Evidence review on the financial effects of nature-related risks

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TNFD Taskforce on Nature-related Financial Disclosures

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Executive summary

Aims and methodology

In line with the expectations of investors, regulators, standard setters and policy-makers, and in response to the Taskforce on Nature-related Financial Disclosures (TNFD) recommendations, corporates and financial institutions are beginning to understand how nature-related risks and opportunities emerge from their dependencies and impacts on nature. This calls for an integrated approach to identify, assess and manage material nature-related dependencies, impacts, risks and opportunities.

This report investigates how nature-related risks can lead to material financial effects on corporates and financial institutions. It demonstrates how nature-related risks may affect an entity's cash flows, cost of capital and access to capital over different time horizons, and thus influence investor decisions and capital allocation.

Although clear linkages exist, nature-related issues are frequently not considered financially material in corporate reports, especially from a single materiality perspective. Additionally, despite being a critical pathway to potential risk affecting the financial prospects of a business, dependencies on nature remain poorly understood and typically underexplored. Many companies continue to struggle to implement robust risk assessment methods, particularly with assessing the financial implications of these risks.

This report synthesises evidence on nature-related risks that could create material financial effects for corporates and financial institutions. It also identifies evidence gaps, presents insights from corporates and financial institutions on their risk assessment approaches and related challenges, and sets out recommendations for corporates, financial institutions, academia, regulators and standard setters.

This report draws on three key sources:

- Landscape analysis: A nature-related financial risks database was created with over 600 entries from 360 sources, covering 17 physical, five transition and six systemic risks. This database includes academic research, case studies, company reports and news articles (Section 2);
- Corporate and financial institution engagements: Five interviews and a review of public disclosures provided insight into current practices for assessing the financial materiality of nature-related risks (Section 3); and
- Stakeholder engagement: Ongoing dialogue with academia, NGOs, experts and market participants, including a virtual workshop in May 2025, provided additional cross-cutting insights.

The database is not based on a comprehensive systematic review. Feedback and suggestions of additional evidence can be provided by responding to the accompanying public consultation (See Section 1.4).

Key Findings

The **evidence of financial effects of nature-related risks for businesses and the economy is extensive**. The evidence spans sectors, scales, hazards, time horizons and types of effect, with high-quality analysis across evidence types. However, **company-specific evidence is limited** in the academic literature, mainly due to the reliance of these studies on publicly available data. Company level financial effects are well-documented for water scarcity and reputational, liability and policy risks based on other reports and news, with moderate evidence on native species outbreaks.

Full causal chains (from dependencies and impacts to financial effects) are rarely fully mapped, with transmission channels remaining underexplored. The database includes an abundance of studies analysing individual parts of a causal chain (e.g. the link from a subdriver, such as wetland loss, to a natural hazard, such as flooding; or from a hazard, such as flooding, to business losses, such as in the insurance industry). However, there are few studies examining the full causal chain.

Evidence of financial effects at the company level varies by driver of nature loss. The strongest evidence of material financial effects covers:

a. **Water scarcity** leading to greater capital and operational expenditures and operational disruption/shutdown as well as the effect of internalising water stress into credit analysis;
b. Firm value effects stemming from **liability risk** (litigation resulting from the effects of pollution, marine degradation, wider environmental degradation as well as fines);
c. **Reputational risk** related to deforestation, pollution, water scarcity and wider environmental degradation spanning a range of sectors;
d. **Policy risk** leading to negative effects on firm value, capital and operational expenditure, operational disruption and stranded assets; and

There is moderate evidence of native species outbreaks damaging assets in the energy sector.

Limited evidence exists for financial effects of invasive species at the company level, despite extensive research showing significant and increasing costs at the economy-wide level.

Interviews and disclosure reports reveal **evidence to demonstrate that information on nature-related risks is important to investors** and that omitting, misstating or obscuring such information could reasonably be expected to influence investors' decisions.

Financial institutions are generally more advanced than corporates in applying quantitative methods for nature-related financial materiality assessment. Corporates tend

to use qualitative methods, such as stakeholder input. Corporates in particular find the TNFD LEAP approach useful to contextualise how their impacts and dependencies on nature might create material risks to the business.

Scenario analysis is seen as a promising but under-utilised approach, despite the guidance produced by the TNFD about how companies and financial institutions can begin to incorporate scenario thinking into their strategy and risk management. Building on their familiarity with 'top down' policy-aligned climate scenarios, interviewees noted a desire to have access to global scenarios from credible sources. For example, financial institutions referred to the central banks and supervisors network, the Network for Greening the Financial System (NGFS), to support robust internal assessments.

Financial institutions tend to use top-down, portfolio-level tools like heatmaps to identify their exposure to nature-related risks. They remain constrained by limited and inconsistent corporate disclosures to date for companies in their portfolios. Given the breadth and type of portfolios they are managing, and as nature-related disclosures among investees are still nascent, most financial institutions rely on proxies. Multiple indicators and metrics are needed to construct a comprehensive assessment.

Recommendations

Different stakeholders can take action to advance the assessment, management and disclosure of financially material nature-related risks.

- **Academia** should address the gaps in evidence of financial effects from nature-related risks, particularly at the company level and linking the full causal chain – from impacts and dependencies on nature through supply chains to financial effects on the business – across a wider range of geographies, sectors and risk types. Studies on transmission channels and interactions between nature, climate and social risks would support more robust materiality assessments and scenario development.
- **Data providers** should improve transparency on coverage of nature-related impacts, dependencies and risks within data products and sources to ensure data is not misinterpreted. Many capture only a fraction of the transmission channels covered in this evidence review. Data and analytic tools to inform an understanding of dependencies on nature in direct operations and value chains is notably absent.
- **Corporates and financial institutions** need to build internal capability to assess the financial effects of nature-related risks stemming from their dependencies and impacts on nature. For both corporates and financial institutions, applying structured approaches such as the TNFD LEAP approach can help. Financial institutions can improve portfolio-level assessments despite current data limitations, using available indicators and engaging with investees to understand their nature-related exposures. Scenario analysis offers a practical entry point to identify and communicate potential financial effects and both corporates and financial institutions can draw on TNFD's scenario guidance to make progress, while the NGFS further develops its approach to nature

scenarios. All organisations can disclose their thresholds for materiality – along with assumptions, risk mitigation measures and limitations – to enhance the credibility of risk assessments.

- **Standard setters and regulators** are encouraged to provide clear, consistent and practical guidance that reflects the growing body of evidence on the financial materiality of nature-related risks. The continuation of the NGFS nature scenarios work is particularly important to support risk assessments by financial institutions. Standardised frameworks, metrics and scenarios are needed to support a level playing field in disclosure and risk assessment expectations. Leadership from regulators and supervisors is essential to catalyse further progress.

1. Introduction

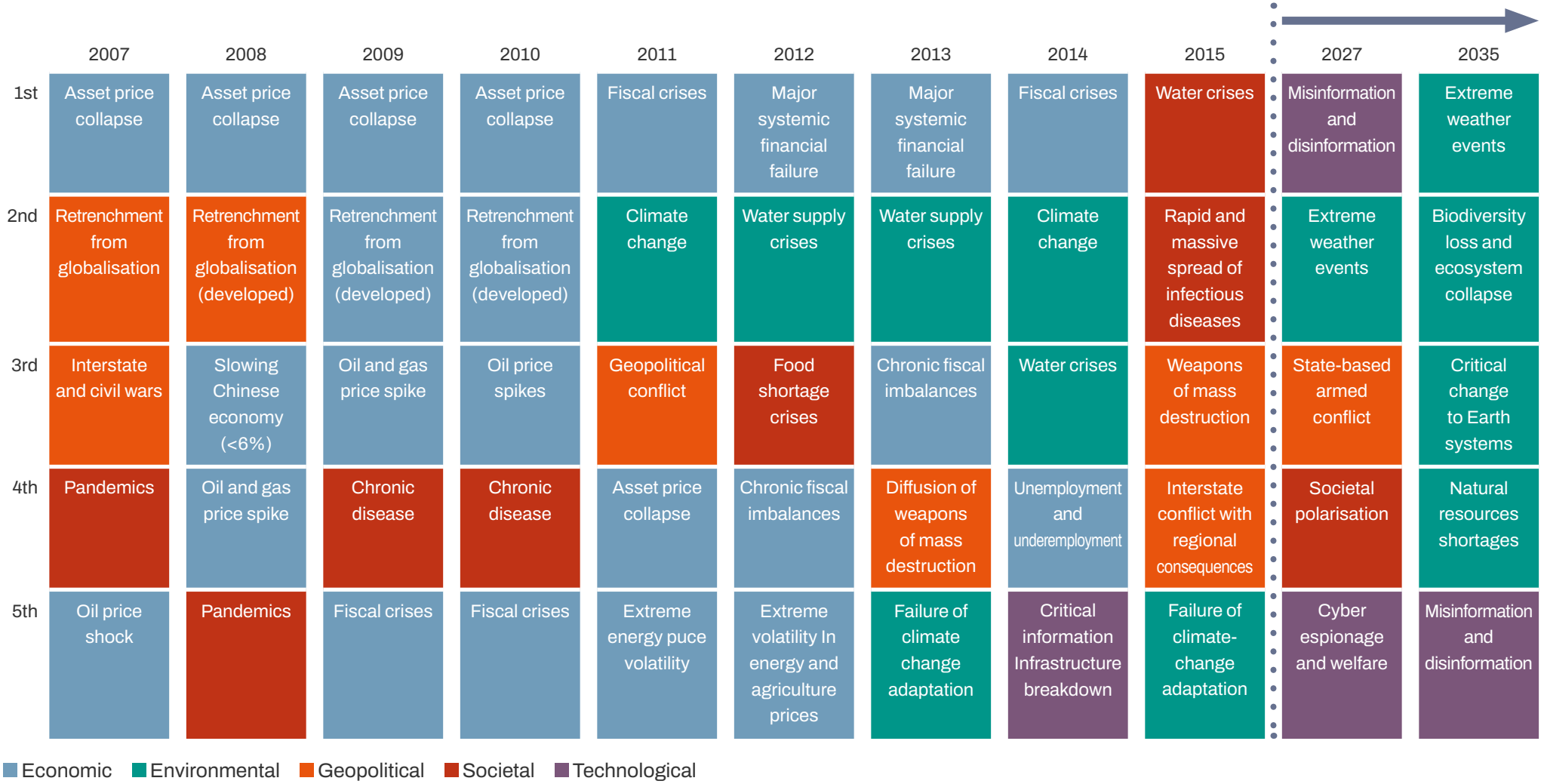
1.1. Background

Our society, economy and financial system are embedded in nature (Dasgupta, 2021). Nature degradation has reached unprecedented levels with a quarter of species at risk of extinction and an almost 50% decline (on average) in the extent and condition of natural ecosystems (IPBES, 2019). Six out of nine planetary boundaries have been breached beyond the 'safe operating space for humanity' (Richardson et al., 2023). The repercussions from nature degradation cascade through a range of channels to businesses, our economy, financial system and society more broadly.

In the evolution of the global risks identified by the World Economic Forum's Global Risks Report over time (see Figure 1), in 2007 none of the top five risks were environmental.[2] However, between 2011 and 2015, climate change and water risks emerged among the top five long-term risks (over the next 10 years). The latest report in 2025 includes 'Extreme weather events', 'Biodiversity loss and ecosystem collapse', 'Critical change to Earth systems' and 'Natural resources shortages' as the top four global risks in the long term (10 years). This shows growing recognition among leaders globally of increasing nature-related risks. What happens in the next five to 10 years will be critical in halting and reversing nature loss and supporting our economies, financial systems and way of life.

2 In 2006, the first edition of the report classified 'climate change' as an emerging risk that could 'become irreversible over the next 10 to 20 years and 'biodiversity loss' as an outlier, potential risk(s) 'that have not yet penetrated public consciousness, but which might have severe consequences' (WEF, 2006, p. 3).

Figure 1: Evolution of global risks in terms of impact (severity). 2027 and 2035 correspond to the short-term and long-term global risks in the 2025 report.



Source: Authors based on World Economic Forum's Global risks reports 2015, 2025.

The financial system plays a critical role in shaping the world we live in, by providing finance that facilitates investments in capital assets, including natural capital, and managing nature-related financial risks (Dasgupta, 2021). Investment decisions, whether at the household, individual, company or government level, on a daily basis can either contribute to or hinder achieving nature-positive outcomes.[3] Nature-negative financial flows were estimated at USD 7 trillion annually (~7% of global GDP), which is likely a conservative estimate (UNEP, 2023). The funding gap to meet the Sustainable Development Goals was estimated at USD 4.2 trillion (Joint UN SDG) and at USD 900 billion to meet biodiversity goals (Barbier, 2022).

Given the increasing prominence of environmental risks in the global risk landscape (Figure 1), assessing nature-related risks is a key first step to ensure the resilience of corporates and financial institutions, as well as of economic and financial systems. Aligning financial flows towards nature-positive outcomes cannot be achieved unless risks are properly assessed and priced (Ranger et al., 2023).

While there has been significant progress on assessing climate financial risks to date, assessing nature-related financial risks is still relatively limited among the majority of financial actors (WWF France and AXA, 2019, Sood et al. 2025, Sood et al. 2024, Sood et al., 2022). As demonstrated in Section 3, nature-related risk assessments are now increasingly being conducted by financial institutions, supported by the TNFD's recommendations and additional guidance, which includes guidance on risk assessment methods (TNFD, 2023).[4] Expanding the scope of climate risk assessments to nature is needed, as a siloed approach can lock in systemic risks (Ranger et al., 2023) and underestimate the financial risks of climate change by not considering natural capital, ecosystem services and their feedback loops comprehensively (Dasgupta, 2021).

At a macroeconomic level, scenario analysis has been used to estimate that environmental degradation at least doubles the climate risk to the UK. Projected GDP impacts by 2030 are larger than those from the financial crisis for either a domestic or international scenario of environmental degradation (-6% versus the baseline) and larger than the COVID-19 pandemic for an antimicrobial resistance scenario (-12% versus the baseline) (Ranger et al., 2024). An important conclusion from this analysis is that at least half of the financial risk to the UK comes from abroad. This shows how the local dimension of nature can cascade through supply chains into effects far away from their origin, whether non-economic (e.g. health impacts), economic or financial.

3 See Annex II: Glossary for the definitions of nature-related concepts used throughout this paper.

4 Annex 4 of the TNFD LEAP approach includes guidance on risk assessment methods for measuring nature-related risks and opportunities, including heatmaps, asset tagging and scenario-based approaches. This guidance is the result of targeted pilots made with a group of asset owners, and can be used in various phases of LEAP depending on the needs of the assessment (e.g. whether using heatmaps to link assets to sectors and locations in the Locate phase or measuring the magnitude of nature-related risks with scenario-based approaches in the Assess phase).

The Kunming-Montreal Global Biodiversity Framework (GBF), a landmark international agreement to halt and reverse biodiversity loss by 2030 and achieve full recovery by 2050, was signed by 196 countries in 2022 (CBD, 2022). Two years earlier, the Finance for Biodiversity Pledge was initiated by 26 financial institutions (with USD 3 trillion assets under management) as a call to action for global leaders and a commitment to protect and restore biodiversity through their activities (Finance for Biodiversity Foundation, 2020). To date, the number of signatories totals 200 financial institutions in 28 countries comprising USD 23 trillion assets under management (Finance for Biodiversity Foundation, 2025).

In response to the expectations emerging from investors, standard setters, regulators and policy-makers, including those set by Target 15 of the GBF, and the TNFD recommendations, corporates and financial institutions are increasingly recognising how their nature-related risks (and opportunities) stem from their dependencies and impacts on nature. This reinforces the importance of taking an integrated approach to identifying, assessing and managing all nature-related dependencies, impacts, risks and opportunities[5] for an organisation to respond to possible effects on its financial position, financial performance and prospects resulting from the degradation of nature. In line with TNFD definitions, dependencies and impacts are of an organisation *on nature*, and risks *to*, and opportunities *for*, the organisation.

1.2. Need for this assessment

Dependencies and impacts on nature can create financially material risks and opportunities for businesses. Companies both depend on and impact nature through their activities and value chain(s). Importantly, the interaction and compounding effect over time of dependencies and impacts can lead to a company negatively impacting the ecosystem services it depends on (TNFD, 2023).

From a sustainability disclosure perspective, while the International Sustainability Standards Board (ISSB) focuses on a single (or financial) materiality approach to meet the needs of global capital markets, the Global Reporting Initiative (GRI) enables organisations to publicly disclose their impacts in a way that meets multi-stakeholder information needs, and the European Sustainability Reporting Standards (ESRS) use a 'double materiality' approach which covers both impact and financial materiality. According to European Financial Reporting Advisory Group (EFRAG) definitions, impact materiality pertains to the material information about the undertaking's impacts on people or the environment related to a sustainability matter; financial materiality pertains to the material information about risks and opportunities related to a sustainability matter (EFRAG, 2024). According to ISSB definitions, information is material if omitting, misstating or obscuring that information could reasonably be expected to influence decisions of primary users, i.e. existing and potential investors, lenders and other creditors.[6]

5 Collectively referred to by the TNFD as 'nature-related issues' or DIROs.

6 The definition of 'material information' in ISSB Standards is aligned with the corresponding definition used in ESRS related to 'financial materiality'. See Educational material – Sustainability-related risks and opportunities and the disclosure of material information (ISSB, 2024).

