. FAO stat, data from industry, literature and scientific articles.

Spatial scale: country

Possibilities and restrictions how to use the methods

Advantages:

- easy/hands-on
- compatible with global database sets, e.g. FAO stat (need area of the given land use type (m2))
- global application
- shows results on ecoregional scale (finer scale than country)
- includes both effects of habitat conversion and fragmentation.

Limits**:**

- PDF-Unit may be converted to be useful, only includes the impact driver of land use and land use change
- does not include the taxonomic groups: amphibians, reptiles and flying mammals (due to lack of data)
- does not include different intensity levels
- the transformation CF does not consider what land use type was transformed, but is the same regardless off if it was natural or semi-natural land
- It only includes one land use type for forestry, compared to for example (Chaudhary and Brooks (2018)[26] that includes managed both logged forests (reduced impact logging, selectively logged forests & clear-cut forests) and plantation

2.26 Corporate Biodiversity Footprint (CBF)

CBF	Report: Iceberg Data Lab : *Corporate Biodiversity Footprint – Methodological guide,* April 2022. https://www.icebergdatalab.com/documents/CBF_client_methodological_guide_April_22.pdf				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA-based method	Performance assessment	Assess the activities impacts on biodiversity of a corporate: MSA (Mean Species Abundance) indicator used	Impact	Company with value chain	Quantitative

Short description

The Corporate Biodiversity Footprint (CBF) uses the company data (production and purchase) to model the impacts in MSA.km². First, the pressures are quantified thanks to LCA methods. Then the GLOBIO tool links the pressures into impacts on biodiversity, that are given in MSA.km².

Impacts drivers :

- Land and sea use change: land occupation, land transformation, encroachment, fragmentation, and water
- Pollution: soil and water eutrophication, soil, water and air acidification, water ecotoxicity, soil ecotoxicity, ocean pollution
- Climate change
- Overexploitation: not considered yet
- Invasive species: not considered yet

Implementation example

The CBF was used to assess the portfolio of 350 European actions, to compare the value of CBF per sector.

These results show that the impacts are the most important in the agri-food, metal and chemistry sectors, through their value chains. The main pressures come from land use change for the agri-food sector and from greenhouse gas emissions and pollutants for the metal and chemistry sectors.

In order to compare the companies within a sector, the ratio between the absolute footprint and physical or financial indicators were calculated.

Summary of the implementation example:

Performance assessment: Assessment of the whole value chain impacts of 350 corporates

Evaluation target: a portfolio of 350 actions

Input data: Financial data, information on sectors

Spatial scale: global

Possibilities and restrictions how to use the method

Advantages:

- The impacts calculated are supported by robust scientific frameworks. The scientific committee is composed of ShareAction organism, the *Museum National d'Histoire Naturelle*, I Care consulting company and the WWF. The steering committee : Robeco, AXA Investment Managers, BNP Paribas Asset Management, Karner Blue Capital, Mirova, Sycomore Asset Management and Marshall Wace
- The CBF covers the impacts related to the whole value chain
- It takes into account different pressures on biodiversity
- By default, the CBF can be calculated with secondary data already stored in the tool, that can be completed by primary data when they are available

Limits :

- In GLOBIO, the pressure-impact relationships are based on limited and fragmented scientific data (there is a lack of taxon and ecosystems)
- 2 pressures are not considered yet: the invasive species and the resource consumption
- The marine biodiversity is only partially covered
- The CBF is limited by data availability. When data lack, regional or global data are used.

2.27 MariLCA – Development of simplified characterization factors for the assessment of expanded polystyrene and tire wear microplastic emissions applied in a food container LCA

MariLCA	Corella-Puertas et al. (2022). Development of simplified characterization factors for the assessment of expanded polystyrene and tire wear microplastic emissions applied in a food container life cycle assessment. Journal of Industrial Ecology, 26(6), 1882-1894. https://doi.org/10.1111/jiec.13269				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Impacts of two types of microplastics in the marine environment	Impact	Product	Quantitative

Short description:

Aiming to compare the potential impacts of single-use plastics and their alternatives on ecosystem quality a, this work proposes simplified fate and characterization factors (CFs) for modeling the impacts of two types of microplastics—expanded polystyrene and tire and road wear particles—in the marine environment.

