KPMG

Making nature visible

How digital twin technology can help companies transform the way they monitor, report and verify their biodiversity impacts

KPMG Sweden

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Contents

Glossary of acronyms:

AI	Artificial Intelligence	IBAT	International Biodiversity Assessment Tool
ALS	Airborne Laser Scanning	ICMM	International Council on Mining and Metals
BII	Biodiversity Intactness Index	ISSB	International Sustainability Standards Board
CBD	UN Convention on Biological Diversity	IUCN	International Union for the Conservation of Nature
CBF	Corporate Biodiversity Footprint	LCA	Life Cycle Assessment
CSRD	Corporate Sustainability Reporting Directive	LCIA	Life Cycle Impact Assessment
DR	Disclosure Requirement	LiDAR	Light Detection and Ranging
EFRAG	European Financial Re porting Advisory Group	MSA	Mean Species Abundance
ESRS	European Sustainability Reporting Standards	PDF	Potentially Disappeared Fraction
EU	European Union	SBTN	Science-based Targets for Nature
GBF	Kunming-Montreal Global Biodiversity Framework	STAR	Species Threat Abatement and Restoration metric
GBS	Global Biodiversity Score	TCFD	Task Force on Climate-Related Financial Disclosures
GRI	Global Reporting Initiative	TLS	Terrestrial Laser Scanning
IAS	Invasive Alien Species	TNFD	Task Force on Nature-related Financial Disclosures

Executive summary

Together with climate change and pollution, the ongoing loss of biological diversity represents one of three key pressing planetary crises. As awareness of the importance of biodiversity for our economies and societies grows, so increases the expectation that businesses mitigate their impacts and transition to nature-positive business models. In this context, the need to 'make nature visible' through the collection, assessment, and disclosure of high-quality biodiversity data is rapidly becoming a necessity.

While the current biodiversity data landscape poses many challenges, digital technologies represent an opportunity that could help companies reduce the cost of, and reap the benefits from, the transition. For this report, KPMG Sweden has collaborated with Hexagon AB's green-tech subsidiary R-evolution to specifically discuss the role that 'digital twin' technologies can play in enhancing the monitoring, reporting and verification of corporate impacts on biodiversity.

Focusing on the case of R-evolution's Green Cubes Digital Reality solution and its application to conservation and restoration efforts in the mining sector, the report suggests that by embedding digital twins within a comprehensive biodiversity strategy, companies can enhance existing measurement approaches and effectively integrate nature in their business models.

As the world's biodiversity continues to deteriorate, the private sector is increasingly expected to contribute to global goals to protect and restore nature. For companies, the transition to a nature-positive trajectory is not only essential to mitigate their negative impacts on biodiversity – it also represents a significant business opportunity.

By underpinning ecosystem services ranging from clean air and water to food production and flood control, biodiversity is the foundation of our economic and social systems. Estimates suggest that USD 44 trillion, or over half of the world's gross domestic product, could be potentially threatened by nature loss. Despite its importance, global biodiversity continues to deteriorate.

To halt and reverse negative trends in biodiversity, it is not enough to preserve those natural areas that are still intact today. Our societies and economies must put nature on a path to recovery by dramatically scaling up ecosystem restoration efforts and promoting a fundamental shift in production and consumption patterns, in line with the vision of the Kunming-Montreal Global Biodiversity Framework.

This transition to a nature-positive trajectory requires the full involvement of the private sector. All businesses depend upon, or have an impact on, biodiversity and ecosystem services. At multiple levels, companies are also increasingly impacted by regulatory and supervisory initiatives aimed at assessing, managing, and disclosing nature-related risks and opportunities.

While the integration of biodiversity in corporate strategies and business models represents a challenge for businesses, it also offers a significant opportunity, estimated to unlock USD 10 trillion annually by 2030. Beyond regulatory compliance, the advantages for early movers can include direct cost savings through resource-use efficiencies, reduced exposure to environmental risks, and new revenue opportunities such as those offered by nature-based solutions and emerging markets for biodiversity credits.

The availability of biodiversity data and metrics to support the transition to a nature-positive economy is rapidly expanding, but the challenges faced by companies on biodiversity monitoring and reporting remain.

The transition to a nature-positive future depends on the availability of up-to-date, reliable data to help monitor trends in biodiversity. For companies, collecting biodiversity data means being able to (i) assess and manage the negative impacts of business operations on nature; (ii) set targets and measure progress; and (iii) ensure a return on nature-related investments. As biodiversity emerges as a key topic across various mandatory and voluntary frameworks for sustainability reporting, such data also becomes necessary for companies to be able to identify and disclose their nature-related impacts, dependencies and risks.

Displaying a high degree of alignment, frameworks such as the European Union's Corporate Sustainability Reporting Directive (CSRD), the Task force on nature-related financial disclosures (TNFD), and the Global Reporting Initiative's new GRI 101: Biodiversity 2024 standard will contribute to enhancing the transparency and comparability of corporate biodiversity disclosures. While they offer a certain flexibility, these initiatives also clearly indicate that corporations will increasingly have to report against multiple metrics and related quantitative data points.

In recent years, the availability of biodiversity data and metrics has grown dramatically. At the same time, several challenges remain, including in terms of the efforts required for the collection of primary data as well as in relation to the quality and coverage of secondary data sources. Furthermore, companies may find it hard to navigate the fast-evolving landscape of biodiversity measurement tools and approaches. The relevance of these challenges is confirmed by the current rates in global biodiversity reporting – for the 2022 financial year, less than half of all the world's 250 largest companies by revenue disclosed their biodiversity risks.

The growing application of digital technologies to biodiversity monitoring can help companies comply with emerging disclosure requirements and transition to strategic, nature-positive action. Enabling both real-time monitoring and predictive modelling, 'digital twin' solutions represent a particularly promising innovation.

While current measurement tools and approaches have various levels of granularity and are useful at different stages of corporate maturity on biodiversity, they all have specific limitations. At the same time, a wide range of digital technologies are now being applied to biodiversity monitoring and reporting. Leveraging the opportunities offered by increased computational power and expanded capacities for data collection, storage, sharing and visualisation, these technologies could complement existing tools and help companies meet the growing expectations of investors, regulators and other stakeholders.

Digital twins, which can be defined as digital models of physical entities made possible using sensors and other devices that transmit data between the model itself and its real-world counterpart, represent a particularly promising innovation. Through advanced data capture equipment and analytics, digital twins promise to enable both real-time monitoring of biodiversity and cutting-edge predictive modelling and scenario analysis, thus supporting the planning and implementation of ecosystem conservation and restoration activities.

An example of a digital twin in the field of biodiversity is Green Cubes Digital Reality, which has been developed by green-tech company R-evolution. A Green Cube consists of a range of geolocated data points that are attached to a cubic meter within a plot of land, having been collected through technologies such as satellite imagery, LiDAR instruments, audio and camera traps, soil sampling, handheld radars, and air pollution sensors. This 'unit of nature' can be used to compare the differences between two locations over time and across a wide range of values such as forest height and profile, flora and fauna richness and abundance, soil quality and biodiversity, and air pollution, among others.

Digital twin solutions can especially benefit those sectors, such as mining, that exert a large footprint on biodiversity but are also critical to meeting global societal goals. For these sectors, digital twins offer the opportunity to minimise impacts while simultaneously improving operational efficiency and supporting the implementation of nature-positive practices.

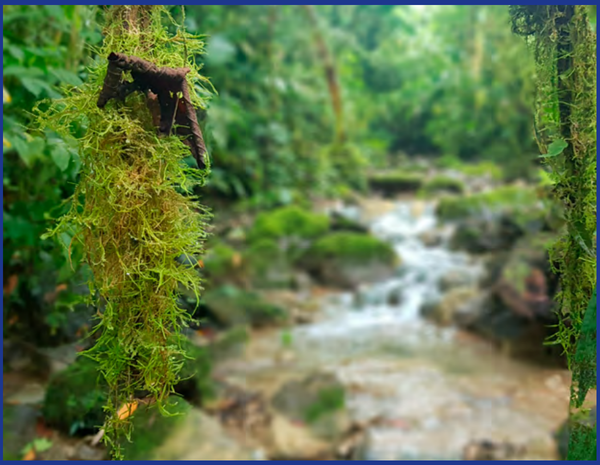
In this report, the mining sector is used as a case study to illustrate the potential application of digital twins to biodiversity monitoring and reporting. Mining represents one of the top 5 industry sectors with the highest impact on biodiversity, with 40% of all mining activity globally occurring in areas with declining ecological integrity. At the same time, it is also vital to the energy transition, as estimates suggest that 6.5 billion tons of end-use materials will be required for this purpose between 2022 and 2050.

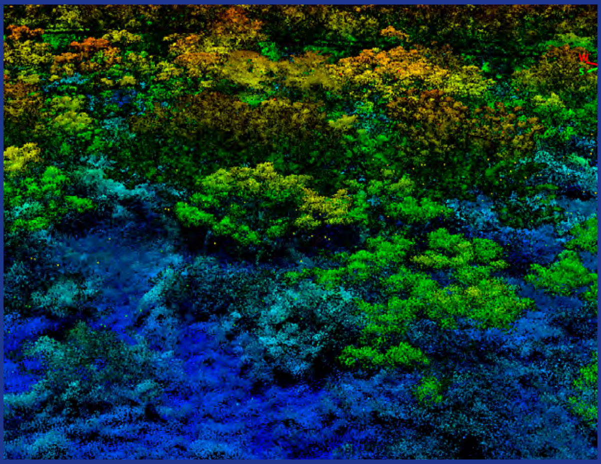
Due to its relevance to biodiversity, the mining sector is already subjected to significant regulatory requirements, and companies are also likely to face increasing pressure to report high-quality biodiversity data as part of the relevant disclosure frameworks. Nevertheless, an industry benchmarking conducted by KPMG Sweden shows that current levels of maturity on biodiversity monitoring and reporting still present significant margins for improvement.

In this context, digital twin solutions such as Green Cubes Digital Reality could have multiple use cases, including (i) enhanced data collection and analysis to support environmental impact assessments, licensing applications and mine rehabilitation activities; (ii) the generation of reliable data to be reported as part of corporate sustainability disclosures; (iii) the use of real-time information and predictive modelling to better integrate biodiversity in a company's strategy and business model; and (iv) the creation of new revenue opportunities through high-integrity carbon and biodiversity credits.

To ensure that digital twin solutions are deployed effectively and efficiently, companies must consider such solutions as part of a comprehensive journey towards greater maturity on biodiversity.

While most companies will likely face a growing need to improve the availability and quality of their biodiversity information, they will also have to ensure that the related data, tools and technologies are embedded in a coherent biodiversity governance strategy. Taking a comprehensive journey towards greater maturity on nature-related topics, including the consolidation of available data, the full assessment of biodiversity impacts, dependencies and risks, and the identification of priority sites where digitally-enabled monitoring is most beneficial or urgent, will ensure that digital twins add real value and support companies in their nature-positive transition.





1. A time for action

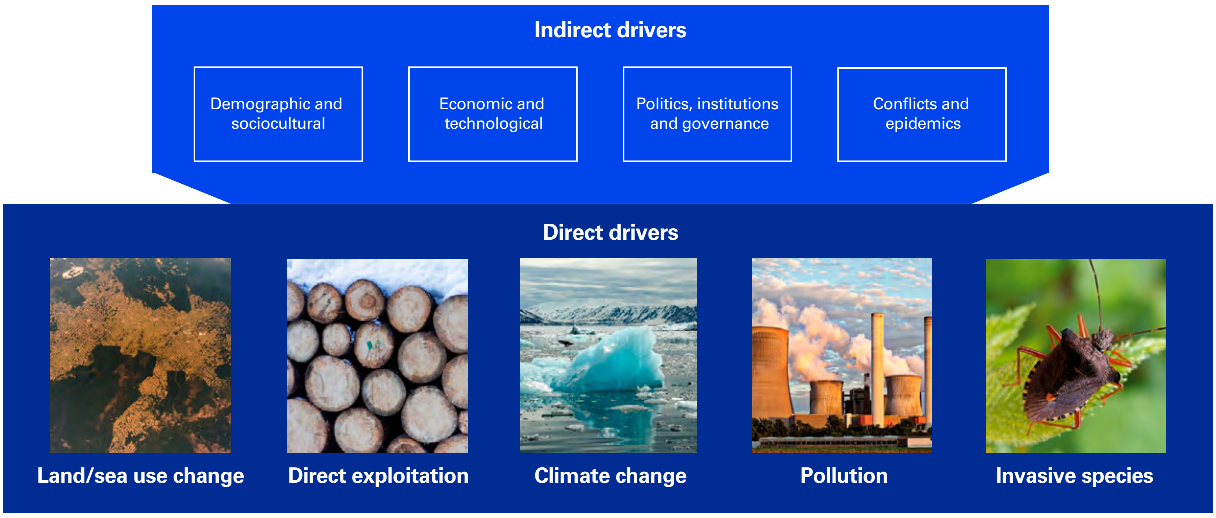
1.1. From biodiversity loss to nature positive

Biodiversity refers to the variety of all life forms on Earth and the ecological complexes of which they are part, including at the level of genes, species and eco-systems. By underpinning the provision of ecosystem services such as clean air, food, and water, disease and flood control, and climate regulation, biodiversity plays a significant role in the global economy. Estimates suggests that USD 44 trillion, or over half of the world's gross domestic product, could be potentially threatened by nature loss.[1]

Despite its importance, biodiversity is rapidly declining. Across the globe, the loss of species and ecosystems are disappearing faster than any time in human history, resulting in the deterioration of many of nature's vital contributions to human well-being[2], resulting in the deterioration of many of nature's vital contributions to human well-being and potentially contributing to the transgression of the planetary boundaries that ensure the stability of the entire Earth System.[3]

The main drivers of biodiversity loss are changes in land- and sea-use (i.e. the transformation of natural landscapes to human-dominated environments, for example the conversion of forests into grassland or urban areas), the direct exploitation of organisms (e.g. through hunting, timber extraction and fishing), climate change, pollution, and the introduction and spread of invasive alien species (IAS) [see Figure 1]. These drivers, which have accelerated during the last 50 years, are increasingly interacting with each other and leading to biodiversity loss through pathways such as changes in the extent and composition of habitats, effects on the composition of biological communities and on species populations, extreme weather events, increased concentrations of pollutants in the environ-ment, and changes in the distribution of diseases and pests.[4]

Figure 1. **Main drivers of biodiversity loss.** Source: KPMG, based on IPBES (2019).



1 WEF, 2020, The Future of nature and business, New nature economy report II, World Economic Forum (https://www3.weforum.org/docs/WEF_The_Future_Of_Nature_And_Business_2020.pdf) accessed 16 October 2024.

2 IPBES, 2019, Global assessment report on biodiversity and ecosystem services, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (https://www.ipbes.net/global-assessment) accessed 16 October 2024; WWF, 2024, Living planet report 2024 – A system in peril, WWF (https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/5gc2qerb1v_2024_living_planet_report_a_system_in_peril.pdf) accessed 23 October 2024.

3 Katherine Richardson and others, 2023, 'Earth beyond six of nine planetary boundaries' Science Advances, 9(37), eadh2458 (https://doi.org/10.1126/sciadv.adh2458)

4 IPBES, 2019, Global assessment report on biodiversity and ecosystem services, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (https://www.ipbes.net/global-assessment) accessed 16 October 2024.

“Despite its importance

to our economies and societies, biodiversity is rapidly declining, the loss of species and ecosystems occurring faster than any time in human history.”