The analysis presented in this report focuses on how nature-related risks, stemming from a company's impacts or dependencies on nature, may originate material financial effects for corporates and financial institutions. This focus aligns with one of the key aims of the ISSB's research project on Biodiversity, Ecosystems and Ecosystem Services (BEES) to look at evidence of financial effects on an entity's prospects. In particular, this paper and the ISSB share the aim of improving understanding of how and to what extent nature-related risks may affect an entity's cash flows, access to and cost of capital over the short, medium or long term, which may influence investor decision making and resource allocation.[7]

Uncertainty around biodiversity litigation or regulation has been associated with a risk premium requirement by investors (Garel et al., 2024). The analysis, which sampled over 2,100 listed companies, used a 'Corporate Biodiversity Footprint' (CBF) metric to explore whether investors priced impacts on biodiversity and found that those stocks that had large CBF lost value both following the Kunming declaration in October 2021 – the precedent to the GBF – and the launch of the TNFD in June 2021 (Garel et al., 2024). Another analysis showed that those companies in the infrastructure sector that manage biodiversity, pollution and water risk more effectively have better refinancing options in the long-term by 93 basis points (bps). This signals a positive market response to an increase in environmental regulation on these three criteria (Hoepner et al. 2023). Another study on investors' views around biodiversity risk found that: 1) around 70% of respondents (based on 668 surveys) considered biodiversity risks (both physical and transition) 'at least moderately' financially material to US companies; and 2) biodiversity risk affects the portfolio returns of US companies (Giglio et al., 2024).

A global survey of Norges Bank Investment Management (NBIM) investee companies in 2025, focused on nature-related risk perceptions, found that: 1) 44% of responding companies consider that nature-related physical risks have financial effects "already today" (28% for nature-related transition risks); 2) according to the responding companies, these financial effects result from a range of sources, including products and services, operations and supply chains, changes in investor demand and reputational damage; and 3) while approximately 40% of companies believe investors consider nature risks in investment decisions, only about 20% of companies think investors assess how these risks affect forecasted cashflows or cost of capital (Gjerde et al.,2025).

Nature is often not deemed material in corporate reports – especially from a single materiality perspective – even where materiality would be expected. Despite being a critical pathway to potential risk affecting the financial prospects of a business, dependencies on nature remain poorly understood and typically underexplored. Evidence from analyses of the first wave of Corporate Sustainability Reporting Directive (CSRD)-aligned sustainability reports suggests that, in relative terms, companies tend to disclose a higher percentage of risks (with respect to impacts) within the topical standard of climate

7 See July 2024 Staff paper agenda reference 2B: Biodiversity, ecosystems and ecosystem services and human capital research projects – Research design and approach (ISSB, 2024).

change (ESRS E1) than other environmental topical standards.[8,9] This suggests that, even when material negative impacts are identified, many companies do not yet perceive a direct translation of these impacts into financially material risks for the European environmental topical standards beyond climate change. Dependencies on nature are also not always or systematically considered.

At a company level, despite growing guidance on nature-related risk assessment (see, for example, Annex 4 of the TNFD LEAP guidance), many companies still face challenges in applying robust risk assessment methods – particularly in translating these risks into financial implications when considering a financial materiality lens. Corporates and financial institutions seek measurable financial evidence to support better risk management and capital allocation. Quantifying financial effects is also key to increasing engagement with nature-related risks among many financial institutions and other key organisations in the finance system, such as standard setters and regulators.

1.3. Objectives and structure of this report

This report has four main objectives:

- Synthesise the evidence related to impacts and dependencies on nature that can lead to nature-related risks that may materially affect individual corporates and financial institutions either directly or indirectly (e.g. through macroeconomic channels);
- Identify gaps in the available evidence of the financial effects of nature-related risks to businesses;
- Present insights from corporates and financial institutions on their methods to assess the financial materiality of nature-related risks, the challenges and lessons learned; and
- Provide recommendations to different stakeholders (corporates and financial institutions, academia, data providers, standard setters and regulators) on next steps and further research needs to further progress the materiality assessment of nature-related risks.

The methodology underlying this report is based on a collection of evidence compiled by the authors through three main sources:

- **Landscape analysis:** A database of existing academic research, case studies, empirical evidence and reports was compiled, providing evidence on the relevant financial effects of nature-related risks on corporates and financial institutions (Section 2). This 'nature-related financial risks database' accompanies this report.

8 E2 – Pollution, E3 – Water and Marine Resources, E4 – Biodiversity and Ecosystems, E5 – Resource Use and Circular Economy.

9 The analysis by Datamaran (2025) reviewed 304 CSRD sustainability statements and 11,208 individual Impacts, Risks and Opportunities (IROs) statements from companies across 21 countries and 57 industries across 11 broad business sectors.

- **Insights from corporates and financial institutions:** Insights were gathered from corporates and financial institutions, including through five interviews on companies' understanding and assessment of the financial materiality of nature-related risks to their businesses, existing corporate reports and learnings from the recently published GRI-TNFD case study report on nature-related DIROs (Section 3).
- **Stakeholder engagement:** Ongoing exchange with academia, NGOs, expert consultants and market participants provided cross-cutting insights that informed the entire report, complementing both the landscape analysis and the interviews. This additional input focused on the available evidence and potential challenges and was collected throughout the six-month duration of the project, including a virtual workshop held in May 2025.

1.4. Public consultation on the nature-related financial risks database

Public consultation: Contribute to the nature-related financial risks database

We invite stakeholders from across academia, industry, civil society and the public sector to provide feedback on the nature-related financial risks database developed as part of this assessment.

In addition, if you are aware of relevant evidence – academic or grey literature, case studies, empirical analyses or corporate disclosures – not currently reflected in the database, please submit additional sources using this link, indicating the nature of the evidence and, where possible, how it contributes to understanding the financial effects of nature-related risks.

The consultation will remain open until 31st December 2025. Submissions will be considered for a future update of the database.

2. Landscape analysis on financial effects of nature-related risks on businesses

The landscape analysis compiled existing research, reports, case studies and other evidence that demonstrate how dependencies and impacts on nature can lead to nature-related risks that materially affect individual businesses, the economy and financial institutions (for example, business performance, profitability and financial stability). A nature-related financial risks database was created to classify the evidence in a systematic way. It focuses on identified evidence of the financial effects of nature-related risks on corporates and financial institutions.

Given the exploratory nature of this research area and the diversity of study designs and reporting formats, a scoping review was conducted to map the existing literature on nature-related financial risks. Given the database is not the result of a comprehensive systematic review, there are likely remaining gaps in the breadth and depth of evidence included. As noted above, a consultation now follows the publication of the database and feedback on any further evidence not yet captured in this analysis is welcomed.

The scoping review was particularly suited to capturing the breadth of available knowledge and clarifying conceptual boundaries within this heterogeneous body of work. By including both peer-reviewed academic studies and grey literature (including case study) reports, it allowed for the identification of key concepts, types of evidence and gaps in current research. The nature-related financial risks database includes over 600 entries based on over 360 sources of information. Both evidence at individual institution-level (e.g. business performance), financial and economic system-level (e.g. financial stability) was collected.

The categorisation of the database was informed by the evidence incorporated into it. The categories in the nature-related financial risks database include:

1. **Publication type:** Peer-reviewed academic papers, reports, news, databases and books.
2. **Evidence type:** Simulation, statistical, case studies (e.g. at the individual organisation level), news, surveys.
3. **Scale:** Local, national, regional, global, company, industry.
4. **Sector:** A range of sectors (including agricultural products, fisheries, real state, metals and mining, energy, consumer goods), differentiating between impacted and impacting sectors when applicable.
5. **Time horizon:** Present, past and potential future events.

6. **Persistence:** Acute, chronic, mix (if physical); acute, gradual (if transition).
7. **Physical/transition/systemic risk:**[10] For rapid screening. Specific company physical, transition and systemic effects are captured in individual columns to provide more detail.
8. **Country:** Country and locality (if available).
9. **Driver origin country:** Country of the company or economic activity that leads to nature degradation.
10. **Driver of nature change:** Based on the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)' five drivers of nature change (see Figure 2) – namely land/freshwater/ocean use change[11], climate change, resource use, invasive alien species and pollution (IPBES, 2019).

Figure 2: The five drivers of nature change (TNFD, 2023)

11. **Subdriver of nature change:** Specific human drivers of nature loss within the wider "driver" categories. For instance, "resource use" includes water depletion and soil depletion. "Land/freshwater/ocean use change" includes wetland loss and monocrop tree plantations.
12. **Nature effect:** The main effect to nature of a subdriver. For instance, if the subdriver is "water depletion", a possible nature effect is "water scarcity." For the subdriver "wetland loss", a possible effect is "flooding."
13. **Nature-related hazard:**[12] A synthesis of the evidence of the nature hazard (see Table 1 for a complete list).

10 See TNFD definitions of nature-related physical, transition and systemic (including ecosystem stability and financial stability) risks in the TNFD Glossary.

11 Note: the TNFD adds 'freshwater' with respect to IPBES definitions.

12 Following NGFS (2023), nature-related hazards are defined as:
- "Physical hazard, which can be acute (e.g., an immediate "shock" or disruption of ecosystem services) or chronic (e.g., long-term decline in ecosystem services resulting from prolonged environmental degradation);
- Transition hazard, which can be sudden (e.g., a new or unexpected change in environmental regulations) or gradual (e.g., long-term, progressive tightening of environmental regulations or change in consumer preferences)."

14. **Typology of sources and transmission channels of nature-related risks:** This includes a nature-related hazard and its transmission channel. For example, soil degradation negatively impacts crop output (physical), while liability for environmental effects of pollution negatively affects investor confidence (transition).
15. **Nature-related non-economic, economic, company effect:** A synthesis of the main effect (e.g. stranded assets, firm value).

As an example, for the liability risks to companies from per- and polyfluoroalkyl substances (PFAS) pollution, the categories 11 to 15 would be as follows: freshwater pollution (subdriver of nature change) leads to a decrease in disease regulation (nature effect), which poses a liability (nature transition hazard) to companies, decreasing investor confidence (transmission channel), which leads to a decrease in firm value (nature-related non-economic, economic, company effect).

The database includes different types of evidence, so while the nature-related hazard is included for all entries, the evidence is not always available for all categories.

There are two main types of evidence. First, non-company nor industry-specific effects that include:

16. **Non-economic human effects:** (e.g. impacts on population affected by food shortages, disease, deaths).
17. **Economic effects:** At the local, national or global scale.

Second, company or industry-specific effects that are documented, with specific categories including: company name, company specific site, physical, transition or systemic effects, company financial losses/gain, company debt, equity and other impacts, and company operational status.

The rest of this section is structured as follows:

- Overview of a transmission channels framework of nature-related risks to businesses (Section 2.1);
- Synthesis of the evidence included in the database (Section 2.2);
- Selected examples and case studies from the nature-related financial risks database on water-related risks (Section 2.3), invasive alien and native species (Section 2.4), land/freshwater/ocean use change (Section 2.5), soil degradation (Section 2.6), zoonotic diseases (Section 2.7) and ecosystem stability risk (Section 2.8); and
- Summary of key gaps in the evidence included in the database (Section 2.9 and Annex I).

2.1. Transmission channels framework

Transmission channels for nature-related risks are pathways through which nature-related hazards translate into physical and transitions risks that can affect the economy at micro, sectoral/regional and macro levels (adapted from NGFS, 2023, 2024). These hazards can propagate through the economy via businesses and their supply chains and/or the financial system.

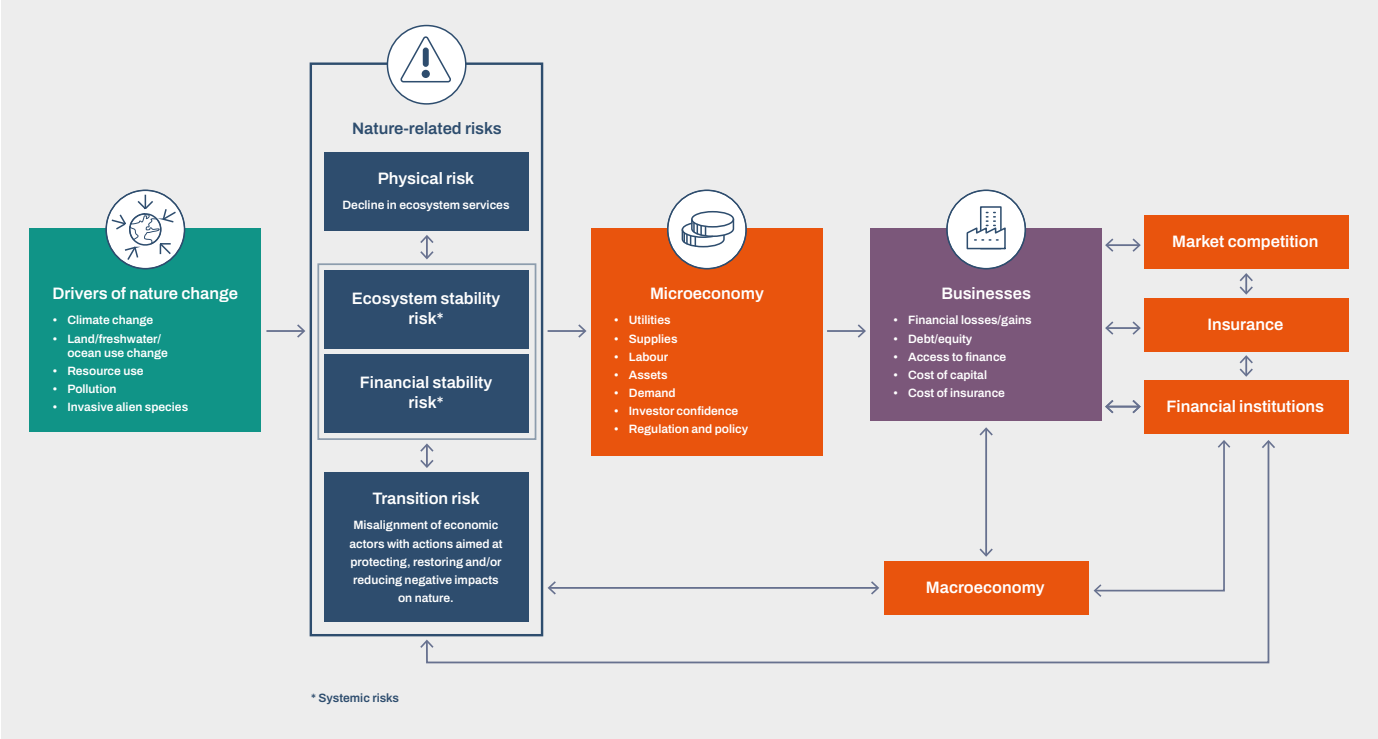
The framework represented in Figure 3 shows how drivers of nature change (resulting from both business activities or external factors) can be sources of nature-related risks for businesses, and how these risks can potentially materialise as financial effects via business-level or economy-wide channels, reflecting the complete nature-related risk causal chain from driver of nature degradation to financial outcomes.[13]

Following TNFD definitions, the five drivers of nature degradation can lead to three types of nature-related risks: physical risks, transition risks and systemic risks. Nature physical risks (either acute or chronic) result from nature degradation leading to a decline in ecosystem services. Nature transition risks result from a misalignment of economic actors with actions aimed at protecting, restoring or reducing negative impacts on nature. These manifest through changes in regulation and policy context (policy risk), changes in market dynamics (market risk), substitution of products or services (technology risk), changes in perception concerning an organisation's nature impacts (reputational risk) and legal claims (liability risk). Nature systemic risks result from a system breakdown, as opposed to failure of different parts of the system, and are categorised as ecosystem stability risk and financial stability risk (TNFD, 2023).

All nature-related risks are grouped as they can interact with each other. For example, ecosystem stability risk can potentially lead to nature-related physical or transition risks, which can compound and generate financial stability risk. Financial stability risk could also result from financial contagion driven by risks not related to nature (TNFD LEAP guidance, 2023).

13 The nature-related risk causal chain examines the linkages through which nature-related risks originate from the drivers of nature degradation and lead to effects through dependencies and impacts on nature. This is in line with what is called the 'impact chain' in Ranger et al. (2023) The Green Scorpion: the MacroCriticality of Nature for Finance. Oxford: Environmental Change Institute, University of Oxford.

Figure 3: Sources and transmission channels framework of nature-related risks to businesses



Source: Authors based on NGFS (2024)

Nature-related risks can affect businesses through five main channels: 1) directly through microeconomic channels (utilities, supplies, labour, assets, demand, investor confidence, regulation and policy), or indirectly through: 2) the macroeconomy (implications for prices, productivity, investment, socio-economic changes, fiscal balances and trade and capital flows – and particularly affecting inflation and gross domestic product (NGFS, 2024)), financial institutions, including 3) lenders (e.g. cost of capital and access to finance) or 4) insurance companies (e.g. availability and cost of insurance) or 5) other businesses (represented by market competition).