Results:

The main factors influencing the endpoint charaterization factors were rate of plastic degradation and the rate of sedimentation.[50,51,52]

Whereas the fate of expanded polystyrene is sensitive to the different fragmentation, degradation, and sedimentation scenarios, for tire and road wear particles the fate is primarily sensitive to sedimentation.

[50] Bulle et al. (2019). IMPACT World+: a globally regionalized life cycle impact assessment method. *The International Journal of Life Cycle Assessment*, *24*, 1653-1674. https://link.springer.com/article/10.1007/s11367-019-01583-0

[51] Hauschild & Huijbregts, (2015). Book : Life Cycle Impact Assessment. ISBN: 9401797439 , 9401797447 , 9789401797436 and 9789401797443. https://findit.dtu.dk/en/catalog/55538b682db86a581300009e.

[52] Lavoie et al. (2021). Aquatic micro- and nano-plastics in life cycle assessment: Development of an effect factor for the quantification of their physical impact on biota. Journal of Industrial Ecology, 26(6), 2123-2135. https://doi.org/10.1111/jiec.13140

In all types of plastic packaging, climate change and land occupation and transformation were the main impact drivers.

Implementation example:

Not available.

Summary of the implementation example:

Risk assessment: potentially disappeared fraction of species (PDF)

Evaluation target: product

Input data: primary and secondary

Spatial scale: global

Possibilities and restrictions how to use the method

Not available.

2.28 MariLCA - An effect factor approach for quantifying the impact of plastic additives on aquatic biota in LCA

MariLCA	Tang and Traverso (2022). An effect factor approach for quantifying the impact of plastic additives on aquatic biota in life cycle assessment. The International Journal of Life Cycle Assessment, 27(4), 564–572. https://doi.org/10.1007/s11367-022-02046-9				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Preliminary approach to facilitate the characterization of chemical impacts related to marine plastic within the LCA framework	Impact	Product	Quantitative

Short description:

This preliminary work provides a first step towards including the impact of plastic-associated chemicals in LCA. Although the toxicity of different additives to aquatic biota may vary significantly, it is recommended to consider additives within the impact assessment of marine plastic. The generic EF can be used, together with a future EF for adsorbed environmental pollutants, to fill a gap in the characterization of plastic-related impacts in LCA.

Main goal:

This paper presents a preliminary approach to facilitate the characterization of chemical impacts related to marine plastic within the LCA framework. [52,53,54,55]

Methods:

The toxicity of plastic additives to marine biota is currently a less understood impact pathway and also the focus of this study. Relevant ecotoxicity data were collected from scientific literature for a subsequent additive-specific effect factor (EF) development, which was conducted based on the USEtox approach. Extrapolation factors used for the data conversion were also extracted from reliable sources.

Results:

EFs were calculated for six commonly used additives to quantify their toxicity impacts on aquatic species. Triclosan shows an extremely high level of toxicity, while bisphenol A and bisphenol F are considered less toxic according to the results. Apart from additive-specific EFs, a generic EF was also generated, along with the species sensitivity distribution (SSD) illustrating the gathered data used to calculate this EF. Further ecotoxicity data are expected to expand the coverage of additives and species for deriving more robust EFs. In addition, a better understanding of the interactive effect between polymers and additives needs to be developed.

Implementation example:

Summary of the implementation example:

Risk assessment: potentially disappeared fraction of species (PDF)

Evaluation target: product

Input data: secondary

Spatial scale: global

Possibilities and restrictions how to use the method

Firstly, due to a general lack of effect data, ecotoxicity data for freshwater species were also included to calculate the EFs. Secondly, the majority of the compiled data are acute values which need to be extrapolated, and the calculation of 95% CIs did not consider the proportion of extrapolated values. Finally, as the compiled data come from diverse sources, uncertainty can arise from differences in toxicity test methods, exposure concentrations, etc.