Traditionally, land-use change (for terrestrial and freshwater ecosystems) and overfishing (for marine ecosystems) have had the largest negative impact on biodiversity. At the same time, climate change and pollution, which already affect human health and well-being in multiple direct ways (e.g. floods, heatwaves, exposure to harmful chemicals), are emerging as important drivers of biodiversity loss in their own right. For this reason, biodiversity loss is now considered together with climate change and pollution as one of three intersecting ‘planetary crises,’[5] which are all fundamentally rooted by unsustainable patterns of production and consumption’.[6]

Negative trends in biodiversity and ecosystems are projected to continue or worsen in many future scenarios of socioeconomic change. However, it is still possible to halt and reverse biodiversity loss and to put nature on a path to recovery, in line with the 2050 long-term goals and 2030 intermediate targets agreed by the Parties to the United Nations (UN) Convention on Biological Diversity (CBD) in 2022 as part of the Kunming-Montreal Global Biodiversity Framework (GBF) [see Figure 2 on page 9]. To do so, it will not be enough to mitigate pressures on biodiversity and reduce the rate at which species and ecosystems are disappearing. The world will effectively have to bring the net rate of nature loss to zero (for example by preserving intact natural areas and compensating for unavoidable losses through ecosystem restoration) and eventually move to a nature-positive trajectory characterised by a fundamental shift shift in business models and consumption and production patterns [see Figure 3 on page 10].[7]

5 Inger Andersen, 2020, ‘The triple planetary crisis: Forging a new relationship between people and the earth’, United Nations Environment Programme (https://www.unep.org/news-and-stories/speech/triple-planetary-crisis-forging-new-relationship-between-people-and-earth) accessed 16 October 2024.

6 United Nations Environment Programme, 2024, Global resources outlook 2024: Bend the trend – Pathways to a liveable planet as resource use spikes, International Resources Panel (https://www.resourcepanel.org/sites/default/files/documents/document/media/gro24_full_report_1mar_final_for_web.pdf) accessed 17 October 2024.

7 Harvey Locke and others, 2021, A nature-positive world: The global goal for nature, Nature Positive Initiative (https://www.naturepositive.org/app/uploads/2024/03/A-Nature-Positive-World-The-Global-Goal-for-Nature.pdf) accessed 16 October 2024.

Figure 2. **The 2050 goals and 2030 targets of the Kunming-Montreal Global Biodiversity Framework.**
Source: KPMG, based on CBD (2020).

4 overarching global goals for 2050:

- **A** — Nature loss is halted and on the way to recovery
- **B** — Biodiversity is sustainable used and managed for the benefit of present and future generations
- **C** — The monetary and non-monetary benefits of biodiversity are shared fairly and equitably
- **D** — Finance and resources are mobilised and aligned to fully implement the Global Biodiversity Framework

23 targets for 2030:

Reducing threats to biodiversity

1 Plan and Manage all Areas To Reduce Biodiversity Loss
2 Restore 30% of all Degraded Ecosystems
3 Conserve 30% of Land, Waters and Seas
4 Halt Species Extinction, Protect Genetic Diversity, and Manage Human-Wildlife Conflicts
5 Ensure Sustainable, Safe and Legal Harvesting and Trade of Wild Species
6 Reduce the Introduction of Invasive Alien Species by 50% and Minimize Their Impact
7 Reduce Pollution to Levels That Are Not Harmful to Biodiversity
8 Minimize the Impacts of Climate Change on Biodiversity and Build Resilience

Meeting people's needs through sustainable use and benefit-sharing

9 Manage Wild Species Sustainably To Benefit People
10 Enhance Biodiversity and Sustainability in Agriculture, Aquaculture, Fisheries, and Forestry
11 Restore, Maintain and Enhance Nature's Contributions to People
12 Enhance Green Spaces and Urban Planning for Human Well-Being and Biodiversity
13 Increase the Sharing of Benefits From Genetic Resources, Digital Sequence Information and Traditional Knowledge

Tools and solutions for implementation and mainstreaming

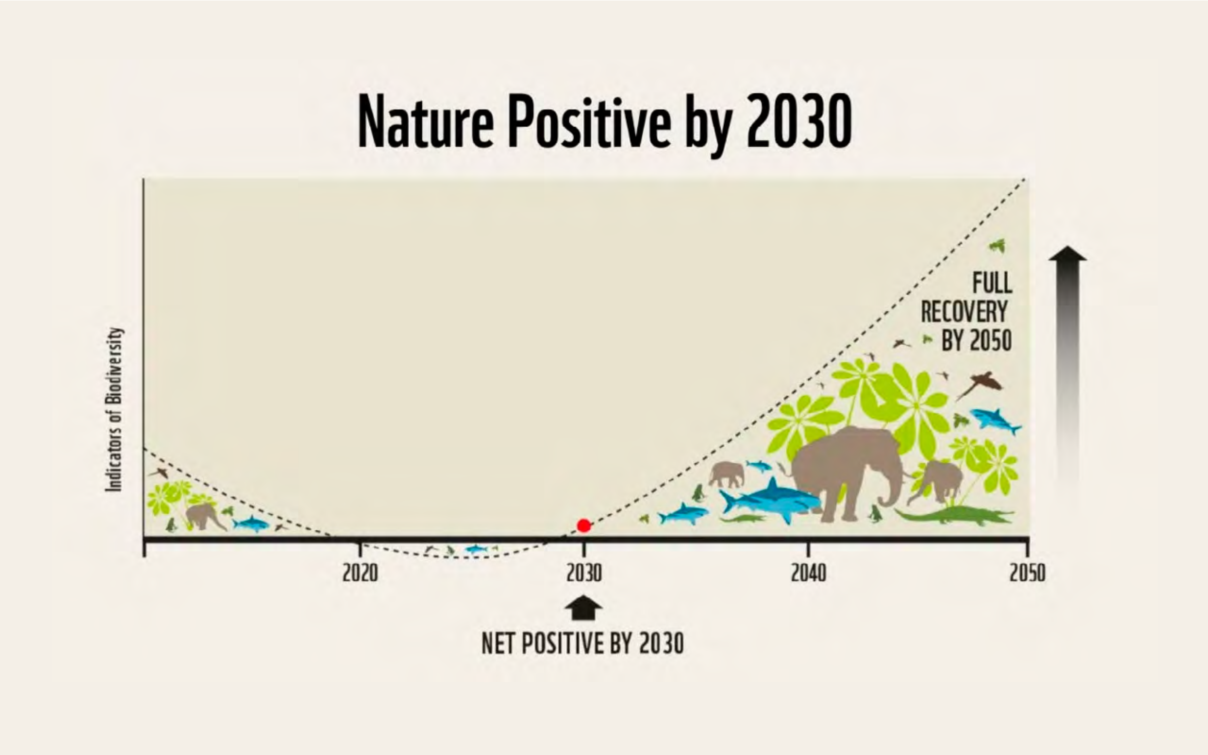
14 Integrate Biodiversity in Decision-Making at Every Level
15 Businesses Assess, Disclose and Reduce Biodiversity-Related Risks and Negative Impacts
16 Enable Sustainable Consumption Choices To Reduce Waste and Overconsumption
17 Strengthen Biosafety and Distribute the Benefits of Biotechnology
18 Reduce Harmful Incentives by at Least $500 Billion per Year, and Scale Up Positive Incentives for Biodiversity
19 Mobilize $200 Billion per Year for Biodiversity From all Sources, Including $30 Billion Through International Finance
20 Strengthen Capacity-Building, Technology Transfer, and Scientific and Technical Cooperation for Biodiversity
21 Ensure That Knowledge Is Available and Accessible To Guide Biodiversity Action
22 Ensure Participation in Decision-Making and Access to Justice and Information Related to Biodiversity for all
23 Ensure Gender Equality and a Gender-Responsive Approach for Biodiversity Action

"The concept of nature positive

has been defined as a global societal goal to "halt and reverse nature loss by 2030 on a 2020 baseline, and achieve full recovery by 2050."

(Definition from Nature Positive Initiative)

Figure 3. **The trajectory of nature positive by 2030, according to the definition advanced by the Nature Positive Initiative.**
Source: Nature Positive Initiative (2021).



This shift, which will require transformative changes in economic, societal, and governance systems, will not be achievable without a whole-of-society approach, involving not only governments but also local authorities and communities, indigenous people, civil society organisations and, increasingly, the business and finance community. In turn, a whole-of-society approach will only be possible if all these stakeholders recognise the economic value of intact biodiversity, which is still not reflected in market prices even though our economies are fundamentally embedded within nature.[8]

1.2. The opportunities and expectations for business action on biodiversity

Companies may have negative impacts on biodiversity and ecosystems through their core operations, supply chains and investment decisions. For example, companies in industries such as agriculture, forestry and mineral extraction are major drivers of land-use change, resulting in the loss and degradation of habitats, but also contribute to the emissions of chemicals and other pollutants to air, soils and water, which can pose risks to both terrestrial and aquatic ecosystems.[9] At the same time, businesses depend on the goods and services provided by nature as input for their products and processes, including raw materials, clean water, fertile soils, climate regulation, and protection against extreme weather events. In addition, biodiversity loss is also a systemic risk that can affect entire economies and industries, increasing the cost of raw materials and the risk of supply chain disruptions.

In other words, the need for companies to move to a nature-positive trajectory and integrate biodiversity in their strategies and business models is not only essential

8 Partha Dasgupta, 2021, The economics of biodiversity: The Dasgupta review, HM Treasury (https://assets.publishing.service.gov.uk/media/602e92b2e90e07660f807b47/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf) accessed 16 October 2024.

9 IUCN, 2021, Guidelines for planning and monitoring corporate biodiversity performance, International Union for the Conservation of Nature (https://portals.iucn.org/library/sites/library/files/documents/2021-009-En.pdf) accessed 16 October 2024).

to mitigate their own negative impacts, it can also offer a range of benefits in terms of, among other aspects:

- new revenue opportunities (e.g. new markets, products or business models);
- cost savings (e.g. due to resource-use efficiency or efficient product design);
- risk management (including increased resilience to the impacts of climate change and environmental degradation);
- regulatory compliance and avoidance of financial penalties (which in some cases can include the withdrawal of a licence to operate, or a prohibition from placing a non-compliant product on the market);
- improved market valuation and social license to operate.[10]

From this perspective, the transition to nature-positive practices can be seen as a major market opportunity, estimated by the World Economic Forum to unlock USD 10 trillion annually by 2030. For example, at USD 154 billion, it is estimated that current annual investments in nature-based solutions are only a third of what would be needed by 2030[11] in order to meet global climate and nature goals.[12] New, bankable business models for restoring biodiversity across the built environment, energy, extractive and food and land-use sectors could help bridge this gap.

In recent years, in connection with the adoption of global policy frameworks such as the 2030 Agenda for Sustainable Development and, most importantly, the GBF, there has been increased recognition of the role that companies should play in the fight to halt and reverse the loss of biodiversity. Among its 2030 targets, the GBF's Target 15 called on countries to ensure that businesses and financial institutions:

- regularly monitor, assess and transparently disclose their risks, dependencies and impacts on biodiversity;
- provide information needed to consumers to promote sustainable consumption patterns; and
- report on compliance with relevant regulations on access to genetic resources and the sharing of the benefits deriving from their utilisation

At the European level, the EU Biodiversity Strategy to 2030 and other associated strategies under the European Green Deal restated the business case for minimising impacts on biodiversity and investing in nature conservation and restoration, while simultaneously emphasising the importance of better integrating biodiversity considerations in business decision-making.

These global and regional calls have already led to new regulations and demands on companies, ranging from the EU Nature Restoration Law and the EU Deforestation Regulation to the United Kingdom's requirements on biodiversity net gain.[13] In the EU, such calls have also prompted the inclusion of biodiversity in broader efforts to steer private sector finance and investments towards sustainability, as illustrated by the EU Taxonomy for Sustainable Activities, the European Green Bond Standard and the EU Sustainable Finance Disclosure Regulation. Finally, they have inspired a number of regulatory and super-visory initiatives aimed at identifying, assessing and managing nature-related financial risks and opportunities [see Figure 4 on page 12].

The drive towards more ambitious, harmonised and transparent corporate sustainability reporting, including on nature-related topics, is one of the most consequential among such policy developments. The need to improve the quality of biodiversity disclosures is now particularly urgent for the roughly 50,000 companies that are in scope of the EU Corporate Sustainability Reporting Directive (CSRD) [see Table 1 on page 12], as they will have to report against the relevant European Sustainability Reporting Standards (ESRS) if biodiversity or other nature-related topics (e.g. water and marine resources, pollution) are found to be material to their operations or in their value chain.[13]

10 The Biodiversity Consultancy, 2023, 'Net positive to nature positive', The Biodiversity Consultancy (https://www.thebiodiversityconsultancy.com/insights/net-positive-to-nature-positive-144/) accessed 16 October 2024.

11 WEF, 2020, The future of nature and business, New nature economy report II, World Economic Forum (https://www3.weforum.org/docs/WEF_The_Future_Of_Nature_And_Business_2020.pdf) accessed 16 October 2024. .

12 UNEP, 2022, State of finance for nature. Time to act: Doubling investment by 2025 and eliminating nature-negative finance flows, United Nations Environment Programme (https://wedocs.unep.org/20.500.11822/41333) accessed 16 October 2024.

13 For an overview of these initiatives, see FSB, 2024, Stocktake on nature-related risks. Supervisory and regulatory approaches and perspectives on financial risk, Financial Stability Board (https://www.fsb.org/wp-content/uploads/P180724.pdf) accessed 16 October 2024.

Figure 4. **Timeline with key examples of recent regulatory, policy and standard-setting initiatives on business and biodiversity.** Source: KPMG.

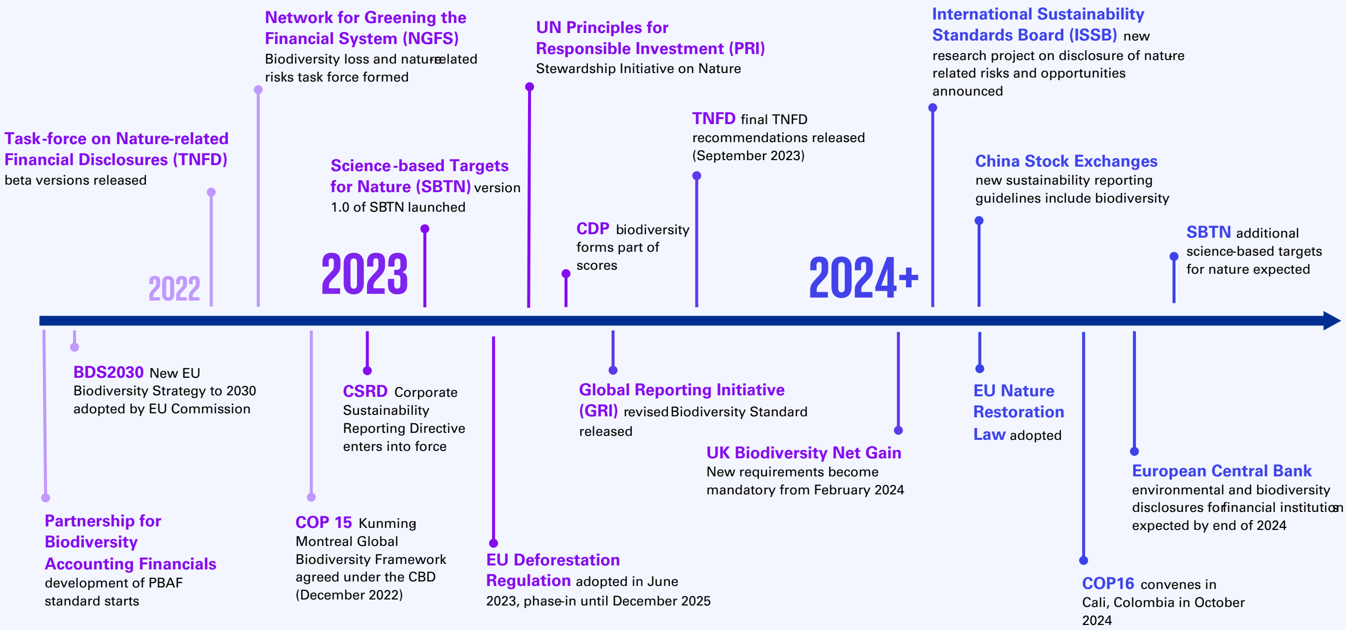


Table 1. **Timeline for the implementation of the CSRD by size of covered undertakings.** Source: KPMG, based on the text of the CSRD.

