

Beyond climate: addressing financial risks from nature and biodiversity loss

December 2022

Summary

There is increasing evidence that central banks and supervisors need to expand their environmental agendas beyond climate change. Globally, the richness and diversity of nature has declined at unprecedented rates over recent decades, posing far-reaching systemic risks for the financial sector.

The impacts of biodiversity loss call for urgent and transformative changes to economic and financial systems. This requires central banks and supervisors to collaborate with other policymakers to determine how the financial sector can manage nature-related financial risks, including how climate change and biodiversity loss interact.

While only a limited number of policy tools have been developed to date, there are a range of options for integrating nature and biodiversity loss considerations into existing policy frameworks. These include updates to microprudential policies and disclosure requirements, and the use of macroprudential assessments and scenario analysis.

Building on the work of the NGFS-INSPIRE study group on Biodiversity and Financial Stability, this paper discusses the theoretical and practical need to extend the scope of central banks' approach to the environmental crisis beyond the current focus on climate change implications to also include the drivers of biodiversity loss, the climate-biodiversity nexus, and the transmission channels of nature-related risk.

This paper is part of a toolbox designed to support central bankers and financial supervisors in calibrating monetary, prudential and other instruments in accordance with sustainability goals, as they address the ramifications of climate change and other environmental challenges. The papers have been written and peer-reviewed by leading experts from academia, think tanks and central banks and are based on cutting-edge research, drawing from best practice in central banking and supervision.



Elena Almeida
(LSE)



Simon Dikau
(LSE)



Nick Robins
(LSE)



Jeanne Stampe
(MAS & SOAS)



Romain Svartzman
(Banque de France)



Thomas Viegas
(Bank of England)



Ulrich Volz
(SOAS & LSE)



Centre for
Sustainable Finance

SOAS University of London



Grantham
Research Institute
on Climate Change
and the Environment

1. Introduction

The need to extend the scope of financial risk beyond climate change

Just as a stable climate enables the conditions for humans to thrive, biodiversity¹ enables the natural world to be productive, resilient and adaptable (Dasgupta, 2021), and to provide ecosystem services² that are vital for the functioning of the global economy. Globally, biodiversity has declined at unprecedented rates over recent decades, with further degradation of the natural world projected. There is an emerging understanding of the significance of the financial impacts of biodiversity loss and nature degradation, although work in this area is nascent. In 2022, 121 central banks and financial supervisors that are members of the Network for Greening the Financial System (NGFS) acknowledged that nature-related risks could have significant macroeconomic and financial implications. To address this, the NGFS set up a 'Biodiversity Loss and Nature-related Risks Taskforce' to extend climate risk assessments to nature. Biodiversity issues are likely to rapidly ascend the international agenda with the post-2020 Global Biodiversity Framework expected to be agreed at the 15th session of the Conference of the Parties (COP15) to the Convention on Biological Diversity (CBD) in December 2022.

In principle, nature-related financial risks (or 'nature risks') share some characteristics with climate-related financial risks: they stem from similar risk channels (i.e. physical and transition), for example. However, nature risks carry distinct challenges that make them harder to identify and assess. They can arise from a wide variety of sources (such as deforestation, species loss, water scarcity and pollution) and are more location-specific (i.e. more local than global). As such, they affect the financial system through multiple sources and transmission channels, which makes them challenging to conceptualise. Climate change and nature loss are also closely interlinked: as well as creating additional sources of financial risks, increased nature and biodiversity loss would exacerbate climate risks.

Structure of the paper

The paper is structured as follows. Section 2 discusses the analytical and practical need to extend the scope of central banks' and supervisors' approaches beyond the current focus on climate change risks and implications, including how the climate-biodiversity nexus creates compounded risks. Section 3 highlights the emerging methodological and practical approaches for central banks and supervisors to integrate broader nature- and environment-related risks into their frameworks. Section 4 summarises.

2. Nature and biodiversity loss in the environmental financial risk framework

When looking to adapt financial policy frameworks to account for environmental risk dimensions, it is essential to understand the underlying transmission mechanisms as well as the financial and economic dependencies and impacts on the environment. While there have been considerable efforts to understand and incorporate the financial implications of climate change, other dimensions of environmental risk have received less attention, particularly the compounding potential of nature-related risks as they interact with climate change in a dynamic way. Addressing only the risks of climate change while treating biodiversity-related financial risks as separate and secondary could lead to an underestimation of risks.

"There is an emerging understanding of the financial impacts of biodiversity loss and nature degradation, but work in this area is nascent."

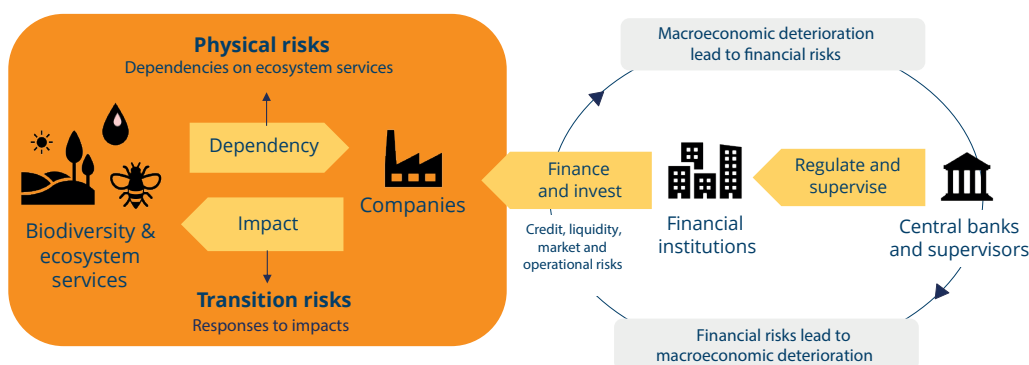
¹Biodiversity is defined in the Convention on Biological Diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems" (CBD, 1992).