2.29 Global Extinction Probability (GEP)

Global Extinction	Verones et al. (2022). Global extinction probabilities of terrestrial, freshwater, and marine species groups for use in Life Cycle Assessment. Ecological Indicators, Volume 142, 109204. https://doi.org/10.1016/j.ecolind.2022.109204

[53] Wiesinger et al. (2021). Deep Dive into Plastic Monomers, Additives, and Processing Aids. Environmental science & technology, 55(13), 9339–9351. https://doi.org/10.1021/acs.est.1c00976
[54] Aurisano et al. (2019). Extrapolation Factors for Characterizing Freshwater Ecotoxicity Effects. *Environmental Toxicology and Chemistry*, *38*(11), 2568–2582.
[55] Fantke et al. (2017). USEtox 2.0 Documentation (Version 1.00). Lyngby, Denmark. ISBN: 978–87–998335–0–4. https://doi.org/10.11581/DTU:00000011

Probability (GEP)					
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA-based method	Risk assessment	To indicate the extent to which regional species loss in the respective area may contribute to global species loss	Impact, Impact drivers	City / Region / Country	Quantitative

Short description

Global Extinction Probability (GEP) is a method that assesses the potential impact of regional species loss on a global scale. It utilizes various factors, including species range sizes, global conservation status, and species richness, to gauge the extent to which regional species loss in a particular area may contribute to global species loss.

Given the inherent heterogeneity of the biosphere, species diversity impacts are typically evaluated at local or regional scales. The challenge arises in comparing or aggregating regional species richness impact metrics, as they refer to different species compositions. GEP addresses this by translating regional species richness impacts into global impacts, enabling meaningful comparisons and facilitating the estimation of global species extinctions.

The methodology involves the development of conversion factors, termed global extinction probabilities (GEPs), specific to the reference location or region. These GEPs are derived based on factors such as species' habitat ranges, IUCN threat levels, and species richness. This approach allows for the calculation of GEPs for any spatial unit and species group with available data on spatial distribution, making it applicable in methodologies LCIA.

Furthermore, GEPs serve the purpose of identifying conservation hot spots, offering insights into regions where irreversible biodiversity impacts are more likely to occur. The results of GEP assessments for various taxonomic groups highlight the varying degrees of risk associated with regional species loss potentially resulting in global species extinctions. Overall, GEP provides a valuable tool for understanding and mitigating the global implications of regional biodiversity changes.

Implementation example

Global extinction probabilities of terrestrial, freshwater, and marine species groups for use in Life Cycle Assessment (scientific article)[56]

The study encompasses the calculation of GEP for a vast dataset, covering over 98,000 species distributed among 20 species groups across marine, terrestrial, and freshwater ecosystems.

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[56] Verones et al. (2022). Global extinction probabilities of terrestrial, freshwater, and marine species groups for use in Life Cycle Assessment. Ecological Indicators, Volume 142, 109204. https://doi.org/10.1016/j.ecolind.2022.109204

The work goes beyond mere calculation by extending GEP assessments to various spatial scales, including grid cells, ecoregions, watersheds, and country averages. The findings reveal a significant variation in GEP values spanning orders of magnitude globally, underscoring the critical importance of considering the spatial dimension in extinction probabilities.

The research proposes a practical application of GEP by suggesting the multiplication of local species loss within a specific spatial unit with the corresponding GEP for that unit. This harmonizes the quantification of biodiversity impacts across diverse impact categories, providing a more unified and comprehensive approach. Such insights are invaluable for supporting environmental decision-making by enhancing the precision and relevance of information in the assessment of global extinctions.

GEP method offers flexibility and transparency but requires careful consideration of spatial scale alignment to ensure accurate and meaningful results. Proper adherence to recommended application methods is crucial for valid assessments of both local and global impacts.

Summary of the implementation example:

Risk assessment: How regional species loss in the respective area may contribute to global species loss

Evaluation target: Species and species groups

Input data: Number of species group in region

Spatial scale: A grid cell, an ecoregion, or any other spatial unit

Possibilities and restrictions how to use the method

Possibilities:

- applicability to various impact driver categories: GEPs are versatile and can be applied to impact driver categories that are species group-specific, such as land use, or those containing a mixture of species groups, like ecotoxicity;
- representing ecosystem quality: The method aims to represent "ecosystem quality" by using entire species groups, ensuring that all included species act as proxies for the broader ecosystems;
- downloadable code for implementation: the code for calculating GEPs based on defined species groups is available for download on Zenodo[57];
- application at different spatial scales: GEPs can be applied to characterization factors (CF) at various spatial scales (e.g., native scale of CF, country level) through simple multiplication, allowing for flexibility in the assessment;
- aggregation to required spatial units: GEPs, initially calculated at the pixel level, can be aggregated to different spatial units, aligning with the specific spatial characteristics of the CFs.

