Chapter 4. Approaches for measurement of business dependencies and impacts on biodiversity.[1]

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Executive summary

1. Methods for measuring business dependencies and impacts exist that are suitable for various spatial and organizational scales *(well established)* {4.2; 4.4}. The appropriate application of methods depends on the level of decision-making (i.e., portfolio to operational level), and the specific purpose to which it is being applied – whether high-level screening, comparing options, tracking change in pressure or reliance or observing change in biodiversity *(well established)* {4.2; 4.4}.

2. Methods vary in their overarching characteristics of coverage, accuracy, and responsiveness and these differences need to be considered when applying them *(well established)* {4.2; 4.4}. Five main categories of methods include participatory mapping and monitoring, location-based observations, spatial analysis, life-cycle approaches and ecological-economic modelling. Within these categories, methods vary in their coverage (both geographical and in terms of impacts and dependencies considered), accuracy (which includes spatial granularity), and responsiveness – their ability to recognise differences caused by business actions (*well established*) {4.2}. The connections between the state of biodiversity and nature's contributions to people and the pressures, reliance and responses of businesses are important to understand both impacts and dependencies, requiring multiple complementary methods. More attention is needed to fully understand the sensitivity of biodiversity to pressure types and implications for the continued provision of nature's contributions to people, especially given the variation across space, time, realms and ecosystems (*well established*) {4.4}.

3. Metrics on biodiversity and nature's contributions to people are often used to express the outputs of methods but in many cases remain limited to certain aspects and *values (well established)* {4.2; 4.3}. Biodiversity and nature's contributions to people metrics are important for assessing the potential or realised impact or a dependency. All biodiversity metrics are limited in their coverage and there is a lack of metrics of genetic diversity for business assessments. Those focused on species assemblages (e.g., the two commonly applied metrics: mean species abundance and endemic species richness) are limited to taxonomic groups for which data are available, and they don't adequately reflect all components of ecological communities and functions needed to understand ecosystem condition. Ecosystem metrics on extent and condition can reflect a wider set of nature's contributions to people values. Metrics of the actual or potential flows of nature's contributions to people either directly measured or modelled from ecosystem data can support the incorporation of local nature's contributions to people values in assessments. The choice of metric is non-neutral and represents different world views and values with implications for the ways in which metrics are interpreted *(well established)* {4.3.3}.

4. The evolution of 'top-down' scalable approaches for assessing impacts and dependencies is important for supporting higher levels of decision-making and addressing gaps in the availability of operational-level information, but these estimates will have less accuracy and are not appropriate for all decisions *(well established)* {4.2; 4.4}. Top-down methods infer the impact or dependency of a large number of activities and include life cycle approaches and economic-ecological models that typically have a more limited set of output metrics. Multi regional input output-based and other sectoral methods can be useful at the portfolio and corporate level for initial screening, making use of business-specific data for more accurate results. Decisions at the value chain level can be guided by more granular life-cycle approaches that can integrate location or region-specific data to estimate changes in biodiversity and nature's contributions to people. These top-down methods connect business pressures to changes in the state of biodiversity, making use of general indicators such as ecosystem intactness. While global-scale models provide valuable insights, they often exclude the consideration of local ecosystem specificities, local (including social and cultural) values, and rights and interests of other groups, including Indigenous Peoples and local communities.

High-level decisions may significantly influence site-level outcomes across wide scales and therefore finding ways to incorporate local knowledge, values, and stakeholder interests into scalable approaches will strengthen both site-level management and high-level decision-making (*well established*) {4.2; 4.4}.

5. Methods that estimate or observe changes in biodiversity and nature's contributions to people for specific locations are required for operational-level decisions, but are not currently feasible to apply at scale *(well established)* {4.2; 4.4}. These 'bottom-up' approaches include both location-based observations, based on expert and scientific assessment, and participatory mapping and monitoring involving the active participation of local stakeholders. They are necessary for operational decisions, such as planning locations of infrastructure or designing management actions. These decisions require site-specific models or methods that consider the characteristics of local biodiversity and nature's contributions to people and recognise the diverse values for local rightsholders and stakeholders *(well established)* {4.4.4}. Location-based observations of the state of biodiversity require interpretation, including the use of counterfactuals, to attribute changes to business activities *(well established).* The outputs of bottom-up methods can feed into secondary datasets used in spatial analysis and improve the accuracy and coverage of other methods over time, but due to their limited coverage and need for variation are challenging to apply across large geographic scales. Methods that make use of remote sensing offer a more scalable approach but are limited to variables that can be remotely detected. Coarse, generalised, aggregate metrics, such as mean species abundance or potentially disappeared fraction of species derived from global models, are not suitable to measure the change in biodiversity outcomes at sites *(well established)* {4.4.4}.

6. Location-specific information is needed to advance the development and application of impact and dependency methods *(well established)* {4.4}. Impact and dependency assessments at higher levels of decision making can apply information with low granularity for the purposes of risk exposure and assessment {4.4.} (well established). For examples, a number of economy-wide studies have been performed on exposure of financial institutions to physical dependency related risks using non-location-specific information {4.2.4.} However there remains need for more granular environmental data that consider the location-specific availability and delivery of nature's contributions to people to the business and other stakeholders, including Indigenous Peoples and local communities. Equally improved and spatially explicit information on value chain activities is needed to improve corporate assessments across value chains. Progress has been made regarding the availability of asset location data of businesses' direct operations, yet value chain assessments rely heavily on the limited general and sectoral background data (well established) {4.4.3}.

7. Scenarios, in combination with models, are important for forward-looking decision-making and risk management, though their use in a business context is still highly variable and not yet making effective use of their potential *(established but incomplete)* {4.2.4.}. Scenarios can be used to understand how impacts, dependencies and associated risks could evolve in the future but there remains a need for a consistent set of nature-related scenarios for this purpose. While economy-wide studies have been conducted to assess long-term systemic risks, this area remains limited and not applicable at the business level and there is a need for stakeholder-driven scenarios and models at appropriate scales for decision-making. These approaches carry significant uncertainty which is limiting their application. Central banks conduct stress tests of financial stability using scenarios of extreme events that lead to the complete loss of services, though this field remains under development and faces several methodological challenges.

8. Effective and equal participation of Indigenous Peoples and local communities in the development and application of measurement approaches is needed for the incorporation of Indigenous and local knowledge and for consideration of the diverse values of nature and social issues. This helps ensure greater accountability and effectiveness in business decision-making

***(well established)* {4.3.1}.** Indigenous Peoples and local communities are custodians of biodiversity and holders of extensive dynamic knowledge relevant to its conservation, restoration and sustainable use, whose ways of life are directly associated with diversity in nature. Measurement approaches that incorporate Indigenous and local knowledge and involve active participation of communities (i.e., participatory mapping and monitoring) can help ensure that impacts, and responses to impacts and business dependencies consider the values and rights of Indigenous Peoples and local communities. (*well established*) {4.3.1}.

9. Uptake and application of measurement approaches by businesses is limited and varies across sectors and geographies *(well established)* {4.5}. Uptake of biodiversity measurement approaches is likely driven by reporting standards and regulation, and therefore more prevalent in sectors that are typically subject to site-level regulations, such as mining, and those subject to regulatory reporting standards such as the financial services sector. Although only a small share (less than 1 per cent) of businesses that provide annual or sustainability reports currently mention biodiversity, this is likely to increase in coming years as a result of emerging reporting standards. Reporting by businesses predominantly relates to impacts, with currently very limited information on dependencies. There is, however, information available on specific dependencies of businesses on individual nature's contributions to people. Most of the businesses that mention biodiversity in their public reports are incorporated in North America and Europe, with some uptake in Asia. This is likely driven by the larger extent of regulatory developments in those regions *(established but incomplete)* {4.5.4}.

10. Integrating metrics and values of nature in accounting and reporting systems for businesses is crucial to transform how impacts and dependencies are managed *(well established)* {4.6.1}. Approaches for integrating metrics and values (monetary or non-monetary) into accounting systems can be characterised by (i) the degree of integration of these metrics and values within existing conventional (non-environmental) business accounts and processes; (ii) the value lens that is applied to nature, and consequently in the way materiality of interaction between businesses and biodiversity is conceptualized. This has implications for how businesses are held accountable for their interactions with biodiversity, and how these are then managed. Political choices associated to the worldviews on which sustainability reporting standards are built on directly influence the level of transformative change that can be achieved through their adoption. Biodiversity reporting and disclosure practices are mostly based on anthropocentric worldviews and present a low level of integration with business financial statements, focusing on managing risk and stakeholders' expectations without providing specific, timebound measures that can indicate effective management of biodiversity (*well established*) {4.6.1}.

11. A small but growing number of 'biodiversity accounting' frameworks and methodologies are being developed that allow more holistic consideration of interactions between businesses and biodiversity *(well established)* {4.6.2}. So far, most existing methodologies remain grounded in an anthropocentric worldview where only instrumental values of nature are taken into account, and propose to establish *ad hoc* accounts separate from conventional business management and financial reports. Approaches which seek a higher degree of integration within business management and financial accounts and which are based on biocentric or pluralistic worldviews, taking into account intrinsic or relational values of nature, have a stronger potential to support transformative change (improvements of governance, valuation, and accountability). They are also better aligned with Indigenous Peoples and local communities values and conceptions of business (*established but incomplete*) {4.6.1}. Such alternative accounting methodologies can link businesses' financial valuation and profit to its commitments to repay its debt to nature. 'biodiversity accounting' methodologies for businesses can apply at various levels of management and decision-making within a business, thus supporting different business functions. There is also emerging innovation of accounting methods at the landscape scale to support the involvement of businesses in collective action. The uptake of business-level biodiversity accounting methods is currently limited, with little knowledge of the outcomes of their application *(well established*) {4.6.2}.

4.1 Purposes of impact and dependency assessments for businesses

4.1.1 Drivers for corporate measurement of biodiversity

Businesses can have different motivations for measuring impacts and dependencies. Measurement can be driven by regulations that are determined by subnational, national and supranational institutions. Measurement can be driven by investors, customers or consumers or by an internal recognition of the value of biodiversity to the business (Aladağ, 2023; Van Tulder, 2015). In all cases, measurement should be unbiased and avoid greenwashing.

Dependency assessments enable the business or financial institution to understand their reliance on nature's contributions to people, and the ecological processes and biodiversity elements underpinning them (UNEP, 2023). Dependency assessments inform the business on risks and opportunities that may be associated with changes in biodiversity and nature's contributions to people. Actions based on a dependency assessment could potentially include nature-based solutions that restore or protect biodiversity in the locations where dependencies occur, and as such businesses may help to achieve their own internally set biodiversity targets as well as national and global biodiversity targets such as those set out in the Kunming-Montreal Global Biodiversity Framework. Nature's contributions to people can also be substituted by businesses by using technological solutions. Substitution reduces business dependence on biodiversity and can reduce financial risk. However, it also reduces incentives to conserve, restore or sustainably use biodiversity. The provision of pollination services for almond production in California presents an illustrative example. This practice has developed into the largest managed crop pollination event in the world (IPBES et al., 2016; Lee et al., 2019; Valido et al., 2019).

Impact assessments enable a business or financial institution to understand the potential, predicted, or observed changes in biodiversity and nature's contributions to people that result from its activities. This can be based on different dimensions of biodiversity (species and ecosystems) (UNEP-WCMC et al., 2022) and different types of nature's contributions to people. An impact assessment can inform business targets and actions to reduce pressures and enhance positive outcomes for biodiversity, at the level of individual operations or value chains or at corporate or portfolio levels. However, the results of an impact assessment do not always provide information on the links between business commitments and actual changes in the state of biodiversity and nature's contributions to people , leading to greater calls for measurable outcome-based targets that reduce impacts (zu Ermgassen et al., 2022).

When conducting impact and dependency assessments to inform action, businesses may consider what is relevant, both for the business and for society. In an effective enabling environment (see **Chapter 6**), these conditions can be aligned, they can however also be (and currently mostly are) in conflict. European policymakers recently formalised the concept of 'double materiality', whereby businesses are required to analyse and report environmental and social issues from both a financial materiality perspective (those issues that can significantly affect the financial results of the business), as well as an impact materiality perspective (those issues where the business significantly affects society and environment) (Baumüller & Sopp, 2022). Inherent in the concept of double materiality is the recognition that issues material to society, but not financially to a business or financial institution, would go unaddressed unless requirements are put in place. The concept of double materiality is variably interpreted and applied in existing reporting and disclosure frameworks globally (UNEP, 2024).

4.1.2 Levels of decision-making and business purpose for measurement

Business decisions can be taken at different levels (**Figure 4.1**), ranging from individual operations on sites through value chains to corporate or portfolio level decisions. Ultimately, all decisions need to guide action that takes place within the landscapes and seascapes where business activities are occurring. These locations include those where resources are produced, transported, manufactured, sold or consumed. Value chains consist of a range of actors that the business can influence upstream and downstream of their operations.

The level at which decisions are made affects the ability to attribute biodiversity outcomes on the ground to those decisions. Higher levels of decision-making may have a bigger scale of the overall impact but also a less direct connection to the outcomes at sites. For instance, financial institutions are connected to biodiversity through the portfolios of businesses they invest in, loan to, or insure. Their influence is indirect – through engagement or by providing or depriving businesses with access to financial services. Similarly, manufacturing businesses are connected to biodiversity through the activities of their suppliers (upstream) and customers (downstream) in their value chains. This does not lessen the responsibility of actors with indirect influence but makes it challenging to attribute changes on the ground to the decisions taken. This effects the applicability of measurement methods that can be applied in this context.

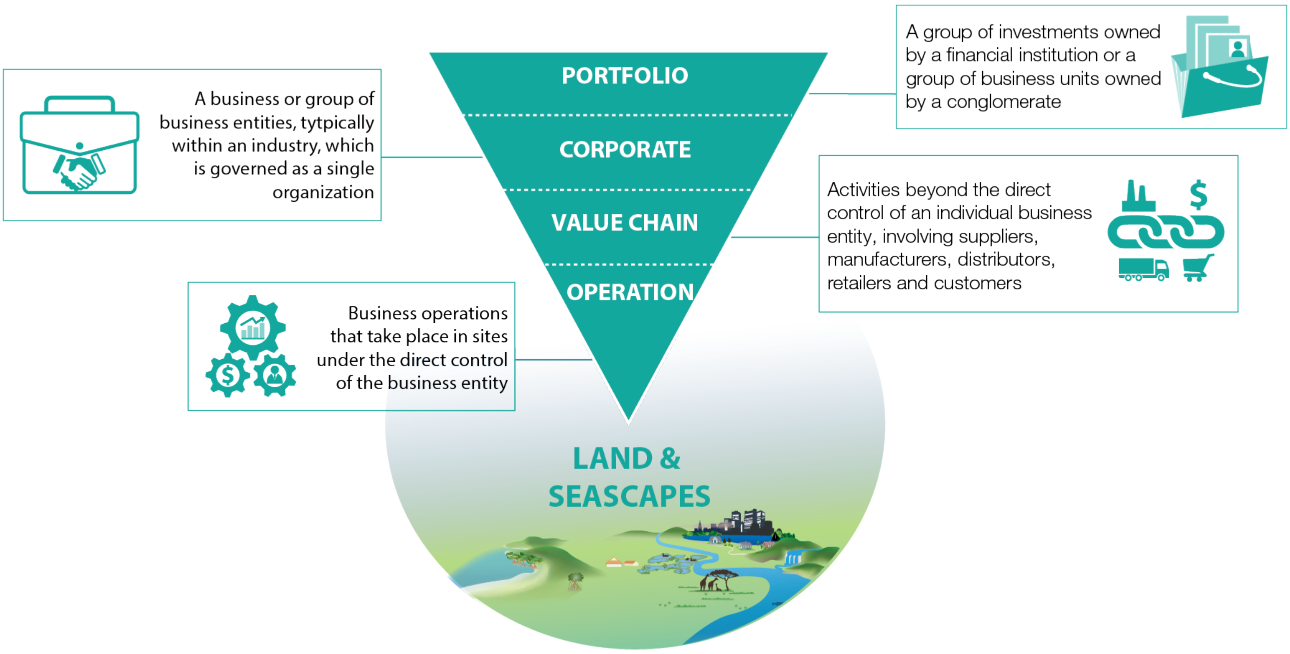

Figure 4.1. Levels of business decision-making which determine the choice of methods

There is no single method or metric that considers all impacts and dependencies at all levels of decision-making. Methods need to serve the specific business and purpose for which they are deployed, including the required scale and scope of assessment.