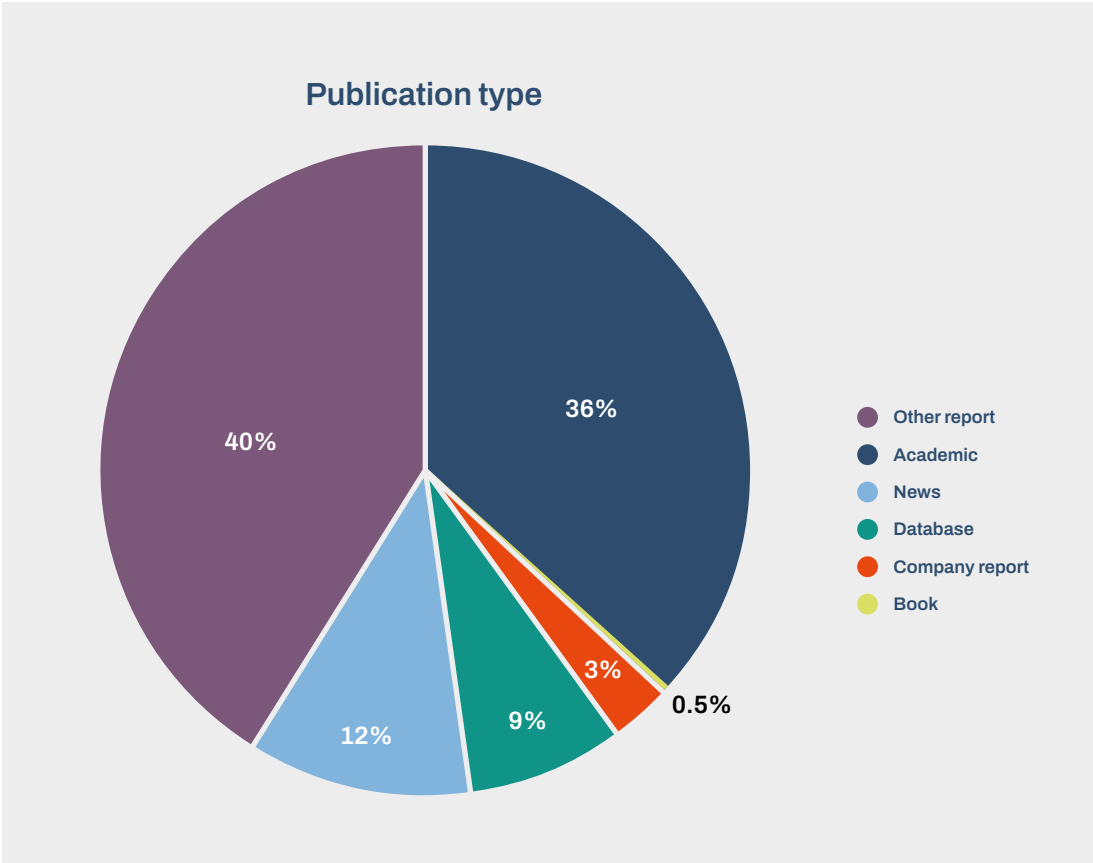
Business effects can materialise as financial losses/gains (e.g. decreased production due to operational disruption, increasing costs or change in market demand), changes in debt/equity valuation, access to finance, cost of capital and cost of insurance; or adjustments to strategic decisions, such as plans for increases in capital expenditure, divestments or asset retirements. Businesses also impact nature through their activities and can increase nature degradation or, conversely, contribute to nature recovery and enhancement. This is important because financial effects on businesses sometimes result from their impacts on nature in the first place (e.g. water pollution by a company leading to liability risk or reputational risk). While not explicitly included in the framework, a business can also mitigate the impact of a nature hazard (cost of response).

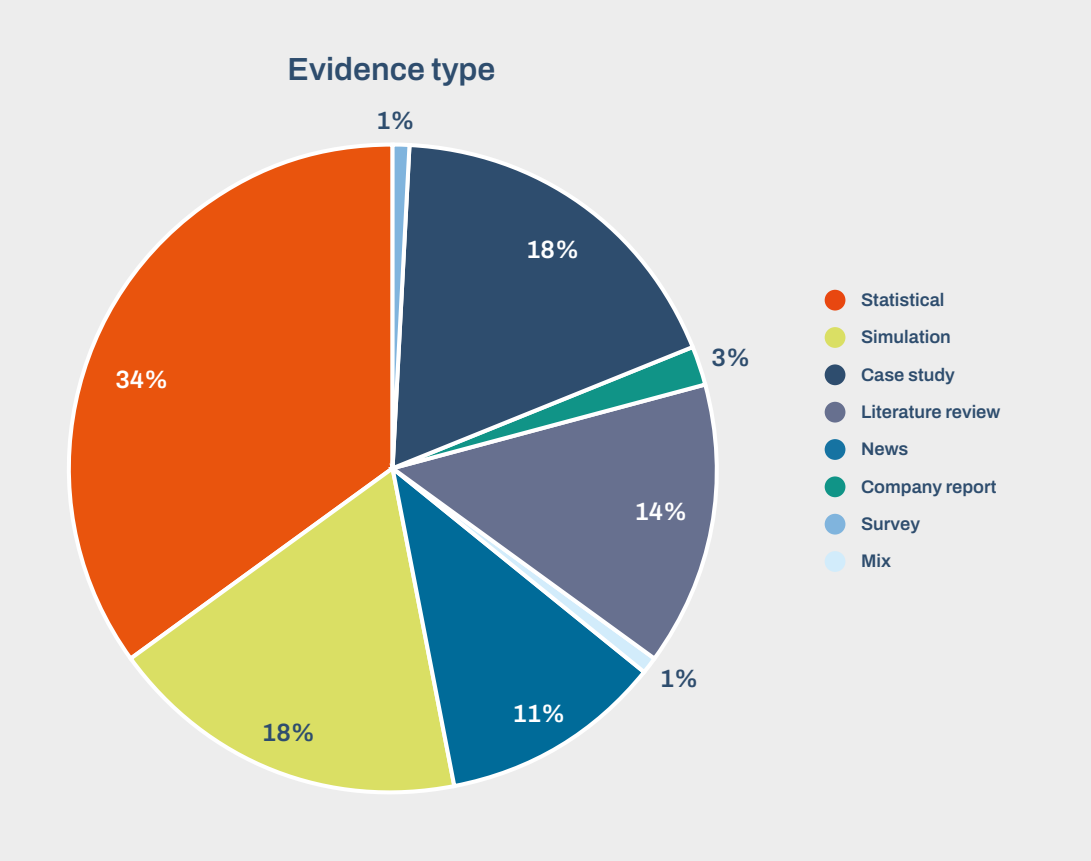
This framework enables compounding and cascading risk analysis that is critical to avoid underestimating the risks. For example, an analysis of the effects on economic, climate and COVID-19 pandemic shocks estimated the compounding effect to be 50% larger than the sum of the individual shocks (Ranger et al., 2021).

2.2. Synthesis of the evidence

The nature-related financial risks database includes over 600 entries, based on 360 sources of information spanning 17 physical, five transition and six systemic risks. It also includes relevant studies on exposure to nature risks. 42% of the entries are based on company or other reports, 36% on academic publications (peer-reviewed or working papers), 12% on news articles and around 10% from other sources. In terms of evidence types, 34% of entries are based on statistical analysis, 18% on simulation studies, 18% on case studies, 13% on literature reviews and 11% on news.

Figure 4: Synthesis of nature-related financial risks database by publication and evidence type





The evidence is synthesised in Table 1 across three categories: non-economic, economic and company level effects. The evidence on economic effects is extensive across most nature-related hazards. For company level effects, the evidence on physical nature-related hazards is extensive on water scarcity, flooding and more moderate on native species outbreaks, harmful algal blooms and invasive alien species (despite research showing significant and increasing costs of invasive alien species to the economy). For transition risk, there is extensive evidence of company level effects for liability, reputational and policy risks. For drought and flooding, there is more extensive literature that was not reviewed as part of this analysis as it is specifically focused on climate-related risks.

The evidence on non-economic effects was not the main focus of this analysis. Entries for this category have only been included in the database when found while looking for evidence of the other types of effects.

Table 1: Synthesis of the available evidence in the nature-related financial risks database of the nature-related hazards as non-economic, economic and company-level effects

Nature-related hazards	Non-economic effects	Economic effects	Company effects
Physical			
Coral reef degradation			
Drought			
Environmental degradation			
Extreme heat			
Fisheries collapse			
Flooding			
Harmful algal blooms			
Invasive alien species			
Mangrove loss			
Native species outbreak			
Pollination decline			
Soil degradation			
Water quality decrease			
Water scarcity			
Wildfire			
Wind erosion			
Zoonotic disease			
Transition			
Liability			
Market			
Policy			
Reputational			
Technological			

Nature-related hazards	Non-economic effects	Economic effects	Company effects
Systemic			
Amazon dieback			
Crop extinction			
Ecosystem services collapse			
Ecosystem stability			
Multi-breadbasket failure			
Regime shift			

Key ☐ (0 – entries) ■ (1 entry) ■ (2-4 entries) ■ (5+ entries) in the database.

In addition to the studies included in Table 1, the database also includes other types of evidence mostly focused on exposure. For example, Galaz et al. (2023) mapped the financial flows of companies operating in emerging and re-emerging infectious diseases hotspots (e.g. where the Ebola virus is prevalent) to their largest owners and found that the top four ownership positions (USD 8 billion to 21 billion) are held by Vanguard, BlackRock, T Rowe Price and State Street corporation. Marsden et al. (2024) analysed exposure to deforestation-related activities (through supply chains) in ecosystems facing possible tipping points and important ecosystems by identifying companies contributing to land use change and degradation in those regions and mapping the financial flows to these companies. The report includes entity-level details for both corporates and financial institutions. Several other studies from central banks have included estimates of their dependencies and the biodiversity footprint of their portfolios (van Toor et al., 2020; Svartzman et al., 2021; Martinez Jaramillo et al., 2022; Boldrini et al., 2023; Ceglar et al., 2023). Notably, Xin et al. (2025) conclude that biodiversity ratings do not affect returns on assets and profit margins nor are they incorporated into institutional investors' decision-making.

Other studies not included in Table 1 but detailed in the database focus on value at risk metrics. For example, Ranger et al. (2023) developed the nature value at risk metric (nVaR) and estimated that 7% to 9% of global GDP is potentially at risk from water-related risks.

The database includes a typology of nature hazards that lead to a range of non-economic, economic and company effects (see Annex I: Landscape analysis synthesis and Table 2). The classification of these effects is based on the transmission channels framework described above, with further detail on specific company level effects. Sections 2.3 to 2.8 highlight specific examples at the company level. Key findings include:

- **Water:** There is extensive literature about water scarcity negatively affecting supplies and operations and leading to capital expenditure, operational expenditure effects

and operational disruption, as well as the effect of internalising water stress negatively affecting firm value through EBITDA. There are some examples of water scarcity affecting investor confidence and leading to firm value effects.

- **Invasive alien species/native species:** There is extensive literature about native species outbreaks damaging assets and leading to operational shutdown and moderate literature on invasive alien species damaging assets and affecting operational expenditure, although there is extensive and increasing evidence at the macroeconomic level (e.g. IPBES, 2023).
- **Liability risk:** There is extensive literature about firm value effects through a decrease in investor confidence. These include litigation on the environmental effects of pollution, marine degradation, wider environmental degradation and fines spanning a range of sectors including agrifood, chemicals, metals and mining, energy, pharmaceuticals and shipping.
- **Reputational risk:** There is extensive literature about negative effects on investor confidence leading to reputational effects, causing financial consequences to businesses related to deforestation, pollution, water scarcity and wider environmental degradation, spanning a range of sectors (metals and mining, chemicals, energy and agrifood).
- **Policy risk:** There is extensive literature about policy risk leading to negative effects on firm value, capital and operational expenditure, operational disruption and stranded assets.

Table 2: Synthesis of the available evidence in the nature-related financial risks database of nature-related hazards at the company level

Nature-related hazards	Capital expenditure	Firm value	Operational disruption	Operational expenditure	Operational shutdown	Regulatory changes	Stranded assets
Physical							
Drought							
Environmental degradation							
Flooding							
Harmful algal blooms							
Invasive alien species							
Native species outbreak							
Soil degradation							
Water quality decrease							
Water scarcity							
Wildfire							
Transition							
Liability							
Market							
Policy							

Nature-related hazards	Capital expenditure	Firm value	Operational disruption	Operational expenditure	Operational shutdown	Regulatory changes	Stranded assets
Reputational							
Technological							
Systemic							
Ecosystem stability							

Key ☐ (0 – entries) ■ (1 entry) ■ (2-4 entries) ■ (5+ entries) in the database.

As noted at the start of this section, some of these gaps are related to a lack of evidence encompassing the whole nature-related risk causal chain (from driver/s of nature degradation -> nature effect -> nature hazard -> financial effect) while others may relate to a lack of proper identification of nature-related risks (e.g. invasive alien species).

The following sections provide an overview of evidence grouped by key themes. Section 2.3 covers water-related risks as there is extensive evidence of effects at the company level in the database. Section 2.4 covers invasive alien species where there are extensive economic effects in the literature, but less at the company level (perhaps due to lack of disclosure or registration as such). Sections 2.5 and 2.6 cover land use change and soil degradation, with a focus on how different types of evidence in the database can be connected. Sections 2.7 and 2.8 cover zoonotic diseases and ecosystem stability risk respectively, where the database contains fewer entries and has less evidence at the company level, yet there is evidence these nature-related risks are increasing over time. Section 2.9 synthesises the main findings and gaps.

2.3. Water-related risks

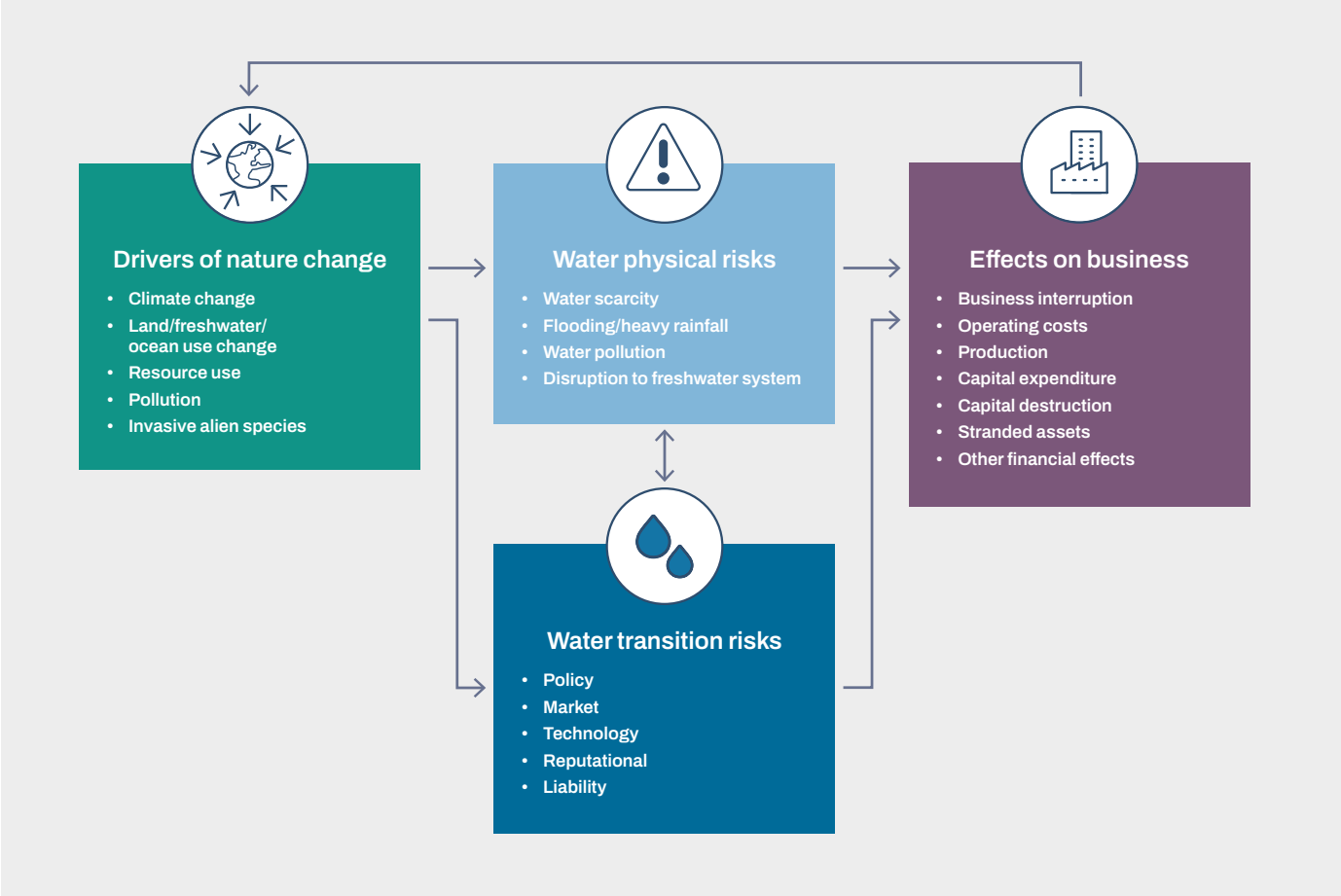
The global water crisis, driven by land use change, resource use, pollution, invasive alien species and climate change, is worsening and the breadth and depth of negative impacts includes an increase in the severity and frequency of water-related extreme weather events (floods, droughts, heatwaves and wildfires) globally (Global Commission on the Economics of Water, 2024):

- Almost 3 billion people and 55% of global food production are located in areas where water storage is declining;
- There has been a doubling of the rate of increase in water withdrawals (relative to population growth) in recent decades;
- There will be an estimated 23% loss in cereal production globally if irrigation becomes unfeasible in areas experiencing extreme water storage declines; and
- Under a business-as-usual scenario, GDP losses are projected to be 8% for high-income countries and 10% to 15% for lower-income countries by 2050, with disruptions of trade and losses of human capital also occurring.

Exposure to water risk could lead to substantial impacts across the real economy. In 2022, 69% of publicly listed companies disclosing water-related data through CDP reported exposure to water-related risks worth up to USD 225 billion, almost double the USD 119 billion those same companies reported it would cost to respond to these risks. Potential impacts reported include disruption or reduction of production capacity (44%), increase in operating costs (24%), reduced revenues (11%), disruption to supply chains (9%), closure of operations (8%) and constraints to growth (5%) (CDP & Planet Tracker, 2022). Potential financial impacts from water-related risks through supply chains were estimated at USD 77 billion (by ~91% of respondents), largely due to physical risk (USD 54 billion of acute physical risk and USD 16 billion of chronic physical risk), regulatory risk (USD 6 billion), reputation and market risk (USD 0.7 billion) and technological risk (USD 0.04 billion) (CDP, 2024).

This section focuses on examples of how these risks have led or could lead to negative effects on businesses through different transmission channels. Readers can refer to the wider resources on water-related risks included in the nature-related financial risks database for more details and/or examples.

Figure 5: Water risk causal chain to businesses



Source: Adapted from Davies & Trémolet (2024)

The nature-related financial risks database includes several examples of how dependencies and impacts on water pose risks to businesses. Organisations dependent on a supply of clean freshwater can experience physical risks where droughts, floods or water pollution events increase in frequency or severity. Organisations involved in extraction or pollution of water can also experience transition risks where regulations increase, they experience reputational damage as a result of their activities, where other users are competing for access to the same water, or their own water cleaning costs increase. Physical water risks include water scarcity, pollution, flooding and heavy rainfall, and disruption to freshwater systems. These can lead to a range of effects on businesses' operational status, operating costs, production, capital expenditure, capital destruction and stranded assets. For example, there is evidence (GIZ, NCD and VfU, 2015) that water scarcity from supply and demand pressures leads to:

- Increasing capital expenditure (e.g. for salinisation technology);
- Increasing operating costs (e.g. higher water tariffs as utility companies need to recover their increasing capex);

- Decreased production (e.g. restrictions on water use and demand management); and
- Stranded assets (due to losses of operating social licenses in, for example, water scarce regions) which can negatively impact revenues, credit warnings and downgrades, and growth.