²Ecosystem services are broadly defined as a range of material and non-material benefits that humans directly and indirectly obtain from nature and that sustain and fulfil human life (Hassan et al., 2005), also described as "nature's benefit to people" in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework (Díaz et al., 2015).

2.1. Understanding the economic and financial implications of biodiversity loss

All real economic activities both depend on and impact nature (see Figure 1). The World Economic Forum (2020) estimates that over half of global GDP is moderately to highly dependent on natural capital assets – the specific elements within nature that provide the goods and services that the economy depends on. Given the breadth of ecosystem services (see ENCORE, 2022), the extent of dependency varies across sectors, companies and economies. On the impact side, real economy activities affect natural capital assets through either inputs (changes in land and sea use or exploitation of natural resources) or outputs (waste, emissions and pollution). Such impacts on natural assets in turn influence their ability to provide ecosystem services.

Figure 1. Impacts and dependencies of economic activity on climate and nature: left unchecked, biodiversity loss could affect financial stability



Source: Almeida and Dikau (2022)

Nature-related risks stem from the same risk factors as climate risks: physical and transition. They also have similar characteristics to climate risks: they are subject to complex and non-linear dynamics, and are likely irreversible when certain critical thresholds, or 'tipping points', are crossed; they are both foreseeable and uncertain; and delayed action increases risk (NGFS, 2022a). However, unlike climate risk, the range of natural assets and ecosystem services that exist means that nature risk is broad in scope and cannot be captured in a single metric (whereas for climate this is possible by using greenhouse gas emissions). The financial risks stemming from nature loss can therefore come from a multitude of sources and materialise in a multitude of ways. Consequently, assessments of potential nature risks and exposures are significantly more challenging to make than for climate risks.

Nature-related *physical* risks stem from the *dependency* of economic activity on natural capital assets and ecosystem services. Loss and degradation of natural assets can lead to the disruption and even collapse of ecosystem services. These risks can be chronic (e.g. the gradual decline of pollinators, reducing crop yields and increasing the costs of manual pollination) or acute (e.g. large-scale pollution events like oil spills or the spread of disease due to reduced natural resistance). Reductions in the quantity and quality of ecosystem services can damage physical assets such as infrastructure and disrupt supply chains and companies'

"Assessments of potential nature risks and exposures are significantly more challenging to make than for climate risks."

operations by affecting resource dependency, scarcity and quality. The trend of widespread and accelerating biodiversity loss is well-documented in scientific studies (e.g. Butchart et al., 2010; Diaz et al., 2019; WWF, 2020; IPBES, 2019),³ and it is expected to continue due to the impacts of land use change, exploitation of species, climate change and the lack of progress on meeting global biodiversity targets (CBD, 2020). Such biodiversity loss results in natural assets becoming less productive, which reduces the provision of ecosystem services and in turn results in economic consequences and financial risks.

Nature-related *transition* risks occur as a result of efforts to halt or reverse nature loss (i.e. moving towards a 'nature-positive' economy⁴) via changes in policy, regulation, technology and consumer or investor preferences. Economic activities that impact natural assets and ecosystem services, such as agriculture and mining, are likely to be affected. There is currently no nature equivalent to 'net zero', but countries are expected to agree nature-related goals and objectives at the UN Biodiversity Conference (COP15) in December 2022, and several countries including the US and UK have indicated they will aim to conserve at least 30% of their land and oceans by 2030 (the '30x30 pledge').⁵ Sector-specific policies, such as deforestation-free supply chain legislation in the UK and EU, and sustainable farming policies and subsidy reform, are other examples of potential sources of transition risk.

Nature-related *litigation* risks, associated with emerging legal cases related to nature loss, are an additional source of risk; they can include pay-outs, fines, insurance costs, financing costs and reputational costs.⁶ Some frameworks (e.g. from the Taskforce on Nature-related Financial Disclosures [TNFD]) have included litigation risk within transition risk, while others argue that litigation should be a separate category, given it will likely play a more prominent role in nature issues than climate ones – as impacts on nature are more localised, causality is easier to establish.

These categories of nature risk can have both micro- and macroeconomic impacts that can be transmitted to the financial system. These include the impairment of assets or collateral, lower corporate profitability, financial risks that materialise as credit, and market, liquidity or business risks. Currently, nature risk that relates to dependencies or physical risks is likely to be more significant as the widespread deterioration of natural capital assets is rarely factored into business model assumptions. However, shifts in consumer sentiment and in the policy landscape suggest that elements of transition risk – including litigation risk – will become more prominent (Setzer and Higham, 2022). In addition, activities that impact natural assets will compound the deterioration of the ecosystem services those natural assets provide, thus increasing the physical risks for firms that depend on nature.

From a financial stability perspective, biodiversity-related financial risks are an emerging area of focus for central banks and financial supervisors. While they are complex and difficult to measure, some central banks and financial supervisors are starting to assess dependencies and impacts of economic activities on biodiversity and ecosystem services (see Section 3.2).

2.2 The compounding effects of nature and climate risks

Climate change and biodiversity loss are inextricably interrelated, and according to NGFS and INSPIRE (2022), these risks should not be treated separately or sequentially. Climate change is currently the third main driver of biodiversity loss at the global scale (after land use change and overexploitation of natural resources) and is likely to become the main driver as it intensifies. Climate change can interact with and worsen aspects of biodiversity like soil moisture, water cycles and the presence of pollinators (IPCC, 2021). In addition to being a direct driver of biodiversity loss,

“Biodiversity loss results in natural assets becoming less productive, which reduces the provision of ecosystem services and in turn results in economic consequences and financial risks.”