At each of the levels of decision-making there are specific purposes for which measurement methods are needed. This includes screening to identify priorities requiring further analysis or action, comparing options by evaluating potential impacts and dependencies of activities relative to alternatives, tracking changes in levels of pressure or reliance of activities, and observing changes in biodiversity and nature's contributions to people. This is a fundamental aspect that drives the selection of suitable measurement methods and is discussed in **Section 4.4** on measurement methods in decision making.

Stakeholders such as governments, civil society, and Indigenous Peoples and local communities (IPLCs), can share different perspectives on how business activities affect and rely on biodiversity and nature's contributions to people. As such, their engagement can provide great insights and benefits for the accurate measurement and valuation of business impacts and dependencies. For instance, the involvement of local stakeholders in participative processes and inclusion of Indigenous and local knowledge at sites and within landscapes is essential to get a full understanding of the changes to biodiversity and nature's contributions to people that are occurring. This also provides an understanding of the consequences of that change, including through affecting local dependencies of IPLCs. This is further discussed in **Section 4.3.1** on IPLCs values and knowledge.

4.2 Metrics and methods for assessing impacts and dependencies

4.2.1 Characteristics for the evaluation of metrics and methods

Metrics and methods for assessing dependencies and impacts of business activities were evaluated using a set of core characteristics[2]. This builds on existing work related to classifications (Addison et al., 2020; Align, 2022; Heink & Kowarik, 2010), but does not represent a complete list of possible evaluation criteria. Aspects such as the data availability or resource needs to apply the method were not included. Furthermore, the characteristics do not apply equally to all aspects of measurement. Their relevance to metrics and impact and dependency assessment methods are indicated in the relevant sections:

Metrics: To evaluate the choice of metrics the following characteristics are important:

- **Interpretability**. Refers to whether a metric has a clear, normative interpretation (i.e., is it clear what an increase or decrease means in terms of outcomes). In some cases, the metric value can easily be interpreted as positive or negative, allowing for comparison and aggregation, in other cases further interpretation is needed to achieve this.
- **Representativeness**. Refers to whether the metric adequately represents the biodiversity component being measured. Some metrics directly measure the component, whereas others can use proxy variables and are therefore less representative of what is being measured.

Methods: For understanding the choice of methods to assess impacts and dependencies the following characteristics are important:

- **Coverage.** This includes geographic coverage that refers to the spatial area covered by the approach. Some are only applicable for certain regions of the world and others have global coverage. It also includes the coverage of relevant business activities whereby there can be variability among methods in being able to assess impacts associated with pressure types (e.g., land use, pollution) or dependencies on nature's contributions to people (e.g., water provision, pollination).
- **Accuracy.** Refers to the degree to which the method can correctly describe the phenomenon it is designed to measure. In this context, this is the extent to which an estimate reflects real impacts and dependencies. Some methods will estimate a potential impact or dependency, while others will measure realised or actual impacts or dependencies. An aspect of this relates to spatial granularity whereby higher resolution methods have more potential to yield more accurate results. However, even highly granular site-level assessments can vary in accuracy based on factors such as survey intensity and data collection methods applied.
- **Responsiveness**. This characteristic enables the method to link the outputs to the activities and actions taken by the business and is closely related to *Attributability* (the degree to which the outputs of the method can be attributed to the activities of a business, rather than detecting changes that can result from multiple actors and natural processes). Responsiveness refers to how the outputs of a method change in response to business actions to manage their impacts and dependencies. For example, the outputs of some methods will respond only to a total reduction in activities, while some will respond to fine-scale management measures at site

[2] Data management report referring to snowball search to identify approaches and families of methods that are addressing biodiversity impacts https://doi.org/10.5281/zenodo.12783316

level. Responsiveness therefore depends on both the ability of a method to show change over time, as well as pick up influences of business actions on output metrics. These characteristics are dependent both on the method and input data used.

These characteristics apply differently to methods used for different purposes and at different levels of decision-making. For example, understanding the impact of a large financial portfolio requires global geographic coverage. Operations-level management would however require high accuracy and responsiveness but does not require global geographic coverage. These different requirements will be further discussed in the following sections.

4.2.2 Metrics

Metrics are used to capture aspects of business impacts and dependencies that were outlined in **Chapters 2 and 3** and include both biophysical metrics on biodiversity and those that represent socio-cultural or economic values. These relate to different components of the IPBES conceptual framework. Metrics on drivers of nature change, often referred to as pressures, can infer potential impact of business activities. Metrics on biodiversity, often referred to as state of nature metrics, can be used alongside metrics of drivers to infer potential impacts of business activities, or be used to evaluate actual impacts when observed change can be attributed to business activities. Biodiversity metrics can also be used to understand the likely resilience of ecosystems and nature's contributions that business depend upon. Metrics on nature's contributions to people can be used to both understand business dependencies as well as the consequences of impacts on biodiversity for people and can relate to both the biophysical provision of nature's contributions to people, as well as the benefits derived. Metrics of human wellbeing can relate to both the direct and indirect impacts of business activities on people and can also capture the benefits of nature's contributions to people.

Metrics can be outputs of methods for assessing impacts and dependencies. In that sense, a given metric may be produced through different measurement methods, resulting in different numerical values. Measurement methods are further discussed in **Section 4.2.3**. A wide range of metrics can be populated with primary data. For example, vegetation cover derived from field surveys. Methods that apply modelling-based methods such as life cycle analysis or input-output modelling produce a more limited range of output metrics. For example, the Potentially Disappeared Fraction (PDF) of species that is derived from information on pressures. Often, the values of a metric are calculated and the results expressed in the form of spatial layers. These spatial layers are then used as inputs to spatial analysis methods for assessing impacts and dependencies. A recent review identified 573 global terrestrial biodiversity spatial metrics for use by government, business and civil society (Burgess et al., 2024).

"State of nature" metrics

Biodiversity metrics that focus on the biophysical state of nature describe the state of genes, species and ecosystems at varying spatial scales. Thematically, these metrics link to the state-based goals and targets of the Kunming-Montreal Global Biodiversity Framework, such as target 4 on reducing the rate of species extinctions. Metrics for capturing impacts and dependencies of businesses on genetic diversity are less available than for species and ecosystems, representing a key gap in assessment needed to inform action (Shaw et al., 2025; Zhu et al., 2024). Two broad groups can distinguish the types of state metrics applied in business decision-making (Burgess et al., 2024).

- The first capture a snapshot of the 'significance' of a location for biodiversity in relation to local or global biodiversity goals. For example, the significance of an area in terms of occurrence of threatened species or a risk of ecosystem collapse. These metrics can be used alongside metrics of drivers and responses to contextualise them in terms of the strategic importance of the biodiversity that has been impacted. As such, these metrics are incorporated in many of the early screening steps of assessment and disclosure frameworks such as the GRI (2024), TNFD (2023b) and SBTN step 1 (2023a).

- The second capture the condition or 'intactness' of biodiversity in a location. These metrics compare biodiversity variables against a reference condition to understand the current state of that variable. For example, habitat quality of an area relative to a pristine state. Inherently, therefore, intactness metrics have implicit value assumptions and worldviews embedded in their production and application, as the metrics depend on what is used as the reference state. This is discussed in **Section 4.3.3**. Alongside metrics of drivers, changes in intactness metrics can be used to infer impacts of business activities on biodiversity, or support understanding dependencies on biodiversity, where the delivery of a given ecosystem service can be linked to intactness of a given ecosystem. While some metrics reflect only the change in intactness caused by a driver, other metrics can quantify the baseline condition before business activities, and the residual condition after business activities (Houdet et al., 2020) to track how impacts accumulate over time.

Table 4.1. Common types of metrics for assessing status and trends in individual focal species and ecosystems in the context of business impacts and dependencies, with examples provided. This table builds from metrics extracted from the list of 'off-the-shelf' tools compiled in **Chapter 3**, supplemented with further literature review. These metrics are assessed against two criteria commonly applied for assessing suitability of metrics for decision making- 'interpretability'- this refers to whether a metric has a clear normative interpretation (is it clear what an increase or decrease means in terms of outcomes) and has a clear unit and scale that allows comparison. 'Representativeness' refers to whether the metric can adequately represent a certain component of biodiversity (Czúcz et al., 2021).

Group	Common metric types and examples	What is being measured	Interpretability	Representativeness
Species				
Significance	Species extinction risk unit, e.g., International Union for Conservation of Nature species threat abatement and restoration (STAR) metric or global extinction probability (GEP) (Mair et al., 2021; Verones et al., 2022) .	Species threat status combined with range size to reflect how pressures at a particular location would contribute to changing extinction risk.	Directional interpretation and metric values can be directly compared and aggregated. Integration of multiple types of information (threat status and range size) makes interpretation challenging. Can be disaggregated based on documented threat, (Salafsky et al., 2008), although threats are often extrapolated across the whole range.	Good representation of component although limited coverage of taxonomic groups due to data availability.
Intactness	Baseline/change in species population size (Houdet et al., 2020).	Change in number of individuals of a species. Can be assessed at many different spatial scales (e.g., local population, metapopulation vs global population size).	Interpretation depends on the focal species being measured as to whether population changes reflects a positive outcome. Information on thresholds and targets required to interpret how local population changes reflect species persistence.	Metric is a direct reflection of intactness at the level of individual species.
	Baseline/change in area of suitable habitat (Turlure et al., 2010).	Area of suitable habitat often applied as a proxy for change in population size of a species.	Clear directional interpretation-information on area requirements for different species often required to interpret changes.	Proxy variable and unlikely to capture full impacts where habitat loss not the key driver of change (i.e., impacts from direct exploitation).

Ecosystems				
Significance	Ecosystem collapse risk classification, e.g., IUCN red list of ecosystems (Nicholson et al., 2024).	Aggregate information on extent, range threat levels and tipping points to assess the threat status of an ecosystem.	Provides a simple and readily interpretable ranking of the significance of ecosystem types in terms of collapse risk.	Does not reflect importance of ecosystems in terms of the biodiversity they contain and their ability to generate nature's contribution to people.
Intactness	Baseline/periodic change in ecosystem extent.	Area coverage of ecosystem type used to assess extent of that ecosystem type within a defined area.	Simple metric that is simple to interpret trends over time.	Extent reflects only one aspect of ecosystems and can mask underlying changes in ecosystem condition.
	Baseline/periodic change in scaled ecosystem condition index (0-1 scale), e.g., Mean Species Abundance, Biodiversity Intactness Index, WET-Health Index, Forest Landscape Integrity Index (Czúcz et al., 2021)	Key characteristics of ecosystems are used to assess condition compared to the maximum and minimum levels found in reference conditions. These characteristics can be specific to different ecosystems (e.g., coral cover, canopy height) or generic (e.g., mean species abundance).	Scaling from 0 to 1 provides a clear interpretation, with 1 being intact and 0 meaning fully degraded. The interpretation of condition indices is heavily driven by the reference condition chosen. For example, whether it is being compared to a historical or more contemporary reference condition.	Condition indices tailored to specific ecosystem types are more likely to represent the condition of specific ecosystems. Condition indices that cover multiple aspects of condition (e.g., encompass function as well as composition) more likely to comprehensively reflect condition.
	Baseline/periodic change in surface area equivalents (area x condition index) (Houdet et al., 2020)	Adjusting the extent of ecosystem by a scaled condition index combines information on extent and condition into one accounting unit.	Condition adjusted areas provide a simple and readily comparable indicator of ecosystem intactness. As an aggregate indicator it can be challenging to interpret what is driving a change.	Combined information on both extent and condition of ecosystems provides good representation of ecosystem change but is dependent on the condition indices used (see row above).
	Time-integrated loss of condition, including potentially disappeared fraction of species (Winter et al., 2017; Woods et al., 2018)	Loss of condition over a given time interval, to assess potential persistent change associated with business pressures. Mainly applied in life cycle assessments (e.g., potentially disappeared fraction of species in a year per unit stressor, such as ha land use or kg emission).	Does not provide a measure of condition against a baseline. This means that while the metric can be used for estimating impacts of a business, it cannot be used to interpret of trajectories in condition of specific ecosystems.	Potentially disappeared fraction of species, and other time-integrated metrics produced from life cycle assessment largely reflect elements of change in composition (e.g., loss of local species richness) so are limited in the extent they reflect component.

Metrics to assess nature's contributions to people

Metrics of nature's contributions to people, often referred to in the context of businesses as ecosystem service metrics, can support an assessment of a business's impact and dependency. These metrics quantify the change in the provision of nature's contributions to people (quantity provided), as well as the actual or potential flow of nature's contributions to people (benefits or values realised). In the context of impact assessment, they capture a change in nature's contributions to people that results from business activities. In the context of a dependency assessment, they capture the provision or benefits of nature's contributions to the business. As such they are referred to in corporate assessment and disclosure frameworks and standards (GSSB, 2025; TNFD, 2023). These metrics link to the goals and targets of the Kunming-Montreal Global Biodiversity Framework, in particular target 11 on restoring, maintaining and enhancing nature's contributions to people.

State of nature metrics can be used to describe the capacity of biodiversity to provide services and inform an understanding of the potential resilience of specific nature's contributions on which businesses depend as well as of the impacts of business activities in a location. Selecting benefit-relevant indicators (Olander et al., 2018) that capture elements of ecosystem state and capacity in units relevant to specific beneficiaries enables the interpretation of the consequences of changes in the metric. For example, metrics such as 'abundance of catchable fish in accessible fishing grounds' can describe impacts on the biophysical state that reflect potential changes in nature's contributions to people provided to local communities or business dependencies. Although ecosystem attributes have a positive link with different types of nature's contributions to people (A. C. Smith et al., 2017) the exact relationship between the state of ecosystems and their capacity to provide nature's contributions to people is complex, often non-linear and context specific. This is especially true for regulating services that provide benefits through regulating environmental conditions and maintaining quality.

Metrics that measure potential or actual flows of nature's contributions to people from ecosystems to beneficiaries, such as crop yield for food provision or volume of available water for water supply, are available to measure state and change in material nature's contributions to people. Flows of regulating nature's contributions to people are more challenging to capture directly in simple metrics, but can be derived from models that quantify potential flows from ecosystem data.

In turn, metrics of flows of nature's contributions to people can be used for both understanding the significance of locations for the provision of nature's contributions to people, and to measure change in flows of services in the context of businesses' impacts and dependencies. Significance of locations can be considered through metrics describing the relative contribution of locations for providing different nature's contributions to people, derived from location-based observations or spatial modelling. An example is the global map of critical natural assets, defined as natural and semi natural ecosystems required to maintain 'local' nature's contributions to people (R. Chaplin-Kramer et al., 2022).

Often flows of nature's contributions to people to businesses are inter-regional, and benefits are realised in locations far removed from the ecosystems providing them (Fisher et al., 2009). This occurs through, for example, the trade and transport of goods as exemplified in the trade of agricultural products where significant dependencies on non-material or regulating nature's contributions to people exist (Marques et al., 2024). A further example is the use of Digital Sequencing Information (DSI), whereby genetic data provide intangible benefits to industries and societies (e.g., through vaccine development and biomedical research) far removed from the source location (Coltman et al., 2025). Equally, services such as flood defence are often provided over large spatial scales (Schröter et al., 2018). Metrics covering actual flows of nature's contributions to people to businesses need to consider these complex tele-coupled processes.

Human wellbeing metrics

The dependencies and negative impacts of businesses on biodiversity and people are multifaceted and inextricably linked, due to the close relationships that exist between the natural environment and human wellbeing, with deeper connections in the case of IPLCs who hold strong cultural ties with nature. Despite the interconnections, social and environmental dimensions of sustainability are often treated independently (Schleicher et al., 2018; Waites et al., 2024). As such, effective corporate measurement of nature-related impacts, dependencies and responses necessitates the incorporation of social metrics alongside the biophysical measures.

Human wellbeing metrics can be used to understand both the direct and indirect impacts of a business activity on people. The latter are those whereby a loss or degradation of biodiversity can cause or exacerbate negative social outcomes such as loss of livelihoods or reduced food security. These indirect impacts on human well-being are captured by metrics of the benefits and values of nature's contributions to people (Dreoni et al., 2022). Metrics of direct social impacts of business activities are important to capture how businesses influence social systems, particularly for IPLCs, that can in turn reduce the ways communities are able to manage their lands (IPBES et al., 2024). They also provide early warning of biophysical changes. For example, the occurrence of conflict and protests in response to an actual or proposed business activity can be a sign of current or future environmental changes, as environmental changes are often closely intertwined with social harms (e.g., polluted waterways, resettlement linked to conversion or exploitation).