Financial year	Companies in scope
2024	Large undertakings already covered by the EU Non-Financial Reporting Directive (NFRD)
2025	Other large undertakings not previously covered by the NFRD
2026	Listed SMEs (except micro undertakings), small and non-complex credit institutions, and captive insurance undertakings
2028	Non-EU companies with a net turnover above EUR 150 million in the EU if they have at least one subsidiary or branch in the EU exceeding certain thresholds

Outside of Europe, similar disclosure requirements are also rapidly emerging, as illustrated by the recent adoption, by three major Chinese stock exchanges, of new sustainability reporting guidelines which include specific articles on biodiversity and ecosystems. Even beyond these regulatory initiatives, however, voluntary frameworks such as the Taskforce on nature-related financial disclosures (TNFD), the Science-based Targets for Nature guidance (SBTN) and the revised GRI 101: Biodiversity 2024 standard released by the Global Reporting Initiative (GRI) are likely to encourage more companies to disclose their impacts on biodiversity in order to meet the demands of investors, regulators and other stakeholders. Failure to do so could expose these companies to significant financial risks. For example, recent research by the European Commission suggests that lending institutions are increasingly incorporating nature-related investor information into their financing decisions,[14] and initiatives such as Nature Action 100 have contributed to outline more ambitious investor expectations for corporate action on biodiversity.

14 Annette Becker and others, 2023, Loan pricing and biodiversity exposure: Nature-related spillovers to the financial sector, JRC Working Papers in Economics and Finance 2013/11, European Commission (https://publications.jrc.ec.europa.eu/repository/handle/JRC135774) accessed 16 October 2024.

"All businesses, regardless of their size, location or sector

depend upon and have a direct or indirect impact on biodiversity and ecosystem services through their operations, supply chains or investment choices.[15] *The need for companies to move to a nature positive trajectory is not only essential to mitigate negative impacts – it is also a significant market opportunity."*

15 UN Global Compact and IUCN, 2012, A framework for corporate action on biodiversity and ecosystem services, United Nations Global Compact and International Union for the Conservation of Nature (https://d306pr3pise04h.cloudfront.net/docs/issues_doc%2FEnvironment%2FBES_Framework.pdf) accessed 16 October 2024.

2. The challenge of biodiversity monitoring and reporting

2.1. The importance of biodiversity data for companies

Whether their objective is to mitigate nature-related risks, or to ensure a return on nature-positive investments, companies need to be able to measure biodiversity trends and impacts due to their operations and along their value chain. For example, biodiversity data may be necessary to assess and manage potential negative impacts at site-level, demonstrate that a company complies with certain regulatory permits, set company-wide targets and actions, and measure progress against stated commitments. Increasingly, as biodiversity emerges as a key topic across various mandatory and voluntary frameworks for sustainability reporting, such data also become necessary for companies to identify and disclose their nature-related impacts, dependencies and risks.

Because biodiversity itself is an inherently multi-dimensional concept, the measures of biodiversity that may be relevant for a company can vary significantly depending on factors such as the impact drivers that the company contributes to, the locations in which it operates, or the type of risk management actions that it needs to implement.

Besides more qualitative, process-based information such as the existence of company-wide biodiversity strategies or site-level biodiversity management plans, the types of biodiversity indicators that are normally used for monitoring and assessment purposes include:

- the distance of a company's site from biodiversity-sensitive areas that may be affected by its activities;
- trends in the population or conservation status of certain indicator species within a given area, especially those known to be impacted by the company's operations;
- the extent (i.e. area coverage) and condition (i.e. quality, in terms of composition, structure and function) of an ecosystem, especially ecosystems that may be particularly threatened, unique or vulnerable to human interference;
- trends in specific pressures (often also referred to as 'impact drivers') exerted on the environment (e.g. emissions of a harmful pollutant to water, or the rate of conversion of a natural area through changes in land use); and
- composite indicators that aggregate different data sources into a single index in order to give an overall indication of the state of, or trends in, biodiversity in a given area (e.g. the Biodiversity Intactness Index, which estimates changes in an area's native biodiversity as a result of human pressures, or the Species Threat Abatement and Restoration (STAR) metric, which measures the contribution of threat abatement and habitat restoration action to reduce the risk extinction of species).

Evidently, each of the metrics that could be chosen to track progress against these indicators has specific data requirements and entails different levels of efforts in terms of data collection and analysis. For example, measuring actual changes in biodiversity at a site level may necessitate in situ monitoring efforts (e.g. field surveys to estimate the number of individuals of a certain species living in the area), while the screening of a potential impact on biodiversity based on the presence of sensitive areas in the vicinity of a company's assets could be conducted remotely, based on existing tools such as the International Biodiversity Assessment Tool (IBAT) which only need the assets' locations as input data. Furthermore, most biodiversity metrics (regardless of their level of complexity) currently require the use of secondary datasets in addition to (or as a proxy for) primary data [see Table 2 on page 15]. While some of these datasets may be open source, others will entail a certain cost, either because the dataset itself is commercial or because a tool is often purchased in order to access and analyse the data.

Table 2. **Example of biodiversity metrics and their reliance on secondary datasets.** Source: KPMG, based on cited sources

Example metric	Type of metric	What does it measure	Example secondary dataset	Purpose of the secondary dataset
Number or extent of assets located in or near biodiversity-sensitive areas	Site location	Number and area coverage of company sites that are potentially impacting biodiversity-sensitive areas	Key Biodiversity Areas (KBAs) and World Database on Protected Areas (WDPA), regional and national protected area datasets (e.g. Natura 2000)	To measure the distance of a biodiversity-sensitive area from a company's area of influence (and thus its potential impact)
Species with habitats in areas affected by operations	State of species	Total number of threatened species (potentially) present in a certain area, and their conservation status	IUCN Red List of Threatened Species and related species distribution maps	To provide information on the range and threat status of species that may be present in the area affected by a company's operations (or that are known to be present based on field surveys)
Extent of land-use change / land-use intensity	Ecosystem extent / Impact driver: land-use change	Change in land cover or in land-use as a result of business activities	Geospatial data layers (e.g. land-cover and land-use maps from satellite imagery)	To overlay with asset location data in order to assess impact of business activities on land cover/land-use change
Mean Species Abundance (MSA)[16]	Condition of ecosystems	Changes in the mean abundance of native species relative to their abundance in undisturbed ecosystem	• EXIOBASE input-output database • Life cycle assessment (LCA) data • GLOBIO pressure-relationship data	• EXIOBASE: to translate company data on products and purchases into data on consumption and emissions (when actual data are missing); • LCA data: to link commodities and emissions to pressures • Pressure-relationship data in GLOBIO model: to turn pressures into impacts (i.e. calculating the MSA for a specific pressure)
Potentially Disappeared Fraction (PDF)[17]	Condition of ecosystems / Species extinction risk	Changes in local species richness relative to a local reference site (normally used in LCA approaches)	IUCN Red List of Threatened Species and related data on threats, distribution and species extinction risk / LCA data, pressure-impact data	To calculate the PDF, based on company data (e.g. purchases, emissions)
Species Threat Abatement and Restoration Metric (STAR)[18]	Reduction of species extinction risk	Potential contribution of threat abatement and restoration activities to reducing species extinction risk	IUCN Red List of Threatened Species and related data on threats, distribution and species extinction risk	To calculate the STAR score, based on the location of a company's assets
Biodiversity Intactness Index (BII)[19]	Condition of ecosystems	Average abundance of native terrestrial biodiversity compared to an undisturbed reference state	PREDICTS database of ecological surveys of multiple sites differing in land use and related pressures	To run statistical models of how biodiversity responds to anthropogenic pressures

16 Mark Goedkoop, Axel Rossberg and Marina Dumont, 2023, Bridging the gap between biodiversity footprint metrics and biodiversity state indicator metrics, PRé Sustainability (https://www.biodiversity-metrics.org/uploads/1/2/7/5/127509512/bridging_the_gap_between_biodiversity_footprint_and_biodiversity_state_indicator_metrics_2e.pdf) accessed 16 October 2024.

17 Ibid.

18 Louise Mair and others, 2021, 'A metric for spatially explicit contributions to science-based species targets', Nature ecology and evolution 5, pp.836-844 (https://doi.org/10.1038/s41559-021-01432-0).

19 Adriana de Palma and others, 2021, 'Annual changes in the Biodiversity Intactness Index in tropical and subtropical forest biomes', Scientific reports 11, 20249 (https://doi.org/10.1038/s41598-021-98811-1).

Despite any feasibility or cost consideration, however, it would rarely be possible for a company to focus on a single indicator to assess its interface with biodiversity. Not only do different indicators capture different dimensions of biodiversity, as noted above, but they also serve different purposes (for example, quantifying impact drivers as opposed to tracking the effectiveness of investments in habitat restoration). In other words, choosing frameworks of indicators (and related metrics) that capture the complex ways in a company interacts with nature can help mitigate the risk of neglecting certain types of impacts or possible trade-offs between them.

2.2. What are the main disclosure requirements on biodiversity and ecosystems in existing reporting frameworks?

As mentioned in the previous sections, the increasing focus on biodiversity within the broader landscape of corporate sustainability reporting has emerged as a key driver of companies' efforts to collect biodiversity data. Many of the recent initiatives in this field have, as their primary aim, to increase the transparency and comparability of nature-related disclosures that can have an impact on investment risk. However, they are also indirectly expected to improve the availability and quality of data as a starting point for taking further business action on biodiversity, from informing corporate strategies and governance to setting targets and monitoring their implementation. Furthermore, to the extent that such initiatives are incorporated into binding regulatory requirements at regional or national levels, they become part of the broader 'biodiversity rulebook' that companies must comply with.

As of 2024, the ESRS, TNFD and GRI represent the three most important frameworks for identifying, assessing and disclosing biodiversity impacts and dependencies [see Box 1 on page 17]. Compared with reporting requirements under the ESRS (and especially the so-called ESRS E4), which are now mandatory for companies that are in scope of the CSRD, the disclosure recommendations contained in the TNFD and GRI 101 are voluntary in nature. At the same time, the GRI remain the most dominant standards for sustainability reporting at a global level,[20] and the work carried out under the TNFD has rapidly assumed a significance comparable to that of the Task force on climate-related financial disclosures in the area of climate change.

20 KPMG International, 2022, Big shifts, small steps. Survey of sustainability reporting 2022, KPMG (https://assets.kpmg.com/content/dam/kpmg/se/pdf/komm/2022/Global-Survey-of-Sustainability-Reporting-2022.pdf) accessed 16 October 2024.

Box 1. **The ESRS, TNFD and GRI frameworks.**

The Global Reporting Initiative (GRI) is an independent not-for-profit organisation that helps develop voluntary global standards for sustainability reporting. GRI standards are currently used by more than 14,000 organisations in over 100 countries. The *GRI 101: Biodiversity 2024* standard, which will be applicable starting in 2026, expands upon and replaces the previous *GRI 304: Biodiversity 2016.* The new framework contains significantly more detailed disclosure requirements compared to the 2016 standard. Not only does it require organizations to report on their sites' proximity to, and impacts on, ecologically-sensitive areas, but it also covers disclosures relating to direct drivers of biodiversity loss, changes in the state of biodiversity, policies against biodiversity loss, and management of biodiversity impacts, among others.

The Taskforce on Nature-related Financial Disclosures (TNFD) is a market-led, science based, and government -supported global initiative, providing a risk management and disclosure framework focused on nature-related financial risks (thus including biodiversity). As part of its 14 recommended disclosures, which include aspects relating to governance, strategy, risk and impact management, and metrics and targets, the TNFD framework has developed a list of core and additional disclosure metrics covering topics such as drivers of nature change, extent and condition of ecosystems, state of species, and impacts and dependencies on ecosystem services. Although the TNFD framework is currently voluntary, a growing number of organisations have already committed to report against the TNFD recommendations over the next two years.

The European Sustainability Reporting Standards sets out the requirements for reporting on biodiversity and ecosystems for companies that are in scope of the EU's Corporate Sustainability Reporting Directive (CSRD). The ESRS E4 standard deals directly with biodiversity, requiring companies to disclose, among other topics, their relevant policies, actions, resources, targets and metrics (the latter covering the main impact drivers of biodiversity loss, state of species, and extent and condition of ecosystems). However, disclosure requirements under other ESRS, most notably ESRS E1 (Climate Change), E2 (Pollution) and E3 (Water and Marine Resources) are also important for understanding the extent of companies' nature-related impacts, dependencies, risks and opportunities. While the CSRD and its ESRS are mandatory for in-scope companies, some disclosures under E4 are framed as voluntary [see Table 3 on page 19].

In the future, the TNFD could even inform the global standard-setting work of the International Sustainability Standards Board (ISSB), as the latter is currently carrying out a research project on biodiversity that explicitly plans to build upon the TNFD's recommendations. Given that a growing number of countries have recently started to incorporate the ISSB standards in their legislation on sustainability disclosures (for example Australia, Brazil and the UK), this could potentially lead to the TNFD recommendations indirectly becoming a binding framework across many jurisdictions.

To put it simply, regardless of whether a company will immediately fall under a mandatory reporting framework, such as the one created by the CSRD, it will likely face growing pressure to align its approach to biodiversity assessment and disclosure to this emerging global baseline. As a result, understanding the disclosure requirements (or recommendations) included in the ESRS, TNFD and GRI can provide important insights into how companies should approach the measurement, assessment and disclosure of their impacts and dependencies on biodiversity.

