ASSESSING BIO-DIVERSITY

A METHODOLOGY TO EVALUATE THE IMPACT OF INVESTMENTS ON BIODIVERSITY

planet A VENTURES

ABBREVIATIONS

BFFI	Biodiversity Footprint for Financial Institutions
CF	Characterisation factor
dLUC	Direct land use change
EU	European Union
FAOstat	Food and Agriculture Organization Corporate Statistical Database
GHG	Greenhouse gasses
GWP	Global warming potential
iLUC	Indirect land use change
IUCN	International Union for Conservation of Nature
KPI	Key performance indicator
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LULUC	Land use and land use change
MSA	Mean species abundance
NPP	Net primary productivity
NPP_0	Global average net primary productivity
OECD	Organisation for Economic Cooperation and Development
PDF	Potentially disappeared fraction of species
VC	Venture capital

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INTRODUCTION

Today's investments shape tomorrow's economies. For too long, investors and asset managers have deployed capital without being able to understand the effects that these investments had on nature. Investors globally are practically flying blind. To address the nature crisis effectively we need to deploy more private capital in the restoration and protection of nature. In order to do this, we need to be able to make smarter decisions on the basis of scientific biodiversity assessments.

Planet A is a VC fund dedicated to supporting European green tech startups that have a significant positive impact on our planet while scaling their businesses globally. We are committed to addressing not only the climate crisis but also the wider nature crisis that is looming behind it and align our mission to the concept of the nine planetary boundaries defined by scientists at the Stockholm Resilience Centre. This is why, unlike ESG funds that aim to limit negative impacts and financial risks, we only invest if a company can demonstrate a positive, quantifiable impact in at least one of four key areas: climate mitigation, resource savings, biodiversity protection, and/or reduction in waste.

We rely on rigorous scientific impact assessments to inform investment decisions and empower founders to manage and improve their impact. Our in-house team of scientists assesses the environmental impact potential of an innovation — be it a product or a service as part of a Life Cycle Assessment (LCA). We found, however, that our scientific method of assessing impact was not really tailored towards addressing biodiversity. That is why we developed a biodiversity assessment method suitable for a VC fund, integrating LCA with the "Biodiversity Footprint for Financial Institutions (BFFI)" method. By sharing our approach, its merits, and limitations publicly we hope to inspire others in the ecosystem.

1. BIODIVERSITY, CHANGES IN BIODIVERSITY, AND BIODIVERSITY LOSS

Humans affect other species in many ways—either directly, e.g. by fishing, hunting or toxicologic effects, or indirectly by changing habitats, e.g. a warming climate affecting water availability, weather patterns, increasing oceanic pH; monocultures destroying a complex web of interdependent species; oversupply of nutrients resulting in a change in species composition and anoxic zones in aquatic systems, and so on. The extensive conversion of land from natural habitats to agricultural land or the built environment has resulted in the fragmentation of and reduction in land available to other species.

In sum, humanity severely affects other species in a negative way. Current extinction rates are a thousand times higher than natural extinction rates (Pimm et al. 2014). The disturbance and destruction of the complex web of interdependent organisms and species is an existential crisis for many species. Scientists are talking about "the 6th mass extinction". Aside from the intrinsic value of other species, this biodiversity crisis will affect humans and economic systems, too. Understanding, managing, and reducing negative impacts on biodiversity is of the utmost importance to avoid a planetary crisis.

In Earth's history, five mass extinction events have taken place (the 'Big Five'). All of these events led to a loss of 75% of estimated species and lasted several hundreds of thousand to millions of years (Barnosky et al. 2011). The most recent (and probably most well-known) is the Cretaceous-Paleogene mass extinction that happened about 66 million years ago (Thomas R. Holtz Jr. 2023). It took place after an asteroid hit our planet. The aftermath drove dinosaurs and many other species to extinction. Overall, the event resulted in an estimated 76% of species disappearing from this planet.

At the moment, the extinction rates are exceeding previous extinction events by far. The estimated extinction rate occurring since 1980 is 71 to 297 times (depending on species) the extinction rate of the Cretaceous mass extinction (McCallum 2015). These numbers do not even include all species that are currently considered 'threatened' on the IUCN Red List. If these are included, the extinction rates are between 8900 and 18,500 times of the extinction rates estimated for the Cretaceous mass extinction event. Given current extinction rates, the magnitude of extinction of the Big Five mass extinction events could be reached within centuries (Barnosky et al. 2011).

Of course, these estimates include many uncertainties regarding past events and the extinction of current species. We do not even know all the species that are driven to extinction each and every single day.

The term "biodiversity" describes the abundance of organisms within a species, the number of species, as well as the interplay of these species and organisms. Biodiversity is defined as 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" (United Nations Conference on Environment and Development (UNCED)/Rio

Earth Summit 1992). Most commonly, biological diversity is subdivided into three categories (Swingland 2013):

- Genetic diversity: The variety of genetic variation within a species population.
- Species diversity: The variety of species within communities.
- Ecosystem diversity: The variety of ecosystems. This includes biotic and abiotic elements.

Researchers also proposed additional descriptions encompassing all three dimensions, e.g. “functional diversity”, defined as the diversity of species traits in ecosystems (Schleuter et al. 2010).

There are five main direct drivers of biodiversity loss (Brondizio et al. 2019): habitat loss, degradation and fragmentation, climate change, pollution and nutrient supply, overexploitation and unsustainable use, and invasive alien species. They contribute to more than 90% of the overall global impact on the biodiversity of terrestrial, freshwater, and marine ecosystems.

1) **The loss, degradation, fragmentation and transformation of natural habitats** to agricultural land as well as human settlements and the built environment has a massive negative effect on biodiversity (Carmona et al. 2020; Piano et al. 2020; McDonald, Kareiva, and Forman 2008; Reidsma et al. 2006; Donal, Gree, and Heath 2001; Tsiafouli et al. 2015). There are contesting views on whether fragmentation alone (that is, without habitat loss) results in a negative impact on biodiversity (Chase et al. 2020; Fahrig and McGill 2019; Hanski and Triantis 2015). Similar to terrestrial ecosystems, aquatic ecosystems are negatively impacted by a conversion of natural aquatic habitats. For example, changes in river and lake topography, the alteration or removal of floodplains, or other water bodies results in impacts on biodiversity (Aarts, van den Brink, and Nienhuis 2004; Heino et al. 2015).

2) The **overexploitation of species**, e.g. by overfishing, fishing of non-targeted species (by-catch), harvesting or monoculture, illegal hunting or logging, is the second largest driver of biodiversity loss (Brondizio et al. 2019; Romero-Muñoz et al. 2021). The impacts are caused by activities of local communities as well as large scale companies. Most importantly, illegal global wildlife trade (Andersson et al. 2021; Fukushima, Mammola, and Cardoso 2020), the overexploitation of certain tree species, e.g., mahogany, Scots pine, Norway spruce etc., and plant species e.g. orchids, American ginseng etc. (The National Wildlife Federation 2023; Fremout et al. 2020) or the global fishing industry harm biodiversity (Fogliarini et al. 2021; Shellem et al. 2021; Woo-Durand et al. 2020).

3) **Climate change** is a major driver of global biodiversity loss that exacerbates many other drivers and impacts (Pimm et al. 2014; Thomas et al. 2004). Climate change is caused by anthropogenic greenhouse gas (GHG) emissions. There is an

endless list of proven and presumed impacts of climate change on biodiversity (Lovejoy, Hannah, and Ainley 2019): Changing environmental conditions, changing temperatures (temporal, spatial and absolute changes in temperatures), changing precipitation (e.g. affecting water availability and erosion), ocean acidification, rising sea levels, etc. affect ecosystems and species within them; changing weather patterns influence almost all species on the planet due to changing seasonal patterns, temperature regimes and cycles and changing water availability; extreme weather events might cause floods, droughts, and wildfires, all of which might seriously affect species; rising sea levels impact coastal ecosystems; melting ice sheets in the Arctic and Antarctic affect species inhibiting these areas. Climate change increases the sea temperature, resulting in an increase in dissolved carbon dioxide. This leads to the formation of carbonic acid, lowering the oceanic pH level, which negatively affects marine species.

4) Other **polluting emissions** cause severe stress on biodiversity, too:
The excessive introduction of **nutrients** into terrestrial and aquatic ecosystems results in toxic cyanobacteria or green macro algae blooms and changes in species composition. Large amounts of dead organic matter from algae blooms are digested by microorganisms (Dybas 2005). These organisms consume oxygen resulting in oxygen depletion. These hypoxic zones range from small coastal areas or estuaries to areas of tens of thousands of square kilometers. Climate change is likely to exacerbate hypoxia (Altieri and Gedan 2015). Another example is the emission of certain pollutants, e.g. **sulfur oxides and nitrogen oxides**, which lead to the formation of dry and wet acidic compounds, e.g. sulfuric, sulfurous, nitrous and nitric acid. If these are deposited to terrestrial or aquatic ecosystems, the proton concentration increases, lowering the pH. This leads to a loss of species (Azevedo et al. 2013). There are numerous other mechanisms leading to **acidification**. For example, the deposition of nitrogen might stimulate nitrification (producing protons), root uptake of ammonium ions resulting in a release of protons or nitrate leaching reducing the buffer capacity of soil. Different soil types have different buffer capacities, making different ecosystems varyingly susceptible to acidification (Clark et al. 2013). Another important driver of biodiversity loss is **pesticides**. There is abundant literature on the negative effects of pesticide use on biodiversity on regional and global levels (Beketov et al. 2013; Geiger et al. 2010; Tang et al. 2021). Inappropriate legislation and risk assessments worsen the situation (Brühl and Zaller 2019). These are just a few examples of pollutants affecting biodiversity. There are many others, e.g. mineral oil and its derivatives, chemicals, heavy metals, particulate matter, or other toxic substances that affect biodiversity.

5) **Invasive alien species** are often intentionally introduced to new environments for economic purposes, e.g. aquacultures, agriculture, pets, indoor and outdoor plants (Molnar et al. 2008). Thereby, organisms, seeds, and spores are introduced to ecosystems where they are not endemic. Many species spread to other

ecosystems unintentionally by human activities, e.g. via freight, in water tanks of ships, seeds and spores transported around the globe (Shabani et al. 2020; Linders et al. 2019; Dueñas et al. 2021; Clavero et al. 2009; Doherty et al. 2016; Molnar et al. 2008). These species compete for resources, modify habitats, hybridize, transmit diseases, and alter ecosystem dynamics.