³Since 1970, wildlife populations have reduced by around 70%, and 14 out of 18 key ecosystem services have declined. See IPBES (2019) for more on recent and projected trends.

⁴A 'nature-positive' global economy is defined as one where economic activity enhances “the resilience of our planet and societies to halt and reverse nature loss” (World Economic Forum, 2021).

⁵In addition, the UK Government announced its intention in 2021 to implement a legally-binding 2030 target on species abundance. More details are expected in the coming months, and legislation will follow COP15.

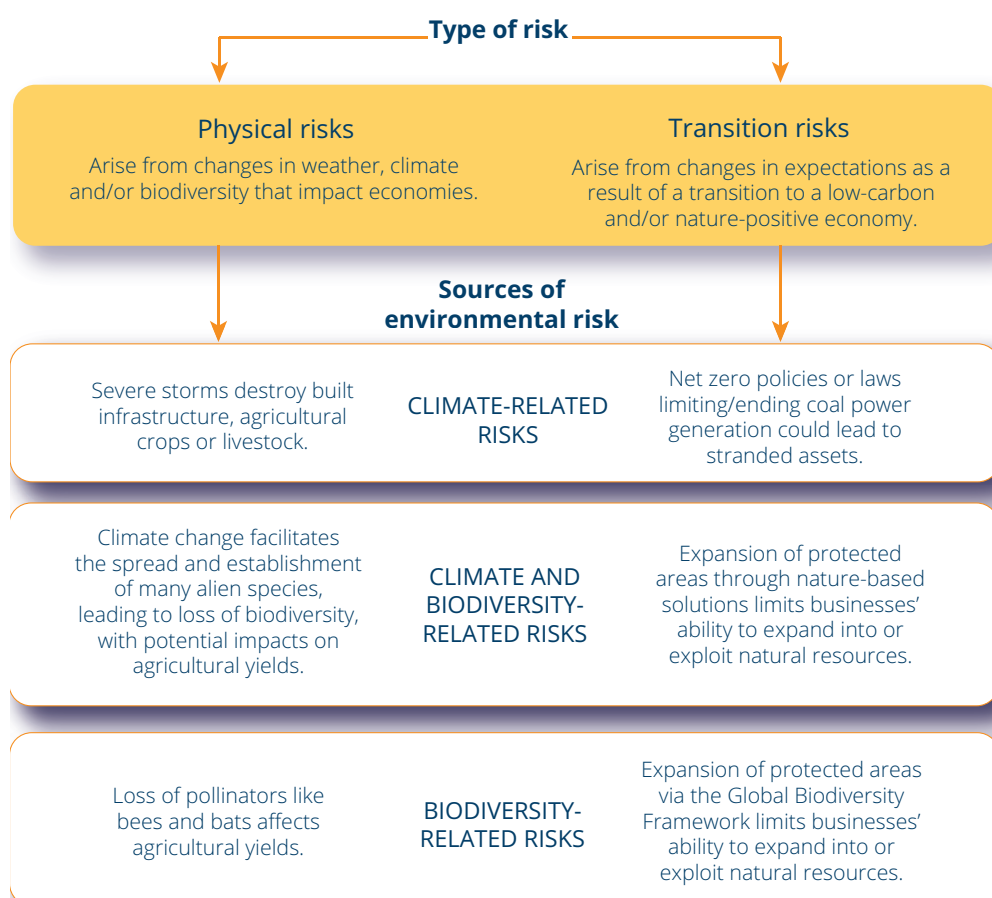
⁶For example, BP had to pay US\$65 billion in environmental damages caused by the 2010 Deepwater Horizon oil spill, including US\$4.5 billion in criminal penalties.

climate change also negatively affects other drivers of biodiversity loss. For example, changes in temperature can lead to drought or the fast spread of invasive species, both of which threaten biodiversity. Meanwhile, biodiversity loss exacerbates climate change through degrading sources of carbon storage, releasing carbon emissions and altering natural infrastructure crucial for climate resilience.

In any interaction between climate and biodiversity, there is potential for synergies and trade-offs. Measures to protect and restore biodiversity, such as protecting forests and mangroves, also mitigate the effects of climate change by sequestering carbon. However, poorly planned reforestation (e.g. planting monocultures), while contributing to climate mitigation efforts, can harm biodiversity (Pörtner et al., 2021) and affect the provision of fresh water (Xiao et al., 2020). Activities such as extracting the minerals needed to develop the technology required for a net zero future can also harm biodiversity. The ability to reach carbon neutrality could therefore be either constrained or enhanced when biodiversity is factored in.

How climate change and biodiversity interact will have implications for the economy and financial sector, as well as for how risks should be assessed. Focussing on climate-related risks without considering other environmental risks, such as biodiversity-related risks, could lead financial institutions to significantly underestimate the risks within their portfolios (Finance for Biodiversity and Vivid Economics, 2021), which could impact the wider financial system (Figure 2).

Figure 2. Examples of interactions between biodiversity- and climate-related financial risks



“Climate change is currently the third main driver of biodiversity loss at the global scale and is likely to become the main driver as it intensifies.”

In reality, these interactions are much more complex given the non-linearity of Earth system processes, and especially if irreversible tipping points are crossed. Biosphere integrity, which relates to processes that regulate the stability and resilience of the Earth system (Steffen et al., 2015), is one of nine ‘planetary boundaries’ identified by the Stockholm Resilience Centre, representing the natural limits within which humanity can continue to thrive. Other planetary boundaries also affect or are affected by biodiversity integrity, underscoring the need to protect biodiversity. For example, limiting land use change is a planetary boundary on its own but is also essential to prevent biodiversity loss. Similarly, the planetary boundaries for phosphorous and nitrogen cycles are largely driven by certain intensive agricultural practices, which must be addressed to protect biodiversity. The Intergovernmental Panel on Climate Change (IPCC) and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) have emphasised that addressing either the climate or the biodiversity loss crisis without consideration of the other could lead to a failure on both fronts (Pörtner et al., 2021).