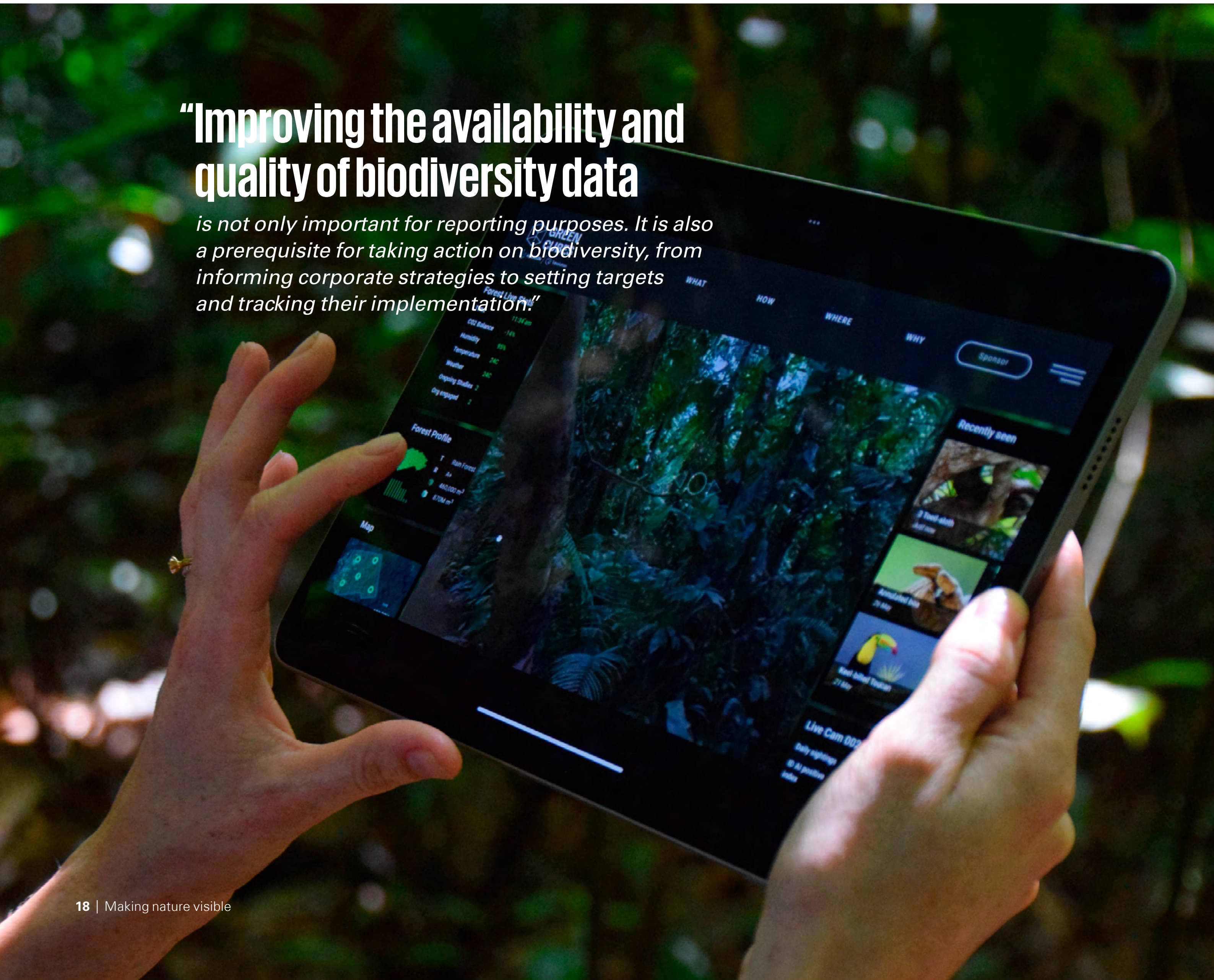
There are some obvious differences between the ESRS, TNFD and GRI. To start with, the ESRS and TNFD are disclosure standards, whereas the TNFD offers a full-fledged approach to risk management and disclosure, which includes (but is not limited to) disclosure recommendations. In addition, the three initiatives use slightly different terminologies to refer to concepts such as those of impact driver or biodiversity-sensitive area, among others, and they also take different approaches to issues such as the level of detail of value chain disclosures, the definition of materiality and the type of impacts and dependencies covered.[21]

21 Johan Lammerant and others, 2024, Biodiversity disclosure initiatives, Thematic report, EU Business & Biodiversity Platform (https://green-business.ec.europa.eu/news/publication-thematic-report-biodiversity-disclosure-initiatives-2024-05-08_en) accessed 16 October 2024.

Nevertheless, as shown by the correspondence table below, the ESRS, TNFD and GRI generally show a high level of alignment in terms of required biodiversity disclosures. More specifically, while they all offer a certain degree of flexibility in the choice of relevant metrics, the three initiatives go beyond a qualitative description of impacts and risk management actions, requiring the disclosure of quantitative data points relating to topics such as the distance of a company's assets to biodiversity-sensitive areas, the nature-related impact drivers that the company contributes to, and its impacts on the state of living species and ecosystems [see Table 3 on page 19].

Of note, all three initiatives also have partly overlapping disclosure requirements with respect to companies' biodiversity strategies, targets and actions, which are not reflected in the table below and are beyond the scope of this report. Furthermore, by explicitly referring to the 'Locate, Evaluate, Assess and Prepare' (LEAP) framework developed by the TNFD, the ESRS and GRI aim to consolidate a common understanding of how corporates should identify, assess and disclose their interactions with nature.[22]

22 In addition to the report cited in the previous footnote, EFRAG and TNFD have also recently published a mapping that provides a more complete picture the overall correspondence between the ESRS and the TNFD disclosures. For more information, see EFRAG and TNFD, 2024, TNFD-ESRS correspondence mapping, European Financial Reporting Advisory Group and Task Force on Nature-related Financial Disclosures (https://www.efrag.org/sites/default/files/sites/webpublishing/SiteAssets/TNFD%20ESRS%20Correspondence%20mapping%20Final.pdf) accessed 16 October 2024.

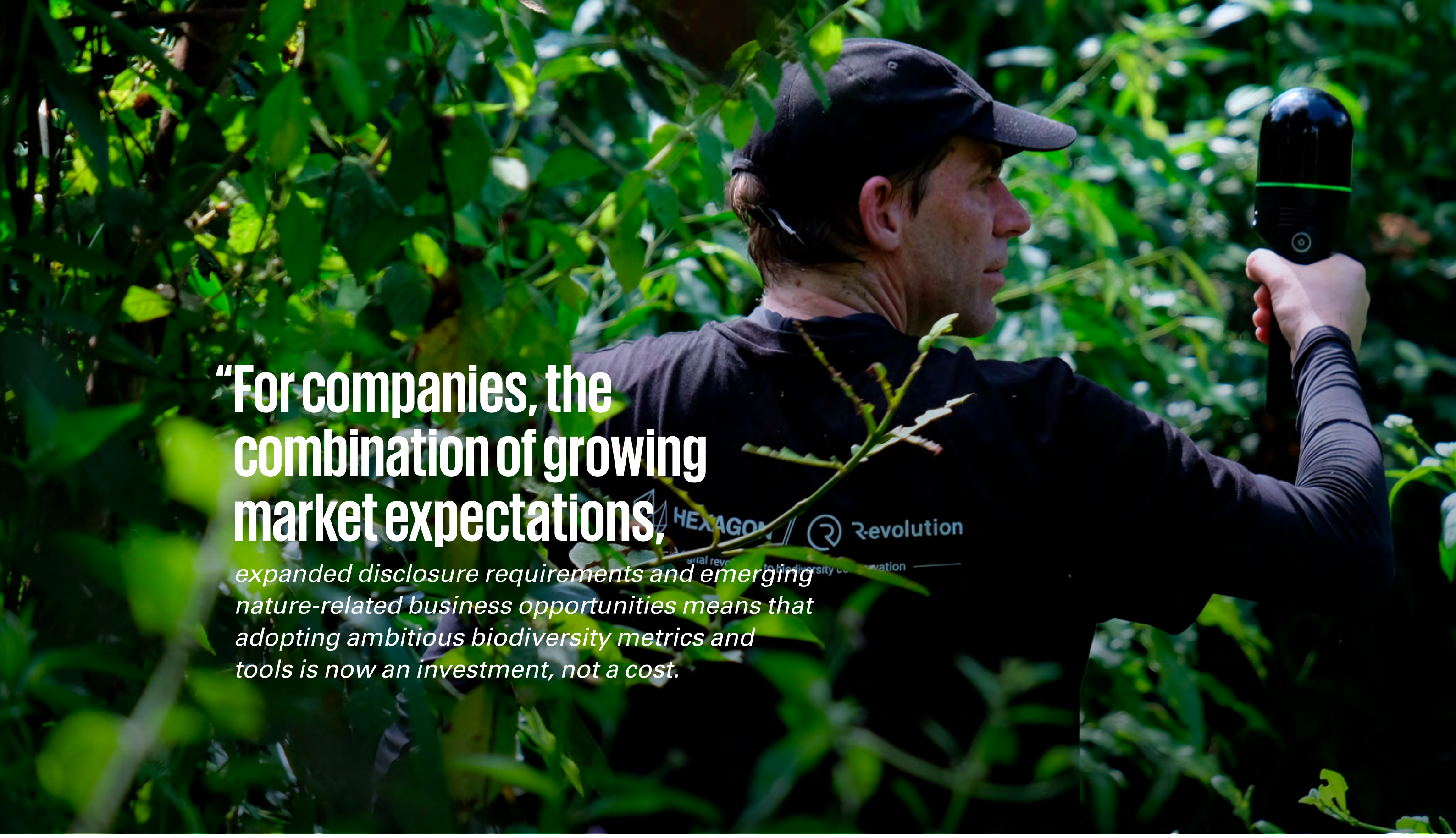


"Improving the availability and quality of biodiversity data

is not only important for reporting purposes. It is also a prerequisite for taking action on biodiversity, from informing corporate strategies to setting targets and tracking their implementation."

Table 3. **Correspondence mapping between biodiversity-relevant metrics contained in the TNFD disclosure recommendations, the GRI biodiversity standards (2024 and 2016 editions) and the ESRS E4-5 disclosure requirements.** Source: KPMG.

Type of metrics	ESRS E4-5	TNFD	GRI
Site location	**Mandatory**: Number and area of sites owned, leased or managed in or near protected areas of KBAs (DR35)	Locations of assets and activities (in own operations or value chains) that meet criteria for priority locations (not a specific metric, but a part of the assessment methodology)	**2024:** Location and size of sites with the most significant impacts on biodiversity; distance from ecologically-sensitive areas (split by type) (101-5) **2016:** Operational sites owned, leased, managed in, or adjacent to, protected areas or other areas of high biodiversity value (304-1)
Impact driver: land-use change	**Mandatory:** Relevant metrics (e.g. conversion of land cover over time; changes over time in the management of the ecosystem; fragmentation of habitats; changes in ecosystem structural and/or functional connectivity) (DR38) **Voluntary:** Land use based on a Life Cycle Assessment (DR36)	**Core metrics**: Total spatial footprint (C1.0); Extent of land/fresh-water/ ocean-use change (C1.1) **Additional metrics:** Land-use intensity (A1.0)	**2024:** Size and ecosystem/land/sea converted (101-6) **2016:** Significant direct and indirect impacts from construction, or manufacturing, mines and transport infrastructure (304-2)
Impact driver: climate change	Cross-reference to metrics disclosed in ESRS E1 (Climate change), e.g. GHG emissions (DR5a)	**Core metrics:** GHG emissions (n/a)	
Impact driver: pollution	Cross-reference to metrics disclosed in ESRS E2 (Pollution), e.g. emissions of pollutants to soil, air and water (DR5b)	**Core metrics:** Pollutants released to soil (C2.0); wastewater discharged (C2.1), plastic pollution (C2.4), non-GHG air pollutants (C2.4) **Additional metrics:** Light and noise pollution (A2.3)	**2024:** Quantity and type of pollutant generated (101-6) **2016:** Significant direct and indirect impacts from pollution (304-2)
Impact driver: resource extraction/waste	Cross-reference to metrics disclosed in ESRS E3 (Water) and ESRS E5 (Waste and circular economy) (DR5c-d)	**Core metrics:** Water withdrawal and consumption from areas of water scarcity (C3.0); waste generation and disposal (C2.2) **Additional metrics:** Total water consumption and withdrawal (A3.0)	**2024:** Water withdrawal and consumption; quantity, type and extinction risk of wild species exploited (101-6)
Impact driver: invasive species (IAS)	**Voluntary:** Metrics used to manage pathways of introduction and spread of IAS, and risks from IAS (DR39)	**Core metrics:** Measures against unintentional introduction of IAS (placeholder indicator – specific metrics not defined) (C4.0) **Additional metrics:** Number and extent of unintentionally introduced IAS (A4.0)	**2024**: Quantity, type and extinction risk of wild species exploited (101-6) **2016:** Significant direct and indirect impacts from introduction of IAS, pests and pathogens (304-2)
State of species	**Voluntary:** Relevant metrics (e.g. species population size, range or extinction risk; trends in species population; threat status of species, changes in relevant habitats) (DR40)	**Core metrics:** Species extinction risk (placeholder indicator – specific metrics not defined) (C5.0) **Additional metrics:** Use of wild species (e.g. quantities of wild species extracted from natural habitats) (A3.5); species population size (A5.4)	**2024:** Quantity, type and extinction risk of wild species exploited (101-6) **2016:** Reduction of species (304-2); IUCN red List species and national conservation list species with habitats in areas affected by operations (304-4)
Extent and condition of ecosystems	**Voluntary:** Area coverage of a particular ecosystem (e.g. forest cover); metrics measuring the quality of ecosystem relative to a pre-determined reference state; species richness and abundance indicators; habitat connectivity (DR41); land-use based on Life Cycle assessment (DR36)	**Core metrics:** Ecosystem condition (placeholder indicator – specific metrics not defined) (C5.0) **Additional metrics:** Area used for the production of natural commodities, by type of ecosystem (A3.4); ecosystem extent (e.g. change in habitat cover) (A5.1); ecosystem connectivity (A5.2)	**2024:** Type, size and condition of affected or potentially affected ecosystems (for both base year and current reporting year) (101-7) **2016:** Habitat conversion, changes in ecological processes, extent of areas impacted (304-2)
Ecosystem services	n/a	**Additional metrics:** Change in the availability and quality of ecosystem services impacted, or that the company depends upon (A6.0-6.1)	**2024:** Ecosystem services (and beneficiaries) affected or potentially affected (101-8)
Positive biodiversity impacts	n/a	**Additional metrics:** Wastewater treated/reused/recycled or avoided (A2.0); pollutants removed (A2.2); waste minimised, reused or recycled (A2.1); water replenished (A3.1); water loss mitigated (A3.3) etc.	**2024:** Area under restoration or rehabilitation, presence of biodiversity management plans etc. (101-2) **2016:** Habitats protected or restored (304-3)



"For companies, the combination of growing market expectations, *expanded disclosure requirements and emerging nature-related business opportunities means that adopting ambitious biodiversity metrics and tools is now an investment, not a cost.*

2.3. Choosing biodiversity measurement tools and metrics for companies: the need for a comprehensive approach

The ESRS, TNFD and GRI frameworks deliberately give companies some flexibility when choosing the biodiversity metrics to disclose in their annual reporting. For example, disclosure requirement 38 (DR38) in ESRS E4-5 states that "if the undertaking has concluded that it directly contributes to the impact drivers of land-use change, freshwater-use change and/or sea-use change, it shall report *relevant metrics*". Similarly, while the TNFD encourages organisations to report against indicators of ecosystem condition and species extinction risk (metric C5.0), it defines them as *placeholder indicators* owing to the lack of widely accepted metrics that could be used when disclosing such impacts.[23]

The approach chosen by the ESRS, TNFD and GRI reflects the broader challenges that are involved when seeking to monitor and report on the impacts of business activities on biodiversity. Some of these challenges relate to the intrinsic multi-dimensionality of biodiversity and to the availability and quality of the data that are needed to measure biodiversity impacts, aspects that have been introduced in section 2.1. For instance, it may be difficult for a company to collect primary data at site-level, as impacts on biodiversity may occur at multiple spatial and temporal scales and include not only direct impacts but also impacts that emerge as a result of cumulative or indirect pathways (for example, the increase in wildlife harvesting that may result from the development of new road infrastructure in biodiversity-rich areas). At the same time, there may gaps in existing secondary data sources (e.g. global and regional biodiversity databases), as these could have limited coverage beyond certain priority taxonomic groups and ecosystem types.

Besides data collection, another important challenge for companies seeking to improve their understanding of their nature-related impacts and dependencies is represented by the progressive emergence of a large number of tools and approaches to measure biodiversity (including many developed in-house by companies themselves) which can differ widely in terms of conceptual basis, methodology, purpose, scope, feasibility, and underlying data requirements [see Table 4 on page 21]. Several of these tools (or slightly modified versions of them) are also increasingly used by financial institutions in order to assess the biodiversity impact of their investment decisions, thus highlighting the importance of portfolio companies progressing to a higher level of maturity in their own use of such instruments.

23 For an overview of approaches to measure ecosystem condition, see Jacob Bedford and others, 2023, Measuring ecosystem condition – A primer for business, Aligning accounting approaches for nature, UNEP-WCMC, Capitals Coalition, Arcadis, ICF and WCMC Europe (https://capitalscoalition.org/wp-content/uploads/2023/10/Align_eco_condition_primer.pdf) accessed 16 October 2024.