2. A FRAMEWORK FOR INVESTORS TO ASSESS THE IMPACT OF BIODIVERSITY

As biodiversity loss becomes an ever more urgent challenge, financial institutions are looking for ways to quantify the impacts and dependencies of their finance and investment activities on biodiversity. Regulatory instruments in the EU, such as the Sustainable Finance Disclosure Regulation, the Taxonomy Regulation, or the Corporate Sustainability Reporting Directive are slowly but surely moving beyond “just climate” to require financial institutions to also address biodiversity and ecosystems.

But the timelines fall short of the shift required to tackle the current rate of biodiversity loss and its consequences. In other words, moving beyond mere compliance is essential if investors are to play a role in effectively restoring and protecting biodiversity and ecosystems (Federal Agency for Nature Conservation 2022; World Economic Forum 2022). Recent research shows that biodiversity is gaining momentum in the investment industry and that companies benefit from assessing their impact on biodiversity or disclosing information on management practices and the valuation of ecosystem services (Ali et al. 2023).

Financial institutions and companies can find guidance to set science-based targets for nature and disclose their nature-related risks with the SBTN (Science Based Targets Network) and the TNFD (Taskforce on Nature-Related Financial Disclosures). There are several biodiversity assessment tools and methodologies for financial institutions developed by different initiatives and companies as shown in Figure 1 (see more at the EU’s Business @ Biodiversity report (Lammerant et al. 2021) and the Finance for Biodiversity Foundation 2022). The usability of these approaches depends on the focus area of the organization conducting the assessment and on the scope of the assessment.

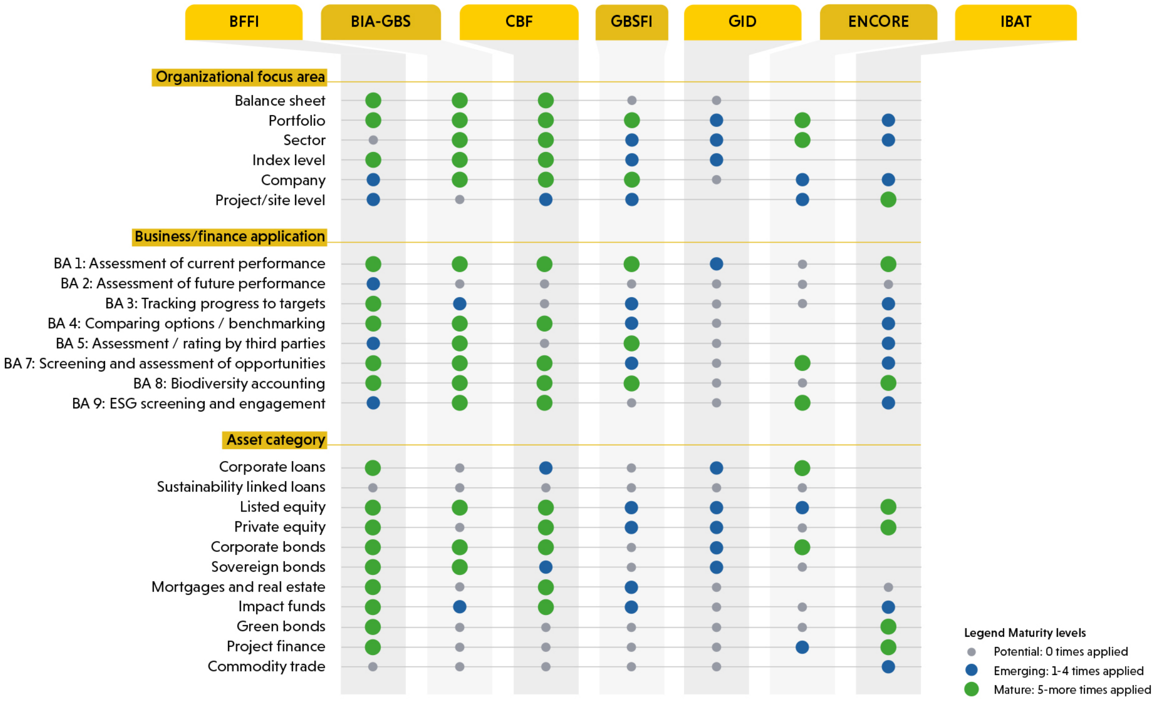

Figure 1 *Overview of existing biodiversity measurement approaches for financial institutions. Source: Finance@Biodiversity 2022.*

As a VC, our operational focus regarding biodiversity assessment differs from financial institutions, such as banks, in that we manage a limited number of early-stage investments. In our investment process, we conduct detailed assessments of all investment opportunities using Life Cycle Assessment (LCA). Planet A's assessment, therefore, does not depend on aggregated, sectoral approaches since we have a comprehensive understanding of all material, resource, and emission flows of the startup companies we assess.

Based on these criteria, there are a several potential methods fit for VC (Finance for Biodiversity Foundation 2022; Lammerant et al. 2021):

The Biodiversity Footprint Methodology (BFM);

The Product Biodiversity Footprint (PBF);

The Life Cycle Impact Assessment (LCIA) method ReCiPe;

The Environmental Profit and Loss (EP & L) method; and

The Biodiversity Footprint for Financial Institutions (BFFI) (Broer et al. 2021).

All researchers and institutions publishing these frameworks provide rough guidance while keeping detailed information and used data confidential, making it impossible to apply these approaches. Thus, we have built a methodology based on the BFFI framework and combined it with our LCA approach. In the following, we explain both approaches and their integration into Planet A's impact assessment approach.

2.1. General description of our approach

We use the Biodiversity Footprint for Financial Institutions (BFFI) and integrate it into our LCA approach.

2.1.1. The overarching framework: Biodiversity Footprint for Financial Institutions (BFFI)

The BFFI framework was developed by CREM, Pré Sustainability, and ASN Bank to measure the biodiversity footprint of economic activities that a financial institution invests in. It follows a LCA-based approach to quantitatively model a company's biodiversity impact based on their revenue, business activities, and related input and output based on stressors from the ReCiPe method (Huijbregts et al. 2017).

It has many advantages like covering many financial/business applications, allowing the 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. Its downsides include no coverage of Scope 3 downstream emissions, no biodiversity state data, covering direct exploitation only partially and requiring external expertise/support from developers to perform the assessments (Finance for Biodiversity Foundation 2022).

2.1.2. The backbone of impact assessments: LCA

While the BFFI provides an overarching framework and guidance on how to evaluate the impact on biodiversity, a Life Cycle Assessment allows for assessing the impact of a product or a service, business models, and many more economic aspects. LCA is a methodological framework to assess the environmental impacts of human activities, business models, specific technical processes, or services. Common applications include certification, compliance, policy support, and environmental hot spot analysis. At Planet A, we apply a LCA framework that helps to assess the consequences of a decision or a change in an evaluated system. We apply this methodology to evaluate innovative startups and the consequences of our investment decisions. We published a white paper explaining our approach and how we apply it.

2.1.3. Planet A's tailored approach for biodiversity impact assessment of startups

We developed a four-step procedure building on the BFFI framework and LCA methodology (Figure 2). We added more data and included additional scientific methods to yield more wholesome and robust results.

- **Step 1: Understanding the potential investment**
- First, we check if the activities of the startup potentially negatively affect biodiversity. We only apply the biodiversity impact assessment to startups where biodiversity is material to the business model of the startup. As a rule of thumb, we would conduct a biodiversity assessment on top of our usual LCA if a startup's activities could substantially affect any of the following indicators:
    - Freshwater eutrophication
    - Freshwater acidification
    - Freshwater ecotoxicity
    - Marine eutrophication
    - Water scarcity
    - Human toxicity cancer
    - Human toxicity non-cancer
    - Particulate matter formation
    - Terrestrial acidification
    - Land transformation
    - Land occupation (see midpoint level indicators marked in orange in Figure 3)

  This step comprises an assessment of the startup's activities, present and planned products, and the market environment of the startup. This also includes an assessment of the supply chain, including raw material supply, production processes, the potential use of the products, and their end-of-life. Additionally, we identify and describe potentially replaced products/activities or behavior changes. We conduct a first rough assessment of potential biodiversity impacts using this information as well as available scientific literature.

- **Step 2: Data collection and modeling**

  In the second step, we take a closer look at all processes of a company. In addition, we evaluate which other mechanisms, processes, and aspects might change if a company scales. Once we know all these changes, we gather data of all material flows, resource uses, and emissions related to all these processes.

- **Step 3: Assess the environmental pressures and the impact on biodiversity**

  The previously gathered information is then linked with the impact on biodiversity. We do this by using the IMPACT World+ framework, an established LCA method (Bulle et al. 2019, see 2.2.

for more). This method allows us to link all data gathered in the second step with environmental pressures that affect biodiversity, e.g. climate change, land occupation, land transformation, ecotoxicity, eutrophication, acidification, etc.

- **Step 4: Interpret results and take an investment decision**

  Once the potential impacts on biodiversity are known, this will feed into the investment decision.