2.3. Methodological challenges in measuring nature-related financial risks

The complexity of biodiversity makes it difficult to measure. Unlike climate change, where a common unit of measurement (tonne of CO₂ equivalent) can be used to track and communicate its effects, no single metric will comprehensively capture all dependencies and impacts related to biodiversity (Kedward et al., 2020). Another challenge is the non-linearity of the effects of biodiversity loss and the uncertainty associated with them. While there is a consensus that crossing critical ecological thresholds may lead to catastrophic and irreversible consequences, it is hard to predict exactly where these tipping points lie (Hillebrand et al., 2020). Dasgupta (2021) claims that these conditions could give rise to ‘green swans’, i.e. potentially systemically important financial risks triggered by the impacts of human activity on nature (Bolton et al., 2020a; 2020b).

Although biodiversity loss could lead to cascading impacts over time, biodiversity is highly localised in terms of immediate impacts and dependencies. Therefore, different objectives, applications and required associated levels of detail will require different measurement approaches. The dynamic interactions between the natural environment and economic and financial activities also mean that financial institutions cannot routinely apply the same measurement approaches over time, as factors such as the particular drivers of biodiversity loss may change (NGFS-INSPIRE, 2022).

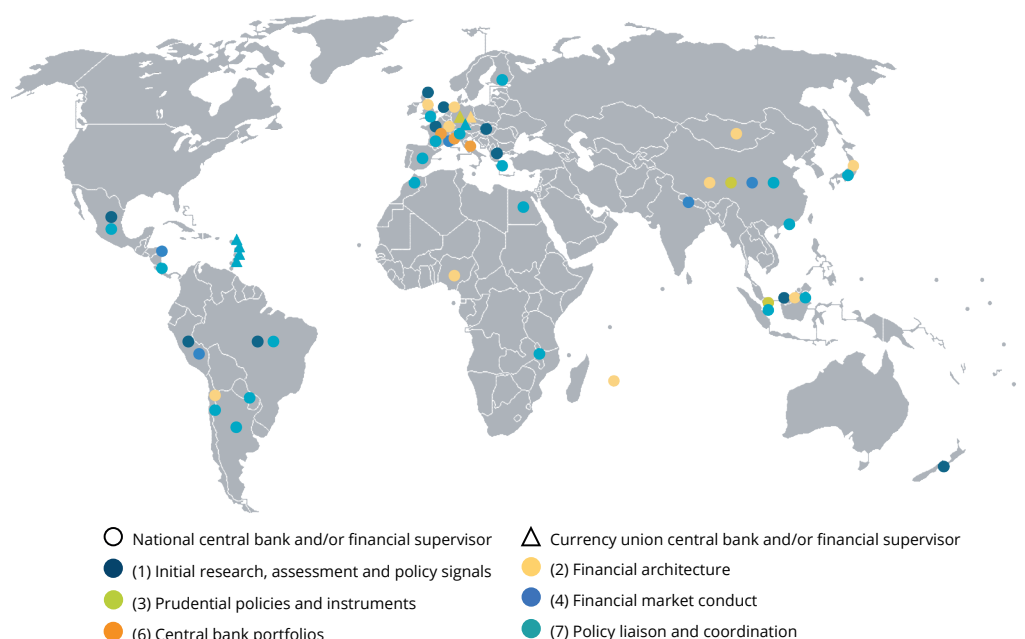
A challenge when assessing the linkages between biodiversity and the economy is the substitutability of ecosystem services, i.e. whether losses in natural capital assets can be substituted by increases in physical and human capital. Most biodiversity–economy models do not factor in the non-substitutability of natural capital assets and thus take a ‘weak sustainability’ approach (Dietz and Neumayer, 2007). Instead, a ‘strong sustainability’ approach (ibid.) is needed, which recognises that an increase in manufactured or human capital cannot adequately replenish existing stocks of natural capital assets, particularly in the context of biodiversity collapse.

“No single metric will comprehensively capture all dependencies and impacts related to biodiversity.”

3. From theory to application: lessons to date

Increased awareness and understanding of the economic consequences and financial risks associated with nature and biodiversity loss have resulted in a growing number of central banks and financial supervisors becoming active in this area (NGFS-INSPIRE, 2022) (see Figure 3). Despite only a limited number of policy tools having been developed and tested, there are a range of options for the integration of nature and biodiversity loss considerations into existing policy frameworks.

Figure 3. Overview of biodiversity-related actions by central banks and financial supervisors



Source: Kunesch et al. (2021) (in NGFS and INSPIRE, 2022)

“There are a range of options for the integration of nature and biodiversity loss considerations into existing policy frameworks.”

This section explores what central banks and financial supervisors have already done across policy functions and highlights some of the potential challenges and areas for further work.

3.1. Microprudential policy and disclosure

One area where biodiversity and nature considerations can be incorporated into existing policy frameworks is through updates to microprudential policies and disclosure requirements. This should be in line with the Basel Pillar 1 requirement of minimum capital requirements for banks and the Pillar 2 requirement of appropriate regulatory supervision of the financial sector to maintain financial stability.

Microprudential policies

Under the Pillar 2 supervisory review requirements, supervisors will need to make further progress on integrating climate-related risks into their supervisory assessments, as the Basel Committee on Banking Supervision (BCBS) is further strengthening climate-related supervisory expectations through the publication of a common baseline for internationally-active banks and supervisors.⁷ While this will support the progress made by financial supervisors in their integration of climate-related risks (NGFS, 2021), there is still limited integration of environmental risks such as biodiversity loss, despite international agreement on its significance (NGFS, 2022a). This common baseline for climate can, however, be used as a foundation upon which to layer considerations of biodiversity loss.