Table 4. **Illustrative list of existing biodiversity measurement tools for companies.**
Source:KPMG, adapted from Johan Lammerant and others (2022) and Finance for Biodiversity Foundation (2024).

Name of tool	Type of application	Scope	Metrics	Input data needed	Main limitations
ENCORE	Sector-level screening of impacts and dependencies	Company-level (site-level for spatial data layers)	Materiality ratings	Categories of productive activities according to the International Standard Industrial Classification of All Economic Activities (ISIC); asset location (for spatial data layers)	For sector-level screening: Only indicates potential impacts and dependencies, based on a generic sector-level screening; some impacts and dependencies may be missing from knowledge base
IBAT	Location screening (+ assessment of potential to reduce species extinction risk with STAR)	Site- or company-level	Distance of location from protected areas and areas of high biodiversity value outside pro-tected areas; STAR	Asset location	Coverage of certain protected areas of threatened species may be limited, depending on underlying databases
Biodiversity footprinting tools using biodiversity impact assessment models (e.g. Corporate Biodiversity Footprint; Global Biodiversity Score)	Assessment of impacts via biodiversity impact assessment model (e.g. GLOBIO)	Company-level	MSA	Basic assessment: Turnover by industry and country Refined assess-ment: Corporate financial, operational and environmental data (where available)	Relies on sector and product averages to assess impacts throughout value chain; assesses potential rather than actual impact; partial coverage of certain pressures, species and ecosystems in the GLOBIO model
Biodiversity footprinting tools using LCIA methods (e.g. GID Biodiversity Impact Data)	Assessments of impacts via life-cycle impact assessment (LCIA) model (e.g. ReCiPe)	Product-/ project-level or company-level	Species-year, MSA, PDF, STAR	Company purchasing data (or actual resource inputs and emissions data if available)	Captures potential rather than actual biodiversity footprint due to use of sector averages; certain pressures, species and ecosystems not covered in ReCiPe model
Biodiversity Indicators for Site-based Impacts (BISI)	Assessing bio-diversity manage-ment performance by aggregating biodiversity impacts at site-level	Site- or company-level	Choice of metrics tailored to assessed site	Asset location; state-pressure-response data collected at site-level	Coverage of certain pressures, species and ecosystems may be limited in the relevant secondary datasets; relies on the quality of primary data

Of note, there have been several attempts to systematise existing biodiversity measurement tools, with recent examples including the thematic reports of the EU Business @ Biodiversity Platform[24] and the closely-related guide on biodiversity measurement approaches published by the Finance for Biodiversity foundation.[25] However, it may still be difficult to navigate the growing complexity of this landscape. Cost considerations are likely to be an important factor, and the baseline maturity level of a company on biodiversity issues may also influence its ability or willingness to adopt a specific combination of tools (and related metrics). For example, corporates that have not yet mapped how they interact with nature in those areas where their assets are located will not be able to assess which data points they should collect or for what purposes, and therefore which tools and approaches could best support their efforts.

24 Johan Lammerant and others, 2022, Assessment of biodiversity measurement approaches for businesses and financial institutions, Update report 4, EU Business @ Biodiversity Platform (https://green-business.ec.europa.eu/news/fourth-update-report-biodiversity-measurement-approaches-now-available-2022-12-16_en) accessed 16 October 2024.

25 Finance for Biodiversity Foundation, 2024, Finance for biodiversity. Guide on biodiversity management approaches, 3rd edition, Finance for Biodiversity Foundation (https://www.financeforbiodiversity.org/wp-content/uploads/Finance-for-Biodiversity_Guide-on-biodiversity-measurement-approaches_3rd-edition-1.pdf) accessed 16 October 2024.

In the past, these challenges contributed to rates of global biodiversity reporting that lagged far behind those for climate change. According to a KPMG study, less than half of all the world's 250 largest companies by revenue disclosed their biodiversity risks in the 2022 financial year, compared with the 80% that reported climate targets and the 61% that did so specifically adopting the TCFD framework.[26]

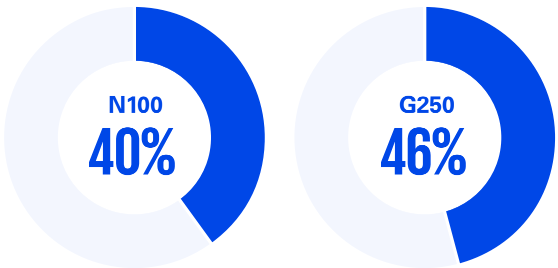
Going forward, however, the combination of growing market expectations, expanded disclosure requirements and emerging nature-related business opportunities will make it increasingly difficult for companies to avoid disclosing their biodiversity impacts. In addition, it will likely influence how companies approach the selection of measurement tools and related metrics. First and foremost, it will be impossible for companies to rely solely on qualitative descriptions of significant impacts on biodiversity, or on process-based information on the undertaken risk management actions. Even relatively less demanding disclosure standards, such as the current *GRI 304: Biodiversity 2016*, will soon be superseded and will require a more robust reporting of quantitative data points.

Secondly, companies will rarely be able to rely on a single tool, even at very low levels of biodiversity ambition (including basic regulatory compliance). As shown by Table 4 on page 21, ENCORE can be useful for a high-level, sector-based screening, but it does not provide quantitative data points about a company's (actual or potential) impacts. Similarly, even an advanced biodiversity footprinting method may not cover a specific impact driver that is particularly important at a certain site. In other words, different biodiversity measurement tools are built for different purposes, and may provide information that is relevant for different pieces of legislation, reporting frameworks, or internal company processes. As long as a company is required (or chooses) to monitor and report on its biodiversity impacts, it will have to adopt a comprehensive approach that is based on the specific characteristics of its operations and value chain.

Third, many companies will likely start considering the adoption of transparent, scientifically sound biodiversity measurement tools and metrics as an investment, rather than a cost. By enabling more accurate monitoring, reporting and verification of impacts, the collection of high-quality biodiversity data will offer benefits ranging from better risk management to improved market valuation and reputation.

While still in its early stages, the emergence of new markets for biodiversity credits[27] is also expected to accelerate rapidly within the next few years, as is the interest towards the development of higher-quality carbon credits that incorporate nature-positive outcomes.[28] From this perspective, companies that are willing to leverage the use of cutting-edge data to monitor their impacts on the conservation and restoration of ecosystems could contribute to expand the future supply of high-integrity carbon and biodiversity credits, which represents an enabling condition for the development of these markets and an additional revenue opportunity.[29]

Global biodiversity reporting rates (2022)



Base: 4,581 N100 companies and 240 G250 companies that report on sustainability or ESG matters. N100 = worldwide sample of the top 100 companies by revenue. G250: world's largest companies by revenue based on the 2021 Fortune 500 ranking. Source: KPMG (2022).

26 KPMG International, 2022, Big shifts, small steps. Survey of sustainability reporting 2022, KPMG (https://assets.kpmg.com/content/dam/kpmgsites/xx/pdf/2023/04/big-shifts-small-steps.pdf) accessed 16 October 2024.

27 Biodiversity Credit Alliance, 2024, Definition of a biodiversity credit, Issue paper no.3, Biodiversity Credit Alliance (https://www.biodiversitycreditalliance.org/wp-content/uploads/2024/05/Definition-of-a-Biodiversity-Credit-Rev-220524.pdf) accessed 16 October 2024.

28 UNEP, 2023, State of finance for nature 2023: The big nature turnaround – repurposing $7 trillion to combat nature loss, United Nations Environment Programme (https://doi.org/10.59117/20.500.11822/44278) accessed 16 October 2024.

29 WEF, 2023, Biodiversity credits: Demand analysis and market outlook, Insight report, World Economic Forum (https://www3.weforum.org/docs/WEF_2023_Biodiversity_Credits_Demand_Analysis_and_Market_Outlook.pdf) accessed 16 October 2024.

3. The opportunity: digital twins for biodiversity monitoring and reporting

3.1. Complementing existing metrics and tools with digital twins

The examples of tools and metrics that have been discussed in this report can provide companies with varying levels of data accuracy, timeliness and granularity, among other dimensions of data quality. Although each of these tools may be useful at different stages of a company's journey towards higher levels of maturity on biodiversity monitoring and reporting, they all come with specific limitations. Most importantly, even advanced methods such as biodiversity footprinting necessarily represent an approximation of the complexity that characterises ecological systems.

From this perspective, the rapid expansion of new digital technologies that promises to revolutionise the field of environmental monitoring[30] represents a further opportunity for companies that wish to reap the benefits offered by the evolving societal, regulatory and market expectations on biodiversity. Having first appeared in the 1960s, applications such as space-based Earth Observation techniques have since benefited from massive increases in computational power and expanded capacities for data storage, sharing and visualisation, such as those offered by machine learning and cloud-based storage tools. At the same time, innovative approaches for the on-the-ground collection of biodiversity data have also emerged, ranging from environmental DNA analysis to bioacoustics and genomics. If deployed at scale, these technologies (which are often collectively referred to as 'nature tech')[31] could help companies minimise their own impacts and align their business models with a nature-positive trajectory. In addition, they could help the same companies design other conservation and restoration projects outside of their immediate areas of influence, as well as track the success of such projects in a more transparent way. A report co-authored by Nature4Climate and KPMG, among others, has recently collected a broad range of case studies of nature-tech solutions, highlighting how they could support different types of corporate actions on biodiversity.[32]

A particularly influential innovation, which was first developed in the context of engineering and manufacturing industries[33] and is now increasingly applied to the field of biodiversity,[34] is represented by 'digital twin' technologies. A digital twin can be defined as a digital replica of a physical entity or phenomenon, made possible using sensors and other equipment that enable the seamless communication of data between the replica itself and its real-world counterpart.

*A **digital twin** can be defined as a digital replica of a physical entity or phenomenon, made possible using sensors and other equipment that enable the seamless communication of data between the replica itself and its real-world counterpart.*

30 Rebecca K Runting and others, 2020, 'Opportunities for big data in conservation and sustainability', Nature communications 11, 2003 (https://doi.org/10.1038/s41467-020-15870-0).

31 Nature4Climate, 2022, What you can measure, you can manage. How nature tech can help solve the climate and nature crises, Nature4Climate (https://nature4climate.wpenginepowered.com/wp-content/uploads/2022/09/N4C-nature-tech-report-final.pdf) accessed 16 October 2024.

32 Nature4Climate and others, 2024, Integrating nature tech: A guide for businesses, Nature4Climate, Nature Tech Collective, KPMG, Climate Collective and Serena (https://www.naturetechreport.com/) accessed 24 October 2024.

33 Elisa Negri, Luca Fumagalli and Marco Macchi, 'A review of the roles of digital twin in CPS-based production systems' Procedia manufacturing 11, pp.939-948 (https://doi.org/10.1016/j.promfg.2017.07.198).

34 Koen de Koning and others, 2023, 'Digital twins: Dynamic model-data fusion for ecology', Trends in Ecology and Evolution, 38(10), pp.916-926 (https://doi.org/10.1016/j.tree.2023.04.010).

By providing a digital model of this counterpart, a digital twin can be used for purposes of simulation, analysis, monitoring and development. The physical entity could be a product, a manufacturing process, an industrial asset or, in the case of biodiversity, an ecological system. In this last sense, digital twin technologies are increasingly seen as a potential game-changer, as they could drastically improve the capacity of organisations (including companies) to monitor, assess and predict changes in biodiversity and ecosystems driven by human activities.[35]

To develop a digital twin in a natural environment, such as a rainforest ecosystem, data are collected and continuously updated in real-time (or near real-time) from various sources, including sensors (both remote and in-situ), audio and camera traps satellite imagery, human observation, and digitalisation of existing knowledge. This information is compiled to create a highly detailed model of the study plot, allowing for the application of analytics and machine learning to gain insights that would be impossible to obtain with any single layer of data. The resulting digital twin is a dynamic dataset that reflects the ongoing changes in the studied plot, as opposed to 'static' datasets such as historical species distribution maps. By recording past data, it enables the use of this knowledge to predict future conditions and test possible interventions and risk management actions. At the same time, the digital twin can also be used to track real-time progress across a wide range of biodiversity metrics and even provide enriched data to be used for reporting purposes.

An example of a digital twin solution that can be applied to biodiversity conservation and restoration activities is Green Cubes Digital Reality. This tool, which provides a digital twin approach to the collection, processing, classification and visualisation of environmental data in terrestrial ecosystems, has been developed by R-evolution, the green-tech subsidiary of global industrial technology company Hexagon. As part of its wider collaborations with providers of cutting-edge solutions for the collection, assessment and reporting of sustainability data, KPMG Sweden has recently formed a partnership with R-evolution. The aim of the partnership is to leverage the Green Cubes methodology to enhance companies' monitoring, reporting and verification of their biodiversity impacts, in combination with some of the other established tools and metrics discussed in this report.

3.2. Green Cubes Digital Reality

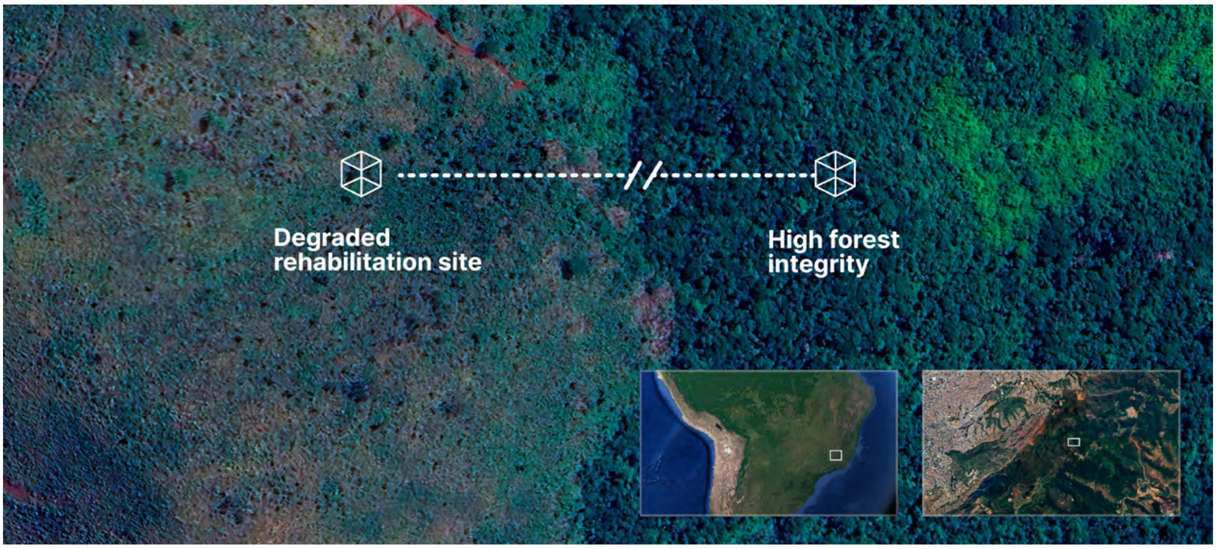
According to the Green Cubes Digital Reality methodology developed by R-evolution, a Green Cubes digital twin can be defined as a range of data points attached to a cubic meter within a site (i.e. a Green Cube). This Green Cube can then be used to compare the differences between two sites over time and across a wide range of values such as forest height and profile, complexity indexes of flora and fauna richness and abundance, soil quality and biodiversity, and air pollution, among others. In the example below [see Figure 6 on page 25], a Green Cube is used to compare a point from a forest ecosystem exhibiting a high degree of integrity,[36] which is adopted as a reference point for a successful ecosystem restoration outcome, with a degraded plot within a mining site in Brazil. Using computational power and artificial intelligence (AI), the digital twin model is able to simultaneously compare hundreds of thousands of Green Cubes between sites.