Restrictions:

[57] Verones et al. (2022). Global extinction probabilities of terrestrial, freshwater, and marine species groups [Data set]. https://doi.org/10.5281/zenodo.6412149

- spatial scale alignment: it's crucial to match the spatial scale of GEPs with the corresponding CFs. Failure to do so can lead to inaccurate assessments, emphasizing the importance of proper aggregation;
- country level application: when using CFs at a country level, both the CF and the GEP must be aggregated on a country basis. The code for GEP implementation accommodates this, suggesting an area-based average for converting ecoregion CFs to a country level before multiplication;
- caution against incorrect application: multiplying the GEP before aggregating to another spatial level is discouraged, as it yields different results and prevents the GEP from adding up to 1 globally;
- relevance of different ecosystem types: considering the distinctiveness of terrestrial, freshwater, and marine ecosystems, reporting impacts separately for each ecosystem type is recommended to demonstrate their individual relevance;
- equal importance of local and global CFs: both regional/local CFs and global CFs are emphasized for a comprehensive assessment. Global CFs highlight worldwide and irreversible species loss, while local CFs assess impacts on the functioning of local ecosystems.

2.30 MariLCA - Characterization factors for microplastic impacts in life cycle assessment: Physical effects on biota from emissions to aquatic environments

MariLCA	Corella-Puertas et al. (2023). MarILCA characterization factors for microplastic impacts in life cycle assessment: Physical effects on biota from emissions to aquatic environments, Journal of Cleaner Production, Volume 418, 13819. https://doi.org/10.1016/j.jclepro.2023.138197				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA	Performance assessment	Providing characterization factors for assessing the impacts of aquatic (marine and freshwater) microplastic emissions	Impact	Product	Quantitative

Short description:

This work contributes to MarILCA's output by providing characterization factors for assessing the impacts of aquatic (marine and freshwater) microplastic emissions through the impact category of physical effects on biota and ultimately the ecosystem quality damage category.

Methods:

First, the existing exposure and effect factor (EEF) for micro- and nanoplastic emissions in aquatic compartments [52] is updated using additional toxicity data, delivering a generic EEF of 1067.5 PAF m^3/kgin compartment.

Second, fate factors (FFs) are developed for eleven different polymers (EPS, PS, PA/Nylon, PP, HDPE, LDPE, PET, PVC, PLA, PHA, TRWP), three shapes (sphere/microbead, cylinder/microfiber, microplastic film fragments) and five sizes (1, 10, 100, 1000, 5000 μm). To calculate the FFs, a detailed degradation model and a simplified sedimentation model are proposed.

Polymer density and size play a major role in the fate, whereas the influence of the shape is less relevant.

Ultimately, the EEF and FFs are combined to deliver midpoint and endpoint characterization factors (CFs).

Data sources: Corella-Puertas et al. (2022)[58]

Implementation example:

Fate factors are created for:

2.2.1. Marine water

2.2.1.1. Degradation rates. Based on Chamas et al. (2020)[59], this work assumes that the degradation of microplastics occurs perpendicular to their surface

2.2.1.2. Sedimentation rates. Sedimentation rates are proposed for three classes of polymers: low density (positively buoyant, <0.8 g/cm^3 such as EPS), medium density (close to seawater density, 0.8–1.1 g/cm^3 such as HDPE, LDPE, PP and PS) and high density (negatively buoyant, >1.1 g/ cm^3 such as PA, PLA, PHA, PET, PVC and TRWP).

2.2.2. Freshwater - According to the PLP guidelines, around 30% of microplastics emitted into freshwater compartments will be trapped in freshwater sediments, whereas the other 70% are estimated to be transferred into marine compartments.