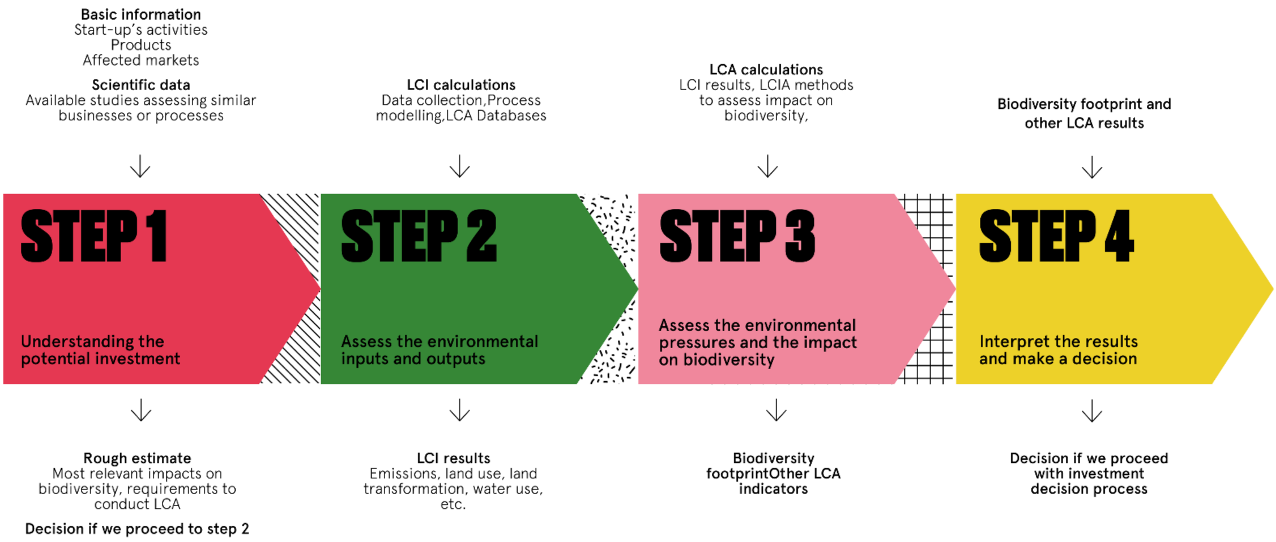

Figure 2 *Overview of the biodiversity assessment methodology. Adapted from the BFFI methodology (Broer et al. 2021).*

Chapter 2.3 describes in more depth how these steps are integrated into our overall startup assessment process.

Impact assessment is a quasi-continuous process as the startups scale and sometimes pivot. Step 2 and step 3 are repeated at regular intervals post-investment to check alignment with the goals and KPIs along with motivating the founders and providing them with unique insights on focus areas to maximize their impact.

2.2. Procedure to assess the key drivers of biodiversity loss

The LCA approach we chose allows the assessment of three out of the five main drivers of biodiversity loss:

1. Land Use Change;
2. Climate Change; and
3. Pollution.

These drivers can be assessed using LCA and are included in the IMPACT World+ methodology in a regionalized manner (Bulle et al. 2019). Overexploitation/unsustainable use as well as invasive species are currently not included in any existing LCA methodologies. To our knowledge, there are no applicable methods to assess the impact of specific human activities on these drivers in a holistic and quantifiable manner, integrating all five drivers of biodiversity loss. Figure 3 shows the structure of the IMPACT World+ and how emissions and resource use contribute to different stressors on biodiversity loss.

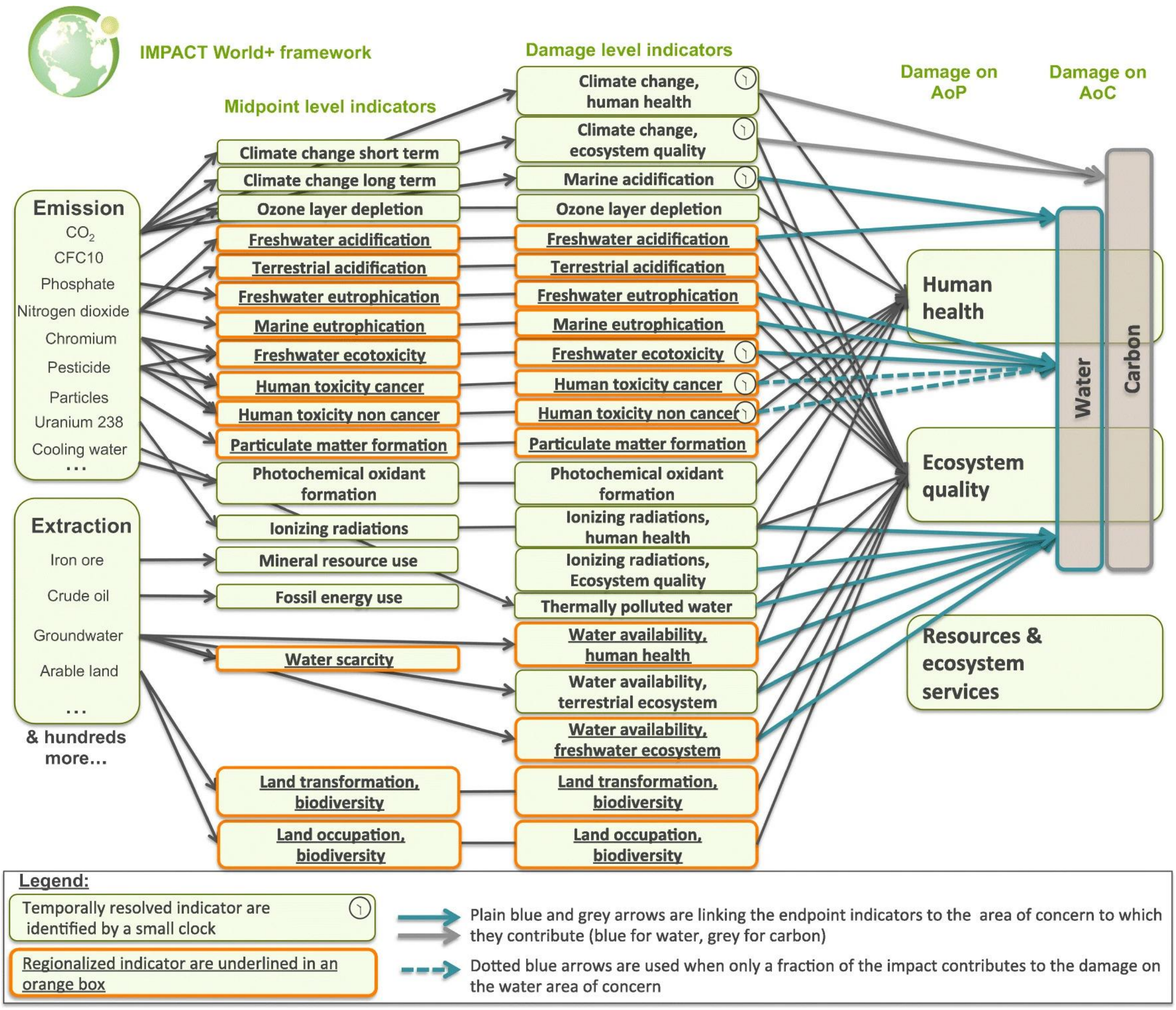

Figure 3 *Overview of the IMPACT World+ framework. The 'emissions' and 'extractions' are the outcomes of the LCI calculations. The LCI results are linked with certain stressors (expressed by midpoint and endpoint indicators). These indicators are linked with the impact on biodiversity (Damage on Area of Protection (AoP): Ecosystem quality. Figure taken from (Bulle et al. 2019) distributed under the terms of the Creative Commons CC BY 4.0 license.*

The result of this LCA approach to assess impact on biodiversity is expressed by the share of species that potentially disappears on a specific area for a specific time. The so-called potentially disappeared fraction of species (PDF) is closely linked with the mean species abundance (MSA), which is another unit for measurement of biodiversity. The PDF is the naturally occuring MSA minus the MSA in a specific land use regime, i.e. PDF = 1 - MSA. The unit of the indicator is the **potentially disappeared fraction of species (PDF) in a surface area of one m² over the duration of one year**. The PDF is the ratio of the current **species richness** in a certain land-use type in a specific location and the natural species richness in that specific location. **It, therefore, includes only species richness, not other dimensions of biodiversity like genetic or ecosystem diversity.**

To illustrate the unit, please consider the following example:

- The disappearance of 50% of species over a period of 1 year affecting an area of 100 m^2;
- The disappearance of 10% of a species over 10 years affecting an area of 50 m^2; and
- The disappearance of 1% of species over 1000 years affecting affecting an area of 5 m^2

are considered to have the same impact on biodiversity (50 PDF*m^2*a).

The biodiversity footprint using the IMPACT World+ method expresses a temporal disappearance of species (Bulle et al. 2019), i.e., a situation where a particular species becomes temporarily absent or extinct in that region for a certain period of time due to various factors and does not necessarily imply a permanent extinction of the species. Temporarily disappearing species can reappear in the same area at a later time if the conditions that led to their absence change i.e. with the positive regional biodiversity impact of the startups under assessment.

We now explain in more detail how the three main drivers of biodiversity loss are considered in the LCA.

2.2.1. Land-use and land use change (LULUC)

Biodiversity is affected by changes in habitat size, fragmentation of habitats, and changes in habitat characteristics. Land-occupation, i.e. the maintenance of land in a non-natural state, also affects biodiversity. The impact of land use is modeled by comparing species richness in different land-use types to the species richness in natural habitats in the same biome according to de Baan, Alkemade, and Koellner (2013). **Land occupation** is responsible for preventing a natural state of biodiversity (Figure 4). **Land transformation** results in a sudden change in species abundance. The recovery of the land (far in the future) is also assigned to the transformation activity. The regeneration times used in the characterisation model were taken from Curran, Hellweg, and Beck (2014).