Water scarcity leading to business interruption. A study on water risks to India's thermal power sector, where high water stress impacts 40% of thermal power plants, estimated that disruptions due to water shortages in 14 out of the 20 largest companies led to over USD 1.4 billion in revenue losses between 2013 and 2016 (WRI, 2018). Another analysis of the financial impacts of water shortages on the thermal power sector in India, using asset level data, found negative impacts on quarterly earnings of up to 17.4% (from 2014 to 2017) due to outages in electricity generation (WRI, 2019). In 2017, African Rainbow Minerals – a mining company with operations in South Africa and Malaysia – experienced USD 100 million of revenue losses, which resulted from interruptions to water supply in South Africa that led to three to four weeks of production losses (CDP, 2019).

Water stress increasing operating costs. An analysis of the risk from water stress to corporate bonds in 24 companies across the mining, beverages and power utilities sectors estimated that the full internalisation of water usage costs could lead to negative impacts on credit ratios (GIZ, NCD and VfU, 2015). Examples of rising Net Debt/EBITDA ratios include: Barrick Gold (20% to 3.3x); Vedanta (65% to 3.85x); Glencore (341% to 1.72x); Rio Tinto (265% to 2.96x); EdF (26% to 3.55x); Eskom (194% to 27.63x); Sempra energy (97% to 6.74x); Femsa (272% to 2.27x), with an average value of 80% for mining, 98% for power utilities and 28% for beverage sectors.

Water stress leading to increases in capital expenditure. Water stress poses a risk to copper mining in Chile, the largest copper producing country with over a quarter (27%) of global production (WEF, 2022), because the majority of its reserves are located in regions under high water stress (Fitzsimons and Warren, 2024). Several bills have been presented to congress to make desalination plants mandatory for large mining companies (Biblioteca Nacional del Congreso de Chile, 2023). While a law has not been passed yet, several mining companies have already invested in desalinisation plants. For example, in 2024, Antofagasta minerals inaugurated a desalination plant in Los Pelambres and expansion plans are underway (from 2024 to 2027) with an investment cost of USD 2 billion (Antofagasta PLC, 2024). In 2018, the Minera Escondida mine (owned by BHP Billiton (57.5%), Rio Tinto (30%), JECO Corporation (10%) and JECO 2 Ltd. (2.5%)) inaugurated its desalination plant after a USD 3.43 billion investment (BHP, 2018). Anglo American currently has two desalination plants under construction in Chile, one in its Collahuasi operation and another in Los Bronces (Anglo American, 2025). Freeport is also planning a desalination plant at its El Abra mine in Chile as part of a USD 7.5 billion investment (S&P, 2024). Aside from the increase in capital expenditure, this has implications for operating costs, given the higher cost of water from desalinisation plants.

Freshwater flooding leading to capital destruction. In 2011, a 'mega flood' in Thailand resulted in over 800 casualties, negatively impacting 1.9 million households, displacing 2.5 million people and resulting in USD 46.5 billion economic damages, with USD 32 billion affecting the manufacturing sector (Haraguchi & Lall, 2015), leading to a 2.5% decrease in global industrial production (UNISDR, 2012). Seven industrial parks containing over 800 companies (56.7% Japanese operated or owned) were inundated and complete drainage of the facilities extended between 33 and 62 days, leading to the closure of 62 businesses (Haraguchi & Lall, 2015). For the automobile sector in particular, it took as much as 174 days for factories to recover from flood damages (e.g. Honda's factory in Rojana industrial park). Negative impacts on net profits (% versus 2010) were: Toyota (USD 2.5 billion, -57.5%); Honda (USD 2.7 billion, -59.7%) and Nissan (USD 3.6 billion, -9%) (Haraguchi & Lall, 2015).

Water shortages leading to stranded assets. Following concerns and protests over water shortages, a referendum led to an USD 650 million to USD 680 million asset impairment of Constellation Brands' partially constructed Mexicali brewery in Mexico because of the company's inability to sell or operate the brewery (Constellation brands, 2021). Protests over water overextraction and pollution led to the closure of a USD 25 million Coca-Cola new bottling plant in India, although neither indirect losses (to the supply chain) nor reputational damages are quantified (The Ecologist, 2014). Starbucks relocated part of its operations due to water shortages, moving its Ethos water bottling plant from California to Pennsylvania due to drought (Los Angeles Times, 2015). Other examples of water-related stranded assets include Barrick Gold's Pascua-Lama gold mine (USD 7.5 billion), Exelon's Oyster Creek nuclear power station (USD 0.9 billion) and TC Energy's Keystone XL Pipeline extension (CAD 7.6 billion) (Planet Tracker & CDP, 2022).

Litigation over water pollution leading to financial effects. Pollution from PFAS, also known as 'forever chemicals', led to a USD 1,185 billion settlement between Chemours (USD 592 million), Corteva (USD 193 million) and DuPont (USD 400 million) with United States Public Water Systems (DuPont, 2023) to resolve all water claims related to PFAS. Other relevant examples of PFAS-related settlements include 3M's settlement of up to USD 12.5 billion (3M, 2024) and BASF's of USD 316.5 million (Reuters, 2024). Kidde Fenwal reached a USD 730 million settlement over PFAS in firefighting foam products causing water and soil pollution and ultimately filed for Chapter 11 bankruptcy protection in a New York court (Reuters, 2024). Notably, PFAS pollution clean up, if uncontrolled, could surpass USD 1.6 trillion in the UK and Europe in the coming years (The Guardian, 2025; The Forever Pollution Project, 2025). Importantly, an analysis by the Minnesota Pollution Control Agency found that while PFAS cost USD 50 to USD 1,000 per pound, the estimated cost of removing PFAS from municipal wastewater is between USD 2.7 million and USD 18 million per pound, depending on the size of the wastewater facility (MPCA, 2023).

Pollution leading to increases in capital expenditure and operating costs. Costs associated with water quality management have been estimated at USD 100 million annually by Anglo American for three of its sites in North America (CDP, 2019). In 2024, the Water

Services Regulation Authority in England and Wales (Ofwat) proposed a GBP 6 billion nutrient pollution reduction programme (Ofwat, 2024).

Pollution negatively impacts human health. Our database includes a handful of examples. These were not the focus of the landscape assessment, as some of these costs are borne at the government level, but they can cascade to businesses effects, for example, through labour, reputational or liability risks. In 2019, The Lancet Commission on Pollution and Health estimated that 1.4 million deaths were attributable to water pollution (Fuller et al., 2022). A literature review on the impacts of water pollution on human health estimated that water pollution is related to 80% of diseases (Lin et al., 2022). Multiple drivers related to pollution and human health can compound or interact and materialise as a non-economic, economic and company effect. For example, deforestation reduces the effectiveness of water treatment and eventually child health as forests also act as water filtration agents. In Haiti and Honduras, for instance, children near deforestation sites tend to have a greater incidence of diarrhoea (Rasolofoson et al. 2021). In Malawi, net gain in forest cover during a 10-year period was associated with a 34% decrease in the probability of the children experiencing diarrhoea (Johnson et al. 2013).

2.4. Invasive alien species

A global systematic review of studies published between 2005 and 2018 has estimated that invasive alien species[14] accounted for over 10% of global nature degradation on land, freshwater and sea (IPBES, 2019). Another recent global systematic review specifically focused on invasive alien species concluded that 85% of documented impacts are negative and span across impacts on food, soil, freshwater quantity, materials, pollination, water quality, ocean acidification, biological formation, climate regulation, air quality, regulation of extreme events and energy (IPBES, 2023). Examples abound, including health impacts due to the spread of invasive alien mosquitos leading to dengue fever, zika, malaria and West Nile fever; real estate impacts from Japanese knotweed; and negative impacts of invasives on fisheries and agriculture (IPBES, 2023).

Four-fold increase in global costs of biological invasions per decade. Since 1970, global costs of biological invasions[15] have quadrupled per decade and are projected to continue rising (IPBES, 2023). In 2019 alone, global costs from invasive alien species totalled USD 423 billion, with over 66% leading to reductions in food supply (IPBES, 2023). The global cumulative costs (1970 to 2020) of biological invasions totalled USD 1.738 trillion, with 51% (USD 895 billion) of costs in the US, 9% (USD 163 billion) in Australia, 7% (USD 127 billion)

14 *"Invasive alien species – A subset of established alien species that spread and have a negative impact on biodiversity, local ecosystems and species. Many invasive alien species also have impacts on nature's contributions to people (embodying different concepts, such as ecosystem goods and services and nature's gifts) and good quality of life."* (IPBES, 2023, p. xiii).

15 *"Biological invasion – a process that transports (moves) and introduces a species outside of its natural range, intentionally or unintentionally by human activities to new regions where it may become established and spread."* (IPBES, 2023, p. xiii).

in India, 5% (USD 83 billion) in Brazil, 2% (USD 34 billion) in Canada and 2% (USD 31 billion) in China (IPBES, 2023). To put it into context, global economic losses from climate, weather and water-related hazards totalled USD 4.3 trillion between 1970 and 2021 (World Meteorological Organisation, 2025).

Cumulative costs of biological invasions estimated at USD 1.26 trillion in North America, approximately USD 433 billion in Asia, USD 140 billion in Europe and USD 17.8 billion to 78.9 billion in Africa. In North America, cumulative costs (between 1960 and 2017) from biological invasions were estimated at USD 1.26 trillion, with a 10-fold increase in annual average costs (USD 2 billion in the 1960s to above USD 26 billion in the 2010s) and largest costs borne by the agriculture sector (USD 527 billion) and the forestry sector (around USD 35 billion) (Crystal Ornelas et al., 2021). In the US, the cumulative costs from biological invasions (from 1960 to 2020) totalled USD 1.22 trillion (with an upper bound of USD 4.52 trillion) with approximately USD 510 billion of impacts on the agriculture sector (Fantle Lepzyck et al., 2021). Notably, USD 896 billion (73%) of costs were due to damages and approximately USD 47 billion were due to management expenditures (Fantle Lepzyck et al., 2021). In Asia, cumulative costs (between 1965 and 2017) from biological invasions were estimated at around USD 433 billion, with the highest costs in India and China (Liu et al., 2021). In Europe, cumulative costs (between 1960 and 2020) of invasive alien species were estimated at USD 140 billion, increasing exponentially over time, from approximately USD 24 billion in 2013 to USD 140 billion in 2020, and with the largest costs impacting agriculture (26%) and forestry (18%) (Haubrock et al., 2021). In Africa, the cumulative costs (between 1970 and 2020) from biological invasions were estimated to be USD 17.8 billion to USD 78.9 billion, with the largest impacts on agriculture (Diagne et al., 2021). Another study estimated that the annual cost of invasive alien species to African agriculture was USD 66 billion, using a mixed methods approach of literature review and stakeholder survey (Eschen et al., 2021).

Pests and pathogens leading to global crop yield losses above 40%. A survey on global crop losses due to 137 pests and pathogens estimated yield losses of 30.0% (24.6% to 40.9%) for rice, 22.5% (19.5% to 41.1%) for maize, 21.5% (10.1% to 28.1%) for wheat, 21.4% (11.0% to 32.4%) for soybean and 17.2% (8.1% to 21.0%) for potato, with highest losses mapped in regions with high food insecurity and growing populations (Savary et al., 2019).

Fall armyworm leading to annual yield losses of USD 7.7 billion to USD 12.1 billion in Africa. Fall armyworm is the invasive alien species with the most documented negative impacts on cultivated areas and is one of the top five invasive alien species negatively impacting quality of life (IPBES, 2023). Maize crop losses due to fall armyworm have been estimated at around 4% in South and North America and around 6% in Sub-Saharan Africa (Savary et al., 2019). Notably, much larger yield losses have been estimated at the country level: 58% in Zimbabwe (Chimweta et al., 2020), 49% in Benin (Houngbo et al., 2020), 46.5% in Ethiopia (Kumela et al., 2019), 45% in Ghana and 40% in Zambia (Day et al., 2017) to name but a few. See IPBES, 2023 table 4.26 for more references. Annual yield losses from fall

armyworm for African agriculture totalled USD 9.4 billion, with low and high estimates ranging from USD 7.7 billion to USD 12.1 billion (Eschen et al., 2021).

Company level effects on power utilities and shipping sector. In 2001, an invasion of jellyfish blocked the seawater intake pipes of Israel Electric Corporation's two largest power plants, resulting in USD 50,000 in costs (Galil and Zenetos, 2002). Invasive zebra mussels led to damages to the cooling system of the Ascó nuclear power plant in 2002 and the Garoña nuclear plant in 2007 (Rodriguez-Labajo et al., 2009). Native species outbreaks have also led to negative effects. For example, jellyfish pipe blockages include the shutdown of the St. Lucie Nuclear Plant in Florida in 2011 (National Geographic, 2013); the shutdown of the nuclear power station in Torness, Scotland in 2011 (BBC, 2011); the shutdown of the nuclear reactor at Diablo Canyon in California in 2012 (NBC News, 2012); the shutdown of the Oskarshamn nuclear power plant in 2013 (The Guardian, 2013); and the shutdown of the Marchwood power station in England in 2021 (BBC, 2021). In 2013, the nuclear power station in Torness, Scotland was shut down due to seaweed clogging its cooling system (The Guardian, 2013). Several shipping companies have been fined by the U.S. Environmental Protection Agency (EPA) for breaching the Clean Water Act, with Swire Shipping incurring USD 137,000 of penalties for untreated ballast water discharges; MMS Co receiving USD 200,000 of penalties (The Maritime executive, 2023) and CMA CGM incurring USD 165,000 of penalties (BloombergNEF, 2023). The Clean Water Act, which regulates the discharge of pollutants and regulates water quality standards in the US, specifically mentions aquatic invasive species identification and tracking as part of its risk assessment and response framework for ballast waters discharge (US Government, 1972).

Box 1: Invasive alien species and the banana industry

The banana market has a global revenue of approximately USD 167 billion (Statista, 2025) with 105 million tonnes of production in over 150 countries (Banana link) and over 19 million tonnes exported in 2024 (FAO, 2025).

Panama disease is a fungus[16] that spreads through contaminated soil particles, which can adhere to vehicles, animals, tools and clothes, travel through water (irrigation systems, storms or even typhoons) and through infected plants (FAO, 2019). The Race 1 strain of the disease was responsible for wiping the 'Gros michel' banana variety from the market in the 1960s, which was replaced by the Cavendish banana variety (Ordonez et al. 2015). The new Panama disease strain, Tropical Race 4 (TR4), can persist in the soil for decades and lead to 100% yield destruction, posing huge risks to smallholders' livelihoods (approximately 400 million people). It is considered 'one of the most

16 Fusarium oxysporum f.sp. cubense (Panama disease of banana) "is considered invasive because it can be distributed from location to location and from country to country with traditional planting material. Also, once established it can spread within plantations in runoff water and in soil on the tyres/wheels of farm machinery, feet of farm animals and shoes of farm workers. Once farm soil is contaminated, susceptible cultivars can only be grown with great difficulty and with much crop loss. Tropical race 4 (TR4) isolates of the pathogen threaten the production of Cavendish cultivars, which produce the bulk of export bananas." CABI Compendium (2021).

aggressive and destructive fungi in the history of agriculture and the world's greatest threat to banana production,' given that 80% of global banana production is potentially at risk from it (FAO, 2019).

Over the past decades, TR4 has destroyed the Cavendish plantations in Taiwan (1960s) and in Indonesia and Malaysia (late 1990s) before expanding to other countries (Ordonez et al., 2015), with annual losses of USD 253 million, USD 121 million and USD 14 million respectively (FAO, 2019).

In 2019, Colombia, one of the top five banana producers in the world, declared a national state of emergency due to the spread of the TR4 Panama disease (Science, 2019). In 2020, the Food and Agriculture Organisation of the United Nations (FAO) established the TR4 global network as a platform for global cooperation and coordination to fight the TR4 disease (FAO, 2020). As stated in the latest Agricultural Outlook produced by OECD and FAO, the global banana industry is at high risk from TR4 – present in 21 countries – given that it can affect a much larger range of varieties than previous strains and there is no way to eradicate it, with further spread posing risks to livelihoods and cascading into higher costs for importing countries (OECD-FAO, 2024).

Itochu Group, owner of Dole, a leading company in the banana industry, reported losses of 40% in banana production in the Philippines due to droughts, typhoons, pests and diseases under its TCFD disclosures (Itochu Group, 2022). As a management strategy, the company conducted a climate change risk assessment as part of its global risk management process, which included using environmental risk management for trend analysis. As a result of these analyses, concentration of production was identified as a serious risk. Risk mitigation strategies included expansion of agricultural land, measures against diseases and pests, and the introduction of irrigation equipment for bananas (Itochu Group, 2022). As pineapple cultivation was also identified to be exposed to the same risks, similar mitigation strategies were implemented (Itochu Group, 2022).

Chiquita, one of the largest banana companies in the world, identified TR4 as 'Most important' in its materiality assessment and addressed the importance of collaboration and investment in biosecurity (Chiquita, 2025). Chiquita was one of the founding members of the World Banana Forum, an open industry-led initiative across a range of stakeholders, including farmers, government officials, trade unions, scientists, retailers, NGOs, shippers and traders, founded in 2009, which also coordinates response efforts on TR4 (Chiquita, 2017).