Social metrics can represent different dimensions of human well-being. While income is a common and often easier to measure metric, well-being is a multi-dimensional concept including elements such as food/nutrition, health, education, living standards, social relations, security, safety from risk (including risks from nature), cultural values and freedom of choice (Schaafsma et al., 2023). Gender equality is an important consideration given the differing roles that men and women play in the value chains of businesses, as exemplified in the agricultural sector (Doss, 2018). As for biodiversity, human wellbeing metrics can be 'static' based on the existence or prevalence of key aspects that can be used for risk screening purposes at wider scales (e.g., social hotspot database – indicators include child labour, poverty levels (Proforest, 2019). Publicly available geographical information on social issues is much scarcer than data for the environment but country level databases exist for social risk mapping in the case of global supply chains (Sihvonen et al., 2024). Risk metrics and indices, such as the Human Development Index, are composite values that can indicate overall trends but are typically not responsive to individual interventions and do not reflect the full dimensions of human well-being. Locally specific (and locally developed) metrics and indicators based on primary data studies are needed to reflect human wellbeing outcomes of economic activities in a given location (Dreoni et al., 2022). There are also potentially opportunities to engage with and (with consent) draw social metrics information from existing, autonomous community-based monitoring and information systems (Farhan Ferrari et al., 2015).

4.2.3 Methods

Ways to measure impact and dependency encompass a broad range of methods. These make use of monitoring data at different levels of aggregation and transformation. This ranges from methods that collect primary observations on biodiversity and nature's contributions to people directly, to ones that apply outputs from models or meta-analyses. Methods and associated tools for measuring biodiversity and their application in corporate assessment is a rapidly developing field and we can expect further advancements with the deployment of Artificial Intelligence in the field of ecological monitoring. For example, applications linked to remote sensing, the ability to combine multiple data sources and types, and predicting species responses through advanced models (Reynolds et al., 2025).

Methods integrate metrics on biodiversity or nature's contributions to people, described in **Section 4.2.2**. Metrics on human well-being are largely captured in the form of nature's contributions to people, although some methods (e.g., participatory mapping and monitoring) potentially enable a broader set of human well-being metrics that can capture direct social impacts. Metrics can be integrated as inputs in the form of spatial data or produce metrics as outputs to measure impacts and dependencies. For impact measurement, measuring the connections between drivers and state is important – measuring drivers by themselves does not capture a robust understanding of impacts, and measuring the state of nature in the absence of drivers prevents an understanding of who is responsible. An understanding of impact can be based on either the biophysical change in biodiversity or those that captures the consequences for people through nature's contributions to people-related indicators.. To fully assess dependencies, it is necessary to capture both the reliance of an activity on nature's contributions to people as well as the resilience of that dependency. The latter incorporates metrics of the state of nature underpinning the supply of nature's contributions to people (UNEP-WCMC, 2023). Many of the methods can be used for both impact and dependency assessments but in different ways. For example, location-based observations of ecosystem condition can be used to understand the resulting impact of a business activity known to drive ecosystem degradation, or the resilience of a dependency when a business activity is known to rely on nature's contributions to people provided by that ecosystem.

Methods differ in the characteristics described in **Section 4.2.1** and their suitability to assess impacts and dependencies across different levels of decision-making. Methods can be grouped into 'method categories', each of which comprises a non-exhaustive list of example methods that share certain characteristics. We evaluate methods at the level of categories. There are five categories of methods as highlighted in **Chapters 2 and 3,** namely: location-based observations, participatory methods, spatial analysis, life cycle approaches and economic-ecological modelling (**Table 4.2**)[3]. These method categories are not mutually exclusive and are often used in combination. For example, participatory methods can be used in combination with other method types, particularly location-based observations, as indicated by the sub-category on co-monitoring. These methods can provide input data to spatial analysis and models, which in turn are able to be used within life cycle-based approaches and economic-ecological models. When incorporating the results of community-based monitoring, ethical considerations can apply, for example ensuring free, prior and informed consent from Indigenous knowledge-holders (Newing et al., 2024).

Table 4.2. Method categories for measuring biodiversity impacts and dependencies of business activities.

Method category	Description
Location-based observations These methods use primary data collection to assess impacts and dependencies through taking direct measures of the state of biodiversity and nature's contributions to people at specific locations, such as through field observations, remote sensing, as well as emerging survey methods such as eDNA and	

[3] Data management report referring to a snowball review to identify approaches and families of methods addressing biodiversity impacts (10.5281/zenodo.12783316).

bioacoustics. This includes museum collections and ex situ collections that can form the initial surveys and local monitoring of natural resources and their use (such as hunting and fishing).	
Field survey	Field surveys are a systematic approach to collect data in a specific region or for a specific issue and include ecological surveys, experiments and observations, eDNA techniques, as well as qualitative social surveys including questionnaires.
Remotely sensed products	Based on remotely sensed data they can monitor changes in physical characteristics of an area over time. Limited to features that can be detected remotely.
Participatory mapping and monitoring Methods that involve collaboration with external stakeholders, rightsholders or communities, including IPLCs.	
Incorporation of results from autonomous community-based information and monitoring systems	Incorporation of conclusions/results (and/or, in some cases, underlying data and information) provided, by agreement, by autonomous community-based information and monitoring systems, for example of IPLCs (Farhan Ferrari et al., 2015). These systems may use indicators derived from one or a combination of Indigenous and local knowledge, human rights approaches or scientific methods, or other approaches, to monitor nature and/or socio-cultural health (Danielsen et al., 2009; IPBES et al., 2024).
Co-monitoring with communities or local people	This involves co-generation of relevant data through scientists working alongside directly-affected communities or local people (including IPLCs), which may include co-development of indicators, co-collection of data and/or joint data interpretation. Indicators may be derived from e.g., traditional and local knowledge, scientific methods, human rights-based, or other approaches (Danielsen et al., 2009).
Citizen-based approaches, in some places known as citizen-science	This involves collection of scientific data by the public on nature indicators proposed by scientific researchers (Danielsen et al., 2009).
Spatial analysis These methods involve using spatial data and models to infer impacts and dependencies on nature. Location-based observations, which feeds into secondary databases, and participatory methods can provide an input to these methods, e.g., for maps of species populations or habitat extents.	
Spatial overlay	Static overlays (e.g., business operations and biodiversity data layers).
(Geo-)spatial models	Geospatial modelling helps to perform scenario studies, based on the spatial interaction of the underlying data. Spatial predictions extrapolate into the future (forecasting) from existing data using scenario assumptions. Spatial modelling can show the current (and potential future) distribution and composition of ecosystems and land area and can include species distribution models, habitat prioritisation models, ecological connectivity, network analysis of trophic systems, hydrological models and modelling of ecosystem services.
Life cycle approaches Includes both full life cycle assessments (ISO14040) or ones that draw from life cycle thinking, such as applying characterisation factors to assess potential impacts of pressures within value chains. Life cycle	

approaches quantify impacts on either midpoint level (where impacts are not comparable across impacts but standardized within each impact category) or endpoint level (where impacts are assessed specifically for human health, biodiversity loss or loss of natural resources).	
Life cycle assessment	Quantify environmental impacts for a number of pressures for several impact categories simultaneously, allowing for highlighting trade-offs between impacts and improvement potentials. It includes the supply chain or total life cycle of a product or service. Regarding biodiversity, current life cycle assessment models do not contain many models for impacts on ecosystem services yet, and the focus is mostly on species loss.
Characterization factors (non-full value chain)	Application of life cycle impact assessment models to only one flow or emission, without considering the entire life cycle of a product. For example, assessing the biodiversity impacts of one m2 of land used for a certain purpose without a larger system boundary or value chain.
Economic – ecological models Uses information about the economy to determine the contribution of different pressures (caused by economic activities) to ecological changes and biodiversity loss. These can be both qualitative and quantitative. The chain of logic follows the sequence of economic drivers, to environmental pressures to state-of-nature. Likewise, economic information can be used to trace where in the economy relevant dependencies on nature exist, related to the demands of economic activities of inputs derived from natural capital. A wide range of models fit here, covering different parts of economy and geographies: from micro-economic, to sectoral, regional and landscape scale, to macro-economic or global. Several of these models can be used for scenario analysis, by analysing the consequences of choices and decisions on economic structures, and financial and environmental policies.	
Qualitative assessment methods	Methods that qualitatively map the impacts and dependencies of economic activities on nature
Environmentally extended multiregional input-output analysis (EE-MRIO)	Shows actual, mostly global, trade flows either in monetary or physical terms and can therefore help to trace impacts through the whole economy. An environmentally extended multi regional input output analysis uses the trade flows to calculate environmental pressures, by applying characterisation or intensity factors.
Integrated assessment Models (IAMs)	These are models that combine knowledge from multiple disciplines—such as economics, climate science, agricultural and energy systems—to analyse the interactions between human and environmental systems. They have often been used to evaluate the potential impacts of climate change and to assess policy options for mitigation and adaptation in scenario assessments. Likewise, they are used to assess the consequences of economic and demographic trends on biodiversity loss and the delivery of nature's benefits to society.
Computable general equilibrium (CGE) models	These are economic models that use actual economic data to simulate how economies might respond to changes in policy, technology, demography or environmental changes. They represent the behaviour of different agents (households, firms, government) and ensure that supply and demand are balanced across all markets. They can be used to assess different economic structures and policies, as part of policies for transformative change.

This review of methods is limited to their ability to measure the actual or potential changes in biodiversity and nature's contributions to people that result from business activities or affect business dependencies. To further understand the consequences of impacts and dependencies, valuation methods (monetary and non-monetary) can be used (see **Chapters 2 and 3**). While some methods express impact in monetary terms, many don't and represent impacts in other units. Footprints are a particularly commonly used category of approaches for different environmental pressures (like land-use, greenhouse gas emissions, and other) that has evolved in time and is also used to calculate impacts and dependencies on biodiversity. Footprint analyses are, however, not well defined or delineated, and also have a large overlap with several methods already present in **Table 4.2** like LCA and MRIO analyses and are therefore not included in the table (biodiversity footprint definition is further discussed in **Box 4.1**).

Box 4. 1. Biodiversity footprints

Definition, scope and use of biodiversity footprints

Businesses increasingly mention the term 'biodiversity footprinting'. There is, however, a lot of variation in footprint definitions (Matuštík & Kočí, 2021; TNFD & PBAF, 2023). The term stems from a broader development around 'environmental footprinting'. The term 'ecological footprint' was first used to capture the global environmental consequences of consumption (Wackernagel & Rees, 1998; World Wide Fund for Nature, 2010), mostly determined by land-use and greenhouse gas emissions. An important aspect was to give a different view on responsibilities, beyond that of national territories. Some scholars have noted that the promotion of carbon footprints, including by fossil-fuel businesses, can function as a calculative device that allocates responsibility and potential regulatory costs (e.g., carbon taxes) across the value chain rather than concentrating them on energy producers (Naef, 2024; Turner, 2014) .

The footprint concept evolved into a set of indicators that covers a broad set of environmental and even socio-economic subjects. Footprints usually focus on one issue only, such as land-use or carbon, in contrast to a full life cycle assessment that aims to include all relevant environmental impacts. Footprint indicators currently include subjects like material flow, nitrogen and carbon emissions, and finally effects on biodiversity. Together these indicators are referred to as the 'footprint family' (Galli et al., 2012; Matuštík & Kočí, 2021; Ridoutt & Pfister, 2013; Vanham et al., 2019)

The Institute for European Environmental Policy (2021) proposed a definition of biodiversity footprint for decision-making: "The impact of a commodity, company, person or community on global biodiversity, measured in terms of biodiversity change as a result of production and consumption of particular goods and services". The footprint standard developed by the Partnership for Biodiversity Accounting Financials (PBAF) (2022), defines it as: "Model-based biodiversity footprinting approaches, where a potential impact on biodiversity is quantified based on quantified changes in impact drivers or pressures and pressure-impact models."

These definitions leave room for the variety of methods outlined in **Table 4.2** and can make use of a range of the metrics outlined in **Table 4.1**. Footprinting can therefore be used to both model a potential impact using generalised metrics (using characterisation factors), and measure observable changes on the ground (TNFD & PBAF, 2023); see Section 4.4 for further description of these purposes).

Common biodiversity footprinting methods

Several methods have been developed to calculate footprints at different scales and scopes and can be categorized as 'top-down' based on life cycle approaches and economic-ecological models, and 'bottom-up' based on location-based observations (see Section 4.3 for further description of these categories)

Top-down footprinting represents model-based calculations of biodiversity loss, that deliver an estimate or proxy of what truly happens on the ground (TNFD & PBAF, 2023). Footprints of products and services are determined by performing Life Cycle Analysis, which is formally described in an international standard (ISO, 2006). It is based on data inventories of material and environmental flows, from which biodiversity impacts are inferred. For calculating the footprint a whole economy or national financial system, EEMRIO (environmentally extended multiregional input output) models are used that use monetary transactions between economic sectors as the basis for calculating environmental effects. Combinations are also possible, for instance for the footprint of large a organization like the Oxford University (Biggs et al., 2021; Bull et al., 2022). Central to these footprinting methods is the perspective of a value chain or product life cycle (clearly present in the definitions of biodiversity footprints by (Institute for European Environmental Policy, 2021; PBAF, 2022; TNFD & PBAF, 2023), whereby, all environmental flows to and from each economic activity in every step of the value chain have to be assessed. This includes all steps from extracting natural resources, processing and transporting raw materials; producing and transporting products; selling products to consumers, and treating end-of-life products (waste treatment).

To calculate a biodiversity footprint, the effects of multiple environmental pressures are combined to produce a composite indicator for biodiversity loss. Different methods have been developed to calculate the combined effects of environmental pressures on biodiversity, using different metrics and giving different weights to each pressure (De Weert et al., 2025; Goedkoop et al., 2008; Verones et al., 2020; Wilting et al., 2017)

Next to these model-based calculations, performing a biodiversity account for the level of individual business operations has been proposed by Houdet and Teren (2022). Instead of using generalised indicators, location-based biodiversity data is used to calculate biodiversity gains and losses, by summing up the total negative and positive changes in the extent (area) and quality (ecological status) of ecosystems occurring at specific operational sites. Such accounts can be used as part of a whole value chain assessment, providing a more representative picture of biodiversity encountered at specific locations for operations in the value chain.

Table 4.3 provides a list of the available categories of methods and their varying characteristics. As each category consists of multiple methods, there will be considerable variation in their characteristics, for example, regarding required input data, model performance, impact types covered/ability to assess and metrics included. The table, however, provides a broad overview of the characteristics for each category, noting this variation.

Table 4.3. Characteristics of impact and dependency measurement methods

Example categories	Coverage	Accuracy and spatial granularity	Responsiveness
Location-based observations			
Field survey	High potential for coverage of impacts and dependency types due to range of metrics that can be populated, with data from specific locations. Mostly conducted over small spatial scales and therefore low geographical coverage.	Potential to achieve high accuracy as data can reflect details of real-world conditions at high spatial granularity. Accuracy of results will depend on specific survey protocol applied; survey intensity and the features being surveyed.	Observed changes based on field survey or remote sensing may be caused by influences other than business activities and actions. Further interpretation, such as comparing to a counterfactual often required to attribute to business activities and actions.
Remote sensing	Limited to variables that can be remotely detected and can vary in the spatial coverage measured with some datasets having global coverage.	Remote sensing products will have varying spatial resolution, with higher resolution assessments emerging over time. The accuracy of measurement will depend on the feature with greater suitability to certain environments (Erfanifard et al., 2025), as well as the level of ground truthing.	
Participatory mapping and monitoring			
Incorporation of results from autonomous community-based information and monitoring systems **Co-monitoring with communities or local people** **Citizen-based approaches, in some places known as citizen science.**	High potential to represent diverse values and provide qualitative and quantitative results across a range of impacts and dependency types for specific locations. Although mostly site-specific some methods can cover extensive Indigenous territories. Despite global prevalence of information, may lack universal metrics and accessibility of information to support larger scale assessments (N. Johnson et al., 2021).	Potential to achieve high accuracy as data can reflect details of real-world conditions at high spatial granularity	Potential for high responsiveness due to continual monitoring. Ability to attribute changes to business activities and actions, due to the combination of quantitative and qualitative knowledge types.