For example, the 2022 European Central Bank (ECB) thematic review on climate-related and environmental risks highlights the efforts by most financial institutions to develop granular and forward-looking approaches to manage these risks.⁸ The review led to an adjustment of the Supervisory Review and Evaluation Process (SREP) scores for a small number of institutions, which will impact their Pillar 2 capital requirements (ECB, 2022).

⁷In June 2022, the Basel Committee on Banking Supervision (BCBS) published *Principles for the effective management and supervision of climate-related financial risks* as a common baseline for internationally active banks and supervisors.

⁸107 significant institutions under the direct supervision of the ECB and 79 less significant institutions under the supervision of national authorities from eight EU Member States participated in the review.

Meanwhile, within the Pillar 1 minimum capital requirements framework, there are ongoing discussions on whether and how prudential capital requirements can be calibrated to account for climate-related financial risks within financial institutions. In a recent consultation, the European Banking Authority (EBA) concluded that mechanisms in the Pillar 1 framework do already allow for the inclusion of environmental risks. Nevertheless, the EBA encouraged further development in the use of these mechanisms – which include internal models, external credit ratings, valuation of collateral and financial instruments – to account for environmental risks (EBA, 2022).

Notwithstanding progress being made on Pillar 1 and 2 frameworks, several challenges make it difficult to incorporate biodiversity loss into these existing frameworks, including: limited and poor-quality data (KPMG, 2020); the lack of well-developed risk assessment methodologies; significant uncertainty over the transmission channel of nature-related financial risks (EBA, 2022); the non-linearity of nature loss; and uncertainties in time horizons. In particular, the EBA noted that reliable information on the impact of environmental risks on financial losses is critical for the analysis and quantification of any potential risk differentials between ‘green’ and ‘non-green’ (i.e. environmentally harmful) assets to justify and determine the feasibility of adjusting prudential treatment.

To advance supervisors’ further analysis of potential adjustments to existing capital frameworks and increase the resilience of financial institutions to climate-related and environmental risks, the NGFS (2022a) has identified three key strands of work: (i) use of scenario analysis and stress testing to better understand the range of potential climate and environmental-related risk differentials; (ii) assessment of the relevance and extent to which financial institutions should consider counterparties’ transition plans; and (iii) understanding of the impact of environmental risks on credit ratings and internal credit risk modelling at financial institutions.

Financial architecture and market transparency

For effective supervision of financial institutions in the context of environmental risks and maintaining financial stability, prudential authorities require complete, consistent, comparable and reliable disclosures. In turn, financial institutions require sufficient disclosures from those they lend to, invest in, and underwrite. The BCBS describes disclosure requirements as “a fundamental component of a sound banking system” and highlights that the quality of climate disclosures was clearly linked to the capture of climate-related risks within the Basel regulatory framework (BCBS, 2022). Disclosure requirements for climate risks would include a consistent baseline climate reporting standard for users and preparers of disclosures (IAIS, 2022). By extension, the same would apply to biodiversity-related risks.

In general, high-quality disclosures are considered critical for financial institutions to appropriately price in biodiversity-related risks and opportunities, allocate capital, and exercise stewardship. In this context, securities market regulators require disclosures to achieve the regulatory objectives of investor protection and improved market transparency and efficiency. While effective disclosure frameworks will have to be supplemented by other measures, there are indications that the reflection of climate risks in disclosures and credit ratings can contribute to the relevant risks being priced in (Carbone et al., 2021; Safiullah et al., 2021). Some jurisdictions such as France and the EU have made biodiversity-related reporting mandatory for companies and financial institutions. In December 2020, the Monetary Authority of Singapore issued 'Environmental Risk Management Guidelines' which requires all in-scope financial institutions to make environmental-related disclosures in accordance with international reporting frameworks, such as the TCFD. The loss of biodiversity is

“Some jurisdictions such as France and the EU have made biodiversity-related reporting mandatory for companies and financial institutions.”

highlighted as one aspect of environmental-related risks to be assessed. Supervisors can consider guidelines for financial institutions in how they disclose biodiversity impact as a way to show leadership through microprudential supervision levers.

A promising development on this front is the convergence towards the IFRS Foundation's International Sustainability Standard Board's (ISSB) sustainability-related disclosure standards as a global baseline of standards that are interoperable with other jurisdictional initiatives, such as the EU's European Sustainability Reporting Standards (ESRS). The ISSB can also provide linkages with other financial statements, such as the disclosure of the impact of sustainability issues on an entity's financial position, financial performance and cash flows. In the EU, the ESRS adoption also raised the issues of the relevance (and interdependency; see EFRAG, 2022) of the double materiality approach (from both the impact and financial perspectives) as opposed to the concept of financial or single materiality. Both the ESRS S1 and IFRS S1 exposure drafts (ISSB, 2022) reflect the concept of 'dynamic materiality', where over the medium- and (especially) the long term, a sustainability impact may become financially material and translate into financial effects due to changes in technology, policy, consumer preferences or investor decisions. To the extent that capital providers increasingly seek information about biodiversity impacts, the ISSB's definition of materiality based on the information needs of primary users of general purpose financial reporting should also capture such information.