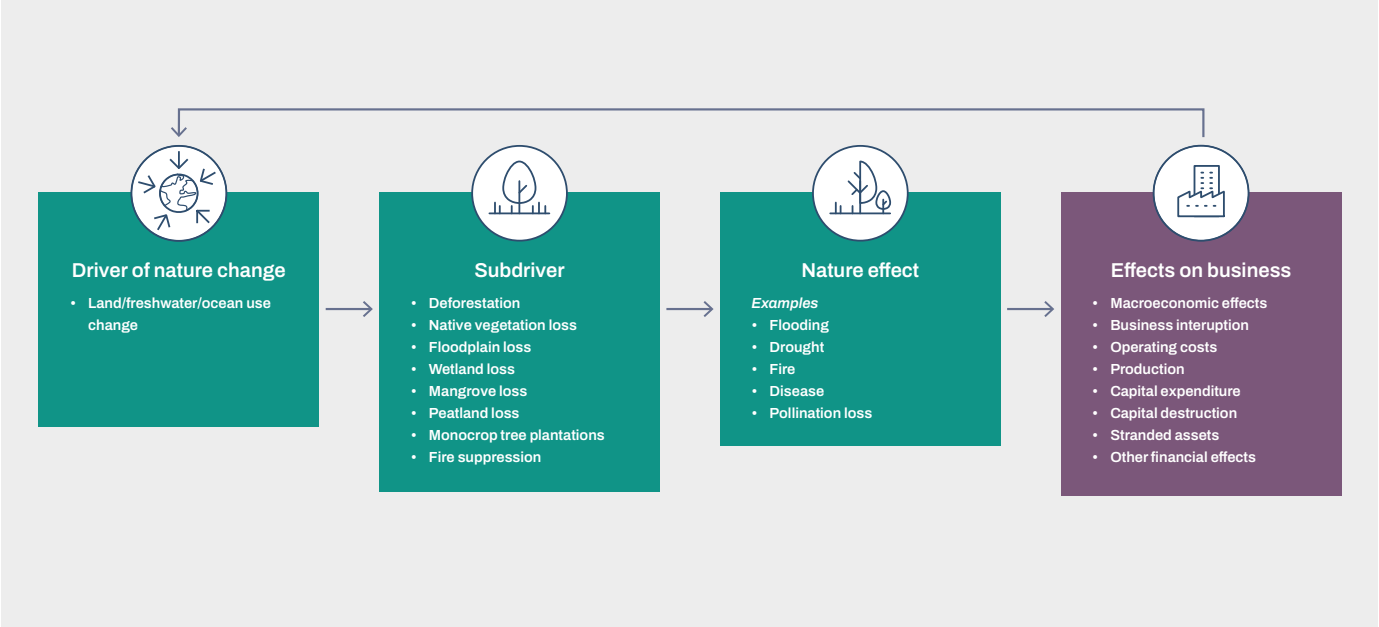
The compounding impacts from Panama disease, Banana Bunchy top virus (BBTV) and banana skipper butterfly pests were estimated to cost USD 35 billion (CABI, 2017). A recent analysis has estimated global losses from TR4 to be USD 493 billion, discounted over 40 years, with a five-year delay in developing and introducing a banana variety resistant to TR4 costing USD 94 billion (Figuereido Silva, 2023).

2.5. Land/freshwater/ocean use change as a driver of natural disasters and decline in pollinators

Deforestation, wetland loss and monocrop tree plantations are examples of land and freshwater use change that exacerbate the magnitude and frequency of natural disasters such as flooding, drought and fire. As well as worsening the consequences of these natural disasters, including those made more likely by climate change, they also directly contribute to climate change through loss of carbon capture (see the discussion on fire in this section as well as Section 2.8). The nature-related financial risks database focuses on studies that explicitly explore the human effects of such land use change-driven natural disasters (Figure 6). Sometimes, human effects, such as deaths, are not explicitly macroeconomic or financial. Often, however, explicit macroeconomic impacts are detailed as well, such as the extent of damages in USD, and more rarely, at the industry or entity level.

Many studies analyse the effects of natural disasters on the economy, including at the industry level (for instance, the impact of flooding on the insurance industry), but do not explicitly link those disasters back to drivers and subdrivers of nature loss. For example, Swiss Re estimates that global insurance losses from natural disasters have been growing at between 5% and 7% annually in the last 10 years, and likely to reach USD 145 billion in 2025, but is not explicit about the causes of this rise. In such studies, disasters are either seen as solely the result of climate change, without a nature loss component, or are left unexplained. Many such studies were identified in this analysis and are frequently referred to in this report.

Figure 6: 'Nature-only' risk causal chain from land/freshwater/ocean use change to effects on businesses



Land/freshwater use change as a driver of flooding

According to Swiss Re, the main cause of the high cost of natural disasters is rising exposure values, the result of economic growth and expanding populations, often in regions susceptible to severe weather conditions. Urbanisation reduces the natural areas surrounding a city. Inflation pressure and increased construction costs drive exposure values higher (Swiss Re, 2025).

Floodplains conversion to urban areas puts real estate and infrastructure at risk of flooding periodically, even when artificial flood defences are built. In many countries, flooding is a naturally occurring event in well-named floodplains. For historical reasons, often attached to the location of ports near the mouths of rivers, entire cities, such as New Orleans, USA, or Brisbane, Australia, were built on floodplains (Horowitz, 2020; Cook, 2023). While the estimated damages of Hurricane Katrina (USD 125 billion) are often attributed to climate change only, the significant conversion of land to urban areas in New Orleans over decades was an important reason for the extent of the damage, suggesting strong interactions between nature loss and climate change (Horowitz, 2020). The same can be said of Southeast Queensland, which incurred AUD 7.7 billion in damage costs during the 2022 floods (Cook, 2018). In 2022, more than 97,000 residential and commercial claims were made, with a total value of AUD 1.36 billion. This left AUD 646 million in uninsured residential and commercial losses. 62% of businesses were forced to temporarily close and around 4,000 employees were not retained (Deloitte, 2022).[17]

Building specifically on wetland not only makes the newly built area prone to flooding, but also makes other nearby, downstream built areas prone to flooding too, even if they were not built on wetland.[18] In the US, between 2005 and 2020, every time 176 hectares of upstream wetlands were lost, an estimated USD 3.1 billion were lost to municipal bondholders as well (Rizzi, 2022). During Hurricane Sandy in 2012, coastal wetland protection reduced property damages by 10% in the American Northeast, and generally saltmarshes have protected 20% of property values in New Jersey (Narayan et al., 2016). During Hurricane Irma, which hit Florida in 2017, an estimated USD 430 million of property damages was caused by wetland losses (Sun and Carson., 2020).

Mangroves play a critical role in providing flood protection for 18 million people around the world – if they were lost, annual damages to property would increase by 16% (USD 82 billion) (WEF 2020). By referencing claims data with its Biodiversity and Ecosystem Services BES Index (Swiss Re, 2020, 2025) Swiss Re isolated the expected risk reduction from the presence of coastal habitats by comparing the areas with highest and lowest natural

17 Only recently has the Queensland Reconstruction Authority started to administer the Resilient Homes Fund, an initiative to buy homes from residents living in the floodplain and rezone the land "non-habitable use" (Cook 2023).

18 A floodplain can contain wetlands especially in areas where water lingers after floods. However, not all floodplains are wetlands, and not all wetlands are on floodplains.

protection. The best-protected coastal areas had a significantly lower rate of insurance policies reporting flood claims each month.

Deforestation increases flood risk. Like wetlands, forests can absorb considerable amounts of water and therefore reduce the risk of flooding in adjacent areas (Brookhuis and Hein, 2016). Large-scale deforestation can also increase the rate of river sedimentation and accretion, thereby reducing carrying capacity, which can lead to river overflow.[19] This effect is most visible in the Ganga-Brahmaputra belt in India, a region that has seen devastating floods in recent years (Brown and Nicholls 2015, see also Nirupama and Simonovic, 2007, Roy 2022). Between 1990 and 2000 across 56 countries, a 10% decrease in natural forest cover led to a 3.5% to 28.1% increase in flood frequency, a 3.8% to 7.9% increase in flood duration, and a 5% deviance in the USD damages due to flooding (Bradshaw et al., 2007, Robalino et al., 2023). In India between 1987 and 2019, a 10 percentage point increase in forest cover reduced deaths due to floods by 13 people and led to a fall in flood damage as a percentage of GDP by 0.35 percentage points (Agarwal et al., 2023).

Monocrop tree plantations decrease flood protection due to less undergrowth and smaller root networks, which absorb less humidity than their native counterparts. In peninsular Malaysia, converting 1% of an area adjacent to a river from native forest to palm oil increased the number of days flooded by 26.8% (Tan-Soo et al., 2016). The practice of logging, common in pine and spruce plantations, also increases the risk of flooding as decaying roots, instead of retaining soil, increase the flow of sediment accumulating into and clogging up river beds (Glade, 2001). In Western Canada, this has led to entire regions being evacuated and transportation infrastructure being severely damaged (Hancock and Wlodarczyk, 2025). In addition, logging tends to leave a thick layer of accumulated dead wood, or forestry waste, on the ground, which further clogs river beds through so-called debris flows and increases the risk of flooding and landslides (Jakob, 2000). Such effects were particularly visible during cyclone Gabrielle in New Zealand in 2023 (Harrington et al., 2023, McClure, 2023), which resulted in insurance claims reaching a record NZD 2.1 billion, property insurers making a loss in the financial year, and an estimated 0.3% rise in inflation (Reserve Bank of New Zealand, 2023).

Land use change as a driver of drought

There is a wide body of evidence showing that deforestation, and especially the loss of native forest, leads to a drier regional climate due to reduced evapotranspiration (Fundacion Tierra, 2023; Stickler et al., 2023; Araujo, 2024; Dons, 1987; Domec et al., 2015). Reduced evapotranspiration can impact raincloud patterns – so-called flying rivers – leading to reduced river flows in affected areas (Araujo, 2024). Loss of trees and hedgerows also increases the risk of wind-led erosion in nearby fields, which exacerbates the effects of drought through loss of topsoil, itself leading to nutrient loss, soil compaction and in turn decreased water

19 Increased sedimentation due to deforestation also causes problems in ports, which must pay substantial dredging costs to clear their port channels (Lyttelton Port Company 2024).

retention (Montgomery, Caruso and Reid, 2020; Robecco and CISL, 2022).[20] The economic implications are numerous, starting with falling energy supply due to reduced river flow. In Brazil's Xingu Basin, deforestation has reduced energy supply by 6% to 36% (Stickler et al., 2013). This phenomenon can affect specific power plants, such as the Teles Pires Plant, which has seen a decrease in average energy generation between 2.5% and 10%, representing close to 10% of the plant's annual revenue (Araujo, 2024 and Rainforest Foundation Norway, 2024).[21] In Europe, between 2015 and 2022, a fall in precipitation led to an estimated reduction of hydropower electricity generation by 18% (Colesanti Senni et al., 2024). The 2022 drought caused nearly half of negatively affected French nuclear power plants to pre-emptively shut down, because water levels were too low to cool down their reactors (Ministère des Aménagements du Territoire et de la Transition Ecologique, 2025).

Deforestation-induced drought has affected food production and could impact food security over the longer term. Bolivia has seen 31.8 hectares of native vegetation deforested for every thousand tonnes of soy produced and experienced an estimated 75% drop in production in 2024 (Tyldesley and Czaplicki Cabezas, 2024, Fundacion Tierra, 2023). In Brazil, which is the world's largest soybean producer, regions that have more than 80% of their area deforested present a delay in rainfall of two weeks every five years, which directly affects farmers, who can no longer harvest twice a year. This has led to USD 760 million of lost soybean production and USD 270 million of lost corn production between 2006 and 2019 (Rainforest Foundation Norway, 2024).

Increased heat exacerbated by vegetation loss also impacts labour supply and productivity. Across tropical areas between 2003 and 2018, deforestation led to a total loss of 0.5 billion potential safe work hours per year (Parsons et al., 2021). Across the world, loss of vegetation in and around urban areas also affects local temperatures (Weng et al. 2004, Melaas et al. 2016), which in turn affects occupational heat stress (Flouris et al. 2018). A one standard deviation increase in the number of hot days between 1995 and 2019 across 93 countries has led to companies' operating income decreasing by 1.3% over a financial quarter, a risk that is not fully anticipated by investors (Pankratz et al., 2023).

Vegetation loss that increases drought can also impact building structure. In France, public reinsurance costs attributed to real estate and infrastructure damage compensation during the 2022 drought amounted to between EUR 2.9 billion and EUR 3.5 billion (Ministère des Aménagements du Territoire et de la Transition Ecologique, 2025).

20 Erosion can also increase the risk of water and polluters runoff.

21 The first harvest is usually soy, which runs from December to March, followed by maize. The rainfall delay has caused the window for maize production to shorten so that sometimes, the second harvesting becomes unfeasible.

Land use change as a driver of fire

Fire, like drought, is usually thought of as the result of climate change. In fact, just as with drought, nature loss plays a significant exacerbating role, beyond its role in contributing to climate change through loss of carbon capture. As humans increasingly encroach on forested land to build roads and houses, they make forests more accessible and increase contact between humans and forests, which mechanically increases fire risk due to human fire sources, such as cigarettes, campfires and explosions. Fire ignition is twice as frequent within the wildland-urban interface than outside of it (Chas-Amil et al., 2013).

Monocrop tree plantations such as pine, eucalypt and palm create additional fire risk. Compared to their native alternatives, they typically have less diverse, high-flammability understories with less moist microclimates. In addition, some soft-wood tree species such as pines and spruces are naturally more flammable than hard-wood species such as oak, maple and ash (Ndalila et al., 2018, Thomas et al., 2013, Jactel et al., 2017). Such plantations are also associated with the practice of logging, which creates forestry waste, acting as kindle in fire ignition and increasing its severity (Lindenmayer et al., 2022).

Box 2: Fire suppression and the California and Canadian fires

Over the past century, humans have increasingly attempted to quickly suppress any starting forest fire, with adverse consequences. Forests need to burn periodically to remove any excess dead wood from the understory – so-called light-burning fires usually only burn living trees on the surface and do not kill them, allowing quick branch regrowth. Over time, however, the practice of quick fire suppression has allowed dead wood to accumulate on the ground and act as kindle for any subsequent fires. This has increased the risk of much wider and more intense fires burning trees to death (so-called crown fires) that are difficult to control. Recent catastrophic wildfire events in the wildland-urban interface, such as the 2016 Fort McMurray wildfire in Canada, occurred where fire had been suppressed since the 1940s. This was one of the costliest natural disasters in modern Canadian history, leading to CAD 3.64 billion in insured losses (Parisien et al., 2020). This was compounded by major flooding in 2020, leaving some insurers to wonder whether Fort McMurray was still insurable (Contant, 2024).

At the beginning of the 20th century, the US also saw a drastic shift from light burning to fire suppression, a practice that is recurrently described as an important cause of the severity of the California fires, greatly exacerbating the effects of climate change, including in the recent Los Angeles fires (Calkin et al., 2015, Parks et al., 2025, BUToday, 2025).[22] California wildfire damages in 2018 totalled USD 148.5 billion, or 1.5% of California's annual GDP. Some 59% of these costs were indirect and often affected industry sectors distant from the fires (52% of indirect losses were outside California), through value-added losses related to supply chain disturbances (Wang

22 Faulty or downed electrical equipment and power lines, notably from utilities like PG&E, have also triggered more fires than would have otherwise been ignited (BloombergNEF 2023).

et al., 2022). High-intensity fires severely affect the Californian insurance industry, with Mercury General and Liberty Mutual increasing their premiums by 12% and 7.5% respectively in early 2025. California's largest home insurer, State Farm, threatened to leave the state if regulators did not allow it to hike premiums by 22%, and has already scaled back its business there, dropping 72,000 existing policies (Sellers, 2025). Between 2007 and 2019, the impact of wildfire smoke on US employees reduced their earnings by nearly 2% of US annual labour income, or USD 125 billion (Borgschulte et al., 2024). In Southern Europe, an average wildfire season leads to a production loss of EUR 13 billion to 21 billion per year (Meier et al., 2023).

Wildfires can also negatively impact water quality. For example, in California, the Tubbs 2017 wildfire led to a "do-not-drink/do-not-boil" order, which remained in place for over a year (Hallema et al., 2019). An estimated USD 300 million was spent by authorities to restore water quality following pollution from ash, soot and burned plastics during the Paradise wildfires in 2018 (Hallema et al., 2019).

Land use change as a driver of pollination loss

Some 75% of all food related crops depend on insect pollination (Potts et al., 2010; Klein et al., 2006). Animal pollination is crucial for optimal fruit set, size and shape and the production of seeds for crops such as sunflowers, rapeseed, courgette, cucumber, aubergine, avocado, coffee, cocoa and palm. **Native forest and vegetation in the vicinity of crop land play an important role in promoting animal pollination by providing habitat for pollinators such as bees.** For example, in Brazil the mean production of rapeseed seeds 25 metres from the nearest vegetation patch varied between 3,368 and 4,656 kilograms per hectare (kg/ha) but fell to between 1,508 and 3,432 kg/ha 325 metres away from it (Halinski et al., 2020).

Globally, fruit yield has declined in various instances due to pollination loss. A good example is palm oil. Countries such as Sierra Leone, Nigeria, Colombia, Thailand, Malaysia, and Indonesia are currently grappling with a decrease in oil palm fruit set. In Malaysia, fresh fruit bunch yields declined from 17.89 tonnes per hectare (t/ha) in 2017 to 17.16 t/ha in 2018, a 4% reduction year on year (Gintoron et al., 2023). Coffee production is facing similar threats from pollination loss as a result of deforestation (Krishnan et al., 2012).

Land use change and transition risks

Transition risks caused by land use change are widespread and intensifying. Already in 2012, a Canadian gold mining company called Infinito Gold was refused the right to conduct mining activities in Costa Rica in 2012. Its share value fell by 50% and it remains in a precarious financial position today (Bonner et al., 2012; Simply Wall Street, 2025). Indonesia has had a moratorium on clearing native forests in place since 2019, which has consequences for financial institutions that are directly or indirectly exposed to such activities, particularly in Sumatra (McCraine et al., 2019). Recently, Brazilian NGO Comissão Pastoral da Terra (CPT) and French NGOs Notre Affaire à Tous, Friends of the Earth France and

Oxfam France submitted a claim stipulating that BNP Paribas, a French financial institution, violated France's 2017 Due Diligence Law by offering financial services to corporations such as Marfrig, one of the world's largest beef producers. Marfrig's suppliers have been facing serious accusations, including engaging in severe deforestation (Banktrack, 2023). As of today, the case is still open (Climate Change Litigation Database, 2025).