Spatial analysis			
Overlay of spatial data layers	Available data layers for overlay analyses will cover a range of variables and metrics. The spatial coverage of data layers for overlay analysis varies from local (e.g., orthophotos) to global (e.g., built from remote sensing data).	Vary in both resolution and accuracy depending on whether data layers are built from direct measurement or model outputs.	Changes identified can be challenging to attribute to specific activities. Often assumed that direct spatial overlap between activities and changes in state is a good proxy for attribution (such as changes in land cover used as proxy for effects of e.g., agricultural activities). Typically represents a snapshot in time, but when using data layers with high update frequency a greater level of attribution and responsiveness to intervention can be achieved. Models can be responsive depending on input data availability. Represents a snapshot in time, that can show effects of interventions if repeated several times.
Spatial modelling	Models can be applied across different spatial areas, focusing on different components of biodiversity and ecosystem services. Some have the ability to be applied globally.	Accuracy depends on the quality of the input data and the complexity of the models, which is highly variable across the world. Accuracy will also depend on the level of ground-truthing	
Life cycle approaches			
Full life cycle assessment (full value chain, several impact categories)	Models that are integrated into life cycle assessment software can have global (like LC-Impact or Recipe) or local coverage (ag Swiss Agricultural Life Cycle Assessment), and can cover a large number of different pressures, for example land use, greenhouse gasses, toxicity and other forms of pollution. Limited to the metrics included in underlying models.		Life cycle assessment outputs are potentially responsive to small changes in the production system (e.g., on a product basis) and can link potential impact estimates to specific activity. The responsiveness will depend on the granularity and specificity of input data.

	Life cycle assessment methods provide an estimate of potential impacts based on pressures. Spatial granularity varies from more spatially resolved characterisation factors (e.g., ecoregion specific factors) to global characterisation factors. They do not track accumulated impacts on specific ecosystems.		
Characterisation factors	Measures potential impacts of one impact driver at a time and often then presents an aggregated footprint using top-down biodiversity metrics, limited to the metrics included in underlying models.	Varying between spatially explicit (watersheds) to globally generic characterisation factors. When site-level pressure data are used, precision is high and the potential for accuracy is higher, as outputs reflect the specific location and activity being measured. If global average pressure is used, precision is low with no spatial specificity (e.g., results are globally applicable) but are likely less accurate for the impact of a specific activity.	
Environmental-economic models			
Qualitative assessment method	Can make use of industry-wide information that can be applied across a wide range of economic activities and geographic scales	Low accuracy for specific business contexts and locations due to reliance on global, regional or industry-wide information	Can respond to changes in the extent of economic activity conducted or invested in but not responsive to company or location specific actions.
EE-MRIO	Measures financial and trade flows globally using broad or more detailed economic sector resolutions. Trade flows are both within and between countries or main world regions. Calculates all inputs over supply-chains to deliver a certain final output.	Broad economic sector resolution means data may be highly aggregated and therefore inaccurate when used in specific business contexts. The spatial granularity of MRIO databases is variable but some have some country level information plus larger "rest of the world" regions included.	Shows trade flows and changes thereof between countries or industry sectors, but not between individual actors or businesses. Can be combined with life cycle assessment in hybrid methods to

			estimate impacts of business activities.
General Equilibrium Models	Just like EE-MRIO based on actual economic data per sector, provided as input-output tables. Depending on the database used, coverage of sectors and geographies differ.	Calculations of equilibrium between (final) demand and supply of goods and services based on cost-equations. Outputs are given in product prices, wages and labour, assuming a preference for cost-minimization. The mathematical formulations represent a hypothetical state of balance or equilibrium in an economy, not necessarily a perfect reflection of reality.	Mostly suitable to analyse consequences of financial, technological, trade and economic policies that affect the financial performance of economic activities.
Integrated assessment models	Range from regional to global coverage, including different populations, economies and sectors. Different coverage of pressure and state variables.	Developed for assessing systemic change at higher levels of aggregation, of contrasting scenarios. As such, an important tool to investigate the inherent uncertainty of future pathways. Especially the geographic consequences in scenario analyses are limited.	Able to analyse consequences of changes in demographic and economic developments and interventions in production and consumption structures.
Key considerations for applying methods to assess impacts and dependencies			
Baselines and counterfactuals: Ecological methods to measure biodiversity and nature's contributions to people – whether using primary location-based field surveys on secondary information in spatial analysis – needs to be coupled with protocols on spatial scale and appropriate baselines to support inferring impacts and implications for dependencies. Emerging methods for setting counterfactuals can support interpreting whether observed changes are a result of business activities or part of wider trends (Devenish et al., 2022, 2024).			
Bundling uncertainties: 'Life cycle approaches' and 'economic-ecological modelling' carry varying levels of uncertainty as they convert available input data into estimated pressure and state outputs. These uncertainties have been categorised as epistemic, parametric, linguistic and decision-based nature (Bromwich et al., 2025). These methods are often packaged together into commercial methodologies and tools, which in turn can compound their characteristics. For example, methodologies may combine taking values from MRIO database, and the characterisation factors then build on each other, which affects the overall accuracy of the output.			

Scientific traceability:

Many available tools have been developed for commercial purposes and not all have received traditional scientific peer-review. Therefore, the level of empirical testing or validation may vary. They may display significant variability in the degree to which scientific traceability is possible to discern and may have limited documentation. Insufficient documentation makes it hard for users to assess the validity of thresholds and metrics chosen and precludes evaluation of how capable the methodology is in delivering on its objectives.

4.2.4 Scenarios

Business and policy decisions require an understanding of possible future trajectories and a means to explore possible outcomes of different decisions. Scenarios, through linking to models, can provide a systematic way of assessing the environmental consequences of alternative long-term socio-economic developments (IPBES, 2016). Scenario analysis is often applied in addition to the assessment of the current situation and past trajectories and can be used to inform stakeholders on how decisions and actions may contribute to societal goals.

In a business context, several reports (NGFS, 2023; TNFD, 2023a) emphasize the importance of using scenarios to inform strategy, specifically to understand potential future states of nature, examine trajectories of impacts and dependencies, and assess nature-related risks and opportunities. For example:

- Assessing 'business as usual' and other scenarios can help to evaluate potential global future developments under current and alternative policies, and thus identifying the need for action based on trajectories of impacts and dependencies (e.g., climate change affects nature's contributions to people and might aggravate impacts of business actions)
- Scenarios can help understand potential changes (threats and opportunities) to the future supply chains of businesses (through changes in background data resulting from the scenario models). For instance, decarbonized electricity or increased use of biobased materials can alter impacts and dependencies in the future.
- Sector- and country-level results of scenarios can help identify the required or expected contribution of specific sector/regions and potentially economic players to biodiversity loss. This might translate into policies and restrictions for businesses in the future.
- Scenarios can help identify acceptable or even sustainable pathways for the global economy that reach global biodiversity and climate targets, and identify the contribution of specific business actions in these pathways.

Business use of long-term global scenarios

Long-term global scenarios help understand business and financial implications of possible futures. A variety of scenarios of global development exist. For instance, the set of long-term scenarios based on shared socioeconomic pathways, which explore the potential future impacts of ongoing societal development on a global scale. They were designed to complement the representative concentration pathways , which focus solely on greenhouse gas emissions trajectories. There are five socioeconomic pathways scenarios, which can be used to calibrate integrated assessment models, leading to highly differing outcomes and thus normative choices and uncertainties. These global scenarios can inform a variety of models to investigate possible biodiversity outcomes, and the consequences of those for society and the economy (Simkin et al., 2022). The uncertainty associated with models in scenario analysis is, however, poorly evaluated and no single set of scenarios and models can address all spatial and temporal scales. Participatory approaches to develop locally relevant scenarios and models is recommended for meaningful analysis at a finer spatial scale (IPBES, 2016).

Based on the IPBES methodological assessment report on scenarios and models, experts engaged in a participatory process that led to the development of the Nature Futures Framework, for deriving multiscale and integrative nature-people scenarios (Pereira et al., 2020). The Nature Futures Framework is a tool for modelling desirable futures, applying a multiscale approach, and explicitly incorporating diverse values and perspectives on human-nature relationships. The Nature Future's Framework builds on the values of nature (intrinsic, instrumental and relational) and provides an opportunity for businesses to forecast a wider set of impacts and dependencies on biodiversity (see **Section 4.3.3**).

Such global scenarios are not meant to predict the future, but to show the effect of a potential future state under the given assumptions. See for instance scenarios that combine pathways that meet targets for both limiting climate change, securing food supply and reversing biodiversity (Ambrósio et al., 2024; Kok et al., 2023; Leclère et al., 2020).

Scenarios and financial risk

Some studies have assessed the consequences of long-term nature scenarios on the economy and financial stability of the economic system, both at the global level exploring systemic risks (J. A. Johnson et al., 2021) and at a more regional level, investigating stability of financial of institutions in the European Union region (Boldrini et al., 2023).Such studies assess outcomes of economic-ecological models and spatial ecosystem service models under a range of policy scenarios to support identification of future economic risks faced by sectors and regions. These studies provide a high-level understanding of potential risk that is useful to inform policy development, but assumptions and uncertainties inherent in these models limit their application in decision making.

Scenarios can also be used to assess the economic and financial consequences of short-term sudden shocks in environmental conditions. This is consistent with the stress-testing performed by central banks to assess the financial stability of the financial system (banks, insurances, pension funds) under their supervision (Daniëls et al., 2017; Holden, 2006). Shocks are defined as sudden disruptions (both severe and plausible) that may cause economic effects that undermine the financial position of businesses. An example could be the sudden collapse of pollinator populations that significantly impacts the yields of pollinator dependent crops (Dicks et al., 2021). Examples of stress testing in the field of climate change are widely available (modelling shocks like heat stress or flooding) (Caloia & Jansen, 2021; Weber, 2024), and the existence of climate scenarios has informed assessments of climate-related risk as part of risk management and strategy processes (TCFD, 2020). For biodiversity this is less common, although TNFD (2023a) has tried to addressed the need to develop nature scenarios to move beyond static sensitivity analysis to a more dynamic assessment of nature-related risks based on plausible futures.

NGFS (2023b) define risk as a combination of three elements: hazards or shocks occurring, exposure of financial capital to these shocks, and vulnerability including the capacity to cope with the shocks. There are several methodological challenges in assessing risks related to impacts and dependencies on biodiversity. For instance, the use of economic models based on generalised computable general equilibrium models is commonly used to assess changes in economic structures, related to transformative change. But due to the basic principle of calculating an equilibrium, they cannot provide information on shocks, limiting their usefulness in stress testing (Prodani et al., 2023).

Interpreting scenario analyses

Lack of standardized modelling approaches, scenarios and timeframes considered make it difficult to compare scenario-based assessments, as differences among modelling approaches and scenario runs can be high. This leads to several questions to be answered when interpreting results:

- What scenario or scenarios were chosen (e.g., shared socioeconomic pathways) and what do they consider (e.g., implementation of key international environmental agreements)?

- How does this scenario choice align with the purpose and timeframe of the scenario assessment? Global assessment scenarios are typically run for 2030, 2050, while financial institutions use scenarios with a 3–5-year time horizon for stress testing.

4.3 Values in decision making

4.3.1 Indigenous Peoples and local communities' values and knowledge

Incorporating IPLCs' knowledge and values in business impact assessment and management responses

IPLCs play a vital role in maintaining connections with nature and sustaining livelihoods and are central in achieving global commitments on biodiversity. The Kunming-Montreal Global Biodiversity Framework validates their importance as custodians of biodiversity and holders of broad traditional dynamic knowledge essential for its conservation, restoration and sustainable use (CBD, 2024). IPLC's ways of life are directly associated with diversity in nature. For example, while just nine plant varieties represent 66 per cent of global agricultural production, the Indigenous peoples of the Amazon use around 200 tree species as timber sources and 100 other species for several types of products (WWF, 2022). IPLC's ways of life generate Indigenous and local knowledge about biodiversity and nature's contributions to people, which can match and enhance results from scientific enquiry (Danielsen et al., 2014; Legge et al., 2024; Nagendra & Ostrom, 2011; Zhao et al., 2016), and can inform management interventions (e.g., management of wild fires (Rodríguez et al., 2023)). Given the significant values associated with nature for IPLCs, the harm to nature caused by business activities can have severe consequences. Equally business impacts on IPLCs can affect their stewardship of nature and further aggravate environmental degradation (IPBES et al., 2024). Measurement methods that incorporate Indigenous and local knowledge and involve collaboration with IPLCs are needed to ensure that business impacts and response actions respect the values and rights of IPLCs alongside long-term conservation or business objectives.

Respecting the values and rights of IPLCs

To assess the holistic well-being of IPLCs', including the nature they steward, it is important to understand the ways in which IPLCs' use and engage with nature, and how the activities of businesses may affect them. The monetary values of land and resources for businesses through their dependencies do not capture the broader values of other groups, such as cultural, spiritual and medicinal values. Still, Indigenous and local knowledge does not broadly inform business assessments, and there is limited consideration of the wider values of nature to IPLCs in business assessments of their impacts and dependencies on biodiversity.

Most impact measurement methods stop at biophysical impacts and neglect the consequences of biodiversity loss and ecosystem degradation for people. The use of metrics of nature's contribution to people and well-being can help address impacts on those that benefit from nature (see **section 4.2.2.**). However, these impacts can have particularly strong repercussions for IPLCs, since, in addition to supporting their economies and livelihoods, biodiversity is central to the identity, customs and traditions of many IPLCs. The value of nature to IPLCs cannot generally be adequately represented purely in monetary terms using traditional valuation methods, as these generally underestimate its importance. For example, many intangible benefits arise from the interconnections between economic and socio-cultural, spiritual and capacity benefits. These diverse values would therefore be excluded from the planning and implementation of business policies (Costanza et al., 1997; Gosal et al., 2018; Sangha et al., 2019)..

Addressing this requires first and foremost recognition and respect for IPLCs own valuation systems and perspectives. Complementing this, there are a range of techniques that can supplement business valuation of biodiversity dependencies and impacts to better incorporate the values of IPLCs. These include methods for non-monetary valuation of cultural ecosystem services, which covers a collection of methods that gather information about emotions, symbols, cognition or ethics related to the importance of biodiversity using quantitative, qualitative, hybrid and deliberative methods (Arias-Arévalo et al., 2018). Governments and businesses must also make an effort to understand – through collaborative approaches with IPLCs the extent of business impacts on IPLCs. These can include, for example interruption of food supply and quality, loss of traditional knowledge and cultural identity, or loss of sacred places for ritual practices (Yletyinen et al., 2022).

Social and cultural impact assessments and use of social indicators of business activities can be used alongside those that measure the state of nature and nature's contributions to people (see **Section 4.2.2**). These should adhere to clear performance standards that recognize traditional knowledge and sacred sites, including those adopted by the Conference of the Parties to the Convention on Biological Diversity (CBD, 2004), and should involve affected IPLCs in the assessment and decision-making process. Indicators related to social performance may exist in some circumstances as a means of maintaining a social license to operate that relates to the acceptance and approval of a business activity by local community members and stakeholders (Bice & Moffat, 2014). However, the full relationship between impacts on biodiversity and impacts on IPLCs from business activities is rarely captured. Social indicators should assess both outcomes (harm to people that is linked to biodiversity loss) and processes (e.g., effective participation of IPLCs in decision-making processes that affect their rights, cultures, livelihoods and lands and the use of genuine free, prior and informed consent processes). Unfortunately, many existing frameworks and guidelines for consulting IPLCs fail to incorporate many of the indicators used to measure impacts on them (Instituto Kabu et al., 2022; Juruna da TI Paquiçamba et al., 2017; Povo Munduruku/Takuara & Conselho Indigenista Missionário, 2021; Yanomami et al., 2019). Integrating Indigenous perspectives into ecosystem accounting is also a critical area for further work (see **Section 4.6.**).

Improving decision-making through incorporating Indigenous and local knowledge

Beyond respecting special rights of Indigenous Peoples and also the relevant rights of local communities, it is important to acknowledge the role of Indigenous and local knowledge to improve business assessments and responses, and therefore to reduce impacts on biodiversity (and people) at the local level. So far, Indigenous and local knowledge has not been incorporated in the widely used indicators on biodiversity and nature's contributions to people, although there is potential for it to significantly enhance the quality of decision-making. Emphasis must be placed on co-development of measurement and monitoring frameworks with IPLCs. This requires a focus on dialogue and co-learning, where the autonomy of Indigenous Peoples is recognised, self-determination and nationhood is honoured, and Indigenous knowledge systems are recognised (Agrawal, 1995; Reed et al., 2023).

IPLCs monitor the impact and dependence of biodiversity and nature's contributions to people using proprietary methods through observations of biodiversity over time. This is distinct from scientific research, which often relies on periodic monitoring (Peacock et al., 2020a) and is not as representative of the diverse values of biodiversity. Some scientific methods may also be considered disrespectful or inappropriate by Indigenous and local knowledge holders, for example because they harm animals or generate changes in animal behaviour (IPBES, 2024).