A global baseline of sustainability disclosure standards will likely address the serious shortcomings (IOSCO, 2021) relevant to biodiversity risk in value chains such as: incomplete and inconsistent information, especially quantitative information; a lack of consensus definitions and comparability; cherry picking and selective reporting against multiple standards; and a lack of linkage between sustainability issues and impact on financial position and performance. With the completed consolidation of the Value Reporting Foundation and Climate Disclosure Standards Board (CDSB) into the ISSB, preparers can utilise the Sustainability Accounting Standards Board (SASB) standards, which cover 77 industries and include biodiversity-related issues such as ecological impacts, pollution (via air quality, wastewater and waste management) and the CDSB's application guidance on biodiversity-related disclosures.

Other components to enhance market transparency include:

- Science-based and interoperable taxonomies covering the full range of green, transition and environmentally harmful activities.
- Inclusion (or transparency on the extent of inclusion) of biodiversity into external reviews such as second-party opinions, third-party certifications, environmental, social, governance (ESG) ratings, and assurance and auditing.
- Transparency on the extent of consideration of biodiversity in sustainable fund products and of ESG integration claims by asset managers.

3.2. Macroprudential assessments and scenario analysis

To date, most of the application of macroprudential assessments and scenario analysis by central banks and supervisors has focused on the dependencies and impacts of nature and biodiversity on domestic financial institutions and the wider system. Specifically, assessments have explored the activities of financial institutions to gauge potential system-wide vulnerabilities to different forms of nature- and biodiversity-related financial risk. This also applies to financial supervisors who can take steps to incorporate biodiversity loss into the climate risk-related elements of their supervisory frameworks.

“A global baseline of sustainability disclosure standards will likely address the shortcomings relevant to biodiversity risk in value chains, such as incomplete and inconsistent information.”

Methodologies and tools already exist to assess both biodiversity dependencies and impacts, with a small number of central banks – including De Nederlandsche Bank, Banque de France, Bank Negara Malaysia and Banco Central do Brasil (see Box 1) – having published such assessments. While such biodiversity assessments are not risk assessments,⁹ they can illustrate the extent to which different economic sectors directly depend on or impact certain natural assets and ecosystem services. Thus they can also show the extent to which financial firms and the financial system as a whole are exposed to potential nature or biodiversity risks through financial services provision to the real economy.

On the physical risk side, these assessments have identified the parts of the financial system that are highly dependent on ecosystem services and are therefore more likely to be directly affected by a physical shock. To date, the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) database has formed the basis for dependency assessments. It has been used in combination with domestic financial sector data for assessments of nature- and biodiversity-related financial risks in the Netherlands, France, Malaysia and Brazil.¹⁰ For example, for the Netherlands, van Toor et al. (2020) found that 36% of financial institution portfolios of listed shares are highly or very highly dependent on at least one ecosystem service. Broadly similar results have been found for France, Brazil and Malaysia (Svartzman et al., 2021; Calice et al., 2021; World Bank and Bank Negara Malaysia, 2022). Through linking natural capital assets, ecosystem services, economic activities and sectors, and financial sector activities, these assessments have supported the identification of areas of relative importance – either from the ecosystem service or economic sector perspective – which has in turn helped to support microprudential understanding, focus and efforts in this area.

On the transition risk side, such an assessment identifies parts of the financial system that are associated with high adverse impacts on natural assets and ecosystem services and are therefore more likely to be affected by a potential transition shock. A variety of tools have been used to estimate the impact or ‘biodiversity footprint’¹¹ of portfolios, both at the financial institution and system-wide level. This includes the GLOBIO model developed by PBL Netherlands Environmental Assessment Agency, the Global Biodiversity Score (GBS) developed by CDC Biodiversité, and the impact drivers dataset within ENCORE. Using the footprint approach, van Toor et al. (2020) and Svartzman et al. (2021) found that the Dutch and French financial systems have, through their holding of equities and bonds, significant impacts on biodiversity loss. Using ENCORE, World Bank and Bank Negara Malaysia (2022) found that around 90% of commercial loans by Malaysian banks were channelled towards sectors that ‘highly’ or ‘very highly’ impact various natural assets and ecosystem services. Among all impact drivers, the ones individually impacted the most through such bank lending were greenhouse gas emissions, water use and terrestrial ecosystem use.

These static macro-financial assessments of the potential vulnerability of domestic financial systems to nature-related financial risks enable an approximation to be made of the exposure to potential shocks related to biodiversity loss. Further work is being conducted to better understand their transmission channels and their impacts on companies, financial institutions and the system as a whole. By considering the systemic nature of such risks for financial systems and the potential financial instability implications of nature and biodiversity loss, it will be possible to explicitly address nature risks in relevant macroprudential instruments (e.g. regulatory capital requirements and buffers).

“Biodiversity assessments have identified the parts of the financial system that are highly dependent on ecosystem services and are therefore more likely to be directly affected by a physical shock.”

⁹Actual risk exposure is conditional on the strength of the transmission channel, including the location of production processes and mitigating actions.

¹⁰ENCORE links 21 ecosystem services, derived from eight types of natural capital asset, to 86 types of economic production processes. It then scores the dependency (or materiality) of each economic production process to ecosystem services, with dependency being a function of the degree of disruption to productive processes if the ecosystem service were to disappear, and the expected resulting financial losses. See: <https://encore.naturalcapital.finance/en/about>

¹¹A ‘biodiversity footprint’ is expressed as the loss of species and populations in ecosystems as compared with the ‘pristine’ natural state of an ecosystem.