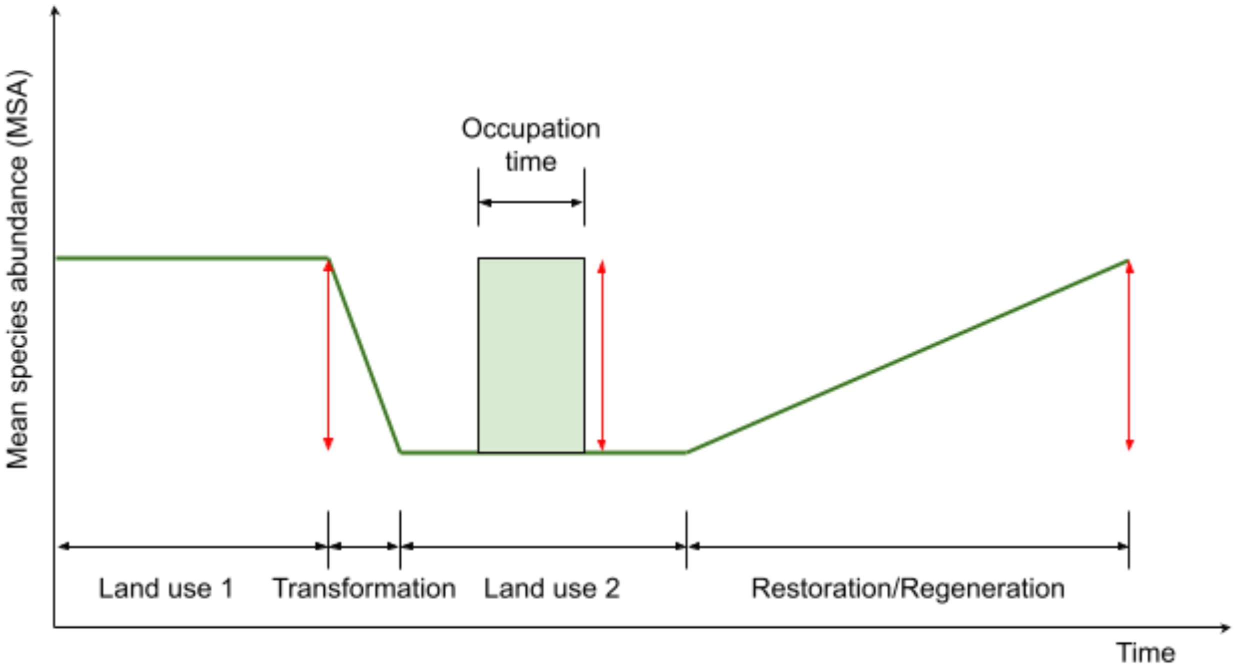

Figure 4 *Impact of LULUC on mean species abundance (MSA). If land is converted from one specific land use type (e.g. natural state, land use 1) to another type of land use (e.g. agricultural land, land use 2), the MSA changes. Once the land is converted, the land remains in the state of land use 2 for a specific period of time. A product system or service might occupy land for a specific period of time. The occupation is burdened with the reduction of MSA over its duration. At an undefined future point in time, land might return to its natural state (or is converted to another state). The transformation of land is burdened with the restoration or regenation of land. The depicted principle is used in the applied LCIA method (Bulle et al. 2019) Figure adapted from Berger et al. (2018).*

The framework proposed by Schmidt et al. (2015) for indirect land use change was used and populated with data. The underlying assumption is that land is a globally traded commodity. A change in demand for agricultural commodities or space for other purposes, e.g. built environment, forest plantations, etc. are perpetuated through different ecoregions and land use types. Further, the IMPACT World+ method uses the work of Chaudhary et al. (2015), which differentiates between different ecoregions, includes different land use types and various plants and animal species, which helps quantify the impact regionally. A detailed description of the underlying assumptions and the data is provided in the technical annex.

2.2.2. Climate change

There are numerous ways in which climate change affects biodiversity (see chapter 1). To account for the additivity of impacts, a time-integrated temperature increase model is applied (Myhre et al. 2014). The damage to the ecosystem, i.e. the extinction of species, as a result of increasing temperatures is modeled according to Thomas et al. (2004). Further, technical parameters as explained in the technical annex help accurately account for all the cause-effect relationships related to climate change, e.g. accounting for an increase in ocean acidification driven by an increase in atmospheric GHG concentrations.

2.2.3. Pollution and nutrient load

The pollution of natural environments results in pressures on biodiversity. The Impact World + method includes the impact of acidifying, eutrophying and toxic pollutants on terrestrial and marine environments. Other pollutants, e.g., toxic or ionizing compounds and chemicals resulting in the formation of photochemical oxidants and particulate matter are considered for terrestrial ecosystems. Thermal pollution of water bodies is included as well.

To date, there is no operational method in LCA that models the impact of micro and macro plastic pollution on biodiversity. A first quantification approach exists (Woods, Rødder, and Verones 2019), but the method is not operational yet due to the lack of models and data regarding the fate of plastic pollution and damage modeling. There are many unknowns, e.g. the fate of ocean debris or microplastic in the environment, the risk of entanglement of certain species in macro plastic, the effect of micro plastic intake of different species, and residence times of plastic pollution. Aside from the LCA method, databases need to be improved as current databases do not contain micro and macro plastic emissions in their inventory.

The data collection and model building process is described in detail in the technical annex of this report.

2.3. Integrating the biodiversity assessment into the investment process

In our daily work, we assess the environmental and economic potential of a multitude of innovative startups. In the first step of this assessment procedure, we screen all companies based on our investment focus, our knowledge and hypotheses on different sectors and topics, as well as their potential economic prospects and environmental impacts (Figure 5). At this stage, we use scientific literature, reports, studies, our own models, and our knowledge base to form a first opinion. If we decide to proceed with the investment process, we will run our first rough LCA calculations. This requires data and information we obtain from founders, scientific publications, statistics, databases, and industry experts. In the subsequent step, before we sign an agreement, we run a full-fledged LCA. This step requires an even deeper evaluation of the startup and the systemic changes that might arise if the company scales. We test different scenarios and parameter assumptions to evaluate the sensitivity of our models and we apply other statistical methods such as Monte-Carlo simulations to deal with uncertainties. If we are confident that a startup will bring a significant change for the better (and ticks all of our other boxes), we invest. Based on our LCA results, we define key performance indicators (KPI) for impact with each startup that we track and report on annually. In addition, we use our LCA studies to assist our portfolio companies to better understand and improve their impact.

ANCHORING IMPACT IN EVERY STEP OF OUR INVESTMENT PROCESS

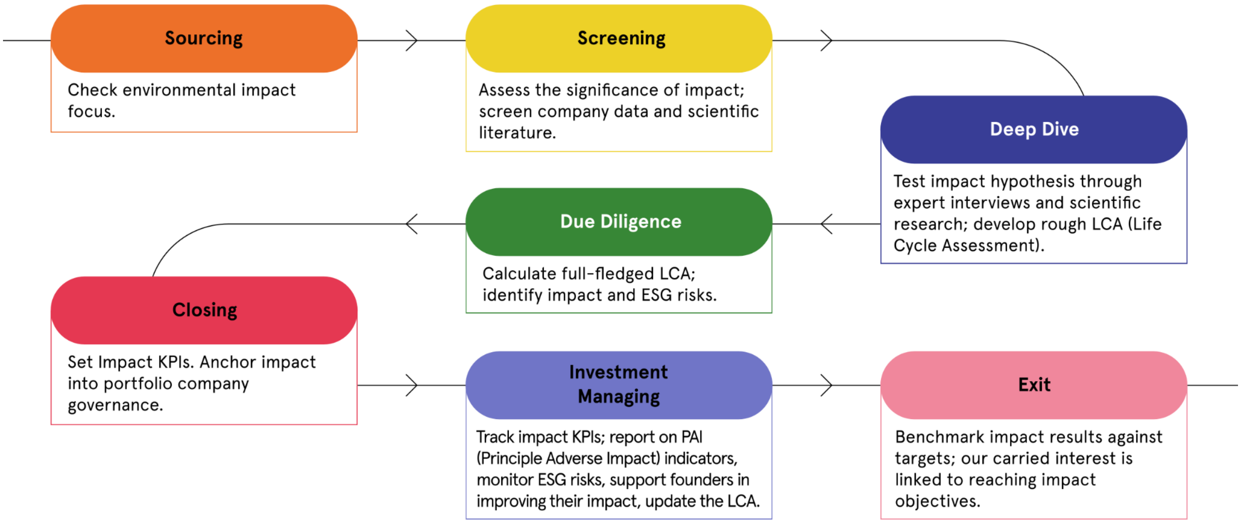

Figure 5 *Impact assessment anchored in Planet A's investment process.*

The biodiversity assessment will take place as part of this process based on the assessment of the potential impact on biodiversity as explained in section 2.1.3 of this report. During the screening or deep dive stage, we rely on scientific studies, the companies' own data and estimates to determine if and how a startup affects, addresses or is affected by the main drivers of biodiversity loss and/or gain. At the due diligence stage, we conduct a fully fledged assessment according to the methodology described in this report evaluating a startup's impact on biodiviersity. The limitations of our method are discussed in the technical annex.

3. CONCLUSION AND OUTLOOK

Planet A always tries to stay ahead of the curve and update its methodologies in accordance with the best available data, covering all relevant data points and selecting the most comprehensive impact assessments methods to yield most accurate and robust results. The presented methodology relies on the most recent frameworks as well as actual, complete, and comprehensive datasets. It will enable us to make reliable and informed investment decisions in regards to the impact on biodiversity.

These frameworks and datasets allow for a good estimation of the impact of an economic activity on biodiversity. However, several aspects of a comprehensive biodiversity assessment are lacking:

- Two dimensions of biodiversity, genetic and ecosystem diversity, are not covered in any method available at the moment.

- No applicable method is able to assess the impact of alien invasive species or overexploitation on biodiversity.
- Several stressors, such as destruction of marine environments, e.g. by bottom-trawling or buildings/infrastructure, micro plastics, change in turbidity of water bodies, ecosystem fragmentation, pharmaceuticals and endocrine disruptors, acoustic pollution/noise, electro-magnetic radiation, dust, odor, vibration, and light pollution are not covered yet.
- Likewise, it is challenging to cover certain activities that can positively affect biodiversity, e.g. dedicated action to increase biodiversity, protection and creation of protected areas and biotopes, and actions targeting specific species. Some of these activities can be assessed with existing frameworks but it remains a huge challenge to integrate these frameworks into larger holistic frameworks covering multiple stressors and benefactors of biodiversity while delivering quantitative results.

We keep an eye on the scientific debate and the community working on these topics. Whenever possible, new frameworks and datasets will be included in our methodology. We consider this an ongoing process. This is the first time a VC develops and publishes a method to evaluate the impact of investment opportunities on biodiversity. Therefore, we are pleased to engage with other actors and scientists in this field to improve methods, frameworks, and practices in the ecosystem and beyond.

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5. TECHNICAL ANNEX

This technical annex is a part of Planet A's effort and commitment to share practices with other stakeholders. It explains all the scientific and practical details of the methodology for an audience with an interest to dive deeper and an understanding of LCAs.