Indigenous and local knowledge methods include, for example, the perception of the abundance and diversity of species, or the flow of nature's contributions to people such as food and water. Indigenous and local knowledge often provides insights on the interaction between species abundance or behaviour and environmental conditions (IPBES, 2024; Stewart, 2023). Often the records of these observations do not follow conventional methodological standards and may be recorded in maps, calendars, life plans, and stories – or they may not be captured at all. In addition, different forms of knowledge may be held by different members of the community. For example, in some places, women may have a greater knowledge of the location of certain medicinal plants, and children may hold knowledge of bird species, due to the unique interactions with them in everyday life (IPBES et al., 2024).

Indigenous and local knowledge indicators can sometimes be termed biocultural as they jointly consider biodiversity and human quality of life. They are locally-based, contextualized indicators that can generate an understanding of diverse phenomena in remote locations. Indigenous and local knowledge indicators can be considered accurate as they reflect local specificities and values, but they are difficult to upscale (McElwee et al., 2020). Indigenous and local knowledge can however be relevant input data for models (for example, it can be considered in the Integrated Valuation of Ecosystem Services and Trade-offs Models (InVEST).

Critically, however, Indigenous and local knowledge should be used on the basis of collaboration and agreement with knowledge holders, in processes that include knowledge-holders in interpretation and decision-making, rather than extracting Indigenous and local knowledge for potentially inappropriate use in external, non-consensual (IPBES, 2024). In fact, translating Indigenous and local knowledge into external scientific systems is often inappropriate as it is learned in practice and cannot always be taken out of context. In addition, some forms of knowledge are sacred.

There are however many examples of community-based monitoring programmes that combine Indigenous and local knowledge and scientific methods, that demonstrate how this can provide a more holistic understanding than conventional science can provide alone (Peacock et al., 2020b). For example, in the Arctic region community monitoring of biotic, abiotic and socio-cultural components including methods such as transects, interviews, focus groups and participatory mapping exercises has been used to inform natural resource management, commercial fisheries, tourism, industrial development, and planning for oil and gas (Murray et al., 2014). A further example is the Imalirijiit project in Quebec, Canada where a partnership between the local community and researchers monitored the biodiversity and water quality in response to rare earth mining projects using a variety of Indigenous and local knowledge and scientific methods (Imalirijit and Nunami Sukuijainiq, 2020).

Such integrated knowledge can provide a more comprehensive understanding of the impacts of business activities on biodiversity and nature's contributions to people. There are some examples of this informing business responses. For example, the Moana project in New Zealand, which built a bridge between traditional Indigenous knowledge and science to inform the seafood industry, highlighting the important role of collaboration rather than consultation to bring knowledge systems together Examples of business uptake of this form of knowledge outside of IPLCs businesses themselves are less apparent in the literature. (Souza et al., 2023).

4.3.2 Underlying value assumptions in methods and metrics

Valuation in the context of biodiversity is a process of formulating 'indicators of quantitative measures (monetary or non-monetary) and qualitative preference rankings/ratings, perceptions and Indigenous and local knowledge narratives that indicate importance of nature to people' (IPBES, 2022). Different methods for assessing impacts and dependencies of businesses on biodiversity, apply different value assumptions and implicit worldviews (**Table 4.3.**) (IPBES, 2022; Pascual et al., 2023), which has important implications for how interactions between businesses and biodiversity are framed in terms of materiality, responsibility and accountability (discussed further in **Section 4.6**).

Methods that produce biophysical metrics of impacts and dependencies (reviewed in **Section 4.2**), without any further specific valuation tools or methods applied, cannot be assumed to be neutral. Metrics are often interpreted compared to reference or target ecological states that are defined through non-neutral scientifically informed socio-political and legal processes (Bouleau et al., 2009, 2017) For example, where impacts on species populations are compared to national or global targets on reducing extinction risk, impacts are largely valued based on a biocentric worldview assuming an intrinsic value of biodiversity.

Methods that further interpret biophysical metrics by applying market and non-market economic valuation methods (described in **Chapter 2**) are based on an anthropocentric worldview that conceptualises biodiversity as a source of economic or utilitarian value for the business or society (notably through nature's contributions to people). Impacts on biodiversity can cause changes in the provision of nature's contributions to people that result in a gain or loss of wellbeing to people or business profits Monetary values can then be derived through understanding the market and non-market values of these changes in nature's contributions to people (Dasgupta, 2021).

Other monetary valuation methods used in the context of business impact and dependency assessment can be consistent with a biocentric or pluralistic worldview. Methods based on conservation or restoration costs can capture the costs of the actions required to achieve a target state determined by a diversity of values (European Commission et al., 2024, pp. 292–294; Kervinio et al., 2023; Rambaud, 2024; Vanoli, 1995). For instance, in a biocentric worldview, companies would need to estimate the costs of the actions necessary to preserve and restore ecosystems previously impacted by their productive activities (Rambaud, 2024).

Table 4.4. Worldviews and value lenses that influence the interpretation of business impacts and dependencies. The lines of the table are based on the categories of the IPBES Values Assessment (IPBES, 2022; Pascual et al., 2023).

Worldviews	Interpretation of business impacts and dependencies on biodiversity	Example measurement methods that support interpretation
Living from or in nature Anthropocentric (prosperity, livelihoods, health) Specific values: instrumental	Business impact on biodiversity as the degradation (or improvement) of utility and instrumental values of nature's contributions on which this given business or other organizations or society depend.	Biophysical methods for dependency measurement Market and non-market economic valuation methods of impacts and dependencies as well as the assessment of impacts to health or other components of wellbeing.
Living with nature Bio/ecocentric (stewardship, responsibility) Specific values: intrinsic	Business impact on nature valued as a degradation (or improvement) of biodiversity and ecosystem condition based on the intrinsic value. Reference levels for degradation/improvement established based on scientifically informed social-political and legal processes.	Biophysical methods for impact measurements Conservation and restoration costs methods
Living as nature Pluricentric (oneness, harmony with nature) Specific values: relational	Business impact and dependencies on nature valued as a degradation (or improvement) of biodiversity and ecosystem condition and the relational values associated with their conservation in specific places, as established through socio-cultural and political processes	Biophysical and socio cultural valuation methods

4.4 Measurement methods in decision-making

There are a variety of purposes for impact and dependency measurements. This assessment distinguishes four types of primary business purposes for which measurement methods can be applied at all levels of decision making. These purposes often form part of secondary purposes such as risk and opportunity identification, commitment and target setting and reporting:

- **'Screening'** – identifying priorities requiring further analysis or action
  In life cycle assessment and biodiversity literature screening is also referred to as 'hotspots analysis' (Damiani et al., 2023). Its purpose is to identify areas of particular importance (geographically or along the value chain) to guide further analysis or action. These purposes can rely on high-level proxy information about the potential impacts and dependencies associated with a given activity, product or business and / or the location where those activities occur.
  Examples: Identifying investment portfolios of an asset manager with the highest impacts or dependencies on biodiversity, identifying product portfolios or business areas with the highest impacts, identifying types of materials or supply chains with the highest impacts and dependencies, identifying operational locations with the greatest sensitivity
- **'Comparing options'** – evaluating potential impacts and dependencies of business activities relative to alternatives
  This relates to evaluating potential impacts and dependencies of business activities that affect or depend on biodiversity to compare against alternatives. It can support investment decisions, product or process design decisions, supplier or site selection through understanding the expected relative impact or dependency of a given investment, product or operation relative to an alternative. This purpose can rely on proxy information about potential impacts and dependencies but needs to be comparable between specific investments, products, operations etc.
  Examples: Portfolio manager choosing individual securities for an investment fund, manufacturer choosing the types of raw materials for a product, or a specific supplier, business assesses the relative impact of proposed new acquisitions.
- **'Tracking change in pressures or reliance'** – as part of an impact assessment, the potential or actual change in pressures over time, or as part of a dependency assessment, the change in reliance of business activities on nature's contributions to people over time.
  This purpose requires time series information to assess how potential impacts or dependencies are changing over time.
  Examples: Asset manager tracking the change in the overall biodiversity footprint of all investment portfolios over time, corporation assessing the change in its biodiversity footprint, manufacturer tracking the change in the extent of dependencies of the business on biodiversity, credit analyst assessing the change in the risk profile of an investee business
- **'Observing changes in biodiversity'** – showing positive or negative changes in biodiversity and nature's contributions to people that can be attributed or linked to the business activities or action on biodiversity.
  This involves monitoring changes in biodiversity and ecosystem service metrics. For example, the extent and condition of ecosystems, species populations and extinction risk, or the availability of water supply or pollination services that may be impacted or depended upon. Observing outcomes can also involve monitoring changes in the benefits of nature's contributions to people and human wellbeing. This type of measurement can be done through location-based observations as well as participatory mapping and monitoring. For impacts, these changes need to be able to be attributed to the business activities, and for dependencies, these changes need to be linked to the nature's contributions to people the business relies on.

- Examples: Mining business measuring changes in ecosystem condition at their operations, food business measuring changes in pollinator abundance in a key sourcing region, governments measuring the extent of natural ecosystems in an agricultural landscape, a non-governmental organization measuring changes in populations of migratory marine species in areas of offshore energy development

Each of these four business purposes require methods with the appropriate set of characteristics, with increasing accuracy and responsiveness when moving from screening to observing changes (**Figure 4.2**). The characteristics required for a method to be fit for purpose also depend on the level of decision-making. Portfolio level decisions can rely on less accurate information as long as it has the appropriate coverage geographically, typically global, and includes all significant pressures and dependencies. For operational decisions accurate methods become more critical, and the methods need to be location-specific but not globally comparable. These two ends of the measurement spectrum can broadly be described as 'top-down' assessment primarily based on models and secondary data, and 'bottom-up' assessment based on observing realised outcomes with on-the-ground data (**Figure 4.2**). Not all methods can serve all purposes and each carries limitations.

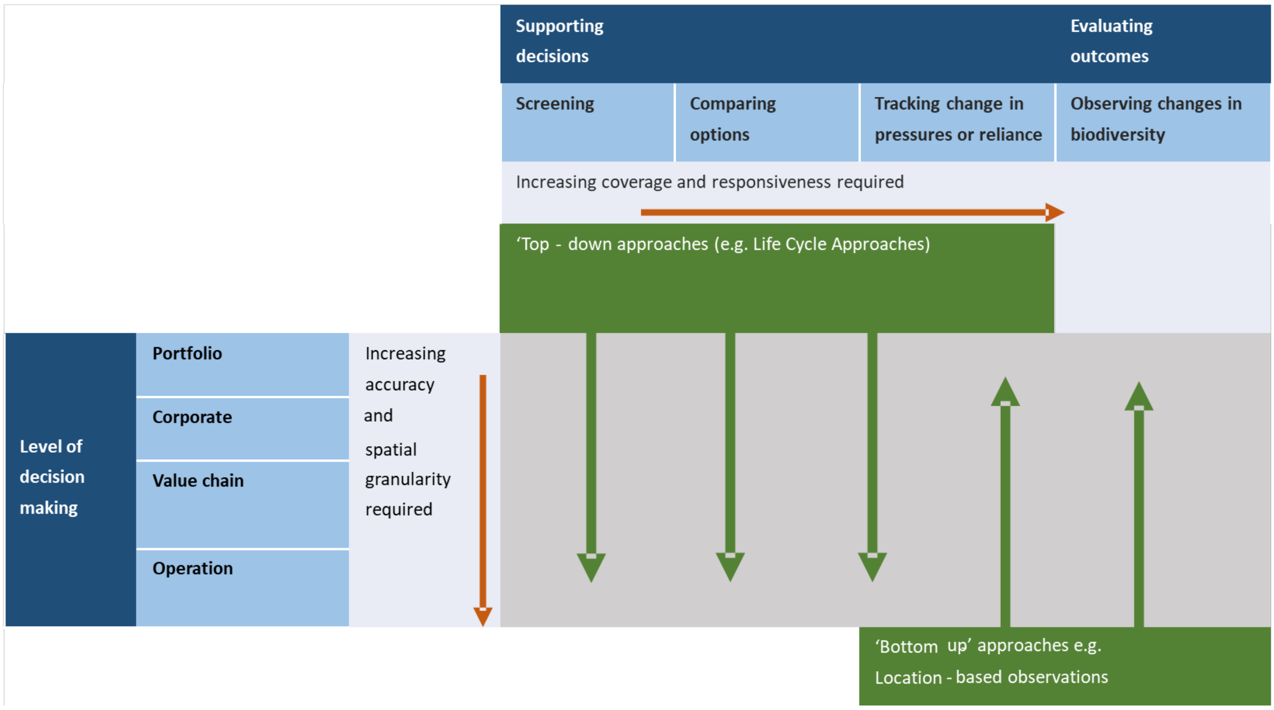

Figure 4.2. The relative application of top-down and bottom-up methods at different levels of decision-making and for different purposes of decision-making

Most of the 'top-down' methods are based on input data representing sectoral or product averages. For life cycle approaches, large databases are often needed to generate the inventory for the assessment, mostly for data on processes happening in the background (e.g., the production of fuel and a farm machine, such as a tractor, for the field operation for an agricultural field). A wide range of tools have developed to support top-down assessments, including many that are listed by industry accountability initiatives such as the TNFD tools catalogue (TNFD, 2025a) and the SBTN step 1 toolbox (Science Based Targets Network (SBTN), 2024). These vary in their scope, coverage of biodiversity, and practicality of application (Barth et al., 2025). Top-down assessments can be supported by biodiversity databases and spatial layers such as Projecting Responses of Ecological Diversity in Changing Terrestrial Systems (PREDICTS) (Hudson et al., 2017) that shows sensitivity of species towards human pressures, the Global Biodiversity Information Facility (GBIF) that currently holds 3 billion species occurrence records, and data layers within the Integrated Biodiversity Assessment Tool (IBAT, n.d.).

Bottom-up assessment methods are based on directly measured quantitative or qualitative data. The outputs of bottom-up methods can feed into secondary datasets used in spatial analysis (Hawkins et al., 2023). These can also feed into top-down methods to improve their accuracy and in theory can be aggregated to carry out impact assessments for entire portfolios or businesses. However, on-ground assessments are currently limited in geographical coverage and are not standardised for the purposes of aggregation. At best data would only be available for the most material impacts of a business' value chain or for a business with a small geographic scope. Data availability therefore underpins the suitability of method applications. Efforts are ongoing to connect the biodiversity monitoring efforts underway across the globe through digital systems, such as the Global Biodiversity Information Facility, and stakeholder networks (Kühl et al., 2020). Nonetheless context specific information that represents the values of diverse stakeholders at locations remains challenging to scale. Further research and discussions on aggregation and for setting standards are required. Therefore, it is currently not possible to measure the realised outcomes of decisions made at the portfolio and corporate level, and for value chains this remains limited to specific commodities and geographies.