Box 1. Examples of macro-financial nature dependencies and impact assessments by central banks and financial supervisors

As of November 2022, the central banks of the Netherlands, France and Malaysia had undertaken dependencies and impact assessments to understand the consequences of nature loss on the financial system. The World Bank has estimated the potential exposure of Brazil's financial system to such risks. The key findings of each study are summarised as follows:

- In 2020, **De Nederlandsche Bank** found 36% of investments by Dutch financial institutions, totalling €510 billion, to be highly or very highly dependent on at least one ecosystem service. It also found that Dutch financial institutions have a total 'biodiversity footprint' equivalent to the loss of 58,000km² of pristine nature, an area 1.7 times the size of the Netherlands (as of 2018). (Van Toor et al., 2020)
- In 2021, the **Banque de France** published an analytical framework to understand biodiversity-related financial risks (which emphasised the complexities involved and the limited substitutability of natural capital assets) and the dependencies and impacts of France's financial sector. It found that 42% of French financial institutions' portfolios comprise securities from issuers that are highly or very highly dependent on one or more ecosystem service. The biodiversity footprint of these securities, through the firms and activities financed, equates to 130,000km² of pristine nature, or 24% of the area of metropolitan France. (Svartzman et al., 2018)
- In 2022, the **Bank Negara Malaysia** with the World Bank found that 54% of Malaysian banks' commercial loans are concentrated in sectors highly or very highly dependent on one or more ecosystem service. They found that individual banks' exposure to one or more sectors that are highly or very highly dependent on ecosystem services ranged from 5% to 83% of total commercial loan portfolios. They also found that, of the commercial loans portfolio, 87% of banks were also exposed to sectors that strongly impact ecosystem services and thus potentially face a higher level of transition risk from changes in regulations and policies. (World Bank and Bank Negara Malaysia, 2022)
- Similarly, the **World Bank** found that 46% of **Brazilian** banks' non-financial corporate loan portfolios, equal to 20% of their total credit portfolios, are concentrated in sectors highly or very highly dependent on one or more ecosystem service. The World Bank also looked at the impact of collapsing ecosystem services on non-performing loan (NPL) ratios, estimating a long-term increase in corporate NPLs of nine percentage points. In addition, it found that 15% of banks' corporate loans were to companies operating in protected areas, a figure that could rise to 38% if all priority areas in Brazil became protected – therefore representing a source of transition risk. (Calice et al., 2022)

A key part of improving understandings of nature-related risk is the development of scenario analysis, as it makes possible a dynamic assessment of the resilience of financial institutions and financial systems to specific nature-related shocks. Central banks typically conduct stress tests to assess the financial sector's resilience to potential economic shocks that cannot be captured with historical data. This is particularly appropriate for nature risks, as there is no historical precedent for the types of nature risks emerging. Therefore, when appropriately designed, scenario analysis can be an important tool in providing a forward-looking assessment of risk. Scenario analysis and stress testing will likely play a key role in managing and mitigating such nature-related risks due to the similarities between nature-related financial risk and climate-related financial risk – namely that they are far-reaching in breadth, scope and irreversibility; the risk is uncertain yet foreseeable; and the size and balance of future risks will be determined by actions taken in the short to medium term (typically within the next decade).

“Scenario analysis and stress testing will likely play a key role in managing and mitigating nature-related risks.”

There is a growing range of environment–economy models and modelling frameworks to help better assess linkages between nature and the macroeconomy and capture the consequences of physical or transition nature-related shocks.¹² There are, for example, integrated models, which include nature in the production function and a feedback loop of the impact of the economy on nature, and macroeconomic models, which include natural capital assets in the production function but exclude any feedback loop from the economy to the environment. Some Computable General Equilibrium models (CGE) introduce land or natural resources in their production functions. The development of nature and biodiversity scenarios is also an increasing focus for the NGFS, who are building on their climate scenario work to explore the role of biodiversity loss in their existing climate scenarios.¹³

No standard scenarios have yet been designed to assess the resilience of the financial system to specific nature-related physical or transition shocks.¹⁴ This is in large part due to the unique challenges in constructing nature scenario analysis (even relative to climate scenarios). For example, for nature-related physical risk, the uncertainties and non-linearities in how they might manifest makes it difficult to build consistent and comprehensive scenarios on how ecosystems will evolve. The multiplicity of pathways and the lack of biodiversity equivalents to the Representative Concentration Pathways (RCPs) used in physical climate risk scenarios also pose significant challenges. On the transition risk side, the lack of specific biodiversity targets or metrics comparable to those for climate change, such as the 1.5 °C (or 2 °C) threshold and CO₂-equivalent, is a major issue.

In spite of these challenges, progress has been made in developing nature scenarios, although to date they have largely focused on identification. For the Netherlands, van Toor et al. (2020) explored the transition risks associated with potential changes in areas protected for nature conservation. They assessed Dutch financial sector exposures to companies already operating in protected land and inland waters (around 15% of the globe) and how they could increase if protected areas were expanded (to cover either 24% or 30%). They found that financial institutions' exposure to companies in protected areas would almost double (from €15 billion to €28 billion) if the protected area increased to 30% of the planet.

The World Bank and Bank Negara Malaysia (2022) explored a set of nature-related events with a range of adverse physical and transition risk scenarios that could affect Malaysian banks. Based on ENCORE and interviews with stakeholders, they identified 21 possible nature-related physical risk scenarios and seven transition risk scenarios that could affect multiple ecosystem services and economic sectors, and impact bank

¹²See Appendix 5 in NGFS-INSPIRE (2022).

¹³The existing NGFS climate scenarios could omit the aspects of biodiversity risks that are not directly related to climate change, such as soil degradation by chemical pesticides or catastrophic outcomes in the event of the collapse of thermohaline circulation. The NGFS scenarios may also already include significant implicit biodiversity loss as part of large-scale negative- or low-emissions technologies, such as biomass with carbon capture and storage.

¹⁴Until recently this was also the case with climate scenarios.

portfolios. They found that the scenarios with the highest banking sector exposure were those that affected a wide range of sectors. These included 'reduced ecosystem services due to continued high resource use, pollution and urban sprawl' (44% of the commercial loans portfolio), the 'sudden and unexpected introduction of new climate policy' (38%) and the 'deterioration of ecosystem services due to continued high rates of deforestation' (30%) (see World Bank and Bank Negara Malaysia, 2022).