"The rapid expansion of new digital technologies *that promises to revolutionise the field of biodiversity monitoring represents an opportunity for companies that wish to reap the benefits offered by the evolving societal, regulatory and market expectations on biodiversity."*

35 For example, the commitment to developing 'digital twins' of various Earth systems has been mentioned as part of political strategies such as the EU's Biodiversity Strategy to 2030 and the Destination Earth initiative. Digital twins are also mentioned as one of the strategic priorities of the UN-backed Coalition for Digital Environmental Sustainability.

36 The notion of ecosystem integrity is used here to refer to an ecosystem which can support and maintain ecological processes and a diverse community of native organisms. According to a well-known definition, ecosystem integrity can be defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organisation comparable to that of natural habitats of the region." See James R Karr and Daniel R Dudley, 1981, 'Ecological perspective on water quality goals', Environmental Management 5, pp. 55-68.

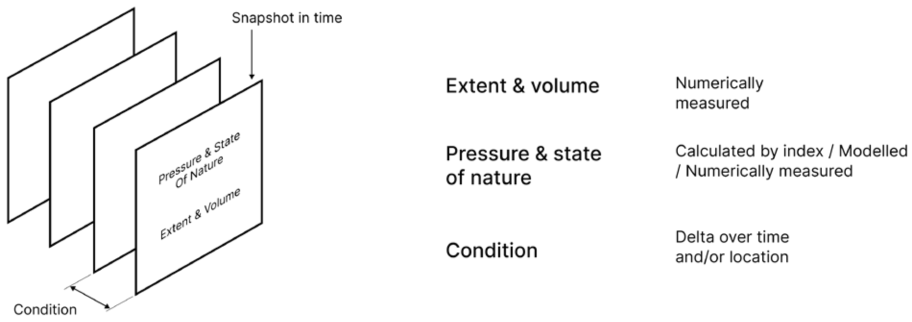
Figure 5. **Two Green Cube data points used to compare a forest characterised by a high degree of integrity with a degraded site. These two development stages are compared across multiple dynamically captured metrics.** Source: R-evolution.



In this way, Green Cubes can offer a means to define end-goal success (based on historical data, on the attributes of an adjacent plot of land that is considered of sufficient integrity by environmental standards, or both)[37] and then measure the impacts of a certain activity on biodiversity over time (or the progress towards the previously-defined end-goal, in the case of restoration activities).

In Green Cubes Digital Reality, the input data are collected through technologies such as satellite imagery, airborne and in-situ Light Detection and Ranging (LiDAR) instruments, on-the-ground audio and camera traps, soil sampling, handheld radars, and air pollution sensors. According to R-evolution, the use of these different but complementary methods aims to build a 'triangle of trust' in the integrity of the generated data, with the use of 'indicative' and modelled data resting on a solid foundation of high-resolution data from airborne sensors and satellite imagery. The data collection efforts are carried out through a subscription model, where the equipment is deployed according to the user's desired frequency. Once collected, the data are processed, classified and visualised through software applications and can thus provide information on multiple metrics. These can be broadly grouped into metrics relating to the *extent and volume* of the ecosystem, metrics relating to its condition, and metrics relating to *pressures and state of nature* [see Figure 5].

Figure 6. **Type of metrics captured by Green Cubes Digital Reality (left side). On the right side, the type of data used to provide information on the three metrics is shown.** Source: R-evolution.



37 It is worth noting that it is not possible to recreate the exact environment that would have existed without human-induced damage, as the regrown forest will develop under a different climatic environment.

Ecosystem extent and forest volume

Ecosystem extent is typically defined as the size (i.e. area coverage) of a particular ecosystem asset (i.e. the contiguous space covered by a specific ecosystem type). Green Cubes Digital Reality captures extent at 5cm resolution using high-fidelity airborne laser scanning (ALS). In addition to the 'conventional', bi-dimensional measure of extent, Green Cubes Digital Reality is also able to provide a 3D representation of forest volume thanks to the use of next-generation ALS instruments that penetrate deep beneath the forest canopy [see Figure 7].

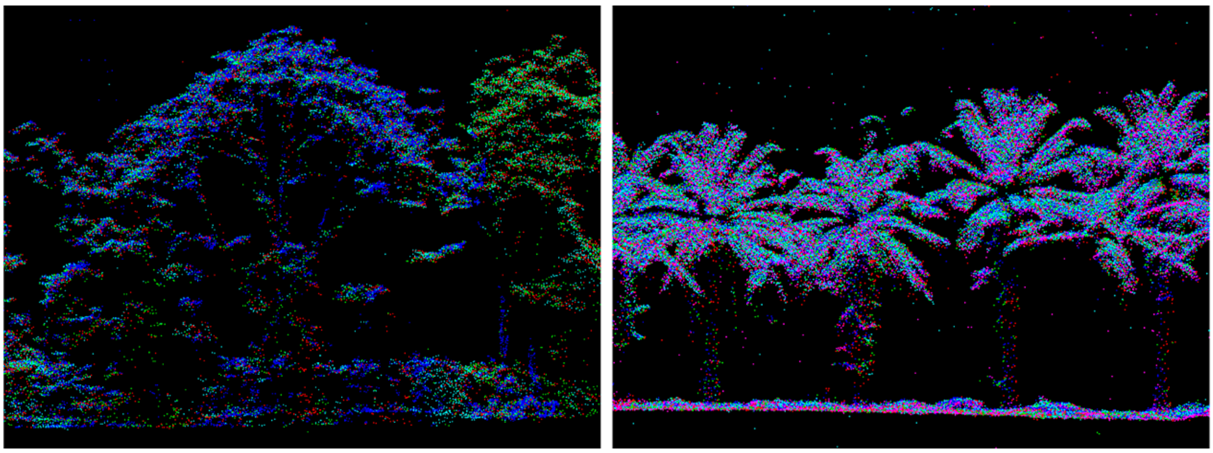
Even in a tropical rainforest environment,[38] these instruments provide sufficient reflection points to capture ground contour maps that are then used to produce digital elevation models (DEM), foliage volume studies and tri-dimensional forest profiles at 5cm resolution. Such data can also be combined with terrestrial laser scanning (TLS) data to measure biomass to 1cm^3 accuracy.

Pressures and state-of-nature metrics

Beyond ecosystem extent and forest volume, Green Cubes Digital Reality can use several data sources to track metrics relating to pressures on biodiversity (i.e. impact drivers including pollution or invasive species) and state of nature. First, certain attributes such as concentrations of air pollutants or levels of noise and light pollution can be measured physically using the devices mentioned earlier. Hydrometers, together with terrestrial radars, can also be used to measure the moisture and compaction beneath the soil surface. In industries such as the extractive sector and agriculture, many of these attributes are already tracked and have rich historical and dynamic data to support the data collection efforts.

For those attributes of an environment which cannot be fully captured through primary data due to logistical limitations, Green Cubes Digital Reality makes use of indexes based on modelled data. Examples of such indexes include tree species (i.e. Leaf Area Index, see Figure 8 on page 27)[39] or amphibian species,[40] with the input data collected through remote sensing (for tree species) or acoustic traps (for frog species). These indexes help measure of the number and abundance of different species without the need to undertake field surveys (or complementing them, especially in cases where these may be expensive or too limited in spatial coverage). The indexes can also be combined to provide an overall understanding of the site's complexity, and changes in the indexes can then be measured over time and against the chosen baseline.

Figure 7. **Cross section of point-cloud data captured using Leica Geosystems Country mapper during Green Cubes' pilot project in La Gamba (Costa Rica). The image showcases the forest's structural detail and ground plane captured at 5cm resolution.** Source: R-evolution.

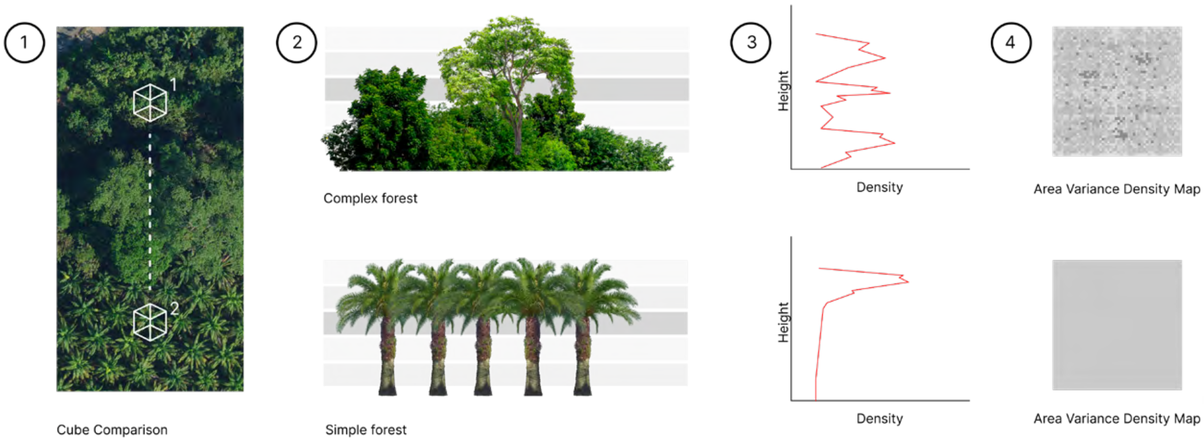


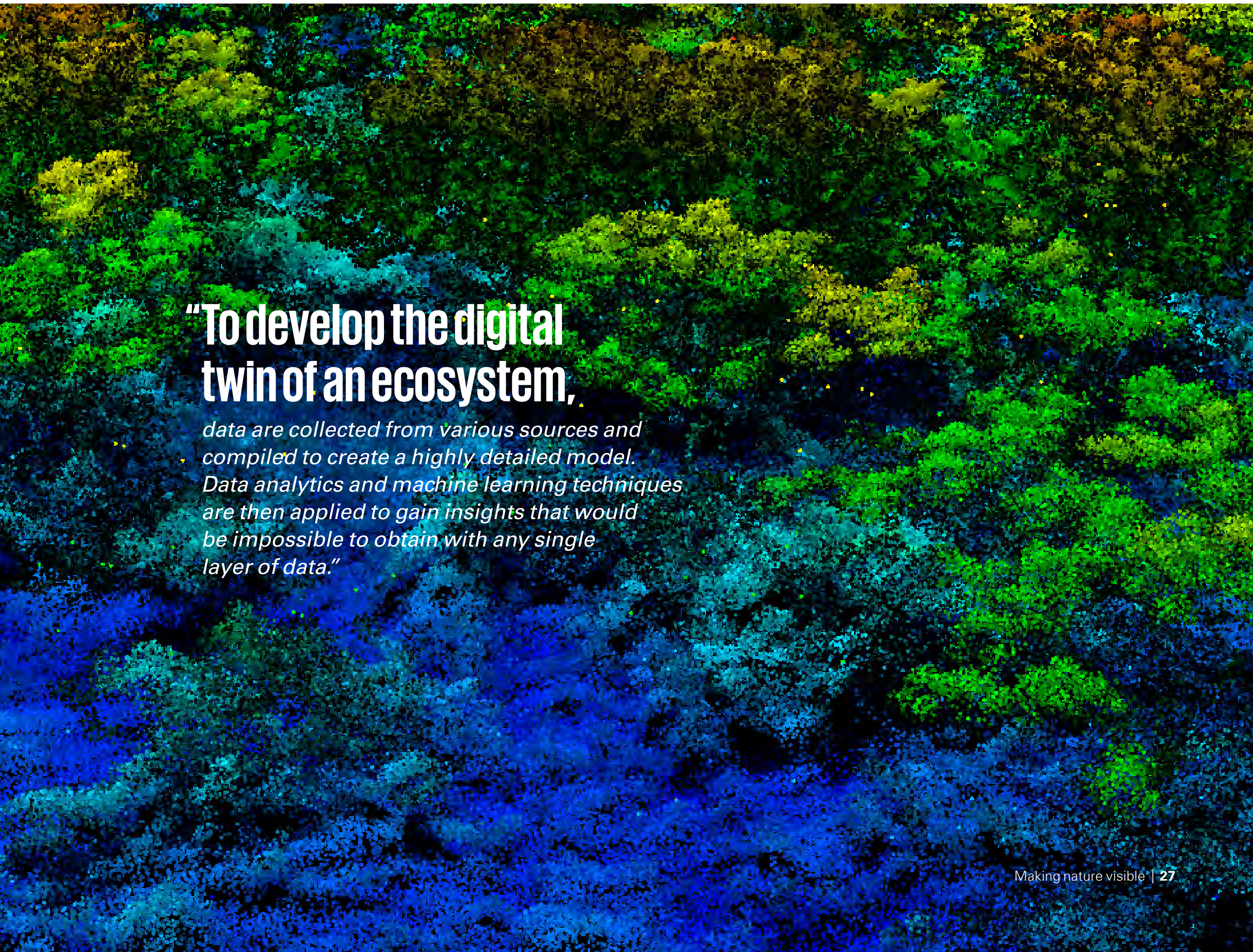
38 Results taken from R-evolution's Green Cube project, La Gamba, Costa Rica 2024, using a Leica Geosystems Country Mapper Lidar scanner mounted on a fixed-wing aircraft.

39 Leaf Area Index (LAI) is a commonly used metric which, in simple terms measures how much light penetrates the forest all the way to the forest floor. It can be broadly defined as the amount of leaf area in a forest canopy per unit area of ground.

40 A recent study sponsored by the Crowther Foundation demonstrated the concept of measuring frog species diversity based on their audio identification. Amphibians are particularly susceptible to water pollution and are generally one of the least resilient taxa in a disturbed forest, making them good indicators of the overall health of an ecosystem. See James Dinneen, 2024, 'How an audacious sonic survey could help revive damaged rainforests' New Scientist (https://www.newscientist.com/article/mg26234911-300-how-an-audacious-sonic-survey-could-help-revive-damaged-rainforests/) accessed 16 October 2024.

Figure 8. **The figure visualises information on forest structure complexity as measured by Leaf Area Index (LAI) taken at different intervals between the canopy and forest floor. From left to right, (1) shows comparison points using Green Cubes between two sites containing a complex intact rainforest and a site of monoculture of oil palm; (2) shows a cross-section sample that demonstrates the difference in tree complexity between the two sites; (3) shows the complexity comparison graphed on a single cross-section. Finally, (4) shows the complexity variance graphed over a 50x50 meter sample plot.** Source: R-evolution.





“To develop the digital twin of an ecosystem,

data are collected from various sources and compiled to create a highly detailed model. Data analytics and machine learning techniques are then applied to gain insights that would be impossible to obtain with any single layer of data.”

Lastly, Green Cubes Digital Reality can incorporate 'indicative' data covering other types of biodiversity components (e.g. data relating to certain pressures such as pollution, or species-level data) which have been collected in collaboration with scientists, local communities or other external initiatives. While these data would not be sufficient to develop a complexity index or a standalone metric, they would nevertheless hold additional valuable insights to monitor biodiversity in the study plot. The primary data collection methodology would be autonomous in-situ collection and peer-reviewed field operations, with tools including video camera traps, acoustic traps and citizen science platforms such as iNaturalist.org.