5.1. Additional information on LCA and Impact assessment using the IMPACT World+ method

The basic principle in LCA-based impact assessment approaches can be explained in a simplified way: first, all resources entering the system and all products or emissions leaving the product system are quantified, the so-called life cycle inventory (LCI). In the subsequent assessment step (LCIA), these flows (resources and emissions) are multiplied by characterisation factors (CF). These factors express the effect that these emissions have on specific environmental mechanisms (= what impact is caused by them). Usually, certain reference substances are used to express the impact in reference to that reference substance. For example, the most commonly used impact method to evaluate emissions affecting climate change is the global warming potential (GWP). The GWP of a greenhouse gas (GHG) is expressed by its CF. The CF describes the relative increase in radiative forcing of a substance emitted over a certain time period, e.g. 100 years. The reference substance used to determine the global warming potential is CO_2. Hence, the unit is kg CO_2-equivalents. Yet, this is not a direct description of the contribution to climate change. Climate change has many consequences that impact the environment, economy as well as health and well-being. It does not matter where in the troposphere GHG is emitted. Due to atmospheric mixing, GHGs are distributed in the atmosphere. In LCA methods, there are also other environmental impacts that strongly depend on the location where an emission takes place or where a resource is used, e.g., water use or emission of acidifying or eutrophying substances have different implications depending on locally prevailing conditions. These spatially explicit emissions are modeled in a similar way but using especially explicit CFs. The underlying principle behind this approach is that certain emissions and resource demands result in specific impacts. The CF expresses the corresponding cause-effect chain, containing the following aspects (Figure A1):

1) Emission of a substance or use of a resource;
2) Fate of the emitted substance (e.g. to where it is transported and how it might be transformed by physical or chemical reactions in the environment);
3) The exposure of organisms in the environmental compartment where the substance or its reaction products is transported to;
4) The damage or effect the substance has on different organisms is response to the exposure.

Step 1 is a result of the LCI calculations. Steps 2 to 4 are included in the CF that is multiplied by 1.

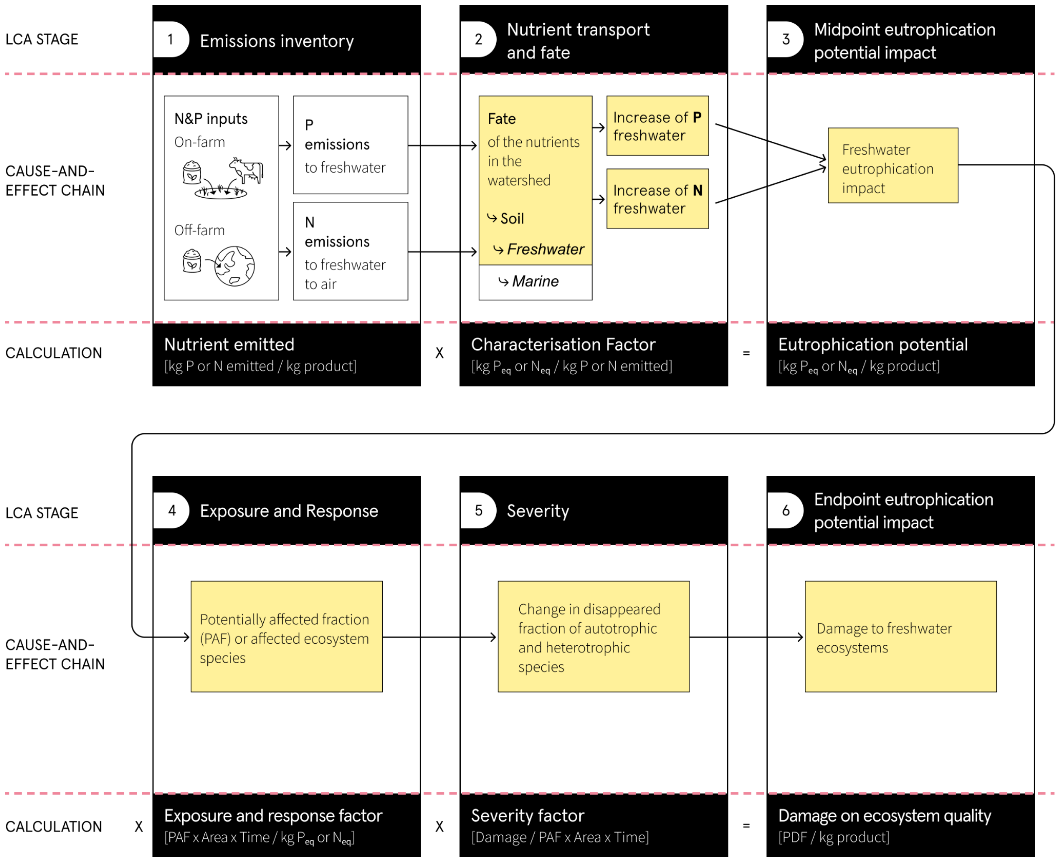

Figure A1 *Exemplary visualization of the cause effect chain modeled to determine the impact of eutrophying emissions. Except from our [LCA whitepaper](#).*

There are many LCA methods that describe different impact pathways and use different models to evaluate the impact of certain emissions or resource uses. The biodiversity assessment framework presented in this paper uses the IMPACT World+ (Bulle et al. 2019), which accounts for local effects on biodiversity. The method allows the inclusion of spatially explicit considerations. The IMPACT World+ framework provides midpoint level indicators with four complementary viewpoints:

1. Midpoint damage indicators;
2. Damage impacts;
3. Damage on Areas of Protection (AoP) namely human health, ecosystem quality, and resource and ecosystem services;
4. Damage on Areas of Concern (AoC) namely the carbon and water footprint.

The loss of biodiversity can be expressed by the AoP viewpoint ecosystem quality. Ecosystem quality can be calculated per midpoint indicator. Additionally, the contribution of each impact category to the overall AoP can be evaluated (Bulle et al. 2019). We decided to use the IMPACT World+ method instead of the ReCiPe method, a commonly used method, because the IMPACT World+ allows a more regionalized assessment. The ReCiPe uses more aggregated factors (Huijbregts et al. 2017) which reduces the resolution of the indicated results.

Independently from the level of aggregation, the characterisation factors used to determine midpoint indicators are expressed in the unit *PDF*m²*a per quantity of emission or resource use (e.g. land or water)*. The unit expresses the **potentially disappeared fraction of species (PDF) in a surface area of one m² over a duration of one year**. The PDF is the ratio of the current **species richness** in a certain land-use type in a specific location and the natural species richness in that specific location. **It, therefore, includes only species richness, not other dimensions of biodiversity like genetic or ecosystem diversity.** The characterisation factor used for an elementary flow emitted to the environment is modeled according to Equation (1) (simplified from Bulle et al. 2019):

$$CF = \vec{1} * \vec{SF} * \vec{ERF} * \vec{XF} * \vec{FF} \qquad \text{Equation (1)}$$

with

FF the fate factor describing the increase of mass of an active substance in a receiving compartment;

XF exposure factor describing a change in the population or ecosystem exposure via a specific impact pathway per mass of active substance in the receiving compartment over an infinite period (for some indicators, it is subdivided into short- and long-term impacts);

ERF exposure response factor describing the change in adverse consequences in response to a change in the population or ecosystem exposure; and

SF severity fate vector that aggregates all responses for a single impact category into damage level units.

Land Use Change (LULUC)

The IMPACT World+ method uses the work by Chaudhary et al. (2015). They differentiate between 804 ecoregions and eight land use types: agriculture, arable (annual crops); artificial areas, urban; forests with extensive use; forests with intensive use as well as pasture, permanent crops for each taxon such as mammals, birds, amphibians, reptiles and plants (Chaudhary et al. 2015). Besides the ecoregions and land use types, local characterisation factors and recovery times are included in the regional and global characterisation factors, where results presented in various other scientific papers are combined (Chaudhary et al. 2015; Curran, Hellweg, and Beck 2014).

Climate change

The IMPACT World+ method includes short- (<100 years) and long-term cumulative impacts (100 to 500 years) of increasing temperatures and increasing oceanic pH levels. The underlying cause-effect includes the increase in atmospheric GHG concentrations per mass of a GHG emitted (fate factor), the rise in temperature per increase in atmospheric GHG emissions (exposure factor), and the potentially extinct fraction of species per rise in temperature (exposure response factor).

The atmospheric increase in GHG concentrations also leads to an increase in ocean acidification. In this case, the cause-effect relationship includes the same fate factor, the rise in oceanic pH levels per increase in atmospheric GHG emissions (exposure factor), the potentially area affected over the time considered per increase in pH (exposure response and severity factor) and the potential fraction of species going extinct as a result of increasing temperature (severity factor).

Pollution and nutrient load

The method applies fate factors for all pollutants that express the quantity of substance deposited per mass emitted, exposure factor that express the share of species affected by the deposited mass and exposure response factors that express the effect on the species as well as damage factors that express the resulting impact[1].

5.2. Details on the Implementation of land use and land use change (LULUC)

Land occupation and transformation are a main driver of biodiversity loss. Modeling LULUC is a challenge and a widely debated topic in the LCA community and beyond. Changes in land use might arise from a change in demand for agricultural commodities, space requirements for infrastructure projects or any other artificial structure, e.g. artificial lakes and dams, agroforestry projects, or any other activity that results in a change in how land is used. The complexity to model these changes arises from the difficulty to link causes and effects. A direct conversion of land, e.g. from a forest to cropland, can be directly linked to an activity of the land owner or user. Yet, most commodities are traded globally and many commodities can be used for multiple purposes such as food, feed, or fuels. Therefore, identifying the cause of an observed land use change is challenging. Another layer of complexity is added by the fact that an increase in demand for a certain commodity might result in a chain of changes potentially triggering the conversion of natural habitats to croplands. Expanding cities might displace crop land. If this displacement is not compensated by increase in efficiency elsewhere or a reduction in demand for the commodities grown on this land, cropland might be expanded into natural areas. This might involve several intermediate steps in which crop types displace other crop types or even other types of land use, ultimately resulting in a conversion of natural habitats in regions far away from the where the first trigger took place.

Often, the distinction between direct and indirect land use change (dLUC and iLUC) is made. dLUC describes the direct conversion of land, whereas iLUC describes a mechanism involving several displacement steps (Figure A2). For instance, if more of a crop is diverted to biofuel production, other cropland might be used to provide the same crop to the food market. The crop that was displaced might then lead to an extension of cropland elsewhere. In reality, there are complex market mechanisms at play governing LULUC.

[1] Please see Bulle et al. (2019) and its supplementary material for further information on the underlying models that are used to express the cause-effect chain. Certain indicators are still labeled as interim.

Figure A2 *Schematic representation of dLUC and iLUC.*

While LUC can be observed or measured with satellite data, identifying the underlying causes is complicated. Different models are available ranging from deterministic models to complex general equilibrium models (Hertel et al. 2019; De Rosa, Knudsen, and Hermansen 2016).