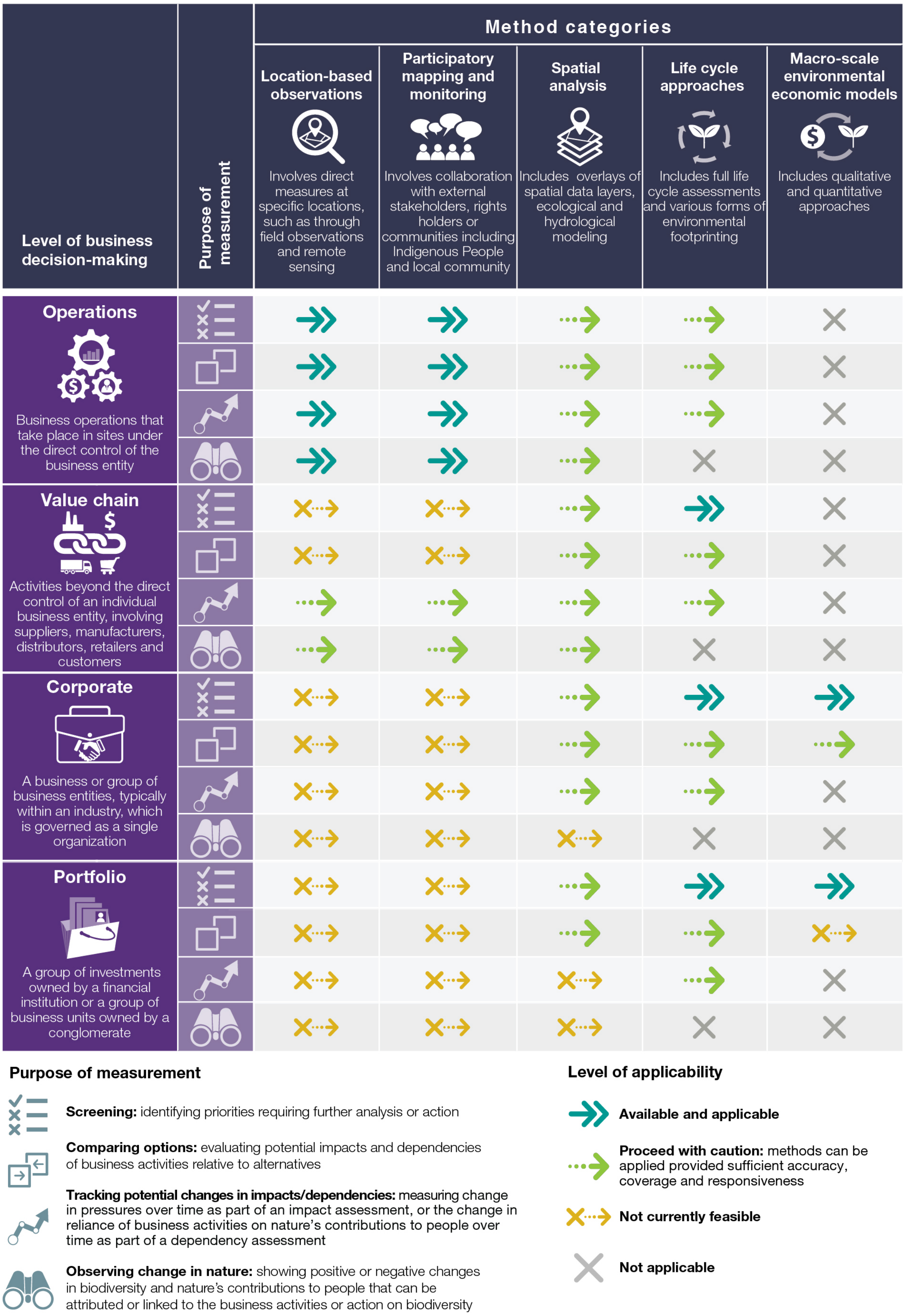

Figure 4.3. Suitability of various categories of methods to measure impacts and dependencies for different business purposes at different levels of decision making.

4.4.1 Portfolio level decision making

Examples of business decisions at the portfolio level:

- **Screening:** asset manager or asset owner wanting to understand impacts and dependencies across their investment portfolios.
- **Comparing options:** portfolio manager choosing a business to add to their portfolio. Business conglomerate deciding on an acquisition.
- **Tracking change in pressure/reliance:** asset manager, asset owner or a conglomerate assessing and reporting on progress towards pressure-based targets. Portfolio manager assessing changes in potential biodiversity impacts or dependencies of their portfolios.
- **Observing change in biodiversity:** financial institution or a conglomerate claiming a positive change in biodiversity attributable to their investments.

Both environmental-economic models and life cycle approaches can be used for screening purposes due to their wide coverage of business activities and wide geographic scope (Kulionis et al., 2024). While MRIO-based methods can provide reliable results at a macroeconomic level, uncertainty increases as the models are used to investigate individual sectors, businesses, and products (Moran et al., 2016). Qualitative tools, such as ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure), can also help to identify hot-spot areas within financial portfolios or parts of portfolios that are particularly dependent on, or impacting biodiversity based on non-spatial industry average information. These methods can therefore identify priority areas of the portfolio for further analysis and have informed a number of macro-economic studies on risk exposure. Some studies are starting to incorporate an understanding of the location specific status of biodiversity and nature's contribution to people through spatial analysis but this remains limited due to a lack of location specific asset level data (Green Finance Institute, 2024; van Toor et al., 2020).

Life cycle approaches can be used to compare the relative impact and dependency of portfolios based on the estimated pressures and reliance on nature's contributions to people of activities within a portfolio. Where more business specific information can be obtained, these methods can also track changes over time. For example, asset managers could potentially use lifecycle approaches or data derived from them to track change in the overall biodiversity footprint of all investment portfolios over time.

Spatial analysis can also be used for screening and comparing purposes where asset-level location data are available, and if the data used cover all the geographies relevant to the portfolio. Asset level data is cited as a key barrier by financial institutions (Christiaen et al., 2025). As global databases of field measurements based on location-based observations evolve, the utility of spatial analysis is likely to increase. However, given the breadth of impacts and dependencies across portfolios it is currently not feasible to measure the change in the state of nature at this scale to determine realised outcomes of portfolio decisions or the resilience of nature's contributions to people underpinning portfolio investments. The relationship between secondary investment or divestment and social and environmental outcomes remains debated and there remains a need for greater empirical evidence to inform decision-making at this level (Kölbel et al., 2020).

Biodiversity footprint datasets currently available on the market for financial institutions can be categorised as life cycle approaches but are typically based on generic multi-regional input-output databases. These do not capture key value chain nuances that differentiate the actual performance of corporations, for example types and origins of materials within the supply chain. These can be useful for screening purposes, but not for investment decisions concerning individual portfolio businesses. There are also considerable gaps between the metrics that they cover and what is needed to support the goals of the Kunming-Montreal Global Biodiversity Framework (Zhu et al., 2024).

4.4.2 Corporate level decision making

Examples of business decisions at the corporate level:

- **Screening:** to understand impacts and dependencies across the whole business to prioritise further action.
- **Comparing options:** setting corporate targets. Informing business model options.
- **Tracking change in pressure/reliance:** business assessing and reporting on the progress towards its targets linked to reducing impacts.
- **Observing change in biodiversity:** business claiming a positive change in biodiversity attributable to its activities.

Similar to portfolio-level decisions, economic-ecological models and life cycle approaches can support initial screening to prioritize hot-spot areas for action. Spatial analysis can also be used providing it has sufficient geographical coverage, and the business has known or estimated location information across operations and value chains.

Life cycle approaches can be used to set and track progress on targets, provided that the methods are responsive enough i.e., they recognise changes in pressures resulting from strategic changes in business activities. For example, actions such as establishing biodiversity conservation areas or shifting to less intensive land use can be recognised by a life cycle assessment but only if it is based on a detailed inventory of local land use. MRIO-based methods are not specific enough for this purpose.

Location-based observations and participatory approaches are required to assess outcomes for biodiversity, and while applicable for priority locations, are generally impractical for use across corporate levels.

4.4.3 Value chain level decision making

Examples of business decisions at the value chain level:

- **Screening:** to understand impacts and dependencies of materials and sourcing regions for one or more of its products.
- **Comparing options:** choosing input materials for a new product or choosing suppliers.
- **Tracking change in pressure/reliance:** assessing and reporting change in impacts or dependencies from adopting a product or switching suppliers.
- **Observing change in biodiversity:** business claiming a positive change in biodiversity attributable to the new product or supplier.

Decisions at this level typically involve product or process design or sourcing and supplier choices. Used with caution, life cycle approaches can be helpful to inform these choices. Life cycle assessment is a key method for assessing broad life cycle impacts and incorporating multiple drivers of biodiversity loss (Hellweg & Milà I Canals 2014), and as such can be integrated in research and product development processes to prioritise product designs with lower potential impacts on biodiversity. These methods bring varying levels of uncertainty with regards to data inputs, coverage and scope of business activities and therefore their application needs consideration of the specific context (Bromwich et al., 2025). To provide comparable results across multiple pressure types, proxy endpoint biodiversity metrics are sometimes used. Although these methods continue to evolve, their coverage of biodiversity components and ability to recognise the spatial variability and local specificity remains limited.

Life cycles approaches can be used together with spatial analysis that incorporate secondary biodiversity data to screen and compare potential impacts and dependencies across suppliers and geographical regions. However, this information should not be directly used for selecting options, for example by an automatic exclusion of whole regions from supply chains. There can still be sustainable practices in high-risk regions. Suppliers from higher-risk regions (identified in the screening phase, or by a due diligence approach) can be scrutinized more carefully using location-based observation and participatory methods, or more detailed inventory data that can better represent actual practices. The application of these methods requires spatially explicit information on the location of activities, and while increasing in availability for direct operational assets for some sectors, is largely lacking for business value chains (Christiaen et al., 2025). A growing number of supply chain tools and initiatives are emerging but there remains a need for granular information on type and extent of activities at specific locations, and business-specific data collection (Beck-O'Brien & Bringezu, 2021).

To measure the outcome of sustainable practices and choices for specific value chain locations where known, location-based observation and participatory methods are required. Outcomes need to be defined locally and involve the active participation of local stakeholders, including IPLC's. It is feasible to use participatory methods and location-based observations to measure change in biodiversity within value chains, although for cost and operational reasons it is challenging for corporates to do that at scale. To achieve transformative change, these methods would need to be scaled up across whole corporate value chains.

4.4.4 Operational level decision-making

Examples of business decisions at the site level:

- **Screening:** to identify high priority sites for management action.
- **Comparing options:** comparing sites for acquisition.
- **Tracking change in pressure/reliance:** assessing and reporting change in impacts or dependencies from choosing specific sites versus others.
- **Observing change in biodiversity:** assessing effectiveness of mitigation measures or resilience of dependencies at a specific location.

Top-down methods are generally not appropriate for estimating the potential impacts and dependencies associated with specific business operations. Economic-ecological models lack the spatial specificity, and life cycle approaches can support an assessment only when spatially resolved input data are included. While it is possible to compare operational sites where data and models are available, it is generally not appropriate to support operational decisions.

Provided there is sufficient resolution and accuracy, spatial analysis can be used to assess changes in drivers or outcomes for biodiversity at specific operational sites, but such methods are limited in the variables they measure and ability to represent locally specific values.

Decisions concerning operational locations such as site design or management practices at sites require information from location-based observations or participatory mapping and monitoring. This has long been recognised by best practice standards for biodiversity baseline studies (e.g., guidance produced by an industry initiative across finance and extractive sectors (Equator Principles, 2022). These methods are required to observe changes in biodiversity to demonstrate outcomes and understand resilience of the nature's contributions to people provided. While efforts to standardise the state of nature metrics for this purpose continue, methods that recognise diverse forms of knowledge and values can and should be used to measure outcomes at this scale (Strange et al., 2024). The use of field surveys and participatory mapping and monitoring that include Indigenous and local knowledge can best consider local specificities and values. Attributing biodiversity outcomes to individual business activities and actions requires the use of counterfactuals, as well as qualitative methods based on expert and local stakeholder perceptions and knowledge (Zavaleta Cheek et al., 2023). Remote sensing, if of sufficient resolution, is a more scalable approach to track change in the distribution of certain ecosystems over time. It is generally less accurate and more limited in the scope of biodiversity and nature's contributions to people that can be measured (e.g., forest cover change), compared to field surveys, but can be effectively combined with location-based observations for a more cost-effective assessment across wider scales (Rhodes et al., 2015).

4.5 Uptake of biodiversity impact and dependency measurement methods by businesses

Although many methods, metrics and tools are available for assessing business impacts and dependencies (see **Chapter 2 and 3 and section 4.2**.), uptake by businesses has been limited (Addison et al., 2018, 2019) . Evidence shows that businesses disclose information about biodiversity and natural capital for a variety of reasons, primarily driven by shareholder and regulatory demands, reputational concerns, and financial considerations (Hassan et al., 2022; MSCI ESG Research, 2023). Emerging policies are expected to drive an increase in nature-related assessments by businesses in the future. Examples of this include the Corporate Sustainability Reporting Directive in the European Union, the Canadian Sustainability Disclosure Standards in Canada, the Australian Sustainability Reporting Standard, and taxonomies for sustainable activities in many geographies. Furthermore, (United Nations Environment Programme Finance Initiative (UNEP FI) & World Wide Fund for Nature (WWF), 2024) reported that at least 29 jurisdictions around the world have formulated nature-related considerations in policy frameworks for the financial sector.

4.5.1 Analysis of business reports on impacts and dependencies

A keyword search was performed across the Alphasense database (AlphaSense, Inc., 2025) of published businesses reports covering around 68 000 businesses worldwide[4]. This showed that less than 1 per cent of businesses (around 500 within the database) refer explicitly to 'biodiversity loss' and 'biodiversity impacts' in their reports over the last 10 years. These 500 businesses mention general environmental assessment approaches, like water and carbon footprints with a relatively high number referring explicitly to life cycle assessments (LCA). The drivers of change most often mentioned were land use (change and occupation) and greenhouse gas emissions, but also invasive species. About 250 businesses mentioned biodiversity footprint or biodiversity impact assessments. A longitudinal analysis shows that the use of the term 'carbon footprinting' started to increase around 2007, 'water footprinting' approximately five years after that, and 'biodiversity footprinting' only since 2020 (**Figure 4.4**). Location-based observations such as field surveys are hardly mentioned, although these types of methods are potentially more likely to appear in operational level management reports rather than corporate level reporting.

Over 500 businesses refer to biodiversity features such as threatened, protected or invasive alien species, and intactness/naturalness, and 360 businesses refer to species richness. More specific biodiversity metrics like 'potentially disappeared fraction of species' and "mean species abundance' (that are often used in life cycle assessment and environmentally extended multiregional input output methods) are only referred to by tens of businesses.

[4]Data management report referring to an uptake analysis on approaches for measurement of business impacts and dependencies on biodiversity and ecosystems https://doi.org/10.5281/zenodo.12786115

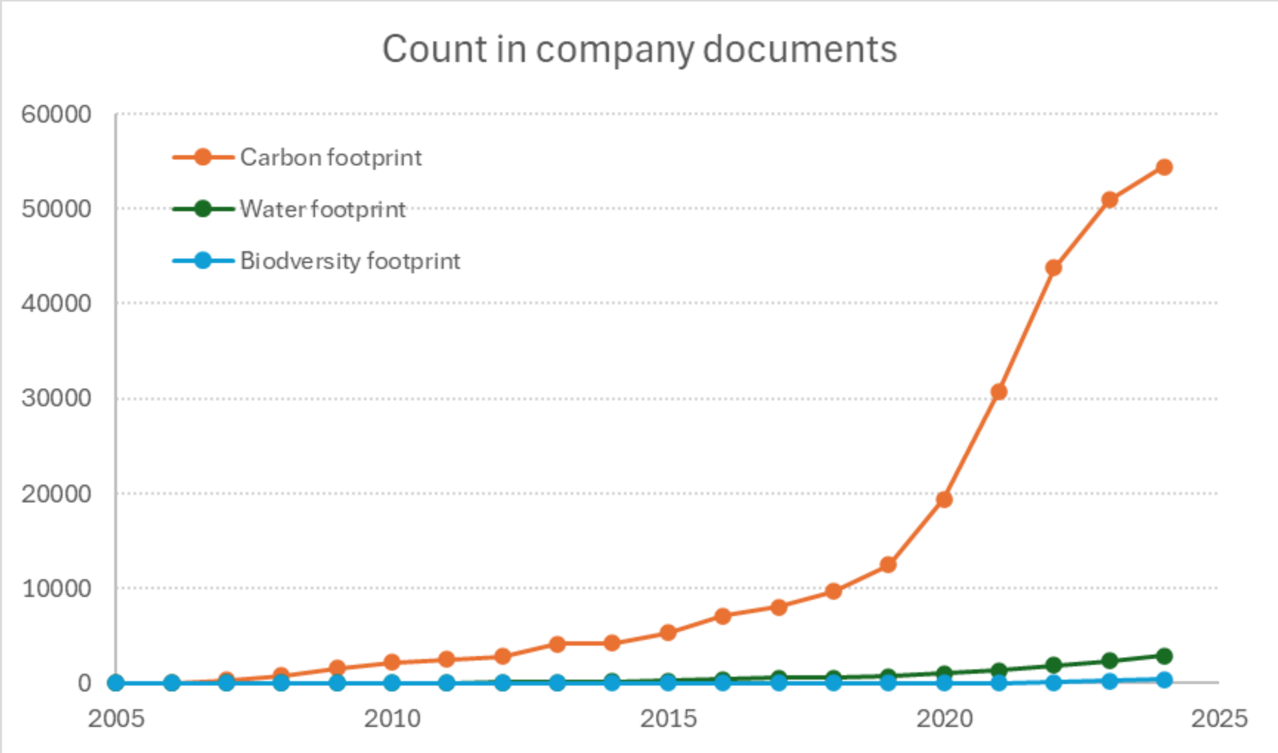

Figure 4.4. Trend in total word use in business documents of footprint keywords.