Ecosystem condition

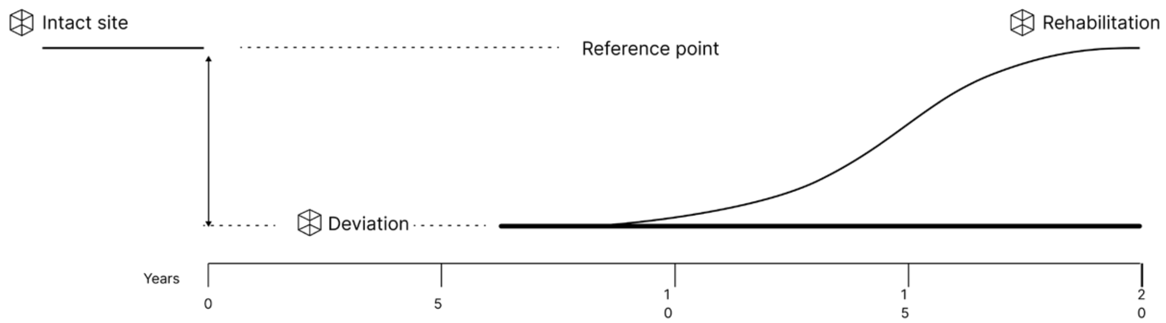
The notion of ecosystem condition in Green Cubes refers to a relative measurement of the quality of both the reference and current sites. It is based on the same metrics captured under the broad category of 'ecosystem extent', but unlike the latter, it provides a comparative assessment of such metrics (either over time at the same site, or between the two sites). This is consistent with other types of approaches to measuring ecosystem condition, such as the Biodiversity Intactness Index or the Mean Species Abundance (MSA) metric, which similarly measure a difference (delta) in biodiversity compared with a previously defined reference condition. By using high-quality data from a currently mature forest (i.e. representing an ecosystem in its minimally- or least-disturbed condition), Green Cubes offers a more realistic representation of the intended reference point, compared with an historical condition or an estimated pre-industrial one.

In the following example [see Figure 9], a Green Cubes metric is used to compare an adjacent ecologically intact site with a degraded site starting to undergo restoration. Overtime, the rehabilitated site is expected to reduce the deviation gap across multiple metrics, though some of them (e.g. species richness) may inherently have a longer time lag than others.

The frequency of data collection for the metrics used by Green Cubes can vary from project to project, as defined by need and scale. It can range from continuous (i.e. camera and acoustic traps) to weekly (low-resolution Earth Observation), annual (e.g. terrestrial or drone LiDAR scanning), or undertaken at three to five-year intervals (Airborne LiDAR scanning). Where the fundamental structure of a forest does not fluctuate greatly over time, such as in a mature forest, a lower frequency of data collection would be sufficient, while in a newly-planted forest quarterly updates would be necessary to intervene in a timely manner.

In the next section, a use case of Green Cubes Digital Reality in the mining sector is presented, in order to illustrate a potential application of the data generated by this type of approach.

Figure 9. **Three Green Cube data points graphed over time. A reference point as an end-goal is determined and then progress towards that end-goal is measured and tracked over time.** Source: R-evolution.



4. Helping the mining sector monitor its impacts on biodiversity through digital twins

4.1. Why is mining relevant to biodiversity?

The mining industry offers a clear case of the difficulties and advantages of enhancing biodiversity monitoring and reporting. It is widely recognised that mining activities can adversely affect biodiversity and ecosystems through, among others:

- changes in land-use and resulting habitat degradation and fragmentation;
- direct discharge from mine tailings and leaching of heavy metals and other chemicals to water and soil;
- emission of air pollutants (e.g. dust, smelter emissions); and
- noise pollution from extraction activities.

According to a UNEP-WCMC analysis using the ENCORE Biodiversity Module, mining's pressures on biodiversity are compounded by the fact that around 40 percent of mining activities globally occur in ecoregions with strong declining trends in ecological integrity,[41] and that 13% of mines owned by companies listed on the MSCI ACWI Investable Market Index (IMI) are located in areas with highly intact ecosystems.[42] In a recent study of over 2,300 listed companies of the MSCI All Country World Index by the Finance for Biodiversity Foundation, 'Metals and Mining' was identified as one of the top 5 industry sectors with highest impact on biodiversity, behind 'Food Products', 'Oil, Gas and Consumable Flues', 'Chemicals', and 'Consumer Staples Distribution and Retail'.[43] From this perspective, not only would more (and better) biodiversity data help companies assess the negative impacts of mining activities, but it could also improve the measurement of progress during the mine rehabilitation phase, which constitutes a central aspect of the mining lifecycle and ,which in many cases, is also a precondition for the approval of licensing permits.

On the other hand, the global demand for minerals is set to continue to grow over the coming decades. For example, some estimates suggest that 6.5 billion tons of end-use materials such as steel, aluminium and copper will be required to support the energy transition between 2022 and 2050,[44] with demand for other high-value materials used for electric vehicles and battery storage technologies (e.g. lithium, graphite, nickel and cobalt) also set to rise rapidly over the next two decades.[45] While this creates further potential risks for biodiversity, it also suggests that the mining sector has a significant opportunity to minimise its impacts while simultaneously contributing to global sustainability transitions. Companies seem to have long been aware of the opportunity – already in 2015, a review of corporate commitments to achieve 'no net loss' and 'net positive impact' on biodiversity found that the mining sector had the most such commitments.[46]

Given the potential relevance of biodiversity to most types of mining activities, this sector is usually already subjected to significant regulatory requirements at the country or sub-national level. For mining companies, improving the monitoring and assessment of their biodiversity impacts can thus be important for complying with these existing regulations. For example, many governments require financial assurance from mining companies to ensure that mine rehabilitation is carried out at the end of the mine life cycle.[47] Collecting biodiversity data can thus be important to prove the success of these rehabilitation activities and obtain the return of the related deposit.

41 Sebastian Bekker, 2022, 'Why the mining sector matters for biodiversity', Global Canopy (https://globalcanopy.org/insights/insight/spotlight-on-biodiversity-risk-and-opportunity-in-the-mining-sector/) accessed 16 October 2024.

42 Samuel Block and Gillian Mollod, 2021, Mining's impact on biodiversity: a rising risk?, MSCI ESG Research LLC (https://www.msci.com/www/blog-posts/mining-s-impact-on-biodiversity/02547548673) accessed 16 October 2024.

43 Finance for Biodiversity Foundation, 2024, Assessment of the biodiversity impacts and dependencies of globally listed companies: A collaborative multi-tool footprinting approach, Finance for Biodiversity Foundation (https://www.financeforbiodiversity.org/wp-content/uploads/FfBF_multitool_report_final_021024.pdf) accessed 16 October 2024.

44 ETC, 2023, Material and resource requirements for the energy transition, Energy Transitions Commission (https://www.energy-transitions.org/wp-content/uploads/2023/08/ETC-Materials-Report_highres-1.pdf) accessed 16 October 2024.

45 IEA, 2022, The role of critical minerals in clean energy transitions, World Energy Outlook Special Report, International Energy Agency (https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf) accessed 16 October 2024.

46 Hugo J. Rainery and others, 2015, 'A review of corporate goals of No Net Loss and Net Positive Impact on biodiversity', Oryx 49(2), pp. 232-238 (doi:10.1017/s0030605313001476).

47 UNDP and UNEP, 2018, Managing mining for sustainable development: A sourcebook, United Nations Development Programme (https://www.undp.org/sites/g/files/zskgke326/files/publications/UNDP-MMFSD-HighResolution.pdf) accessed 16 October 2024.

At the same time, the proliferation of biodiversity disclosure frameworks means that the monitoring of biodiversity impacts at mining sites will become increasingly important for reporting purposes as well. Although many non-EU mining companies will not immediately fall under the scope of the CSRD, some will likely choose (or face pressure) to align their reporting with the TNFD framework or the new GRI standard. Moreover, the fact that many EU-based undertakings covered by the CSRD rely on mineral extraction within their value chain will *de facto* impact the mining sector outside of Europe as well, as such undertakings will require ESRS-aligned data from their suppliers in order to better assess and report on their material impacts on biodiversity and ecosystems.

Lastly, industry standards also have an important influence in the mining sector, and these too have recently started to turn their attention to biodiversity. In January 2024, the International Council on Mining and Metals (ICMM) released a position statement on nature that is significantly more advanced than previous industry-led initiatives in this field, and commits all its members to undertaking a series of ambitious risk management, conservation and restoration actions across their own operations and value chains, as well as at the level of broader landscapes and systems.

4.2. How are extractive sector companies currently reporting their biodiversity impacts?

To understand how mining sector companies are currently measuring and disclosing their biodiversity impacts, KPMG Sweden assessed the most recent sustainability reports published by 16 large corporates with operations spanning different sub-sectors (i.e. diversified mining, precious metals, non-ferrous metals). These were chosen because they are currently among the top 50 mining sector firms by revenue (as of July 2024) and/or because they represent biodiversity 'early movers'. For example, some of these companies have announced the intention to be early adopters of the TNFD Framework and are thus expected to report against its requirements for either the 2024 or 2025 financial year.

The companies' sustainability reports were qualitatively assessed and ranked against a series of criteria including: (i) the framework currently used for their reporting; (ii) the extent of their assessment of biodiversity impacts and dependencies; (iii) the tools and methods used to assess biodiversity impacts at site- and company levels; and (iv) the existence and ambition level of company-wide biodiversity strategies, targets, and metrics (see Table 5).

Table 5. **Benchmarking criteria used for the assessment of mining sector companies' biodiversity reporting maturity.** Source: KPMG.

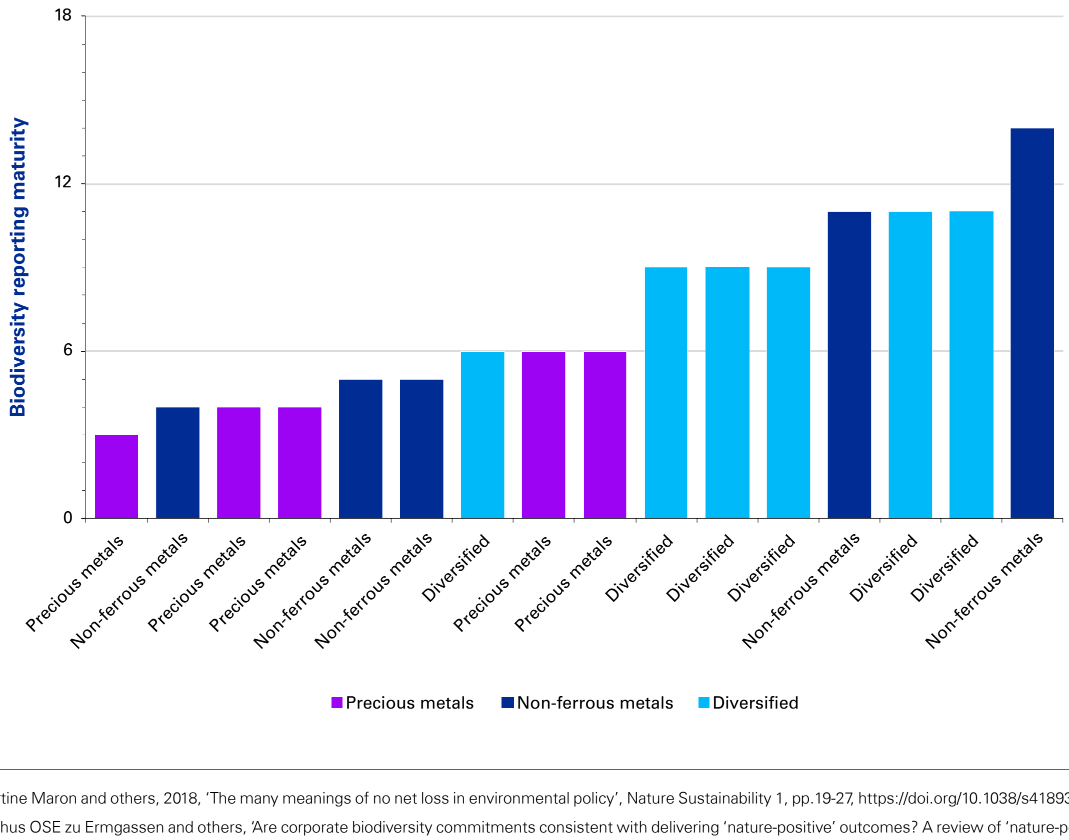
Benchmarking criteria	Low maturity	Medium maturity	High maturity	Future expectations
Reporting frameworks	No reporting	Reporting with own framework or partly using existing voluntary frameworks (e.g. GRI, ICMM)	Fully reports using existing voluntary frameworks (e.g. GRI, ICMM)	Already reports voluntarily against TNFD and/or ESRS E4
Assessment of impact and dependencies	Not conducted	Assessment at site-level only (or other limited scope)	Overall assessment of impact and dependencies in own operations	Overall assessment of impact and dependencies in own operations and value chain
Tools and methods	Does not disclose this information	Uses own approach	Uses established tools (e.g. ENCORE, IBAT, LCA methods)	Complements established tools with advanced datasets, near-real time data etc.
Biodiversity strategy	No strategy (e.g. only site-specific plans)	Limited scope (e.g. general biodiversity policy and risk management approach)	Ambitious scope (e.g. transition plan, definition of adequate actions and resources)	Ongoing implementation of transition plan and shift in business strategy and models
Biodiversity targets	No target (or not disclosed)	Limited scope (e.g. site-specific targets, limited applicability) or not measurable	Ambitious scope (e.g. company-wide, no net loss or net nature positive target), measurable	Ambitious scope, time-bound, aligned with global goals, actionable
Biodiversity metrics	No metrics / only qualitative metrics	Own metrics, or other metrics not aligned with existing frameworks	Metrics partly or mostly aligned with existing frameworks1	Metrics fully aligned with existing frameworks, enhanced by high-quality, entity-specific metrics

KPMG's benchmarking found that even those companies that currently provide best-in-class examples of biodiversity reporting may fall short of emerging investor expectations and/or regulatory or voluntary disclosure requirements under the CSRD and TNFD [see Figure 10]. For example, the proliferation of commitments to achieve 'no net loss' of biodiversity[48] in the strategies of many mining sector companies is not yet reflected in the use of adequate tools to monitor progress against such targets. This is consistent with existing research showing that while the number of corporate biodiversity commitments to deliver nature-positive outcomes have increased, these have often not been formulated in a measurable or time-bound way.[49] In addition, the most widely-used metrics to evaluate biodiversity impacts appear to be those consistent with the *GRI 304: Biodiversity 2016* standard (e.g. covering aspects such as proximity of sites to biodiversity-sensitive areas, qualitative descriptions of significant impacts and extent of areas impacted or rehabilitated, among others), meaning that quantitative measures of impact drivers, trends in affected species and condition of ecosystems are generally not reported.

4.3. The application of digital twins for biodiversity in the mining sector: use cases for Green Cubes

The metrics needed to fully assess mining impacts on nature are both wide-ranging and interlinked, including (but not limited to) the monitoring of dust and water pollution, impacts on species displacement, the introduction and spread of invasive species, and various metrics relating to ecosystem extent and condition. This makes it difficult to rely solely on existing metrics and approaches to measuring biodiversity, especially in a context characterised by the growing expectations of regulators, investors and civil society stakeholders.

Figure 10. **Result of the industry benchmarking on biodiversity reporting maturity conducted by KPMG on a sample of 16 mining sector companies, anonymised and grouped according to their type of operations (diversified metals, precious metals, non-ferrous metals). Each column represents a company. The overall score for each company results from the aggregation of the scores assigned for each of the scoring criteria. A scoring of 'low maturity' for a specific criterion resulted in 0 points, whereas scores of 'medium', 'high', or 'future expectations' corresponded to 1, 2 and 3 points, respectively.** Source: KPMG.



48 Martine Maron and others, 2018, 'The many meanings of no net loss in environmental policy', Nature Sustainability 1, pp.19-27, https://doi.org/10.1038/s41893-017-0007-7

49 Sophus OSE zu Ermgassen and others, 'Are corporate biodiversity commitments consistent with delivering 'nature-positive' outcomes? A review of 'nature-positive' definitions, company progress and challenges', Journal of Cleaner Production 379(2), 134798 (https://www.sciencedirect.com/science/article/pii/S0959652622043700).