Characterization factors include:

2.3.1. Midpoint and endpoint CFs Following the structure commonly used in LCIA [50, 51, 60], CFs for *physical effects of biota* of microplastic emissions are developed at the midpoint (problem) and endpoint (damage) levels.

2.3.2. Uncertainty A Monte Carlo analysis was performed to calculate the uncertainty of the CFs.

[58] Corella-Puertas et al. (2022). Development of simplified characterization factors for the assessment of expanded polystyrene and tire wear microplastic emissions applied in a food container life cycle assessment. Journal of Industrial Ecology, 26(6), 1882-1894. https://doi.org/10.1111/jiec.13269
[59] Chamas et al. (2020). Degradation Rates of Plastics in the Environment. ACS Sustainable Chemistry & Engineering, 8(9), 3494–3511. https://doi.org/10.1021/acssuschemeng.9b06635
[60] Huijbregts et al. (2017). ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. The International Journal of Life Cycle Assessment, 22, 138-147. https://doi.org/10.1007/s11367-016-1246-y

Summary of the implementation example:

Risk assessment: potentially disappeared fraction of species (PDF)

Evaluation target: product

Input data: primary and secondary

Spatial scale: global

Possibilities and restrictions how to use the method

A limitation of the fate factor is that sedimentation only depends on the polymer density, and not on the size or shape. This approach might describe well high-density polymers, which are expected to sediment independently of their size and shape.

2.31 The LANCA® method including BioMAPS

LANCA®	LANCA. Characterization Factors for Life Cycle Impact Assessment, Version 2.0 *Ulrike Bos, Rafael Horn, Tabea Beck, Jan Paul Lindner, Matthias Fischer (*Horn, R. *et al.* (2022) https://publica.fraunhofer.de/entities/publication/954026c0-8325-425f-bd9d-93b70a3368dc *Land use and forestry in the environmental footprint*. Stuttgart: Fraunhofer Verlag.) ISBN 978-3-8396-0953-8				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
Life Cycle Assessment; part of the Environmental Footprint (EF3.1)	Impact Assessment on a product level	Quantifying the impacts on land use and biodiversity	Products and product systems	Entire value/ production chain	Single score or individual impact categories (erosion resistance, mechanical filtration, phys.-chem. filtration, groundwater regeneration, biodiversity)

Short description
As a calculation method LANCA® systematically und quantitatively evaluates land use and its environmental effects in an LCA context. The model is also used to calculate the impact category "land use" in the recent Product Environmental Footprint (PEF, version EF 3.1).
Characterization factors are calculated for different impact categories (erosion resistance, physico-chemical filtration, groundwater regeneration, mechanical filtration, soil organic carbon and biodiversity). Since it is geo-based, the method allows for consistent evaluation from a country-average basis up to location-specific scale. Both changes caused by land occupation and transformation are included and can be calculated. The results then represent a comparative value between the

actual/modeled state and a reference scenario in a theoretical potential natural state. The steps of the calculation are shown in the figure below:

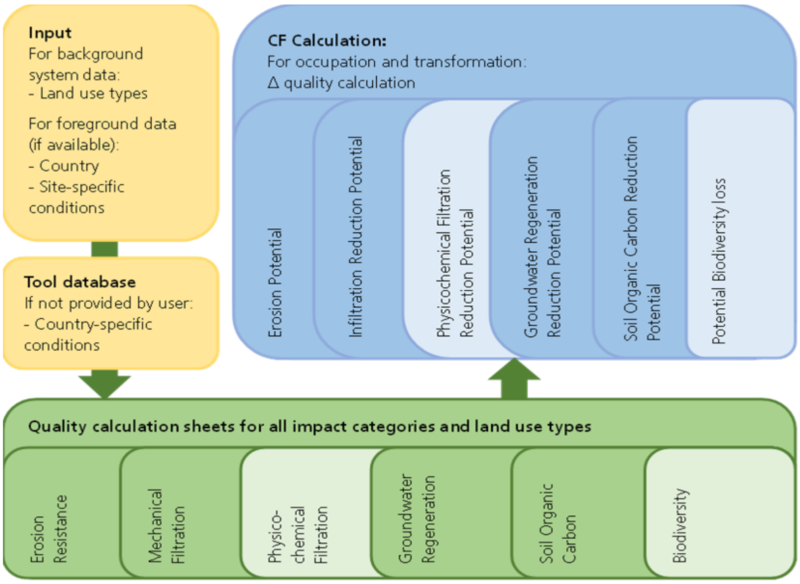

Fig 4: Calculation of LANCA characterization factors. © Fraunhofer IBP

The resulting characterization factors are aggregated into a dimensionless soil quality index. In the most recent version, four (shown in dark blue) of the characterization factors are included in the final index. The inclusion of a new characterization factor representing the biodiversity impacts is planned for the next update along with the implementation of existing characterization factors. This biodiversity characterization factor will be provided by the BioMAPS method (Biodiversity Multi-Scale Assessments of Product Systems), developed in 2023. The application of this method allows for the consideration of impacts on local, regional, and global biodiversity following the framework of a LANCA® analysis. Thus, the BioMAPS method itself is based on fundamental ecological, conservational, and technical requirements for LCAs as well. It provides LCA users with a coherent framework for evaluating the impacts of entire product systems on biodiversity. The main goal is to mitigate negative impacts by identifying and implementing concrete measures at global, regional, and local levels. By analyzing at three different scales, the BioMAPS method allows for a detailed representation of the impacts on biodiversity of the evaluated products or systems, while simultaneously providing characterization factors used in existing LCA data at a country average level in a background database.

Implementation example

Horn et al. (2022) evaluated the land use impacts of different locations and management regimes in forestry wood production[64]. Compared values from Sweden and the Netherlands under management scenarios with various intensities. The results for the separate impact categories, countries and management regimes are shown in fig. 5.

Fig 5: LANCA results for forestry study comparing Sweden (SE) and the Netherlands (NL) by Horn et al. (2022) *(Please note that results for biodiversity could not yet be included in this example)*

<u>Summary of the implementation example:</u>

Risk assessment: Potential Biodiversity Loss

Evaluation target: Forest wood production

Input data: Secondary

Spatial scale: Country

Possibilities and restrictions how to use the methods

Advantages:

- Broad scope including land-use impacts and biodiversity
- Global applicability
- Multi-scale application
- Possible inclusion of foreground data

Limitations:

- Resource intense, especially at more detailed scales
- Limited availability of foreground data for more local analyses

3 Input-Output Model

3.1 On the suitability of input-output analysis for calculating product-specific biodiversity footprints

	Moran et al. (2016). On the suitability of input–output analysis for calculating product-specific biodiversity footprints. Ecological Indicators, Volume 60, Pages 192-201. http://dx.doi.org/10.1016/j.ecolind.2015.06.015				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
EORA/Leontief Method	Performance assessment	How and when MRIO techniques can be useful in the study of biodiversity implicated supply chains	Not available	Product, Value Chain	Quantitative

Short description

The I/O analysis method is based on EORA database which covers 187 countries which includes 26-500 economic sectors per country for a total of S = 15,909 sectors/goods. The supply chain of localized products in 4 countries are analyzed and linked to the I/O analysis method developed by Lenzen et al. (2012)[61] and Moran et al. (2015). The study also presents the application of hybrid LCA MRIO analysis to solve the issue caused by aggregate data used in regular MRIO analysis.

Implementation example

Case study: Forestry in Papua New Guinea

The direct link between logging and extinction of species is identified first. After establishing a link between biodiversity pressure and specific industries/sectors in the country, an I/O analysis was conducted for each produced commodity. Raw logs are the main exports (90% exported) of Papua New Guinea (PNG) and has been increasing continuously but the annual export earnings are very small for PNG. Private logging companies with Malaysian ownership dominate the industry with China being the main consumer and further exporting the processed products around the world with little of the added value of the further processing of timber enters PNG. Japan is also one of the biggest consumers of the PNG timber but also further a big paper producer based on PNG hardwood. The PNG timber mixes up with other timbers in Chinese markets and thus the PNG timber footprint gets linked up to the Chinese products. Through I/O, all these flows related to environmental concerns are traced and clearly shows the forest industry as a main threat driver and thus the PNG timber products are implicated in biodiversity loss.