While around 500 businesses mention 'natural capital' or 'ecosystem services', 'dependencies on nature' is far less. The term 'nature related risks' was referred to by around 450 businesses and might be considered to encompass the way businesses view 'dependencies' for instance when it relates to physical risks[5]. There are only limited results for the specific methods that are used in dependency assessments, with the highest score for natural capital accounting. More specific methodologies like economic or monetary valuation show very low scores, which may indicate that these methods – that are well represented in academic literature on ecosystem services – have not been used for business reporting. Individual components of nature's contributions to people are mentioned more frequently. Water-related contributions, pollination and genetic diversity are referred to by about 500 businesses.

The Integrated Biodiversity Assessment tool (IBAT) was the most referenced tool (around 300 businesses) in the context of impact assessment. Around 200 to 300 reporting businesses mention other widely known tools like ENCORE, and World Wide Fund for Nature's Biodiversity Risk filter that provide an understanding of both impacts and dependencies (UNEP-WCMC & Natural Capital Finance Alliance, 2020). Several of the comprehensive tools that can be used assess dependencies on multiple ecosystem services are mentioned, with over 500 businesses referring to World Wide Fund's Water risk filter and the World Resources Institute's Aqueduct Water Risk Atlas. Water has been identified as a major natural resource in several analyses of financial exposure to ecosystem services due to it's importance across sectors (Boldrini et al., 2023; Svartzman et al., 2021; van Toor et al., 2020). The Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) model that is often encountered in academic literature on ecosystem assessments (like (R. Chaplin-Kramer et al., 2019) is mentioned in only a few reports. The market for tools available to businesses is developing quickly, so it is not possible to provide an accurate view on the uptake of all branded tools.

[5] Data management report referring to an uptake analysis on approaches for measurement of business impacts and dependencies on biodiversity and ecosystems https://doi.org/10.5281/zenodo.12786115

4.5.2 Sectoral and regional patterns

There are strong sectoral and regional patterns of keyword use[6]. Disproportionately more businesses in the materials (mining, forestry, construction), financial (banks, insurance and mortgages) and industrial sectors mention biodiversity related keywords in their reports. Together, these sectors are responsible for about 50 per cent of all mentions. Disproportionately more businesses from Central and Western Europe and North America report on biodiversity impact keywords (together almost 70 per cent of all keyword scores), while North-East Asia is responsible for another 12 per cent. Businesses from Europe, North America and Asia are also more present in reporting on dependencies on biodiversity. There is also a significant number of businesses from South Africa, while businesses in the rest of Africa rarely mention biodiversity.

4.5.3 What's causing the low uptake?

Analyses based on keyword searches of disclosure has limitations, as it does not consider the context in which the keywords are used. Nonetheless uptake can be considered low based on these results, which can be explained by several causes. A discrepancy and time-lag has been mentioned between scientifically available metrics, methods and tools and their practical application by businesses (Carvalho et al., 2023; Maas et al., 2024). Time-lags between method development to uptake can be due to by cost barriers and knowledge gaps in businesses. It may also be due to the perceived complexity of the biodiversity concept by businesses, where biodiversity and nature's benefits cannot be easily covered by a single approach or metric (Addison et al., 2018, 2019; Bull et al., 2022; Lambooy et al., 2018).

[6] Data management report referring to an uptake analysis on approaches for measurement of business impacts and dependencies on biodiversity and ecosystems https://doi.org/10.5281/zenodo.12786115

4.6 Embedding biodiversity metrics and values in business functioning, governance and accountability practices

4.6.1 Approaches for integrating metrics and values of nature into business accounts

Within 'business as usual', accounts of stocks, flows, transactions, budgets and debts are the dominant information used to support both internal strategic management, decision-making and external reporting by businesses. Through systematically recording, classifying, summarizing and assessing organizational events, use of resources as well as financial and non-financial performances, a business takes informed judgements and can be held accountable by stakeholders (Breton, 2018; Carnegie et al., 2021; Duncan, 1909; Richard & Collette, 2008). Transforming these accounting systems and processes to integrate metrics and values (monetary or non-monetary) of nature can therefore underpin transformation of how businesses manage their impacts and dependencies and are held accountable for their interactions with biodiversity.

Approaches and associated methodologies for integrating metrics and values of nature into organizational processes and accounting systems were reviewed[7]. These approaches are not neutral as they are based on social choices and conventions that define what should be made visible or not, how this should be valued, for what purpose and for whom (Hines, 1991; Morgan, 1988) . Different approaches can support different models of corporate governance, i.e., how power and accountability are structured, and how business value is defined and for whom (Feger & Mermet, 2021a; Lamberton, 2005; Rambaud & Richard, 2016; Richard, 2012; DFCG & CNOEC, 2021) **(Figure 4.5)**.

Approaches vary in terms of the degree of integration of metrics and values within existing conventional (non-environmental) business accounts and processes. At one end of the spectrum, nature metrics are fully integrated within business-as-usual accounts. At the other end of the spectrum, *ad hoc* biodiversity accounts are developed but not integrated with business accounts (see vertical axis in **Figure 4.5**). Due to the central role accounts play in business overall functioning**,** deeper integration of nature values and metrics is likely to support the systematic uptake of biodiversity information into strategic management, decision-making and corporate governance. Such integration requires precise framing of how nature metrics and values affect business costs, revenues, financial values and calculation of profit, both positively or negatively.

Approaches to integrating nature metrics into business accounts also vary in terms of the value lens that is applied to nature, and consequently in the way materiality of business impact on nature is conceptualized (see **Section 4.3.2**), with implications on the transformative effects that it may (or may not) produce (Miller & Power, 2013) . On one end of the spectrum are approaches based on anthropocentric worldviews and instrumental values. On the other end are biocentric or pluralistic worldviews that seek to integrate nature's intrinsic and relational values into business accounts (see horizontal axis in **Figure 4.5**). These latter approaches link more directly to business commitments and accountability on achieving ecological reference levels of conservation, as opposed to approaches solely focused on measuring gains or losses of the flows of benefits from ecosystem services (Jones & Solomon, 2013).

[7] Data management report referring to a snowball search of the academic field of biodiversity accounting https://doi.org/10.5281/zenodo.12785745

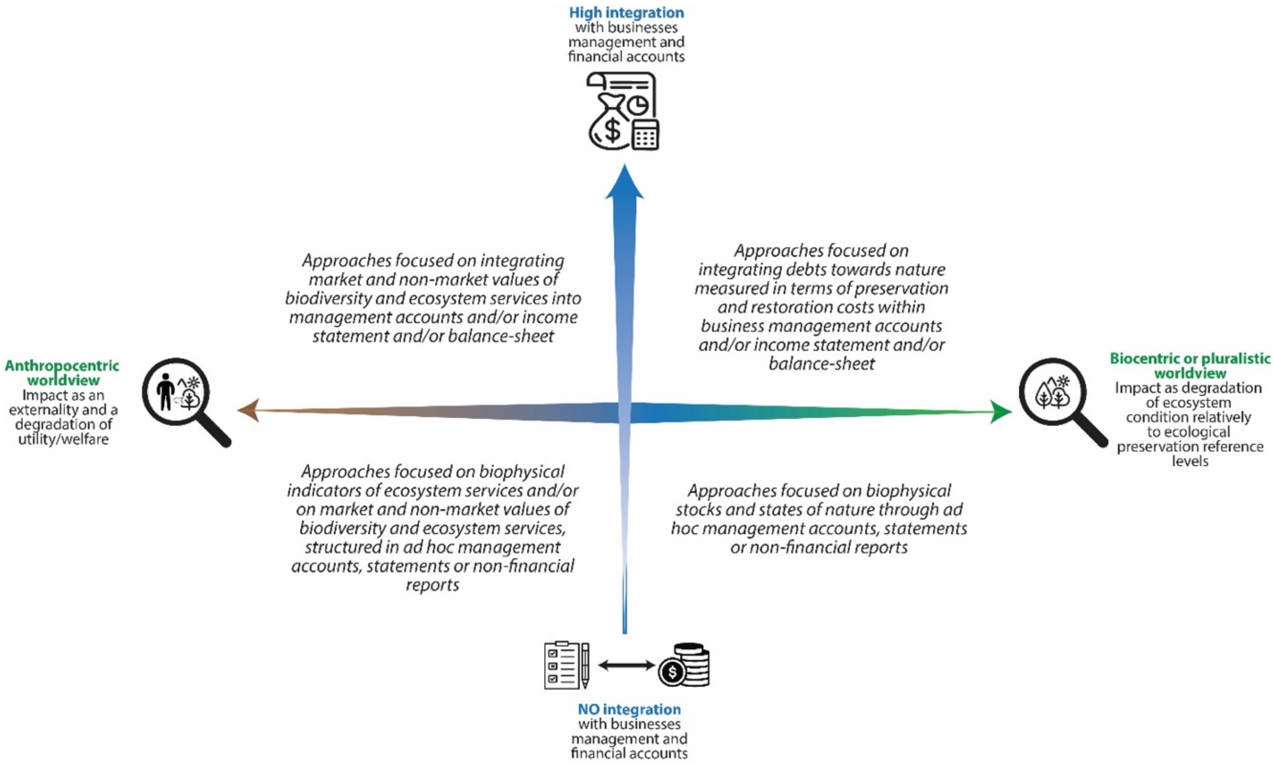

Figure 4.5. Two main axes distinguish approaches for integrating metrics and values of nature into organizational accounting systems and processes: worldview and level of integration within conventional business management and financial accounts. Four main approaches are identified along these axes. For approaches in the upper part of the diagram, monetary valuation is deemed necessary to allow integration of nature metrics and values into business financial accounts and reports, while it is deemed as optional for approaches in the lower part of the diagram.

Policy governance contexts and accountability regimes strongly shape the way business accounts are structured, used and disclosed (Bebbington et al., 2021; Jones & Solomon, 2013). Political choices regarding emerging voluntary and regulatory sustainability reporting frameworks and standards addressing biodiversity issues therefore have a strong influence on the two factors mentioned above (level of integration, worldview and value lens applied) and the level of transformative change that they can achieve (Capitals Coalition, 2020; Negash, 2012; Richard, Bensadon, Rambaud, 2018) (See **Box 4.2** and **Figure 4.6**) (see **Chapter 6**).

Box 4.2. Key findings from research on biodiversity reporting

Biodiversity "reporting" is the act of preparing, disclosing and communicating financial and non-financial information regarding business impact and dependencies on biodiversity to external stakeholders (e.g., investors, regulators, civil society) according to specific guidelines, frameworks or standards (Lamberton, 2005).

Research shows that business reporting on biodiversity is increasing globally, driven by the development of voluntary and regulatory frameworks, standards and guidelines, encouraging more transparency and accountability (Bebbington et al., 2021; Bhattacharyya & Yang, 2019; Oka et al., 2022.). This is especially true in the sectors with most impact on biodiversity and those that are most exposed to regulations and reputational risks, such as large businesses in mining or forestry (Adler et al., 2017; Boiral & Heras-Saizarbitoria, 2017a, 2017b, 2017c).

In most cases, biodiversity disclosure practices are found to be falling short of providing specific, time-bound and measurable indicators necessary for a thorough, continuous and transparent assessment of businesses acting (or not) on their commitments (Addison et al., 2019; Adler et al., 2018; Lamont et al., 2023; Skouloudis et al., 2019; Van Liempd & Busch, 2013). Businesses are often found to be using biodiversity reporting to manage stakeholders' expectations and defend their license to operate rather than disclosing their real impacts and responsibilities regarding biodiversity protection (Boiral, 2016; Cho et al., 2015; Haque & Jones, 2020; Maroun et al., 2018; T. Smith et al., 2019; Syarifuddin & Damayanti, 2019).

Global development and uptake of frameworks and standards for disclosure of business impacts and dependencies on biodiversity is expected to lead to further increase in reporting by businesses (UNEP-FI & UNEP-WCMC, 2024). These include the European Union's Corporate Sustainability Reporting Directive (CSRD) containing the European Sustainability Reporting Standards (ESRS) focusing on both financial risks and impacts on biodiversity based on reference levels (legal or science-based); as well as industry-led voluntary initiatives such as the disclosure recommendations of the Taskforce on Nature-related Financial Disclosure (TNFD, 2023c) and the International Sustainability Standards Board (ISSB; extending International Financial Reporting Standards to sustainability issues) which focuses on financial risk only (IFRS, 2023) .

Depending on whether they focus on impacts on biodiversity, financial risk or both, underpinned by their specific worldviews, reporting frameworks and standards will drive uptake of corresponding accounting methods – more anthropocentric worldviews will favor accounting for potential impacts on ecosystem services flows to infer financial risk, more biocentric or pluralistic worldviews will account for time series change in ecological conditions that can represent the actual impacts of a business on biodiversity and people (see Figure 4.7). Frameworks based on the assumption that business accounting and disclosure of financial risks will ensure that markets manage biodiversity for long-term sustainability have been criticized for being unsupported either by theoretical or empirical evidence (Adams & Mueller, 2022; Ameli et al., 2020; Christophers, 2017; Dempsey et al., 2021; Irvine-Broque & Dempsey, 2023; Le Ravalec et al., 2022; Rainforest Action Network, et al., 2024). So far, existing sustainability reporting standards that include biodiversity requirements do not provide for integration with financial accounting standards – e.g., International Financial Reporting Standards (IFRS), United States Generally Accepted Accounting Principles (US GAAP), other national accounting norms – which limits the possibility to fully integrate nature metrics and values within business accounts.

Corporate governance perspectives and choices shape the structure and content of business accounts by determining what information is material and to whom, and therefore what should be made visible and valued (Müller, 2014; Richard & Rambaud, 2022, 2024). As a consequence, the selection and integration of metrics and values of nature in business accounts will also depend on how businesses integrate nature conservation and sustainable use goals in their governance, how they discharge accountability for it and to whom (Bebbington et al., 2024, p. 2; Larrinaga, 2021). As such, a change of governance can result in a change of accounting approach with implications for decision making and priorities.

Governance approaches can be distinguished according to the extent to which they integrate (or do not) nature protection goals as a core business responsibility relatively to the pursuit of profit (see **Figure 4.6** inspired by Larrinaga, 2021 (Larrinaga, 2021))[8]. On one end of the spectrum, businesses follow the goal to maximize shareholder value, view nature as productive assets and a source of financial opportunities or risk, and therefore integrate metrics and values of nature into business accounts with the aim to understand and show the implications for enterprise value. On the other end of the spectrum, businesses recognize that "radical and systemic shifts are necessary for corporate and societal functioning" (Bebbington et al., 2024; Chaffin et al., 2016; Larrinaga, 2021; Richard, 2012), repurpose their business models to systematically restore nature impacted by their activities, and therefore integrate metrics and values of nature in business accounts in a way that conditions

[8] See supplementary materials in Annex 3 for further details.

financial profit to the achievement of biodiversity goals. The latter approach aligns with IPLCs conceptions of businesses, which often include co-ownership, different purposes and distribution of values for the community and nature.