The industry benchmarking carried out by KPMG Sweden highlights the need for companies to move to a higher level of maturity in their biodiversity monitoring and reporting. Even for companies that already use established tools and metrics to assess their impacts and dependencies at site- or company-level, there is significant scope to make further progress. The required level of data collection, as well as the business opportunities offered by the transition to a nature positive trajectory, suggest that digital twin solutions such as Green Cubes could provide a method for unifying and tabulating fragmented data to enable better monitoring, reporting and verification of biodiversity impacts in and around mine environments [see Figure 11a/b].

Figure 11a/b. **Figure 11a shows an example of Green Cube-based data visualisation to track year-on-year progress on mine rehabilitation across six groups of metrics. Figure 11b shows an example of progress against the same groups of metrics at years 5, 10 and 15, comparing the target values and measured success. NB: the 'indigenous peoples and local community theme' is not covered in this report.** Source:R-evolution.

Figure 11a

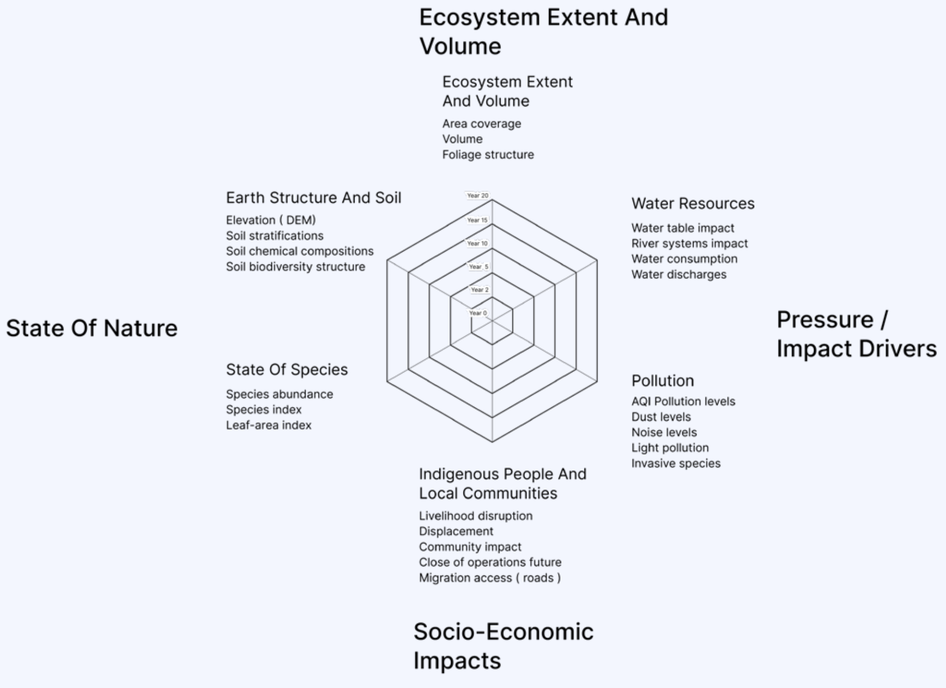


Figure 11b

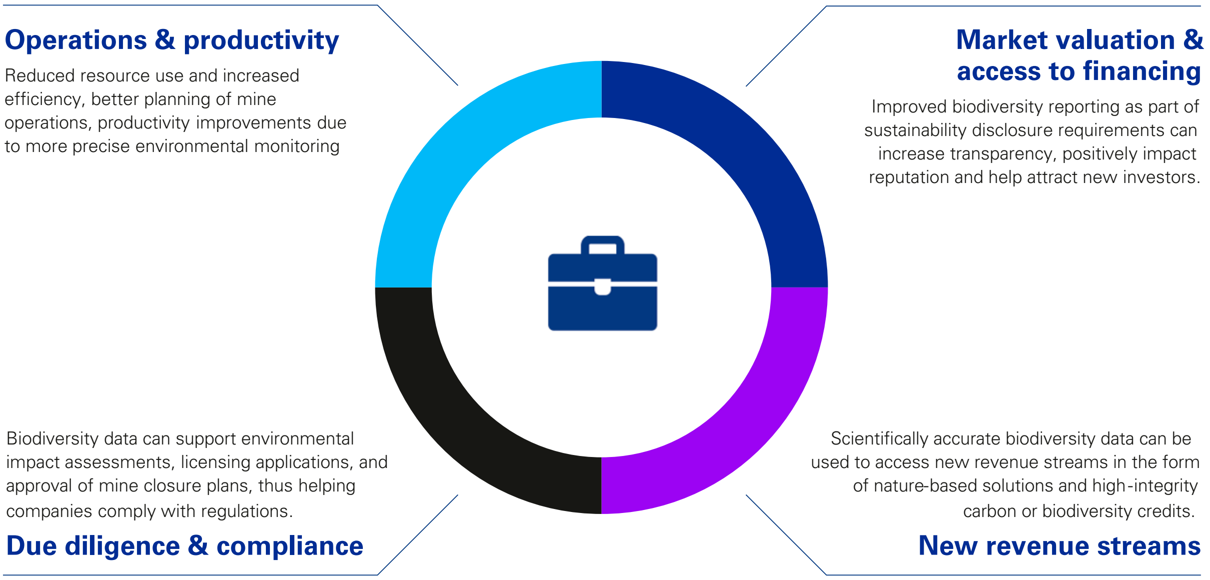
In a project conducted in partnership with the University of Vienna in La Gamba (Costa Rica), Green Cubes has scanned over 2500 million cubic meters at 5cm resolution, generating billions of possible Green Cube comparison points throughout the COBIGA wildlife corridor which connects two of the most biodiverse reserves in the world. These Green Cubes are now getting used to set reference points from ecologically intact sites and used to compare naturally degenerating abandoned palm oil plantations, thirteen-year-old reforested sites, four-year-old reforested sites and six-month recently planted sites across a range of criteria including forest volume and profile, Leaf Area Index as well as fauna populations and sampled soil.

When applied to a company's mining operations, this approach to data collection and analysis could first and foremost form the basis of environmental impact assessments, licensing applications, sustainability reporting and regulatory compliance more broadly. Secondly, Green Cubes could be used as a verification solution in situations where the company intends to sponsor biodiversity conservation or restoration efforts undertaken in plots of land outside of its direct area of influence. Third, since mine rehabilitation is an integral part of business operations and even a legal requirement in many jurisdictions, a digital twin model such as the one developed by Green Cubes could also help measure the success of restoration efforts and make evidence-based decisions as to when interventions are necessary, in order to ensure that restoration goals can be met within financial constraints. Lastly, Green Cubes and other similar models could be useful for internal purposes, for example in the tracking of progress against site- or company-level targets to achieve 'no net loss' of biodiversity.

The data generated through digital twin technologies such as Green Cubes should not be seen as replacing some of the other datasets and tools that have been discussed earlier in this report On the contrary, Green Cubes can provide a means of expanding the availability and quality of such data, and can complement them for enhanced accuracy in monitoring and reporting. For example, species data collected through camera or acoustic traps and then analysed by machine learning techniques could be used and/or reported alongside other metrics relating to the state of species in the area impacted by a company's mining operations.

Importantly, mining sector companies are often already adopting high-accuracy tools such as LiDAR instruments, artificial intelligence and machine learning in order to survey their operations. This would make it easier to make such tools transferable to biodiversity monitoring with the help of digital twin solutions. Together with the capture and management of real-time data, mining also has advanced procedures for scheduling actions, and these procedures could better integrate rehabilitation processes into the various mining life stages with the help of digital twin-enabled prognostics tools. For example, improved biodiversity data could help manage the preparation of the land for rehabilitation concurrently with the production phase (i.e. in plots that have already ceased production), something which could bring considerable savings in terms of total life-cycle time, as well as direct savings in terms of reducing the impact that would then need to be accounted for at the closure of operations [see Figure 12].

Figure 12. **Illustration of potential financial benefits arising from the increased availability and quality of biodiversity data for mining companies.** Source: KPMG, based on TPT Nature Working Group (2024).



5. The way forward: better biodiversity monitoring can shape industries and generate value

While digital twin solutions have only recently started to be applied to the field of biodiversity monitoring and assessment, they are already offering companies the opportunity to increase the availability and quality of their biodiversity data. Accelerating their deployment at scale, starting with sectors that are known to have the largest footprint on the world's ecosystems, could help companies contribute to global efforts to protect and restore biodiversity while better integrating environmental, social, and economic considerations in their operations.

In particular, this report has suggested that by expanding direct collection of biodiversity data and enabling cutting-edge modelling and scenario analysis, digital twin technologies such as Green Cubes could help companies improve their regulatory compliance and align with reporting frameworks such as the TNFD, ESRS and GRI. In addition, they may also support these companies' transition to strategic, nature-positive action. For example, companies that need to carry out ecosystem restoration activities as part of their strategy and business model, or simply to meet current regulatory requirements, may have a major incentive to adopt digital twins as a means of improving the way they monitor, assess and plan such activities. Lastly, the report has noted the significant role that these technologies may play in bringing more transparency and consistency to both present carbon markets and biodiversity credit schemes, by providing them with a robust digital integrity foundation.

While this report has discussed the mining sector as a particularly important use case for digital twin applications, the same approach could effectively be translated to the agriculture and forestry sector. Agriculture and forestry, like mining, depend heavily on land and natural resources, and they can thus benefit from digital twin technologies that create real-time, virtual replicas of agro-ecosystems in order to predict outcomes, optimise operations, and minimise environmental footprints.[50]

50 Warren Purcell and Thomas Neubauer, 2023, 'Digital twins in agriculture: A State-of-the-art review', Smart agricultural technology 3, 100094 (https://doi.org/10.1016/j.atech.2022.100094).

For example, more accurate data on soil health, water usage, and crop growth patterns could help farmers adjust practices to reduce water overuse and chemical inputs (e.g. fertilisers, pesticides) or prevent soil depletion through crop rotation. Additionally, these data could help enhance transparency and trust. In the context of the EU's Common Agricultural Policy or voluntary programs like sustainable agriculture certifications, they could even be increasingly critical for farmers to maintain compliance and access nature-based financial incentives.[51] As with the mining sector, agriculture and forestry will also need to adapt to increasing climate risks, and technologies like remote sensing, AI-driven precision farming, and digital twins are widely seen as necessary to help the sector improve its resilience and maintain profitability in the long term.[52]

Another sector that would potentially benefit from the early adoption of digital twin technologies in the field of biodiversity is the oil and gas industry, which like mining is usually considered a part of the broader extractives sector. Unlike mining, oil and gas operations are often not surface-based, limiting the opportunity to reduce surface impact compared to many mining activities. However, oil and gas operations carry higher risks of incidents such as oil spills from ships and pipelines. Digital twin solutions could thus both reduce the impact of current operations (e.g. by supporting predictive maintenance and the development of strategies to minimise risks) and support future restoration efforts.[53]

Even beyond these priority sectors, this report has shown that most companies will likely face a growing need to improve the availability and quality of their biodiversity information. In order to do so, they will have to understand how to effectively integrate the related data, tools and technologies into their biodiversity governance strategies and reporting efforts, choosing approaches that are tailored to their specific context. In most cases, the expansion of digital twin technologies to cover entire operations or value chains will represent the final step of a longer readiness journey, starting with the consolidation of available biodiversity data, the commitment to improved biodiversity assessment and reporting, and the identification of priority sites where digitally-enabled monitoring is most beneficial or urgent. Through the pooling of both strategic and technical capabilities, such a journey could help companies progress to a higher level of biodiversity maturity and thus reap the opportunities offered by the transition to a nature-positive future.

51 It should also be noted that under the Common Agricultural Policy, investments in digital technologies themselves are supported in various ways as part of a broader European Union push towards the digitalisation of the agricultural sector.

52 Climate-ADAPT, 2023, 'Precision agriculture', European Environment Agency and European Commission (https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/precision-agriculture).

53 GlobalData, 2024, Digital twins in oil and gas, GlobalData (https://www.globaldata.com/media/oil-gas/digital-twins-gaining-rapid-acceptance-in-oil-and-operations-says-globaldata/) accessed 16 October 2024.

How we can help

How can you increase your level of maturity on biodiversity?

Biodiversity a is rapidly evolving field for businesses, including a wide range of regulatory requirements, reporting frameworks, and tools that may be difficult to navigate. A growing number of investors also consider biodiversity as a source of financial risk, and increasingly seek to incorporate nature-related investor information into financing decisions. Depending on your starting point, as well as on the expectations of your stakeholders, progressing to a higher level of maturity in your consideration of biodiversity may entail taking steps to:

- Enhance awareness and understanding of nature-related topics among your internal stakeholders.
- Understand what regulators and other stakeholders expect you to report on, and how you can articulate your biodiversity performance clearly.
- Benchmark your biodiversity performance against that of your competitors or assess the level of maturity among your suppliers.
- Understand how biodiversity relates to other topics analysed as part of your double materiality assessment.
- Undertake a detailed assessment of your biodiversity impacts, dependencies and risks, and identify relevant content and data requirements.
- Align your biodiversity reporting with key mandatory and voluntary frameworks (e.g. CSRD, TNFD, GRI, SBTN).
- Set science-based targets for nature and develop a biodiversity strategy and/or transition plan.

How are KPMG Sweden and R-evolution collaborating to advance companies' transition to nature-positive outcomes?

Together with the other KPMG firms, KPMG Sweden can offer in-depth subject matter knowledge and assurance and reporting expertise to help you integrate nature-related topics in your strategies, business models, operations and reporting efforts. We also collaborate with providers of cutting-edge data solutions, to ensure that you can benefit from the best-available tools and evidence when taking action on biodiversity and other sustainability topics.

With their joint offering [Figure 13], KPMG Sweden and R-evolution can guide you in a step-by-step journey to deploy Green Cubes Digital Reality in your operations, starting with your most critical sites. Simultaneously, we can support you in the identification and reporting of your biodiversity impacts, dependencies and risks, as well as in the adoption of nature-related targets, strategies and transition plans. This will ensure that Green Cubes and other digital solutions are seamlessly embedded in, and add value to, your overarching sustainability strategy.

Figure 13. **Example of a corporate biodiversity readiness journey leveraging the strategic and technical expertise of KPMG Sweden and R-evolution.** Source: KPMG.

	Scoping	Inception	Implementation	Disclosure	Scaling
	One-off	*One-off*	*Ongoing*	*Once per year*	*Ongoing*
KPMG	• Training and awareness • Industry benchmarking • High-level assessment of biodiversity impacts and dependencies at company level • Biodiversity reporting gap analysis	• Screening of interface with nature at site-level and prioritization of sites for Green Cubes roll-out • Selection of relevant metrics for Green Cubes implementation, based on identified high-level impacts and dependencies	• Detailed assessment of nature-related impacts, dependencies, risks and opportunities • Incorporation of Green Cubes–generated data in the assessment, as appropriate	• Definition of reporting ambition and structure • Internal controls for biodiversity reporting • Assurance readiness review of reporting draft	• Adoption/review of targets, strategies and transition plans, as appropriate
R-evolution	• Recommended approach to Green Cubes implementation and metrics analysis • Definition of expected outcome	• Project plan and design for Green Cubes roll-out • Onsite pre-study	• Data gathering • Access to platform dashboard for data visualisation	• Report generation on demand	• Continuous learning and evaluation • Scaling-up to additional location
Complementary tools/guidance	ENCORE	DOPA, IBAT, RED LIST	Relevant biodiversity indicators / footprinting tools Biodiversity Risk Filter, Water Risk Filter	TNFD, GRI, EFRAG	Science Based Targets Network

Related publications

[Getting started on your nature journey]

[The investment case for nature]

[Integrating nature tech: A guide for businesses]

[Big shift, small steps. Survey of sustainability reporting 2022]

[Why it's vital to value nature]

[You can't go green without blue]

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