[61] Lenzen et al. (2012). International trade drives biodiversity threats in developing nations. Nature, 486(7401), 109-12. doi: 10.1038/nature11145. PMID: 22678290

Summary of the implementation example:

Performance assessment: Link between biodiversity threats and production activity of certain industry

Evaluation target: Consumer products

Input Data: EORA database

Spatial Scale: Global

Possibilities and restrictions how to use the method

Not available.

3.2 Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis

	Wilting et al. (2017). Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis. Environmental Science & Technology, 51, 6, 3298–3306. https://doi.org/10.1021/acs.est.6b05296				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
WIOD + Agriculture sector disaggregation from GTAP/GLOBIO	Risk assessment	Assess global impacts of agricultural and forest related activities on biodiversity and key ecosystem services	Impact driver	Country and sector	Quantitative

Short description

The WIOD model's agricultural sector is disaggregated into 14 different subsectors based on more detailed GTAP database. The rest of the world (RoW) in WIOD is further subcategorized into Rest of Oceania, Rest of America, Rest of Asia, Rest of Europe and Africa again based on GTAP. Two major environmental pressure land use and climate change considered. The environmental pressures are transformed into biodiversity loss based on the GLOBIO model.

Impact Driver: Land use

Ecosystem condition 6: Fragmentation by croplands, fragmentation by infrastructure, disturbance by infrastructure, human encroachment of the remaining, surrounding natural habitat

Implementation example

Two main environmental pressures, land use and climate change caused by GHG emissions are considered for the study. Land use data is retrieved from FAO, Global Roads Inventory Project (GRIP), pasture, forestry and built-up land area from GLOBIO, WIOD, EDGAR, UNCC etc. Multiple regression analysis per capita biodiversity footprints are calculated for each 45 countries/regions for 2 variables: per capita expenditures and human population density. The regression analysis shows an increase in land use based biodiversity footprint with income rise.

<u>Summary of the implementation example:</u>

Risk Assessment: Mean Species Abundance (MSA), MSA-loss.ha.yr per kg CO_2 equivalents

Environmental pressures: habitat replacement by cropland (ha·yr), habitat replacement by pasture (ha·yr), habitat replacement by forestry (ha·yr), habitat replacement by urban area (ha·yr), fragmentation by cropland (ha·yr), fragmentation by infrastructure (km·yr), disturbance by infrastructure (km·yr), encroachment (MSA-loss·ha·yr), climate change (kg CO_2-equivalents)

Input data: WIOD + Agriculture sector disaggregation from GTAP

Spatial Scale: Country

Possibilities and restrictions how to use the method

Not available.

3.3 Increasing Impacts of land-use on biodiversity and carbon-sequestration driven by population and economic growth

Exiobase	Marques et al. (2019). Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. Nature Ecology & Evolution, 3 (4), 628–637. https://doi.org/10.1038/s41559-019-0824-3.				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
EXIOBASE	Risk assessment	Assess global impacts of agricultural and forest related activities on biodiversity and key ecosystem services	Impact, Impact driver	Country and sector	Quantitative

Short description

The analysis is based on the EXIOBASE database. The work analyses the global impact of agriculture and forest related activities on biodiversity and sequestration of atmospheric carbon in ecosystem. One dimension of biodiversity under which bird species richness characterized in terms of response to land used for forestry and agriculture and one ecosystem services under which net carbon sequestration is the focus.

Impact Driver: Land use

Implementation example

For biodiversity impact, impending bird extinctions and use of land (amount and type) is estimated. Then two biodiversity impact estimates, non-conservative (quantified for an upper bound estimation of forest areas) and conservative (smaller area of forest activities) are computed. For ecosystem, biomass carbon sequestration lost each year and potential carbon sequestered if current land use stops and natura vegetation begins is estimated. Based on the estimations and the use of IPAT16 to study the socioeconomic drivers of biodiversity loss, the two impact indicators are linked together in MRIO based on Exiobase 3 to quantify the drivers. All world regions included reduction of biodiversity and ecosystem services impacts per unit of Gross Domestic Product (GDP) but were insufficient to reduce the impact from agriculture and forest activities.