In the biodiversity assessment method we present here, we chose the model proposed by Schmidt et al. (2015). The authors provide a framework to build a global land use dataset that can be embedded in LCA models. The fundamental assumption behind this model is that all activities demanding land are equally responsible for LUC. The basic assumption is that land is a globally traded commodity and land requirements lead in the medium- and long-term to displacement effects covering the whole globe. The model includes two key mechanisms that usually fulfill changes in demand for agricultural commodities: land expansion and land intensification. While the former leads to LUC, the latter results in higher expenditures of energy (direct energy consumption in agricultural machinery and transportation processes and indirect energy consumption to produce additional fertilizer and agrochemicals), fertilizers and agrochemicals and irrigation. Land conversion and intensification result in an increase in crop output that is expressed in an area that this expansion and intensification corresponds to (ha-eq.). The following sections explain the most important elements of this model:

5.2.1. Net Primary Productivity (NPP)

Land is not equally productive. To account for this, the Net Primary Productivity (NPP) is used as an indicator of land productivity and quality. NPP is the difference between the amount of carbon that is fixed by plants (accumulated as biomass) and the amount of carbon that is lost through respiration. NPP is a key indicator of ecosystem productivity and is used to estimate the amount of carbon that is stored in vegetation and soils. The MODIS (Moderate Resolution Imaging Spectroradiometer) sensor on board NASA's Terra and Aqua satellites provides global estimates of NPP at a spatial resolution of 1 km and a temporal resolution of 8 days (Numerical Terradynamic Simulation Group (NTSG), University of Montana 2023).

The NPP from MOD17 is reported in units of grams of carbon per square meter per year (g $C/m^2/a$) and can be used to deduce information for several applications, including natural resource and land management, global carbon cycle analysis, ecosystem status assessment, and environmental change monitoring.

In this study, NPP data from 2015 was used as it was the latest data available in a usable format. This data was worked upon using QGIS software and the output is shown in Figure A3. Global average net primary productivity (NPP_0) was calculated at 50880 g C/m^2/year. The ratio "NPP/NPP_0" expresses the relative quality or productivity of land compared to the global average.

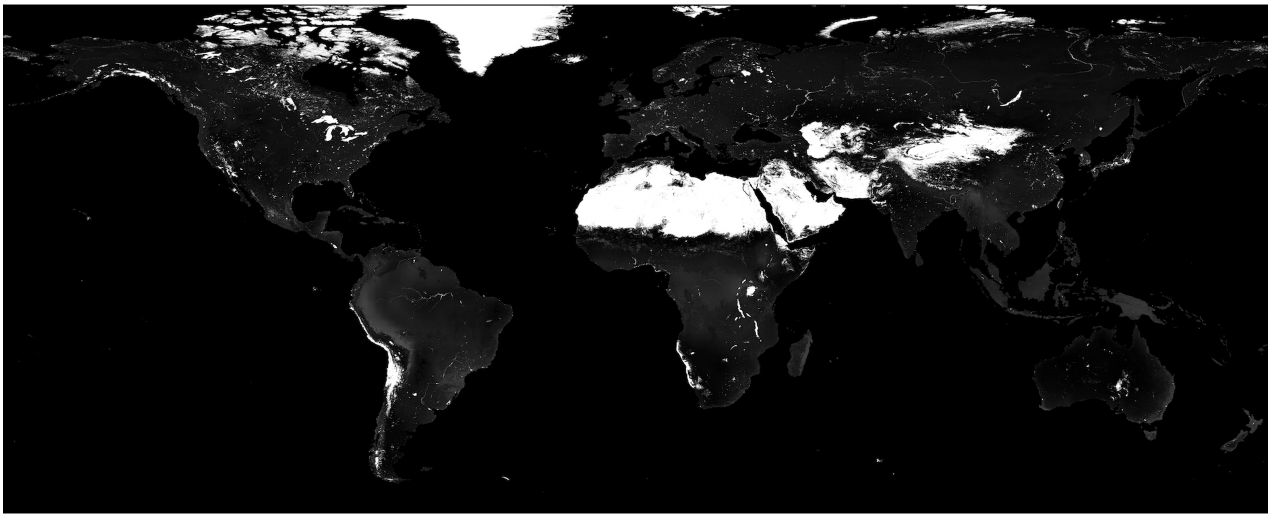

Figure A3 *Raster output from QGIS for calculating the country wise NPP and global average NPP_0*

Table A1 shows the NPP and NPP_0 calculated for different countries from MOD17 NPP data from 2015 using QGIS software. For some countries, data was manually adjusted to represent the entire area (like Antarctica and Palestine) and proxies were assumed for some small islands (like Saint Helena, Saint Pierre and Miquelon, and Wallis and Futuna).

Table A1 *NPP in g $C/m^2/a$ and relative productivity NPP/NPP_0 for different countries.*

Country	**NPP**	**NPP/NPP_0**	**Country**	**NPP**	**NPP/NPP_0**
Australia	3568	0.070	Hong Kong	30944	0.608
Austria	7986	0.157	India	6707	0.132
Belgium	14022	0.276	Indonesia	11524	0.226
Canada	20274	0.398	Iran (Islamic Republic of)	39086	0.768
Chile	29111	0.572	Iraq	39148	0.769
Colombia	9791	0.192	Guernsey	27547	0.541

Country	NPP	NPP/NPP_0	Country	NPP	NPP/NPP_0
Costa Rica	9420	0.185	Isle of man	18383	0.361
Czech Republic	7945	0.156	Jamaica	16140	0.317
Denmark	10957	0.215	Jersey	21614	0.425
Estonia	9664	0.190	Jordan	43400	0.853
Finland	7979	0.157	Kazakhstan	9754	0.192
France	10685	0.210	Kenya	7993	0.157
Germany	9771	0.192	Democratic People's Republic of Korea	6856	0.135
Greece	9223	0.181	Kiribati	58890	1.157
Hungary	8121	0.160	Kuwait	62591	1.230
Iceland	24804	0.488	Kyrgyzstan	13378	0.263
Ireland	9738	0.191	Lao People's Democratic Republic	10676	0.210
Israel	37642	0.740	Lebanon	15298	0.301
Italy	13970	0.275	Lesotho	4579	0.090
Japan	17946	0.353	Liberia	7911	0.155
Republic of Korea	6856	0.135	Libyan Arab Jamahiriya	61978	1.218
Latvia	6560	0.129	Liechtenstein	10976	0.216
Lithuania	6135	0.121	Macao	65535	1.288
Luxembourg	10717	0.211	Madagascar	10832	0.213
Mexico	8933	0.176	Malawi	18582	0.365
Netherlands	16675	0.328	Malaysia	10640	0.209
New Zealand	14411	0.283	Maldives	59541	1.170
Norway	7990	0.157	Mali	38294	0.753
Poland	6587	0.129	Malta	20617	0.405
Portugal	11002	0.216	Marshall islands	60472	1.189
Slovakia	7133	0.140	Mauritania	56140	1.103
Slovenia	8085	0.159	Mauritius	17097	0.336
Spain	8165	0.160	Micronesia (Federated States of)	10530	0.207
Sweden	7669	0.151	Moldova, Republic of	4760	0.094
Switzerland	11820	0.232	Mongolia	20779	0.408
Turkey	6915	0.136	Montenegro	8210	0.161
U.K. of Great Britain and Northern Ireland	11146	0.219	Montserrat	24366	0.479
United States of America	8169	0.161	Morocco	29967	0.589
Afghanistan	30170	0.593	Mozambique	7678	0.151
Albania	8322	0.164	Myanmar	9554	0.188
Algeria	58528	1.150	Namibia	12983	0.255
American Samoa	16859	0.331	Nauru	18994	0.373
Andorra	8965	0.176	Nepal	13114	0.258
Angola	7280	0.143	Netherlands	16675	0.328
Anguilla	26242	0.516	New Caledonia	13058	0.257
Antarctica	47165	0.927	Nicaragua	12251	0.241
Antigua & Barbuda	23005	0.452	Niger	46051	0.905
Argentina	8876	0.174	The former Yugoslav Republic of Macedonia	8004	0.157
Armenia	7938	0.156	Nigeria	5532	0.109
Aruba	32511	0.639	Niue	13406	0.263
Azerbaijan	35015	0.688	Norfolk Island	22480	0.442
Bahamas	25788	0.507	Northern Mariana Islands	27733	0.545
Bahrain	62929	1.237	Palestine	16838	0.331
Bangladesh	10136	0.199	Oman	62158	1.222
Barbados	16493	0.324	Pakistan	29911	0.588
Belarus	5348	0.105	Palau	13917	0.274
Belize	15871	0.312	Panama	8795	0.173
Benin	5904	0.116	Papua New guinea	15039	0.296
Bermuda	42186	0.829	Paraguay	6360	0.125
Bhutan	12102	0.238	Peru	18059	0.355
Bolivia	11823	0.232	Philippines	12140	0.239

Country	NPP	NPP/NPP$_0$
Bosnia & Herzegovina	6696	0.132
Botswana	2479	0.049
Bouvet Island	65535	1.288
Brazil	7865	0.155
British Indian Ocean Territory	51662	1.015
British Virgin Islands	32200	0.633
Brunei Darussalam	12018	0.236
Bulgaria	7167	0.141
Burkina Faso	4752	0.093
Burundi	13432	0.264
Cambodia	7970	0.157
Cameroon	8944	0.176
Cape Verde	29585	0.581
Cayman Islands	22992	0.452
Central African Republic	7409	0.146
Chad	37504	0.737
China	19300	0.379
Christmas Island	45829	0.901
Cocos (Keeling) Islands	47826	0.940
Comoros	17005	0.334
Congo	10310	0.203
Democratic Republic of the Congo	10665	0.210
Cook Islands	24764	0.487
Côte d'Ivoire	6433	0.126
Croatia	8201	0.161
Cuba	11849	0.233
Cyprus	10269	0.202
Djibouti	59323	1.166
Dominica	17624	0.346
Dominican Republic	13063	0.257
Ecuador	13844	0.272
Egypt	63001	1.238
El Salvador	9070	0.178
Equatorial Guinea	9916	0.195
Eritrea	30254	0.595
Ethiopia	10743	0.211
Faroe Islands	18332	0.360
Falkland Islands (Malvinas)	11351	0.223
Fiji	12678	0.249
French Polynesia	15661	0.308
French Southern and Antarctic Territories	36977	0.727
Gabon	10655	0.209
Gambia	6773	0.133
Georgia	7572	0.149
Ghana	8243	0.162
Gibraltar	65535	1.288
Greenland	50946	1.001
Grenada	18558	0.365
Guam	17011	0.334
Guatemala	8565	0.168
Guinea	3785	0.074
Guinea-Bissau	5031	0.099
Guyana	9764	0.192
Haiti	11465	0.225
Heard island and mcdonald islands	64323	1.264