2.6. Soil depletion

As noted in Section 2.5, deforestation can lead to drier soil and resulting declines in crop yield. This section focuses on soil depletion (a subdriver under "Resource Use") and how it can make soil not only drier, but generally poorer, also leading to crop yield declines.

Soil asset stripping

Partly to ensure faster crop cycles, farmers tend to use synthetic fertiliser such as nitrogen (N), phosphorus (P) and potassium (K). Their intensive use, however, does not help the wider soil regeneration from organic matter that is needed to ensure healthy and abundant crops. This can cause farmers to use more and more fertiliser with less and less effect (D'Hose et al., 2014, Jones et al., 2013).

Soil asset stripping is already apparent in developed economies such as the UK, where compared to 30 years ago, median concentrations of copper, zinc and manganese reduced from 4.9 to 3.5 milligrams per kilogram (mg per kg), from 4.6 to 3.6 mg per kg and from 114 to 70 mg per kg respectively (Mayer et al., 2021). As a result, although wheat yields have increased from 2 to 10 tonnes per hectare over the last 50 years in the UK, they are now plateauing (Jones et al., 2013).

The phenomenon is worse in Southeast Asia and Australia (Hedin, Vitousek & Matson, 2003). In India, the intensification of agriculture has led to 49% of soils now being deficient in at least one micronutrient (33% in B and 12% in iron) (Singh, 2009). Despite the increase in fertiliser applications, grain yields there have continued to decline (Samra and Sharma, 2009). Worldwide, fertile soil is being lost at the rate of 24 billion tonnes a year, and 20% of the world's cropland has seen decreased productivity, leading to an estimated loss of between USD 6.3 trillion and 10.6 trillion annually (UNCCD, 2017). Asset stripping can also lead to soil salinisation, which reduces the ability of plants to absorb water, damages plant cells, causes nutrient imbalances as well as poor seed germination and root development. Its effects are particularly prominent in irrigated cropland, for instance, in China and Central Asia (Ma et al., 2008). The UN estimates that 20% of irrigated cropland has salt-induced yield declines, causing an estimated economic loss of USD 27.3 million (UNCCD, 2017; FAO, 2024).

The loss of micronutrients in food produce is also a global health concern. Fruits and vegetables such as apples, oranges, mango, guava, banana, tomatoes and potatoes have lost their nutritional density by 25% to 50% or more during the last 50 to 70 years due to environmental and genetic factors (Drewnowski, 2009; Bhardwaj et al., 2024). Micronutrient deficiency is also associated with obesity (Gardiola-Marquez et al., 2022; Vrieling and

Stienstra, 2023), which has a significant negative impact on firm productivity (Mazhar, 2022; Nagi et al., 2024).

Inflationary effect

Historical data shows that weather events such as droughts, which are exacerbated by subdrivers of nature loss such as native vegetation loss or soil depletion, can cause food inflation. For instance, heat in the European summer of 2022 led to a 0.67 percentage point increase in food inflation (Kotz et al., 2024), and drought generally has a positive inflationary effect on food (Bremus et al., 2020; Cevik and Jalles, 2023). Persistent effects on headline inflation have also been noted, sometimes up to 3 percentage points (Kabundi et al., 2022; see also Barmes et al., 2024).[23]

Scenarios have explored the impact of yield losses exacerbated by a weather event on different actors along the supply chain. Depending on the magnitude of the shock and the number of crops affected in a country, there could be either a localised or more generalised inflationary impact. While some large fertiliser and trading companies could benefit from an inflationary shock, small packaged food companies would see a 45% loss in value due to increased purchasing costs that could not be passed on to consumers without risking losing market share to competitors not connected to the degraded land (Robeco and CISL, 2022). Price disruptions would also affect actors in the supply chain that are dependent on animal feed. Farmers would see their cost of capital increase as their debt burden increases in lean years.

2.7. Zoonotic diseases

Deforestation in tropical areas is known to impact the transmission of zoonoses to humans, leading to epidemics spreading regionally and potentially worldwide. HIV was originally a zoonosis that first appeared around 1920 and 1940 and transmitted from chimpanzees to humans during the expansion of forest logging and mining in West Central Africa, especially in the Congo Basin from 1959 (Guegan et al., 2020). Specifically, forest fragmentation increases edge habitats that are ideal for certain types of vertebrate disease hosts, such as bats. Proximity of humans in these edge habitats in turn increases the probability of these pathogens eventually transmitting to them (Guegan et al., 2023). The spread of ebolavirus, which has resulted in over 15,000 deaths worldwide since 2014, has been enhanced by deforestation and forest fragmentation (Rulli et al., 2017). Other viruses such as nipah have also been shown to have roots in deforestation (Guegan et al., 2020). Although there is still no definitive account of the origin of COVID-19, the most likely hypothesis is that it was originally spread by vertebrates such as bats in these forest edge habitats, spreading to humans either directly or through another animal, such as pangolins, that – along with many other species – were illegally traded from Africa and South East Asia to China in large quantities, for bushmeat consumption or traditional medicine

23 Negligible or negative effects are sometimes also present (Kamber et al. 2013, Cevik and Jalles 2023).

(Wacharapluesadee et al., 2021; Mishra et al., 2021; Zhu and Zhu, 2020). Covid-19 led the world economy to contract by 3.1% in 2020 (IMF, 2020) and the International Monetary Fund estimated that the COVID-19 pandemic would cost the global economy $28 trillion in lost output over the period 2020-2025. Its effects on supply chains and inflation are still felt today (Reuters, 2025).

Forest fragmentation also increases the spread of vector-borne diseases, such as malaria. Those diseases are transmitted by a host, such as mosquitoes, which are not themselves infected by the virus (see also Section 2.3). Nevertheless, mosquitoes act as transmission agents between forest mammals such as chimpanzees, other species of monkeys and humans. Proximity of humans to tropical forests, made more likely by forest fragmentation, will naturally increase the probability of malaria infection. Malaria still causes around 500,000 deaths a year (Guegan et al., 2020). Annual growth rates were 1.3% lower in countries that had a high proportion of their population living in regions of malaria transmission in 1965 than the period between 1965 and1990 (Gallup and Sachs, 2001). Increased malaria incidence leads to premature mortality, medical costs, school absenteeism and high fertility rates and population growth, due to behavioural responses to expected childhood mortality (Sachs and Malaney, 2002).

2.8. Ecosystem stability risk

Ecological regime shifts are large, sometimes abrupt, changes in the structure and functioning of ecosystems that can have far-reaching consequences. These shifts can be triggered by human-induced factors leading to tipping points, often resulting in ecosystems functioning very differently (Dakos et al., 2019). Some of these shifts can pose significant risks to the economy, particularly when they affect vital resources, industries or regions that depend on ecosystem services.

A potential future regime shift is what is often referred to as the 'Amazon dieback'. Section 2.5 mentioned that land use change, such as deforestation or monocrop tree plantations in the Amazon, could lead to increased risk of reduced rainfall, and increased drought and fire in the region, which is exacerbated by climate change. In the future, these could push the whole rainforest beyond a tipping point, causing it to transition from a dense tropical forest to a more open, savannah-like ecosystem. According to one estimate, 20% to 25% further deforestation can be expected to flip the forests into savannah vegetation (Lovejoy and Nobre, 2018). The economic effects could potentially be devastating. First, reduced rainfall, drought and fire could lead to a decline in soybean, coffee and beef production, causing export losses for Latin American countries, and potentially volatile food prices globally. They could also lead to reduced hydropower capacity and increased costs for water treatment and infrastructure, as well as industrial disruptions in water-intensive sectors such as mining and manufacturing. Finally, the Amazon dieback would entail the loss of one of the world's largest carbon sinks and the dying forest could become a major carbon emitter, accelerating global climate change, which would likely lead to an increased frequency of extreme weather events, and in turn, damage to infrastructure, agriculture and housing. In total, the economic loss for

Latin America has been estimated at USD 256.6 billion in cumulative GDP by 2050 – USD 184.1 billion in Brazil, USD 35.3 billion in Colombia, USD 17.6 billion in Bolivia, USD 11.4 billion in Ecuador, and USD 8.2 billion in Peru (Banerjee, 2022). Globally, financial losses could total USD 3.6 trillion (Lapola et al., 2018).

In the US, a form of desertification – usually referred to as the 'Dust Bowl' – occurred in the 1930s due to the interaction between intensive agricultural practices and adverse climatic conditions. Soil degradation, including salinisation, led to increased vulnerability to drought and erosion. By the 1940s, strong winds had swept away 75% of the Great Plains' topsoil and heavy rainfall had dug gullies into the ground. Between 1930 and 1940, losses to farmers amounted to USD 1.9 billion. Importantly, the Dust Bowl had some permanent consequences as eroded areas never fully recovered (Hornbeck, 2012). It also led to high rates of unplanned internal migration (Hornbeck, 2023).

Other forms of regime shifts have occurred or are occurring.[24] The Regime Shifts database, developed by the Stockholm Resilience Centre, includes evidence on 28 regime shifts and 23 case studies that have been added to the database accompanying this report. In Newfoundland, fishing pressure and colder water disturbed the cod spawning grounds and led to a dramatic collapse (Patel et al., 2017). Coffee is also seeing a shift. The most commonly grown types, such as robusta and Arabica, are currently affected by the threat of drought and pests such as 'coffee leaf rust' for Arabica in Central and northern South America, and 'coffee wilt disease' for robusta in Africa. Consequently, farmers have been increasing their focus on alternative species. Of these, 60% are threatened with extinction, mainly due to habitat loss caused by land use change. With a market size of USD 100 billion, this could have significant implications for 100 million coffee farmers, their communities, traders and consumers worldwide (Davis et al., 2019).

2.9. Key gaps in the evidence collected

Researching the academic and grey literature reveals extensive literature analysing the effect of a subdriver, such as wetland loss, on a nature effect, such as flooding. Likewise, there is extensive literature on the consequences of a nature effect, such as flooding, on business losses, such as in the insurance industry (Figure 7). The extensive evidence on those two causation links leads to the logical conclusion that subdrivers can have negative effects on businesses. Despite this, studies explicitly examining this conclusion and the full causal chain (from dependencies and impacts to financial effects) are relatively few particularly in the academic literature. This is a key finding of the landscape analysis. In particular, the evidence on transmission channels is incipient and this database may enable the development of case studies or further research linking together different types of evidence identified across all the individual parts of the causal chain. These are further key findings of the landscape analysis.

24 See University of Exeter's Global Systems Institute (2023) Global Tipping Points Report 2023 and other literature by Professor Tim Lenton. See also the Regime Shifts Database.

Figure 7: Overview of available research on the different causation links along the causal chain

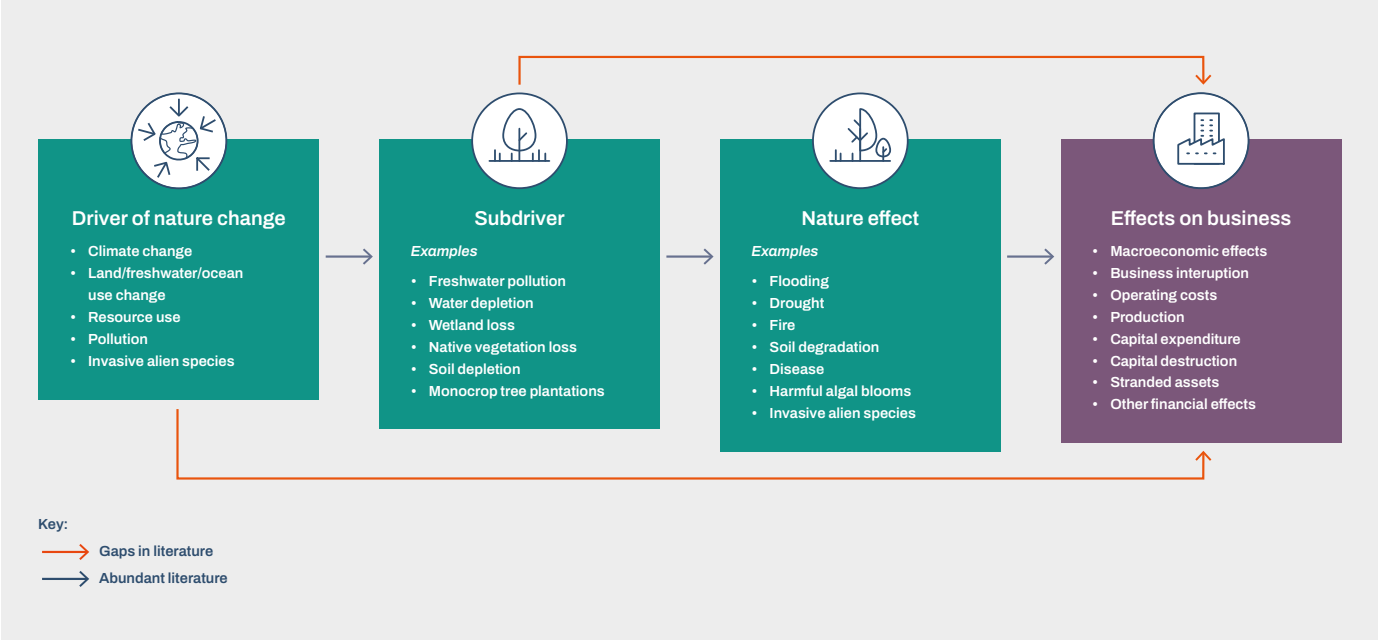


Figure 8 in Annex I synthesises the evidence in the database from the nature-related hazards through primary receptors (of the hazard) to an effect at the non-economic, economic or company level. Following the categories in Table 2, the company level effects include capital expenditure, firm value, operational disruption, operational expenditure, operational shutdown, regulatory changes and stranded assets.

There is extensive evidence on firm value effects spanning 9 physical and three transition hazards, and on operations (expenditure, disruption, shutdown) spanning eight physical and five transition hazards through several primary receptors. For capital expenditure effects, the database only includes evidence stemming from water scarcity and policy hazards. For stranded assets, the evidence includes mostly transition hazards.

As the level of evidence at the company level varies between different drivers of nature degradation, the database and Figure 8 could be a starting point to identify new case studies of company level financial effects from nature-related risks. The database includes only one example of market risk and one of technological risk, both potentially leading to an effect on operational expenditure through increase in costs. Whilst the database includes extensive literature on systemic risks, the evidence in the database is limited across all company level effects. Given the relevance of crop extinction risk evidence to the agrifood sector (see Box 1), this database could enable developing case studies on nature-related risks also for other companies and crops.

3. Assessing nature-related financial risks: findings from company disclosures and engagements

3.1. Background and motivation

Although global policymakers, central banks and supervisors in recent years have issued guidance, regulations and formal communications on the importance of corporate dependencies and impacts on ecosystems[25] – and the potential risks posed by their degradation to businesses and financial institutions – corporate reporting practices have not yet kept pace with these expectations. The topic of nature is often not viewed as material for disclosure in corporate reporting practices, especially from a financial materiality lens.[26]

In light of this – in addition to collecting existing publicly available literature on nature-related financial risks – the TNFD and the University of Oxford carried out interviews with five global corporates and financial institutions, and held a workshop with companies, academia and NGOs in May 2025.[27] The aim of the interviews, workshop and other stakeholder engagements was to gain deeper insights into how organisations are currently measuring nature-related risks, and the thresholds they use to determine whether such risks are financially material.

Insights were gathered from these interviews and existing company sustainability reports on companies' understanding and assessment of the financial materiality of nature-related risks to their business, including methods used and advancements carried out by their risk management teams. This provided insights into how organisations are currently measuring

25 See the 2023-2024 conceptual framework on Nature-related Financial Risks of the Network for Greening the Financial System (NGFS), the 2024 Nature Positive Economy Transition Strategy by the Government of Japan, the Climate and nature plan 2024-2025 by the European Central Bank, the 2025 Nature-related financial risks circular by the Swiss Financial Market Supervisory Authority (FINMA), the 2025 guidelines on the management of Environmental, Social and Governance (ESG) risks by the European Banking Authority, along with ongoing developments from standard setters and corporate reporting regulators in Europe (CSRD) and internationally (e.g. ISSB with its research project on BEES launched in 2024).

26 A number of providers have been collecting databases of first nature-related corporate reports which can be freely consulted. One example is etOso: https://etoso.io/app/adviser.

27 TNFD and the GRI have also published a report collecting perspectives from seven global corporates on how they link nature-related risks and opportunities to the dependencies and impacts on nature from which these arise, the findings of which have also been reported in this paper.

nature-related risks arising from their dependencies and impacts on nature and conducting financial materiality assessments.

Additional stakeholders and external publications from subject-matter experts and companies were also consulted.

3.2. Findings from industry experts

Several organisations have been actively tracking how companies identify and assess nature-related risks. Notably, the Global Association of Risk Professionals (GARP) conducted global surveys on nature risk management over the past two years.[28] Its 2025 global survey included 48 financial institutions.[29]

According to GARP's most recent report, 42% of the 48 firms they interviewed have identified nature-related risks or opportunities – an increase from 25% in 2024. Furthermore, the proportion of firms assessing nature-related risks and opportunities within their risk management and strategic functions has doubled (from 17% and 13% respectively in 2024 to 38% and 25% in 2025). GARP also identified an increase in the perception of nature-related risks from one year to the next, but it observed little change in firms' opinions about how resilient they felt their strategy was to nature risks, across various time horizons – showing that only a minority of firms have actually assessed whether their current strategy is resilient to nature risks, with most firms reporting that they did not know.