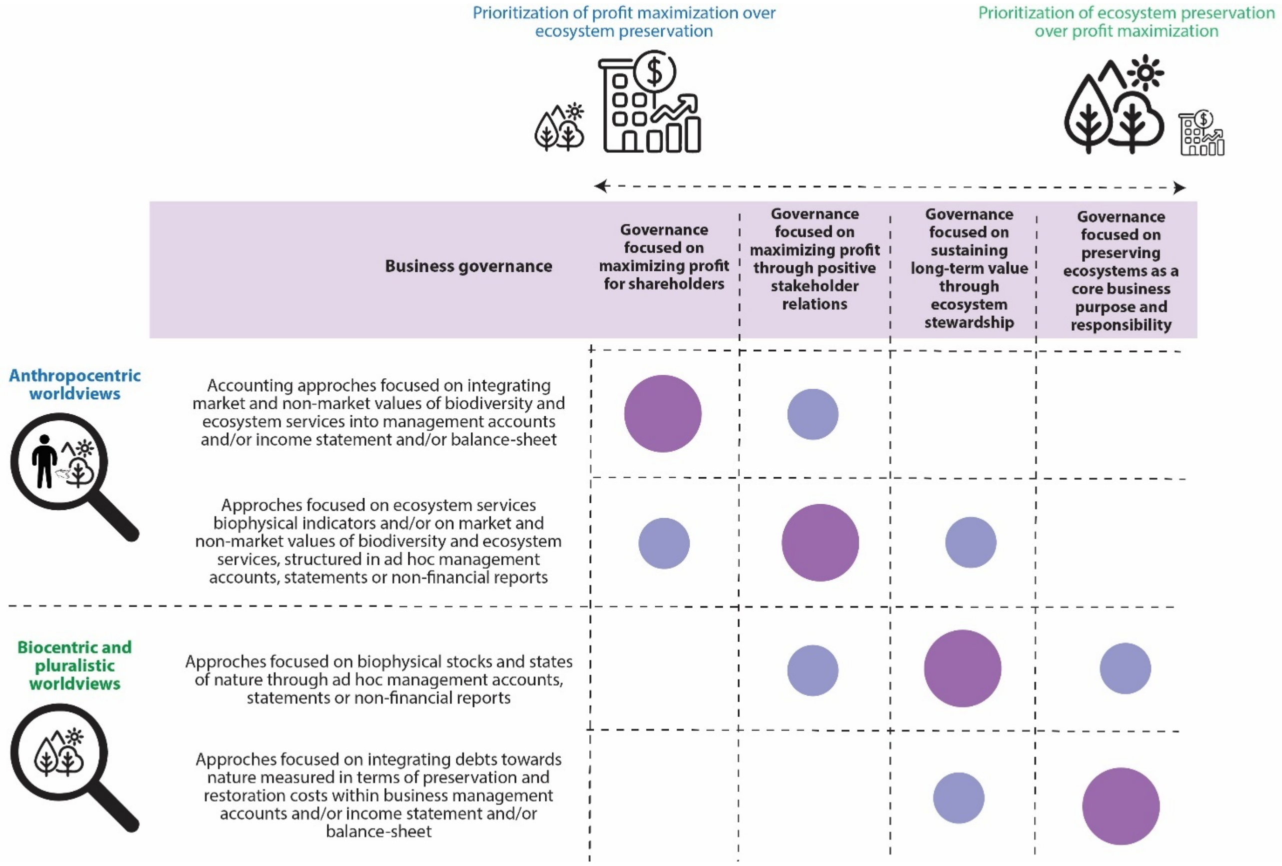

Figure 4.6. Approaches for accounting for impacts and dependencies on biodiversity across levels of transformative ambition. Different approaches for accounting for impacts and dependencies on biodiversity (see **Figure 4.5**) can support different business governance models, with different levels of transformative ambition in terms of business participation in the achievement of global biodiversity goals. They span from 'pristine corporate' governance, where the focus is on financial materiality and maximising profit for shareholders, through to 'transformative sustainability' governance, where the focus is on environmental and societal materiality and where conserving ecosystems is a core part of business purpose (Larrinaga, 2021)

4.6.2 Emerging business biodiversity accounting methodologies

To support the integration of nature metrics and values into business accounting and reporting systems, a growing number of biodiversity accounting frameworks and methodologies for businesses are being developed. Biodiversity accounting refers to methodologies that seek to systematically identify, record, frame, organize, track over time, and value business impacts and dependencies on biodiversity (in monetary and non-monetary terms) according to a set of principles.

These methodologies use a variety of impact and dependency metrics as identified in previous sections of this chapter, are underpinned by different worldviews and use different techniques for integration into business accounts (**Box 4.2**). Some of the methodologies only use biophysical data, while most use a combination of both biophysical and monetary metrics, based on different valuation methods (see **Section 4.3.2**, and **Chapter 2**).

Applications at different organizational levels

Biodiversity accounting methodologies vary in terms of main audiences, purposes, and therefore level of decision-making they have been designed for (**Figure 4.7**). First, at the value chain and operational levels (in particular when the sites are under the direct ownership and management of the business), biodiversity management accounting methods can track transaction costs and benefits associated with management of impact and dependencies (Eftec, 2015; Hanson et al., 2011; Houdet et al., 2009, 2016; Houdet & Germaneau, 2014) . They can assist businesses' managers in risk and performance assessment, as well as strategic planning, business model change and implementation of impact mitigation of specific business units, operations, projects or products (Endangered Wildlife Trust, 2020; Feger & Mermet, 2022; Houdet et al., 2020; Schaltegger et al., 2023). (see **Chapter 5**)

Second, at the portfolio and corporate level, a number of methods are proposed which cover mostly non-financial reporting and disclosure, or integration of biodiversity into financial accounting and reports (balance-sheet and income statement) (Barker & Mayer, 2017; BSI, 2021; Capitals Coalition, 2020; Global Sustainability Standards Board (GSSB), 2025; IFVI & VBA, 2024; Ingram et al., 2024; ISO, 2024; Koshy et al., 2019; Rambaud & Richard, 2015; Roberts et al., 2021) (See **Box 4.2**).

Levels of integration and value lenses

Most of the existing business biodiversity accounting methodologies do not propose complete integration with business management accounts and financial reports and thus do not require changes to existing accounting standards. This limits the influence these methods can have on re-shaping business decision-making, governance and management processes.

Most existing methods are based on anthropocentric worldviews and instrumental perspectives on the value of nature rather than biocentric or pluricentric worldviews (Atkins et al., 2014; Bebbington et al., 2021; Jones & Solomon, 2013). Examples of methods which adopt an anthropocentric value lens and which have a low degree of integration with business accounting systems include methods such as the Environmental Profit and Loss Accounts (Chaplin-Kramer & Green, 2016; Kering, 2015), the 'Impact accounting' method (IFVI & VBA, 2024), or the Natural Capital Management Accounting Methodology (Transparent, 2023) (see lower left quadrant of **Figure 4.7**).

Methods which adopt the anthropocentric value lens but seek a high degree of integration with conventional business accounts include the "integration of natural capital measures" as intangible assets (Koshy & Dickie, 2020) or the "integrating natural capital into financial reporting" (as proposed by Nicholls & Koshy, 2020) (see upper left quadrant of **Figure 4.7**). Methods such as BS 8632 and ISO 14054 and the "corporate natural capital accounting" stream of work on which they are founded (e.g., Eftec (2015); Forico (2023); Ingram et al. (2024); Koshy et al. (2019)) sit in the middle, depending on the levels of integration of proposed "natural capital statements" with their business financial statements (see **Box 4.2**).

Fewer biodiversity accounting methods for businesses are based on biocentric worldviews and intrinsic perspectives on the value of nature, although research efforts seek to further develop such approaches (Asni & Sawarjuwono, 2020; Christian, 2014; Raar et al., 2020; Russell et al., 2017; Samkin et al., 2014). Examples of such biocentric methodologies, with a low degree of integration include extinction accounting (Atkins & Maroun, 2018; Roberts et al., 2021), disclosure frameworks adopting a deep ecology lens (Samkin et al., 2014) or the Biodiversity Protocol (Endangered Wildlife Trust, 2020; Houdet et al., 2020). Even fewer accounting methodologies are based on pluricentric worldviews, and on a relational perspective on values (Birkin, 1996; Rambaud & Richard, 2015).

Under a biocentric or pluricentric value lens, monetary valuation based on conservation or restoration costs is preferred as a complement to the use of biophysical metrics. These represent the actual costs of conservation or restoration actions to be undertaken by a business to restore ecosystems that it has degraded through its activities. Businesses thus have to reimburse the debt that they incurred towards nature while creating economic value, as proposed in the Sustainable Cost Accounting framework (Gray, 1992, 1994; Murphy, 2021) or in the Comprehensive Accounting in Respect of Ecology (C.A.R.E) model (Rambaud & Feger, 2019; Rambaud & Richard, 2015; Richard, 2012) (see **Box 4.3**).

As the uptake of business biodiversity accounting methods keeps growing, more empirical research is needed to systematically track and assess their real world application outcomes. Available research on more general sustainability accounting methods highlights implementation challenges (Adams & Larrinaga-González, 2007; Carn & Pernias, 2022; Hababou, 2022; Herbohn, 2005; Taïbi et al., 2020), and cases of ineffective outcomes for nature exist when ecological limits and critical thresholds are not considered (such as in the case of the triple-bottom line model, despite its large-scale application worldwide (Elkington, 2018).

Box 4.3. Comparison of two biodiversity accounting methods

The variation in business biodiversity accounting approaches outlined in this section can be illustrated by comparing two different methods which envisage the integration of nature within business financial accounts. The first rests on a series of initiatives, which currently aim to consolidate methods under the broad label of Corporate Natural Capital Accounting (CNCA) (Eftec, 2015; Forico, 2023; Ingram et al., 2024; Koshy et al., 2019; Nicholls & Koshy, 2020) and to develop standards under the label of natural capital accounting for organizations (BS 8632 and ISO 14054). The second method labelled Comprehensive Accounting in Respect of Ecology (C.A.R.E) is based on a scientific programme theorized and experimented since 2013 (Feger et al., 2023; Rambaud & Chenet, 2021; Rambaud & Feger, 2019; Rambaud & Richard, 2015; Richard, 2012; Richard et al., 2018) with private businesses and public organizations. This table summarizes key differences, which are further described in Supplementary Material.

Methods	Corporate Natural Capital Accounting (CNCA)	Comprehensive Accounting in Respect of Ecology (C.A.R.E.)
Worldview / Definition of Natural Capital	Anthropocentric; "natural capital" as assets generating benefits to business and society	Pluralistic; "natural capitals" as ecological entities to be preserved individually based on critical thresholds
Valuation Approach	Market and non-market valuation of natural capital stocks and services	Biophysical gap analysis + valuation of prevention/restoration costs to preserve ecosystem integrity
Integration into Accounts	Separate natural capital statements; optional integration via fair value adjustments in financial statements	Full integration into financial accounts; ecological debts recorded as liabilities and affect profit calculation
Accounting Philosophy	Fair value accounting	Historical cost accounting
Practical Implications	Supports risk-opportunity analysis, disclosure (e.g.,	Mandates preservation costs, supports transition planning,

	TNFD), and investment decisions	aligns with CSRD/ESRS and impact materiality focus
Adoption (2024)	~33 early adopters (UK, AU, ZA, DK)	~37 early adopters (mostly France)

Links with biodiversity and natural capital accounting methods at ecosystem and national levels

Biodiversity accounting frameworks and methodologies are also developed at national and ecosystem levels, beyond the formal boundaries of private organizations. At the operational and landscape level, specific "ecosystem-centred accounting" systems and methods are emerging that aim to support collective ecosystem valuation processes, dialogue and negotiation on the assignment of responsibilities within shared landscapes, monitoring of collective ecological targets, and the organization of co-management strategies (Feger, 2024; Feger et al., 2019, 2021; Feger & Mermet, 2017). These methods can support landscape engagement approaches, as described for instance by the Science-based Target Network (SBTN; Step 3 Landscape Engagement target) (SBTN, 2023b). They also have the potential to play an important role in representing IPLCs and in incorporating Indigenous and local knowledge and values in business decision-making, by supporting multi-stakeholder dialogue and accounting for worldviews alternative to Western science and specific to given places (Agrawal, 1995; Arjaliès & Banerjee, 2024; Boiral & Heras-Saizarbitoria, 2017c; Brown et al., 2015; Brown & Dillard, 2015; Manetti et al., 2021; Normyle et al., 2022).

In addition, the importance of interlinking and aligning developments in business biodiversity accounting with diverse methods of national natural capital accounting, and in particular with the System of Environmental Economic Accounting – Ecosystem Accounting (SEEA-EA), is increasingly being acknowledged (European Commission et al., 2024; Feger et al., 2021, 2023; Feger & Mermet, 2021; Grunewald et al., 2024; Ingram et al., 2022, 2024; McKenzie et al., 2025; Surun, 2023). Some suggest that the development of biodiversity accounts at the business level could draw inspiration from the recently adopted SEEA-EA statistical standard (European Commission et al., 2024; Ingram et al., 2022, 2024; McKenzie et al., 2025). Others propose alternative perspectives such as the adoption of a debt towards nature approach, in order to measure and articulate ecological debts from the business level to the national level (Kervinio et al., 2023; Surun, 2023) . These approaches endorse different worldviews regarding how to interpret business impact and dependencies on nature in a policy and public investment context (Bérard, 2019) (see **Section 4.3.2**). Political choices by governments on this matter will have implications on how the business accountability environment is shaped and will ultimately influence business choices in terms of integration of approaches for integrating impact and dependencies in their own accounting systems (see **Chapter 6**).

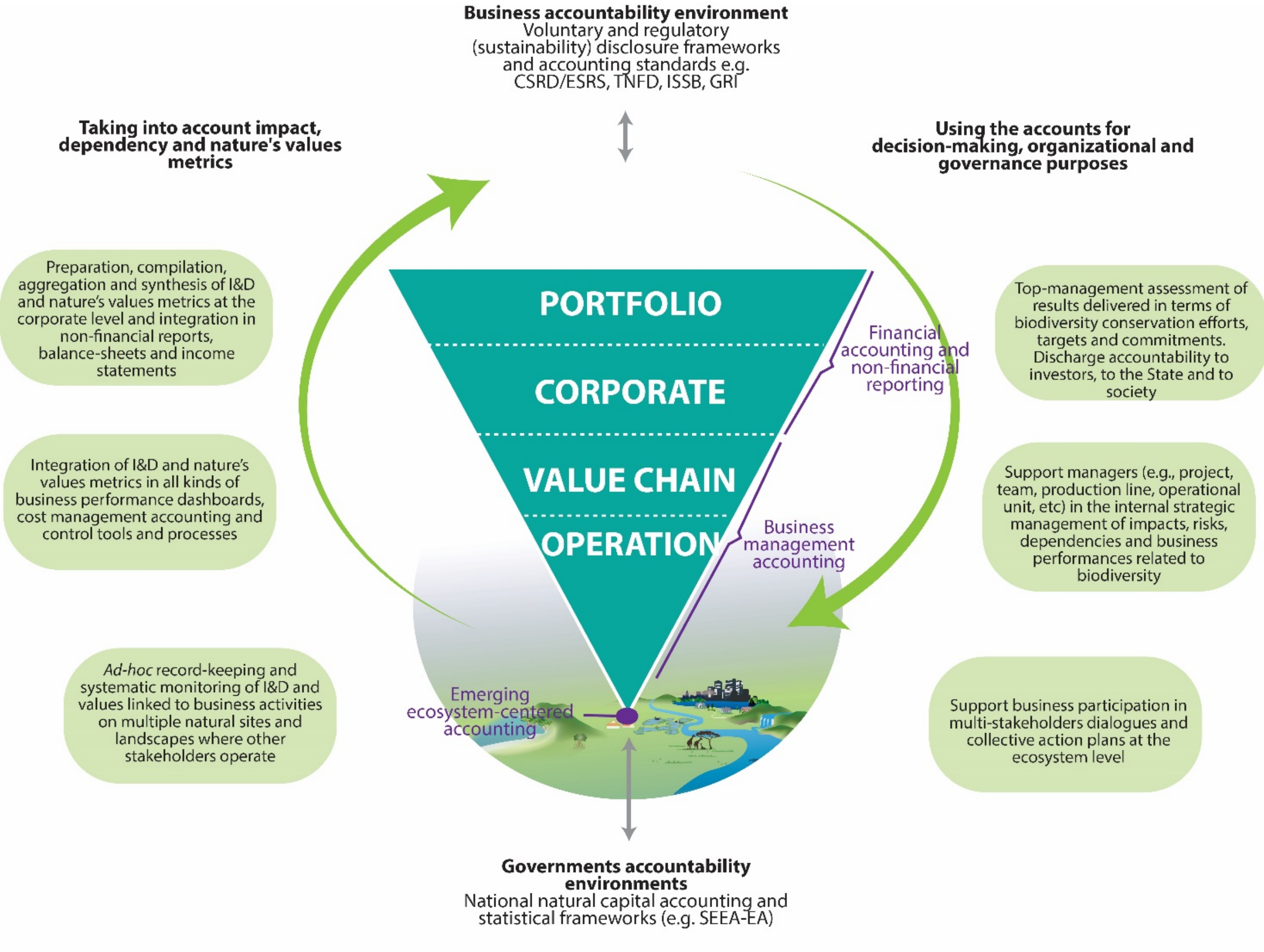

Figure 4.7. Biodiversity accounting methods used by businesses at different levels. Biodiversity accounting methods which can be used by businesses are being proposed and experimented at different levels (Feger & Mermet, 2021) . These levels are linked to one another both in terms of information flow and in terms of organizational decision-making and management processes. They are shaped by the overall existing accountability environment in which business operate.

The development of more comprehensive biodiversity accounting methods that would connect and cover these different levels (business, ecosystem, national) in a consistent vision and value lens (Feger et al., 2021, 2023) could be a key step in bridging the current management and governance gaps between top-down target setting measurement approaches at the national, sectoral and at the corporate level; and bottom-up nature monitoring and valuation across the value chains and at the operational and wider ecosystem level.

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