Country	NPP	NPP/NPP$_0$
Pitcairn Island	29435	0.579
Puerto Rico	16717	0.329
Qatar	65410	1.286
Romania	6842	0.134
Russian Federation	7056	0.139
Rwanda	13931	0.274
Saint Helena	22719	0.447
Saint Kitts and Nevis	23460	0.461
Saint Lucia	17495	0.344
Saint Pierre and Miquelon	20274	0.398
Saint Vincent and the Grenadines	15177	0.298
Samoa	12808	0.252
San Marino	28232	0.555
Sao Tome and Principe	22719	0.447
Saudi Arabia	62318	1.225
Senegal	5752	0.113
Serbia	7553	0.148
Seychelles	36916	0.726
Sierra Leone	4503	0.088
Singapore	44188	0.868
Solomon islands	14512	0.285
Somalia	12089	0.238
South Africa	5069	0.100
South Georgia & the South Sandwich Islands	63332	1.245
Sri Lanka	8725	0.171
Sudan	38646	0.760
Suriname	9820	0.193
South Sudan	6168	0.121
Svalbard and Jan Mayen Islands	55748	1.096
Swaziland	7632	0.150
Syrian Arab republic	29463	0.579
Taiwan	18815	0.370
Tajikistan	30248	0.594
United Republic of Tanzania	11275	0.222
Thailand	7835	0.154
Timor-Leste	11553	0.227
Togo	7017	0.138
Tokelau	65535	1.288
Tonga	18333	0.360
Trinidad and Tobago	15788	0.310
Tunisia	41898	0.823
Turkmenistan	39114	0.769
Turks and Caicos Islands	24449	0.481
Tuvalu	65535	1.288
Uganda	18888	0.371
Ukraine	6129	0.120
United Arab Emirates	64172	1.261
Uruguay	9477	0.186
Uzbekistan	30257	0.595
Vanuatu	16034	0.315
Venezuela	8922	0.175
Vietnam	8745	0.172
United states virgin islands	17537	0.345
Wallis and Futuna	12678	0.249
Yemen	42794	0.841

Country	NPP	NPP/NPP_0	Country	NPP	NPP/NPP_0
Holy See	65535	1.288	Zambia	7719	0.152
Honduras	11186	0.220	Zimbabwe	5186	0.102

5.4. Land Transformation

Land transformation is the conversion of natural ecosystems like forests, grasslands, and wetlands. into semi-natural/built landscapes like cropland, pasture, and urban areas. Numerous factors like population growth, economic development, and the need for food, energy, and natural resources can lead to transformation of land. It can have significant impacts on biodiversity:

1. Habitat loss and fragmentation: Land transformation can result in the loss and fragmentation of natural habitats, which can reduce the availability of suitable habitat for many species and increase the risk of extinction.
2. Changes in species composition: Land transformation can alter the species composition of ecosystems, favoring species that are adapted to human-dominated landscapes and reducing the abundance and diversity of native species.
3. Changes in ecosystem function: Land transformation can alter the functioning of ecosystems, including nutrient cycling, carbon storage, and water regulation, which can have cascading effects on biodiversity and ecosystem services.
4. Increased exposure to invasive species: Land transformation can create new opportunities for invasive species to establish and spread, which can further reduce biodiversity and ecosystem function.

In this study, the OECD's land transformation data for "to cropland" and "from cropland" (OECD 2021) was used for 2019 and 2000 to calculate the transformation of land in hectares over this time period for each country. Subsequently, the land transformation was multiplied by respective "NPP/NPP_0" to account for the difference in quality of land and obtain the area in ha-eq.

GHG emissions due to land transformation between 2000 and 2019 was calculated using the background data of scientific literature from (Richard A. Houghton and Andrea Castanho 2023) and kindly provided by the authors. The direct impact of land transformation on biodiversity was assessed using the CF from IMPACT World+ method. Land use categories of the OECD dataset and the impact assessment method do not match and were adjusted according to Figure A4.

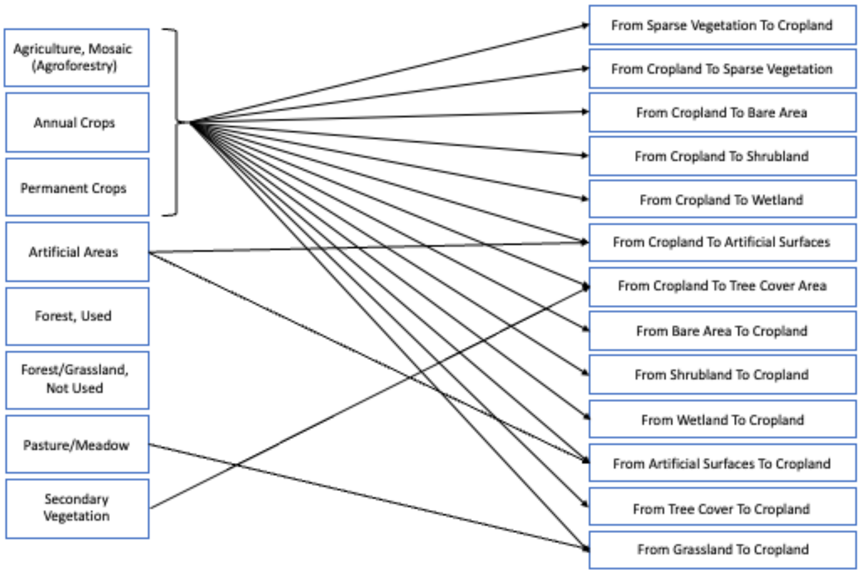

Figure A4 *Matching of Land Use Categories for IMPACT World+ and OECD.*

5.4.1. Land use intensification

Land use intensification refers to the increase in the productivity of land area by use of fertilizers, pesticides, and irrigation. It can have significant impacts on biodiversity, including:

1. <u>Reduction in species richness</u>: Land use intensification can lead to a reduction in species richness, particularly in areas with low productivity, such as grasslands and forests.
2. <u>Changes in ecosystem function</u>: Land use intensification can alter the functioning of ecosystems, including nutrient cycling, carbon storage, and water regulation, which can have cascading effects on biodiversity and ecosystem services.
3. <u>Increased exposure to chemicals</u>: Land use intensification requires heightened use of fertilizers and pesticides, which can result in chemical leaching and hamper biodiversity and ecosystem function.

In this study, to calculate land use intensification, several parameters were calculated as follows:

<u>Area equivalent to yield increase</u>: It was calculated using country wise data on area and yield for different crop types obtained from FAOstat (FAO 2023) for 2000 and 2019. The resultant land use intensified was multiplied with “NPP/NPP_0” to obtain the required ha-eq.

<u>Fertilizer application</u>: Change in nitrogen, phosphorus, and potassium nutrient supply was calculated using country wise fertilizer use data obtained from FAOstat (FAO 2023) for 2000 and 2019. Different types of direct emissions from fertilizer use like N_2O, NH_3, NOx (NO and NO_2), NO_3, phosphorus leaching, and GHG emissions from urea were calculated as per IPCC guidelines (IPCC 2019) and LCA crop database methodology report (Jannick Schmidt and Jonas Ilum Sørensen 2022). We calculated the indirect

(supply chain) impact of fertilizer application along with direct emissions using relevant IMPACT World+ CF.

Irrigation water requirement: Country wise data irrigation water requirement along with percentages of areas equipped for irrigation by groundwater and surface water in 2000 and 2019 was obtained from Aquastat (FAO Aquastat 2023) and used to calculate the impact of irrigation water on biodiversity.

Agricultural energy consumption: Energy use from various sources and direct emissions data was obtained from FAOstat (FAO 2023) for 2000 and 2019. We calculated the total impact of energy consumption using relevant IMPACT World+ CF.

It is important to note that data gaps were filled using data from the previous or the subsequent years e.g. 1999, 2001, etc. for the year 2000 or 2018, 2020, etc. for the year 2019.

5.4.2. Origin of products, global trade, and resulting land use

Existing LCA databases offer only a limited number of processes describing agricultural production processes. For each crop type available in these databases, only a limited number of regionalized datasets is available. Yet, in the globalized world of today, products and services are traded all over the world. To overcome this limitation and to map the physical quantities and flows of any product or service, we use economic and trade data.

We use EXIOBASE, a global, detailed Multi-Regional Environmentally Extended Input-Output database which was developed by a consortium of several research institutes in projects financed by the European research framework programs. This database covers the links between industries and countries, not only in monetary value but also in physical terms (Stadler et al. 2018). Any product or service to be assessed when mapped in EXIOBASE provides trade flows, which form a subset of the global physical (intermediary or elementary) flows considered in this study. The biodiversity impact of the product or service can thus be easily calculated.

EXIOBASE 3rx with land use extension data from 2015 was used to develop this methodology as it is the latest version available with land use data. This version of the database includes 214 countries, 200 products, 163 industries, 6 aggregated land use extensions, and basic pricing in million euros.

Along with converting monetary flows to physical flows, data regarding supply for land (transformation and intensification per country) along with land use (as a global land use market) is also extracted from EXIOBASE for use in our methodology as suggested by Jannick Schmidt and Michele De Rosa 2018.

5.3 Discussion of challenges, unknowns, and uncertainties

All existing tools and methods available to date face limitations when it comes to the assessment of biodiversity and have a scope for improvement, our LCA approach included. This section highlights the challenges, uncertainties, and outlook for our methodology.

5.3.1. Uncertainties: Land use and land use change

LULUC are key drivers of biodiversity loss (see chapter 1). The fragmentation of habitats, the change in habitat size, and the complete disappearance of natural habitats affect biodiversity. Therefore, the impact of LULUC is highly local – this is critical when it comes to data collection. Data used in LCA models is either directly gathered from companies or taken from databases, scientific literature, or other reports. Especially when we use databases in cases where we lack process knowledge for upstream or downstream processes of a company, the data might not fully represent the supply chain of the respective company. For instance, data sets might not be accurate in terms of location or production modalities (e.g. yields, use of agrochemicals). Usually datasets are available for just a number of countries. However, the impact on biodiversity is likely to differ even within countries by a large extent.