While the GARP report clearly shows advancements in the identification of nature-related risks by companies, with nearly three-quarters of those surveyed regarding nature loss as a risk, up from 59% in the previous year, there remains a question of how organisations may go further – beyond risk identification – to assessing the financial materiality of these risks. This involves understanding the potential financial effects of nature-related risks on corporate performance, which usually comes as a second step after the identification of risks. This emphasis is also reflected in GARP's findings: while one-third of firms believe physical and transition nature risks are partially priced in, two-thirds either do not know or do not believe that these risks are currently priced, suggesting a possible gap in the effective measurement of risk.

A recent study by the European Corporate Governance Institute (ECGI) based on NBIM investee companies adds further evidence on corporates' risk practices.[30] This global survey assessed how companies perceive nature risks, their strategic responses and interactions

28 GARP (2025), Global Survey of Nature Risk Management at Financial Firms.

29 29 banks, 11 asset managers, and eight insurers – representing approximately USD 31 trillion in balance sheet assets, close to USD 20 trillion in assets under management, and about USD 2.5 trillion in market capitalisation. The regional spread of firms' operations is distributed as follows: 90% in Europe, 81% in North America, 69% in Asia Pacific, 48% in South America, 44% in the Middle East and 35% in Africa.

30 Gjerde, Snorre and Sautner, Zacharias and Wagner, Alexander F. and Wegerich, Alexis, Corporate Nature Risk Perceptions (April 21, 2025). European Corporate Governance Institute – Finance Working Paper No. 1056/2025, Available at SSRN: https://ssrn.com/abstract=5224376 or http://dx.doi.org/10.2139/ssrn.5224376.

with investors. Some 48% of companies interviewed consider nature risks to be financially material "already today", of which 44% report that physical nature risks are already having financial impacts, and 28% consider transition risks are currently affecting them financially.

Recent findings from CDP disclosures in 2024 signal continuous challenges to quantify environmental risks for large corporates, including financial institutions and non-financial companies, as well as for small and medium enterprises (SMEs). CDP reports that financial institutions that have identified water- and forest-related risks in their portfolio with the potential to have a substantive financial effect on their business were 10% and 15% respectively, compared to 34% and 8.5% for large corporates overall.[31] Data disclosed through CDP also shows that just one in three risks can be financially quantified by large corporates, with only 36% of water- and forest-related risks covered by a potential financial effect value. SMEs appear to face even greater challenges in the quantification of environmental risks, with just one in every 10 risks being financially quantified.

3.3. Findings from interviews and existing company reports

i. Methods to assess financial materiality of nature-related risks

Findings from the interviews conducted by the TNFD and the University of Oxford suggest that financial institutions are, in general, more advanced than corporates in the use of tools, methods and approaches to measure the potential financial effects of nature-related risks.

For instance, one UK-based financial institution conducted an exploratory stress test on nature-related risks and is currently evaluating the integration of this exercise with its existing climate stress testing framework. To carry out the analysis, the institution drew on one of the scenarios from the Nature-related risk in the UK report by the University of Oxford and the Green Finance Institute (GFI),[32] supplementing this with academic literature and other sources to develop potential projections of Gross Value Added (GVA) shocks across eight sectors. These projections were then translated into client-level risk indicators using a scorecard approach, providing a structured means of judging how financially material nature-related risks might be for each client in the affected sectors.

By contrast, corporates often rely more heavily on stakeholder interviews and qualitative assessments to identify financially material risks, rather than deploying advanced quantitative methods. A leading steel manufacturer in India with business interests in energy, infrastructure, cement and paints, for example, developed a questionnaire to engage stakeholders – including communities, regulatory bodies, suppliers, customers, investors and employees – asking them to assess on a scale from 0 to 5 the potential risks

31 Similar datapoints disclosed by CDP last year were accompanied by additional insights, including the view that "considering an overall high number of nature-related risks reported by corporates, financial institutions likely underestimate the risk exposure of their portfolios". See https://www.cdp.net/ja/insights/biodiversity-targets.

32 University of Oxford and Green Finance Institute (2023). Nature-related Risk in the UK: Exploring the Financial Materiality of Nature Loss. https://www.greenfinanceinstitute.co.uk/nature-related-risk-in-the-uk.

and opportunities related to nature. The resulting scores were normalised on a scale of 100, with any topic exceeding a threshold score of 55 deemed material. This exercise was complemented with the use of the WWF Biodiversity Risk Filter and grievance mechanisms to identify risks stemming from the negative impacts on communities.

Even where more sophisticated approaches such as scenario analysis are used, corporates often estimate the financial implications qualitatively. They frequently rely on third-party insights to refine standard datasets or scoring methodologies – such as those from the ENCORE tool (Exploring Natural Capital Opportunities, Risks and Exposure), Global Forest Watch, the WWF Biodiversity Risk Filter, and the World Resources Institute (WRI)'s Aqueduct tool – to make them more context-specific. For example, one Japanese corporate referred to the TNFD's qualitative scenario analysis guidance to conduct impact assessments in the short term (2025), medium term (2030), and long term (2050). These assessments focused on two major uncertainties tied to physical and transition risks.

Corporates often demonstrate a stronger capacity than financial institutions to identify the sources of nature-related risks, particularly how their own dependencies and impacts on nature translate into risks and opportunities for the business. The TNFD-GRI case studies also highlight this point, showing how corporates apply the TNFD LEAP approach to link ecosystem service degradation, such as water scarcity, identified during the Evaluate phase of LEAP, with business risks identified during the Assess phase. This enables companies to consider how operational viability may be threatened by changes in natural systems.

When identifying the sources of risks, financial institutions instead tend to develop qualitative, top-down assessment tools such as heatmaps used at the portfolio level. This is often due to the breadth and type of portfolios they are managing, and the current state of disclosure by corporates in the financial institution's portfolio. These qualitative tools help identify geographies and sectors potentially exposed to physical and transition risks, although the analysis is often not sufficiently granular to account for company level nuances.

Some of the recently published sustainability reports by financial institutions help shed light on these findings. For example, in its 2024 climate and nature disclosures, NBIM discloses its approach to assessing nature-related risks using the ENCORE tool, which enables identification of ecosystem dependencies and impacts by sector. These materiality ratings are then aggregated, but as the data are not company-specific, they are intended to serve as an indication of potential exposure to impacts and dependencies for the portfolio. Alone, they do not show actual exposure nor important company-specific nuances.

ii. Challenges identified

The findings from interviews and company disclosures reveal a number of challenges that corporates and financial institutions face in assessing the financial materiality of nature-related risks.

A first category of challenges relates to those faced by financial institutions when gathering evidence of financial materiality of nature-related risks from the clients or portfolios they are exposed to, such as:

- Translating the multifaceted dependencies and impacts on nature to risks at the borrower/investee-level;
- Uncertainty about how best to assess and aggregate dependencies and impacts on nature across financial portfolios; and
- How these in turn relate to material financial risks for the financial institution.

The lack of yet widespread corporate disclosures (such as TNFD-aligned reports) adds to the challenge, and, while these are growing, what is disclosed is not always easily comparable across companies. This means that financial institutions face data limitations and are forced to rely on modelled or proxy indicators. Proxy indicators for nature-related issues usually tend to make estimates to address the challenge of a lack of one single indicator for nature-related impact drivers or the complexity linked to the location-specificity of nature-related issues.

By contrast to climate-related risks, for which many financial institutions have established quantification methods linked to greenhouse gas (GHG) emissions and carbon pricing, the lack of a single, widely accepted indicator for nature-related risks still makes it challenging to develop such quantitative approaches. Financial institutions need to use multiple indicators (for example, using the TNFD disclosure metrics for dependencies and impacts, such as water withdrawal and consumption from areas of water scarcity) to build a more comprehensive picture to assess nature-related risks in their portfolios.

For example, in its 2024 climate and nature disclosures, NBIM utilised a dataset estimating the cost to society of companies' direct environmental impacts (including emissions, air pollution, water consumption, land use changes and waste) to better understand and break down the different impact drivers across its portfolio. These figures, calculated using the social cost of each impact type, offer a location-specific, company level view of nature-related externalities. The assumption is that since higher costs may increase the likelihood that governments introduce regulations that force companies to absorb some of these costs, impact metrics in this context may be a proxy for financial risk. NBIM uses these data to better understand the underlying impact drivers of its portfolio's estimated natural capital impact and to compare the total weighted natural capital impact intensity of its equity portfolio against the fund's benchmark index.

In its 2024 Nature report, Schroders describes its use of a proprietary NatCapEx model that quantifies the costs or credits that companies in its portfolio would face if all their negative externalities or benefits were priced or financially recognised by society. This model enables

Schroders to understand which companies and portfolios are contributing most to the institution's nature-related impacts, providing deeper insight into the scale and severity of the impacts potentially caused by these holdings, rather than generic industry-level exposure.[33]

Integrating such proxy indicators into stress testing frameworks usually requires internal consultation and debate, particularly with risk management and modelling teams, to ensure assumptions are deemed feasible and proportionate.

Understanding which sources of nature-related risks are most relevant remains a challenge, particularly because of the lack of granular and location-specific data.[34] For instance, in its report NBIM highlighted that while geospatial datasets of asset locations can help to map the proximity of assets to Key Biodiversity Areas (KBAs), such data are not uniformly available. NBIM found that asset-level data are accessible for only 68% of its portfolio companies, representing 77% of its net asset value. While proximity to KBAs is relatively straightforward to assess, this is less true for areas of high or rapidly declining ecosystem integrity, which are also prioritised under the TNFD's definition of sensitive locations. Even once the proximity is assessed, financial institutions still face the additional challenge of translating the proximity to KBAs and sensitive locations into financial risks.

Both corporates and financial institutions face challenges in accurately estimating financial effects. Corporates largely rely on qualitative assessments supplemented by expert judgement and stakeholder engagement and may use standardised scoring tools or narrative scenarios without a direct link to financial statements. Financial institutions, in turn, tend to use directional assessments at a high level – using top-down methods such as sectoral heatmaps – to highlight areas of concern, but often cannot distinguish between clients within the same sector. Even more advanced institutions – that are able to differentiate relative client vulnerability – frequently lack the means to quantify impacts on cash flows, profit and loss or Risk-Weighted Assets (RWAs).

Scenario analysis is widely viewed as a promising approach to support the identification and financial quantification of nature-related risks for both corporates and financial institutions, but methodological uncertainty remains a major barrier to uptake. Many interviewees expressed concern that, without a globally accepted scenario methodology, it is difficult to build credible internal frameworks. Several financial institutions noted that they are awaiting further guidance from the NGFS before proceeding, particularly given the need for a standardised framework that the financial sector can collectively rely on to estimate these

33 NatCapEx is comprised of four pillars of assessment (business model contribution, geographic contribution, management adjustment, avoided nature loss), which result in a net nature impact expressed in a unit of Nature Value/Sales (%) – where a company with a -2% score indicates a loss of ecosystem service worth USD2 per USD 100 of revenue whereas a +2% indicates a contribution to ecosystems worth USD2 per USD 100 of revenue.

34 It should be noted that physical climate impacts are also highly influenced by location-specific characteristics. Additionally, even when considering the nature loss driver of climate change, there is a need for companies to interpret the impact driver indicator into risk measures (such as in the form of potential loss amounts).

risks.[35] One financial institution suggested that the NGFS could establish a globally agreed severity level for nature-related scenarios, which national supervisors would then tailor to their local context.

As highlighted in the TNFD guidance on scenario analysis and discussion paper on advanced approaches to scenario analysis, it is critical for both corporates and financial institutions to identify approaches to scenario analysis that are already applicable, leveraging tools and methodologies that are publicly available. While some financial institutions are advancing using internal methodologies, at least for internal risk management purposes, others cautioned that such efforts are costly and must clearly demonstrate value to justify continued investment.

Some corporates have used scenario-based approaches to estimate (often qualitative) financial effects in alignment with the TNFD recommendations, often making use of the illustrative narratives provided in the TNFD scenario analysis guidance. Examples of TNFD reports including scenario approaches include Hitachi, Jindal Stainless, Philips, Cathay Financial Holdings and Kyuden Group.

iii. Lessons learned

The interviews surfaced a number of practical reflections and insights from corporates and financial institutions, highlighting evolving perspectives on financial materiality and nature-related risk integration.

- **Standardisation is key:** Those interviewed conveyed that regulatory requirements mandating the disclosure of financially material information in a consistent manner would support a level playing field in terms of data availability and disclosure expectations.
    - For example, one financial institution proposed that banks could explicitly report if, and by how much, a borrower's credit rating has been downgraded due to exposure to nature- or climate-related risks. It further suggested that the Basel Committee on Banking Supervision (BCBS) may wish to focus on total exposures to such borrowers (and the corresponding increase in RWAs for banks on the Internal Ratings-Based approach). This, in its view, would drive standardisation across banks and allow supervisors to challenge assessments where appropriate.
    - Other financial institutions noted that standardisation in corporate disclosures – through consistent reporting frameworks and standards and a consistent measurement methodology – would significantly facilitate financial institutions' assessments of nature-related financial materiality in their portfolios by gathering this information consistently and credibly from the companies they are exposed to.

35 In 2023 the NGFS published Recommendations toward the development of scenarios for assessing nature-related economic and financial risks, which lay the groundwork for future development of nature-related scenarios.

  - Financial institutions interviewed conveyed that differing definitions of materiality can create confusion, particularly for those trying to gather consistent information from corporates across jurisdictions. For instance, the definition of financial materiality by the US Supreme Court is not fully aligned with those adopted by other frameworks and standards.[36] Interviewees noted that having standardised definitions would improve clarity and comparability.

- **Thresholds may be affected by risk mitigation:** Only a minority of corporates and financial institutions interviewed have explicitly identified any nature-related risks as financially material. This is often because they believe they have already implemented effective risk mitigation measures. This is also supported by the main findings of the GRI-TNFD case study report.
  - One financial institution stated that while nature-related risks are monitored internally for capital adequacy purposes, the capital reserves currently set aside for climate risk are considered sufficient to absorb broader environmental losses.
  - A Japanese corporate in the pulp and paper sector emphasised that its long-standing commitment to sustainable forest management has helped prevent significant exposure to nature-related risks – though it acknowledged the substantial costs associated with forest maintenance and conservation efforts.
  - In its 2024 sustainability report, Reckitt states that, while palm oil production has long been associated with deforestation risks, such risk can be mitigated for other natural raw materials used (such as soy, cocoa and latex), thanks to its approach to sourcing these commodities from lower risk origins. Mitigation of risk can also be achieved by diversifying sources or switching to alternative materials.
- **Climate and nature risk assessments should be considered together:** Despite the methodological and data-related challenges, many interviewees agree that climate- and nature-related risks should be assessed together.
  - One financial institution warned of the risk of double counting when separate climate and nature scenarios are developed independently, given the strong connections between the two. In such cases, the same companies might appear to default under both scenarios, which may be difficult to justify from a credit risk standpoint.
- **Expectations for heightened risks in the future:** When asked for examples of how nature-related risks have already affected their business, most corporates and financial institutions interviewed acknowledged limited direct impact to date, but anticipate increasing relevance in the near future. This expectation stems from both growing regulatory and investor scrutiny and the likelihood of real-world risk materialisation.

36 The Supreme Court has held that a fact is material if there is "a substantial likelihood that the ... fact would have been viewed by the reasonable investor as having significantly altered the 'total mix' of information made available." See https://www.sec.gov/newsroom/speeches-statements/munter-statement-assessing-materiality-030922#_edn4.

- For instance, FINMA has recently issued regulatory expectations on nature-related risk assessments[37] and companies in the region recognised the growing pressure for their internal risk management teams to focus on those risks.
- Corporates are recognising that an increasing number of their investors expect them to disclose nature-related risks and the potential financial effects on their businesses.
- One Japanese corporate noted that while short-term effects from nature-related risks on financial performance are possible, it expects its implemented mitigation actions to enhance long-term corporate value.

37 See https://www.finma.ch/en/news/2024/12/20241207-mm-rs-2026-01-naturbezogene-finanzrisiken/. It should be noted that the FINMA circular is aligned with the ECB guide on climate-related and environmental risks and the Monetary Authority of Singapore (MAS)'s Guidelines on Environmental Risk Management for Banks in going beyond climate to include broader environmental / nature risks.

4. Conclusions

The evidence synthesised in this report and the accompanying database demonstrate the financial materiality of nature-related risks for businesses and the economy. The evidence spans sectors, scales, hazards and timeframes, with high-quality analysis across evidence types. There is also extensive evidence to demonstrate that information on nature-related risks is increasingly important to investors and that omitting, misstating or obscuring such information could reasonably be expected to influence investors' decisions.[38]

The evidence is stronger for some nature hazards, sectors and transmission channels than others, as illustrated in Table 1. While the evidence of nature-related risks leading to economic and non-economic effects is extensive across a range of hazards, company-specific evidence is less extensive, particularly in the academic literature mainly due to reliance of these studies on publicly available data.

The main findings from the landscape analysis are as follows:

1. There is **extensive evidence on the financial effects of nature-related risks** (physical and transition), which spans a range of sectors, scales, drivers, hazards, time horizons (present, past, future) and effects (non-economic, economic and company level). The effects are relevant to a range of stakeholders, not solely investors and businesses, since some relate to nature-related events that have significant repercussions for society, including the general public, Indigenous Peoples and Local Communities, civil society and governments.
2. While there is high quality evidence across all evidence types, **evidence at the company level** – i.e. company-specific effects that provide a more granular view than the non-economic human effects or economic effects at the local, national or global scale – **is not extensive in the peer-reviewed literature**. This is typically because internal corporate assessments of nature-related issues, including assessments using the TNFD LEAP approach, are confidential internal analyses and evidence of company level effects requires access to company-specific data, which is rarely made publicly available or provided to academia.
3. **The level of evidence at the company level varies between different drivers of nature-related risks.** For example, there is extensive evidence for water scarcity having financial effects on business, while considerably less exists for invasive alien species, despite extensive evidence of significant and increasing costs at the economy-wide level.

38 See Sustainability-related risks and opportunities and the disclosure of material information – Educational material (ISSB, 2024).