Summary of the implementation example:

Spatial Scale: Global

Risk assessment: Bird species extinction

Evaluation target: Bird species extinction and atmospheric carbon sequestration loss due to land use for agriculture and forest related activities

Input data: Exiobase 3, ITAP16

Possibilities and restrictions how to use the method

Not available.

3.4 Consumption-based biodiversity footprints – Do different indicators yield different results?

	Marquardt et al. (2019). Consumption-based biodiversity footprints – Do different indicators yield different results?. Ecological Indicators, Volume 103, 2019, Pages 461-470. https://doi.org/10.1016/j.ecolind.2019.04.022				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
GTAP/GLOBIO3/Newbold et al.2015, 1016/Chaudhary et al. 2015, 2016	Risk assessment	Implication of using different indicators in calculating biodiversity footprints caused by land use	Impact driver	Country and sector	Quantitative

Short description

In the work, the researchers calculate the biodiversity footprints for 140 regions in the world with environmentally extended multiregional input output model (EEMRIO). This model then linked the economic activities to land use and biodiversity loss indicators based on GTAP database. The relationship between biodiversity footprint with the level of prosperity as well as the relationship between population density and

Impact driver: Land use

Ecosystem condition 3: Three alpha diversity indicators (loss of mean species abundance (MSA), relative abundance loss (RA), relative within sample species richness (RWSR) and one indicator of gamma diversity (vulnerability weighted global relative species richness (VGSR) loss).

Implementation Example

The focus is on land use as one of the key pressures on biodiversity. The MRIO model based on GTAP database. The study links the common land use and MRIO framework with different biodiversity indicators and shows that employing the alpha diversity indicators results in selection of countries with highly biodiversity footprints in comparison to gamma diversity indicator. For biodiversity footprint, Wilting et al. (2017)[62] approach is used, which is based on GLOBIO and WIOD. To develop a MRIO table based on GTAP Power Database Peters et al. (2011)[63] is followed and the GTAP database is further aggregated with FAO crop specific areas to 8 GTAP crop sectors. Then the ranking of 140 GTAP regions' alpha and gamma footprints using spearman rank correlations are compared and further biodiversity footprints and land footprint results are compared as well as tested for the added value of biodiversity footprints in comparison to land footprints.

Summary of the implementation example:

Risk assessment: Loss of mean species abundance (MSA), relative abundance loss(RA), relative within sample species richness(RWSR), vulnerability weighted global relative species richness loss (VGSR)

Evaluation target: Biodiversity effects of land use type based on reference land use state

Input data: GTAP,

Spatial Scale: Country

Possibilities and restrictions how to use the method

Not available.

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[62] Wilting et al. (2017). Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis. *Environmental Science & Technology,* 51, 6, 3298–3306. https://doi.org/10.1021/acs.est.6b05296
[63]Peters et al. (2011). Constructing an environmentally-extended multi-regional input-output table using the GTAP database. Economic Systems Research, 23:2, 131–152, DOI: 10.1080/09535314.2011.563234
[64] Horn, R. *et al.* (2022) *Land use and forestry in the environmental footprint*. Stuttgart: Fraunhofer Verlag. https://publica.fraunhofer.de/entities/publication/954026c0-8325-425f-bd9d-93b70a3368dc

3.5 Biodiversity footprint assessment method for corporations

	Geneidy, S. E., Baumeister, S., Peura, M., & Kotiaho, J. S. (2023). Value-transforming financial, carbon and biodiversity footprint accounting. arXiv preprint arXiv:2309.14186. https://doi.org/10.48550/arXiv.2309.14186				
Assessment approach	Assessment type	Main objective	Assessment focus	Scope	Output type
LCA-I/O	Risk assessment	To assess the biodiversity footprint of companies and organizations	Impact	Value chain	Quantitative

Short description

The method has been developed as part of many projects at the University of Jyväskylä. It relies on databases and the company’s consumption accounts.

Implementation example

The method has been applied in a pilot-project to assess the biodiversity footprint of Finnish retail S-Group.

Summary of the implementation example:

Risk assessment: potentially disappeared fraction of species, PDF

Evaluation target: Organization

Input data: Secondary

Spatial scale: Global

Possibilities and restrictions how to use the method

The method is designed for evaluating the impact of companies on biodiversity, specifically through species extinction.

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