5.3.2. Uncertainties: Climate change

Despite the scientific consensus that climate change will increase global mean temperatures, there is still uncertainty about the magnitude of the increase in temperature (globally and locally). The characterisation factors used to model the impact of climate change on biodiversity reflect the potential extinction of species due to habitat loss (Thomas et al. 2004). Thomas et al. (2004) use a well-established empirical formula to estimate the number of species threatened if an area available to them is reduced. How habitat sizes change as a consequence of climate change (and human activities), how species can disperse to other habitat patches of the same type if one patch is reduced, the time-lag between a reduction in habitat size and extinction, the occurrence of new habitat types (given the large shifts in the Earth system that might occur), and the ability of species to adapt to these or to form new species, communities, etc. are some examples of aspects that are yet to be fully understood and included in model predictions.

Additionally, world-leading climate change scientists raise concerns about certain **tipping points** that might be reached after which climate change results in catastrophic consequences (Lenton et al. 2019). There is mounting evidence that these tipping points are more likely to occur even at lower temperature increases than estimated in preceding reports of the Intergovernmental Panel on Climate Change (IPCC). The most critical tipping points are the reduction in or total loss of ice in the Arctic Sea ice, in Greenland, and in the Antarctic, as well as a slowdown of the Atlantic circulation, thawing permafrost, stress on boreal forests from fires and pests, loss of considerable parts of the Amazon rainforest and large-scale die-offs of coral reefs. These large-scale discontinuities in the climatic system are yet not included in any LCIA method (or any other method that seeks to evaluate the sustainability of products, services, or other human activities or behaviors). Undoubtedly, the occurrence of such tipping points is likely to result in severe impact on biodiversity due to the large-scale disturbance of the Earth system. Yet, these consequences are not included in available methods.

Undoubtedly, climate change will affect biodiversity. Therefore, the biodiversity in natural habitats will change over time. Due to the lack of adequate up-to-date precise and spatially accurate data on the biodiversity in all natural environments, these shifting baselines are not included in the existing LCA methods.

5.3.3. Spatial accuracy

The characterisation factors applied in the LCIA methodology differentiates between nine different biomes (de Baan, Alkemade, and Koellner 2013; Bulle et al. 2019). Therefore, even if the precise location of all occurring LULUC or emitting point sources were known, they would not be reflected in the subsequent characterisation step. This is an inherent inaccuracy of all existing LCIA methods.

5.3.4. System boundaries

Accuracy is further compromised by the difficulty of identifying the marginal supply and reduction in supply as a result of a substitution of existing products. In addition, substitution is likely to behave in a non-linear way, e.g. the substituted product or providing supplier might differ if, for instance, 10,000 or 10 million units of a product are sold.

5.3.5. Data sources

LCA-based assessments usually rely on collected or modeled data as well as data contained in existing LCA databases. Several factors might reduce the meaningfulness of these datasets, such as spatial and temporal accuracy, data quality, similarity of individual processes and supply chains modeled in the database with processes and supply chains assessed. For instance, process based databases, such as the Ecoinvent database, contain a limited number of processes describing specific processes and activities. Other databases, such as input-output databases, e.g. the Exiobase[2], aggregate whole economic sectors. These datasets might offer more recent but less accurate data due to the high aggregation of data.

Another major limitation of the applied approach is the reliance on historical data. Trade data and LULUC statistics reflect historical developments that might be a good indication of the immediate future but might be less accurate when it comes to projection impacts far into the future.

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[2] See Lammerant et al. (2021 for all available methods and data used. Almost all methods that are meant to assess the impact on biodiversity of financial institutions on an aggregated level, e.g. for a whole investment portfolio, use the Exiobase dataset. Exiobase is an input-output based dataset linking trade flows between different national economic sectors with emissions and resource demands, including land use (Stadler et al. 2018).

5.3.6. Updates of methods

There are ongoing and increasing efforts to understand and model the impact of human activities on biodiversity. This includes, for instance, collecting better and more spatially resolved data, developing more accurate models that better reflect the links between human activities, changes in the Earth system, and the impact on biodiversity. Many complex cause-effect chains are yet not fully understood, modeled or even known; baselines need to be developed for many biomes, etc. Many species that are driven to extinction are not even known to humans.

Once better models and observations are available, LCIA methods can be developed that allow the inclusion of these aspects into the LCA framework. The LCIA methodology can only be as good as the current state of knowledge. This also implies that there is a certain time delay until new LCIA frameworks or more precise LCI data is available. Therefore, many LCIA methods and LCI data rely on models and data points that might be outdated. This is especially critical when certain aspects change quickly and to a large extent.

5.3.7. Feedback loops and tipping points

There are many positive feedback loops that are reinforcing each other resulting in an exacerbation of the situation. So far, impact assessment methods do not include such feedback loops. These feedback loops could lead to the destabilization of environmental systems and tipping points could be reached that lead to an acceleration of ongoing processes. As addressed above with regards to climate change, tipping points of biodiversity loss could also be reached. Additionally, once these tipping points are reached, a return to the former equilibrium state is not possible any longer.

6. GLOSSARY

Life Cycle Assessment (LCA)	LCA is a scientific technique used to calculate the impact of a product or service over its life cycle. It is a powerful decision support tool that considers a full range of environmental impact categories beyond just GHG anthropogenic emissions. It can be used to quantify the impact on 7 out of 9 planetary boundaries (except atmospheric aerosol loading and novel entities). As explained in our [LCA white paper], we conduct "consequential LCAs" to determine the environmental impacts of a product or service by analyzing the changes in the entire system that result from a specific decision or action i.e. the effect of scaling of a startup with our investment
Life Cycle Inventory (LCI)	LCI is the input and output data across all phases of the life cycle (resources, manufacturing, transport, use, and end-of-life) of a product or service.
Life Cycle Inventory Analysis (LCIA)	LCIA is the process of evaluating the potential environmental impacts of a product or service throughout its life cycle across different impact categories (like climate change, ozone layer depletion, freshwater eutrophication, etc.), based on the data collected in LCI and characterisation factors determined by impact assessment methodologies (e.g. ReCiPe, IMPACT World+, CML 2001).
Potentially Disappeared Fraction of Species (PDF)	PDF is a measure of the fraction of species richness that may be potentially lost due to an environmental pressure such as land use, ecotoxicity, climate change, or eutrophication etc. It is intended as a measure of the local "damage to ecosystems" caused by specific anthropogenic pressures.
Mean Species Abundance (MSA)	MSA is an indicator of biodiversity intactness that estimates the average abundance, richness, or geographic extent of species relative to the expectation in a pristine site. It is a measure of compositional intactness rather than of abundance per se. MSA ranges from 0 to 1, where 1 means that the species assemblage is fully intact, and 0 means that all original species are extirpated (locally extinct).
Characterization Factor (CF)	CF is a parameter used in the LCIA phase of LCA to quantify the potential impact of a substance or activity on a specific environmental category. It is a conversion factor that translates

	the amount of a substance emitted into a specific environmental impact. It is expressed in units of impact per unit of emission and is used to convert inventory data into impact scores. The choice of method for calculating the characterization factor depends on the impact category being assessed and the availability of data.
Land Use and Land Use Change (LULUC)	LULUC information is essential to determine the environmental impacts of anthropogenic land use and conversion. It can have direct or indirect impact. Direct impacts include the conversion of natural habitats to cropland, pasture, or urban areas, which can result in the loss of biodiversity, soil erosion, and changes in hydrology. Indirect impacts include the displacement of agricultural activities to other areas, which can result in deforestation and other land-use changes. LULUC impacts are a significant contributor to the environmental impacts of many products and services, including food, biofuels, and building materials.
Biodiversity	Biodiversity in the context of LCA refers to the variety of life forms and ecosystems present in a given area or system. LCA models use different indicators to assess biodiversity impacts, such as species richness, functional and population effects, and habitat quality. However, assessing biodiversity in LCA is challenging due to the lack of specific data and evolving knowledge.
Land occupation	Land occupation refers to the use of land for a certain activity, which can have negative impacts on biodiversity e.g. agriculture, forestry, mining. etc.
Land transformation	Land transformation refers to the conversion of natural habitats to a different state, which can negatively impact biodiversity. It modifies the physical and chemical properties of the soil, which can result in the loss of biodiversity, soil erosion, and changes in hydrology.
Ecoinvent	Ecoinvent is a widely recognized LCI database that supports environmental assessments of products and processes worldwide. It contains international data on more than 15,000 LCI datasets in various areas. The ecoinvent Association is a not-for-profit organization dedicated to promoting and supporting the availability of environmental data worldwide.

Exiobase	Exiobase is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT) database that provides data for environmental assessments of products and processes worldwide. It was developed by harmonizing and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry. The database covers the relations between industries and countries, not only in monetary value but also in physical terms.
IMPACT WORLD+	IMPACT World+ is a globally regionalized method for life cycle impact assessment (LCIA) that integrates multiple state-of-the-art developments as well as damages on water and carbon areas of concern within a consistent LCIA framework. It is based on a midpoint-damage framework with four distinct complementary viewpoints to present an LCIA profile. It includes 18 midpoint and 27 damage (endpoint) categories. The four viewpoints are midpoint impacts, damage impacts, damages on human health, ecosystem quality, and resources & ecosystem services areas of protection, and damages on water and carbon areas of concern.
Biodiversity Footprint for Financial Institutions (BFFI)	The Biodiversity Footprint for Financial Institutions (BFFI) is a tool developed to measure the impact of financial institutions on biodiversity. It is used to assess the biodiversity impact of financial instruments, including investments and loans, which can have both negative and positive impacts on nature.
Damage on Areas of Protection	Damage on areas of protection in IMPACT World+ refers to the impact categories that are related to specific areas of protection, such as human health, ecosystem quality, and resources & ecosystem services. It is essentially a way of weighting and normalizing results from different endpoint indicators.
Damage on Areas of Concern	Damage on areas of concern in IMPACT World+ refers to the impact categories that are related to specific areas of concern, such as water and carbon. It is essentially a way of weighting and normalizing results from different endpoint indicators. Further, this impact is relevant across human health and ecosystem quality 'Damage on Areas of Protection'.

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