4. At the company level, the **strongest evidence of material financial effects covers**:
    a. **Water scarcity** leading to greater capital and operational expenditures and operational disruption/shutdown, as well as the effect of internalising water stress into credit analysis;
    b. Firm value effects stemming from **liability risk** (litigation on the effects of pollution, marine degradation, wider environmental degradation as well as fines);
    c. **Reputational risk** related to deforestation, pollution, water scarcity and wider environmental degradation spanning a range of sectors;
    d. **Policy risk** leading to negative effects on firm value, capital and operational expenditure, operational disruption and stranded assets;
5. **Evidence linking a whole nature-related risk causal chain is scarce** (i.e. driver/s of nature degradation -> nature effect -> nature hazard -> financial effect/s).
6. **The evidence on transmission channels is still developing.** The nature-related financial risks database highlights the evidence gaps that require further exploration through case studies and research linking evidence across all the links in specific transmission channels.
7. **The literature on nature-related cascading and compounding risks is still limited**, but a number of relevant studies have been identified and included in the database.
8. There has been recent progress in scientific evidence of systemic risks, but **evidence of ecosystem stability risks at the business level is limited.**
9. **Evidence of empirical nature-related financial risks to a specific business or in a specific region can help other businesses with risk identification.** For example, evidence of a specific nature-related risk to a business can help another business within the same sector to identify its risks (e.g. depending on the same supplies). This can also be helpful for different sectors that are operating in the same region (e.g. water shortages that have material financial effects for different sectors in that region).

The main findings from the interviews and reports of corporates and financial institutions show that:

1. **All organisations are advancing in their approaches to assessing nature-related risks, but significant challenges remain, particularly in quantifying financial effects.**
2. **Financial institutions are developing more structured methodologies,** including scenario analysis and portfolio-level assessments, although these often rely on proxy data and assumptions due to limited corporate disclosures.
3. **Corporates are building their capabilities in the assessment of their dependencies and impacts on nature, but continue to rely heavily on qualitative methods and expert judgement** to estimate financial effects from the associated risks.
4. **The absence of standardised data, widespread corporate nature reporting and 'top down' policy-led scenario methodologies remain a significant barrier for financial institutions,** although adoption of the TNFD recommendations (as of October 2024) by

nearly 130 financial institutions, including 25% of Global Systemically Important Bank (G-SIBs), suggests that many have started assessing material nature-related issues in their portfolios with the data and tools available.

5. There is a **growing recognition** among financial institutions and corporates that **nature-related risks are likely to become more financially material in the near future**.
6. **Regulatory pressure and investor expectations are driving demand** for more credible, transparent and financially meaningful assessments.

Given the immediacy of many of the risks highlighted in this report, there are short-term (close to immediate) benefits to corporates and financial institutions from acting now to assess and manage nature-related risks. There are also growth and competitiveness benefits of seizing opportunities to invest in more resilient business models, including through stress testing and scenario analysis, appropriate risk pricing and strategic asset allocation.

5. Recommendations and guidance

These conclusions lead to recommendations for different stakeholders.

i. Recommendations for researchers and data providers

Despite improvements in analyses in recent years, **evidence of the financial effects of nature-related risks at the entity level in the academic literature remains limited**. The evidence base would be strengthened by both granular model-based studies and empirical analyses using company level data. Such evidence has been limited by access to relevant company level data, particularly where companies do not release information that could reveal risks. Increased collaboration, including data sharing, for such studies among researchers and businesses would help.

Focal areas for future research include studies that cover:

- **Whole causal chains.** Linking the whole causal chains to assess the financial materiality of nature-related risks (driver/s of nature degradation -> nature effect -> nature hazard -> microeconomic / macroeconomic / non-economic (e.g. human health) effects -> financial effects) for a range of drivers of nature degradation beyond climate change;
- **A wider range of transmission channels.** Covering a wider range of nature-related risk transmission channels and their financial effects (e.g. at entity level) across a range of regions and sectors; and
- **Complex, cascading and compounding effects.** Considering a combination of nature, climate and other risks and their transmission into financial effects.

There is a need for greater transparency among data providers on which nature-related impacts, dependencies and risks are included within data products, and which are excluded. Many existing data sources capture only a fraction of the transmission channels covered in this evidence review and data on corporate and financial portfolio dependencies on nature are significantly underrepresented in existing data and analytic products. Better transparency, including on metric definitions, meta data and the distinction between observed and proxy or modelled data, is needed to ensure data is not misinterpreted.

ii. Recommendations for corporates and financial institutions

Key insights for corporates and financial institutions emphasise the importance of:

- **Assessment, management and disclosure of nature-related issues, given the evidence of their financial materiality.**
- **A structured and integrated approach to materiality assessment**, providing a clear understanding of how nature-related risks and opportunities stem from an organisation's dependencies and impacts on nature, such as the TNFD LEAP approach.
- **Integrating climate and nature within risk assessments.** The evidence demonstrates that many nature and climate-related risks are strongly interrelated (e.g. water supplies) or compound (e.g. soil erosion and rainfall changes). Assessing these risks independently can underestimate the risks.
- **Building capability** across organisations to assess the financial effects of nature-related risks, for example, through closer collaboration between risk, finance and sustainability teams.
- **Strengthening company level data collection efforts.**
- **Use of existing approaches to risk assessment**, including scenario analysis as a tool for assessing and measuring financial effects from nature-related risks. Both corporates and financial institutions can draw on the TNFD's scenario guidance to make progress, while awaiting further development and guidance from the NGFS on nature scenario methods analogous to those that currently exist with respect to climate change. Even if based on internal or non-standardised methodologies that are not yet mandated by regulators or supervisors, or starting with qualitative approaches, these tools can build internal understanding, inform strategy and lay the foundation for more quantitative methods over time.
- **Establishing clear materiality thresholds.** It is important to define and disclose transparent thresholds for what constitutes a material nature-related risk to the business. This should clarify the assumptions, tools and methodologies used (including potential mitigation factors) to identify potential financial effects from these risks.
- **Recognising that nature-related risks and dependencies and impacts are interrelated, and considering this within risk assessments.** Evidence shows how companies can have impacts on nature, such as water pollution, which feed back on their own operations that depend on ecosystem services and create risks for their business (e.g. rising costs of water).
- **Assessing potential trade-offs between environmental goals** to ensure transparent and balanced risk assessments. For example, considering trade-offs when actions to support the energy transition may negatively impact nature.
- **Financial institutions engaging companies in their portfolios on their own nature-related risk assessment practices**, in particular how they identify and assess the potential financial effects from nature-related risks, the thresholds used and the potential mitigation measures implemented.

iii. Recommendations for standard setters and regulators

The information presented in this report adds further evidence on the financial materiality of nature-related risks and therefore, adds further support to recommendations towards the disclosures of nature-related risks, both from a financial and double materiality perspective. There is extensive evidence to demonstrate that information on nature-related risks is increasingly important to investors and that omitting, misstating or obscuring such information could reasonably be expected to influence investors' decisions.

The evidence in this report further supports the need for standardised reporting frameworks and clear scenarios to be provided by regulators and supervisors. Those reporting frameworks should be consistent with the global policy goals and requirements outlined in Target 15 of the GBF, which calls out the importance of assessing and reporting on nature-related dependencies, impacts and risks.

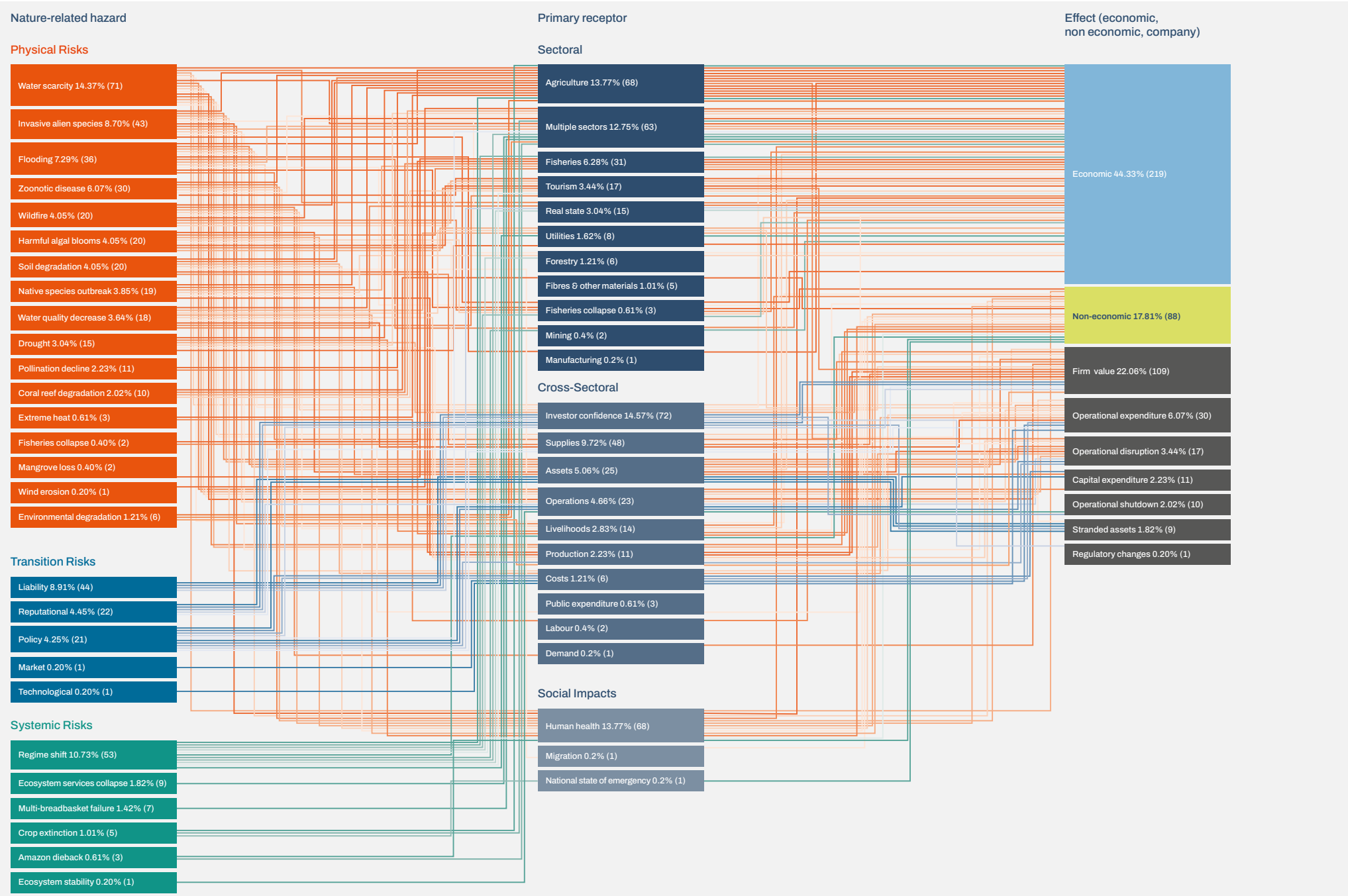
The continuation of the NGFS nature scenarios work is also particularly important to support risk assessments by financial institutions. Given the complexity and wide range of transmission channels, there is a need for clear and practical standards, frameworks, scenarios and methodologies.

Annex I: Landscape analysis synthesis

The figure below provides a synthesis of the available evidence in the nature-related financial risks database of the sources and transmission channels of nature-related risks.

Figure 8: Synthesis of the available evidence in the nature-related financial risks database of the sources and transmission channels of nature-related risks leading to different effects

The numbers in brackets and percentage values in each box in the Sankey diagram correspond to the number of entries in the database for that category. As mentioned in section 2.2, the Sankey diagram corresponds with Table 1 which does not include other types of studies (e.g. exposure) in the database.


Nature-related hazard
Physical Risks
Water scarcity 14.37% (71)
Invasive alien species 8.70% (43)
Flooding 7.29% (36)
Zoonotic disease 6.07% (30)
Wildfire 4.05% (20)
Harmful algal blooms 4.05% (20)
Soil degradation 4.05% (20)
Native species outbreak 3.85% (19)
Water quality decrease 3.64% (18)
Drought 3.04% (15)
Pollination decline 2.23% (11)
Coral reef degradation 2.02% (10)
Extreme heat 0.61% (3)
Fisheries collapse 0.40% (2)
Mangrove loss 0.40% (2)
Wind erosion 0.20% (1)
Environmental degradation 1.21% (6)
Transition Risks
Liability 8.91% (44)
Reputational 4.45% (22)
Policy 4.25% (21)
Market 0.20% (1)
Technological 0.20% (1)
Systemic Risks
Regime shift 10.73% (53)
Ecosystem services collapse 1.82% (9)
Multi-breadbasket failure 1.42% (7)
Crop extinction 1.01% (5)
Amazon dieback 0.61% (3)
Ecosystem stability 0.20% (1)
Primary receptor
Sectoral
Agriculture 13.77% (68)
Multiple sectors 12.75% (63)
Fisheries 6.28% (31)
Tourism 3.44% (17)
Real state 3.04% (15)
Utilities 1.62% (8)
Forestry 1.21% (6)
Fibres & other materials 1.01% (5)
Fisheries collapse 0.61% (3)
Mining 0.4% (2)
Manufacturing 0.2% (1)
Cross-Sectoral
Investor confidence 14.57% (72)
Supplies 9.72% (48)
Assets 5.06% (25)
Operations 4.66% (23)
Livelihoods 2.83% (14)
Production 2.23% (11)
Costs 1.21% (6)
Public expenditure 0.61% (3)
Labour 0.4% (2)
Demand 0.2% (1)
Social Impacts
Human health 13.77% (68)
Migration 0.2% (1)
National state of emergency 0.2% (1)
Effect (economic, non economic, company)
Economic 44.33% (219)
Non-economic 17.81% (88)
Firm value 22.06% (109)
Operational expenditure 6.07% (30)
Operational disruption 3.44% (17)
Capital expenditure 2.23% (11)
Operational shutdown 2.02% (10)
Stranded assets 1.82% (9)
Regulatory changes 0.20% (1)

Annex II: Glossary

Box 3: Key definitions and concepts

- Double materiality: Double materiality has two dimensions: impact materiality and financial materiality.
- Ecosystem stability risk: Risk of an event that leads to a destabilisation of a critical natural system, so it no longer can provide ecosystem services in the same manner as before. For example, tipping points are reached, regime shifts and/or ecosystem collapses occur that generate forms of physical and/or transition risk. This is one form of nature-related systemic risk.
- Financial stability risk: Risk that a materialisation and compounding of physical and/or transition risk leads to the destabilisation of an entire financial system. It is one type of nature-related systemic risk.
- Impact materiality: Information on the organisation's most significant impacts on the economy, environment and people, including impacts on their human rights.
- Invasive alien species: Species whose introduction and/or spread by human action outside their natural distribution threatens biological diversity, food security and human health and well-being. 'Alien' refers to the species having been introduced outside its natural distribution ('exotic', 'non-native' and 'nonindigenous' are synonyms for 'alien'). 'Invasive' means tending to expand into and modify ecosystems to which it has been introduced. Thus, a species may be alien without being invasive, or, in the case of a species native to a region, it may increase and become invasive, without actually being an alien species.
- Nature positive is a global societal goal defined as to 'halt and reverse nature loss by 2030 on a 2020 baseline and achieve full recovery by 2050'.
- Nature-related physical risks: Nature-related physical risks are risks resulting from the degradation of nature (such as changes in ecosystem equilibria, including soil quality and species composition) and consequential loss of ecosystem services that economic activity depends upon. These risks can be chronic (e.g. a gradual decline of species diversity of pollinators resulting in reduced crop yields or water scarcity) or acute (e.g. natural disasters or forest spills). Nature-related physical risks arise as a result of changes in the biotic (living) and abiotic (non-living) conditions that support healthy, functioning ecosystems. These risks are usually location specific.
- Nature-related risks: In line with ISO, the TNFD defines nature-related risks as potential threats (effects of uncertainty) posed to an organisation that arise from its and wider society's dependencies and impacts on nature.

- Nature-related systemic risks: Nature-related systemic risks are risks arising from the breakdown of the entire system, rather than the failure of individual parts. Nature-related systemic risks are characterised by modest tipping points combining indirectly to produce large failures and cascading interactions of physical and transition risks. One loss triggers a chain of others and stops systems from recovering their equilibrium after a shock (acute hazard). Nature-related systemic risk covers more than only risk to a financial system (i.e. financial stability risk). It also covers the risks from the breakdown of natural systems (i.e. ecosytem stability risk).
- Nature-related transition risks: Nature-related transition risks are risks to an organisation that stem from a misalignment of economic actors with actions aimed at protecting, restoring and/or reducing negative impacts on nature. These risks can be prompted, for example, by changes in regulation and policy, legal precedent, technology, or investor sentiment and consumer preferences. They can also arise from activities aimed at restoring nature that no longer align with, for example, revised policies.

Source: TNFD Glossary

Annex III: References

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Annex IV: Interview questions

Risk management

1. To begin with, could you please outline your process for identifying financial and non-financial risks or opportunities for your business?

Materiality

2. Please describe your process for filtering the risks identified with the process above for disclosure purposes, and the context for conducting this materiality assessment (e.g. disclosure purposes).

Nature

3. How are nature-related risks embedded into the risk assessment and materiality processes in your organisation?
    a. Who is involved in the decision-making process of each of these steps (in case separate)?
    b. What issues, if any, have been identified as significant/material from a financial materiality perspective?
4. Can you share a specific example to highlight how nature-related issues have affected your business? For instance, issues that may have affected the financial position or financial performance (effects on cash flows, access to finance, cost of capital…)?
5. What are the methods and tools you utilise to estimate the nature-related financial effects on your business, or in other words, the potential financial materiality of these risks?
    a. Have you faced any challenges with these methods and tools?
    b. Going forward, are you considering the adoption of any other tools and approaches?

Scenarios

6. Does your company implement scenario analysis to assess financial risk?
    a. If not: can you elaborate why?
    b. If so, could you explain the scope and time horizon of scenario analysis and methodologies involved?
7. Does your company implement nature-related scenario analysis more specifically?
    a. If not: can you elaborate why?
    b. If so, could you explain the scenario design (scope, time horizon, drivers), methodologies involved and future plans on scenario development?

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