Scenario modelling has also been used to assess the potential macroeconomic impacts and spillovers from natural disruptions. Johnson et al. (2021) assessed the combined impacts of three potential 'collapses' in certain ecosystems (tropical forests, wild pollinators and marine fisheries) over the course of the decade 2021–2030. The study found that under a scenario where all three ecosystems and their services 'collapse', impacts would occur across regions and income groups, with the greatest annual economic losses being in low-income countries (9.7% GDP loss) and lower-middle income countries (6.5% GDP loss). By feeding these estimates into the IMF's Debt Sustainability Analysis framework, Kraemer and Volz (2022) show that nature loss causes considerable risks for sovereign debt sustainability. Furthermore, Agarwala et al. (2022) show that these can also translate into sovereign credit downgrades.

These scenario analyses suggest that macro-financial risks are large and significant for some countries. Central banks and supervisors therefore need to develop their analytical abilities in this field and, where appropriate, explore how macroprudential responses should be crafted, building on the existing macroprudential toolkit.

3.3. Monetary policy: from macroeconomic assessment to financial market implementation

The monetary policy frameworks of central banks and supervisors are affected by the risk, impact and dependency considerations beyond climate and relating to nature and biodiversity loss in two ways. First, the potentially compounding effect of climate-nature impacts could have additional macroeconomic and price stability implications. Second, monetary policy frameworks may have an inherent carbon or nature-loss bias and could, in some jurisdictions, be adjusted to play a role in scaling up sustainable finance.

In addition to the potential financial stability implications, the macroeconomic importance of natural capital assets means that losses to biodiversity and ecosystems, or measures to reverse them, will likely have implications for output growth and price stability. Current research on the relationship between biodiversity loss and price stability is limited, although parallels can be drawn with the emerging evidence on the relationship between climate change and price stability (see Schnabel, 2022). In theory, the physical and transition risks from biodiversity loss could impact inflation dynamics, either directly or through impacts on the macroeconomy.

On the physical risk side, both acute and chronic impacts from biodiversity loss could affect inflation dynamics. Over a short time horizon, extreme nature-related events could have a significant impact on growth and inflation. For example, disruptions in provisioning services (i.e. pollination, fisheries and soils) would affect the global production of food and other commodities, which could cause temporary price inflation. More generally, the destruction of other capital assets (physical or human) due to the physical impacts from biodiversity loss would reduce aggregate supply, while response efforts (e.g. fiscal support) to such nature-related events by governments could increase aggregate demand over the medium term (see Batten, 2018). The net effect of the nature-related physical shock on aggregate demand

"The physical and transition risks from biodiversity loss could impact inflation dynamics."

and supply impacts, and thereby on an economy's output gap, would determine its impact on short-run inflation dynamics. Over a longer time horizon, gradual losses in biodiversity would reduce the potential size and growth rate of an economy through direct reductions in the stock of natural capital assets, and therefore the aggregate supply of an economy.

On the transition risk side, actions to mitigate biodiversity loss, such as government policies or technological advances, could have potential effects on prices. For example, pricing policies on forms of natural capital assets could potentially precipitate large and long-lasting trends in relative prices. Technological advances such as productivity improvements in the use of natural capital assets (e.g. increased agricultural yields) could also lead to lower prices for certain goods. Changes in consumer sentiment in relation to biodiversity loss could impact purchasing decisions for certain goods and services (leading them to boycott certain products or to substitute them with others), altering relative prices and thus affecting inflation.

The potential for environmental shocks to be supply shocks means there may be limitations to the extent to which monetary policy can combat first-round effects. Cœuré (2018) and Carney (2022) both highlight that environment-related supply shocks will pose a dilemma for central banks, forcing them to choose between stabilising inflation or supporting economic activity. In this context, nature risks should be integrated into the macroeconomic assessments aiding monetary policy decision-making (NGFS-INSPIRE, 2022) by analysing the price stability implications of biodiversity loss.

Central banks may also explore adjusting their monetary policy frameworks to more actively 'green' the financial system by integrating nature and biodiversity-related considerations. Historically used by many central banks, and still prevalent today in emerging market and developing economies, monetary policy instruments including differentiated refinancing operations as well as credit or interest rate ceilings or floors are part of the 'quasi-fiscal' toolbox that is already utilised by some to scale up sustainable finance (Volz et al., 2022). With regard to nature and biodiversity, this could include adjusting the composition of financial assets purchased for monetary policy purposes to support the transition to a nature-positive economy by introducing new nature-related requirements for any purchases. In principle, this could leverage existing reflections that focus on climate change and related risks. Furthermore, central banks could also adopt 'protective' measures to mitigate the exposure of central bank balance sheets to biodiversity risk or implement 'proactive' measures to reduce the impact of monetary policy operations on biodiversity loss (Monnin, 2022).

To date, no central bank has explicitly incorporated biodiversity loss considerations into its monetary policy operations. The data gaps and risk quantification challenges for biodiversity are more severe than for climate change (Kedward et al., 2020). However, central banks, especially those with existing climate-related policy measures, may consider extending such measures to cover specific nature-related risks that are central to the climate-biodiversity nexus, i.e. deforestation and water risk. By using deforestation and water risks as proxies for risks to terrestrial and river or marine ecosystems, central banks can develop a synergistic response strategy to make more rapid progress in addressing these interconnected risks. As data availability and accuracy improve with better corporate sustainability-related disclosures and the development of new measurement tools, central banks can consider a more targeted approach to incorporating biodiversity loss into operational frameworks.

"As data availability and accuracy improve, central banks can consider a more targeted approach to incorporating biodiversity loss into operational frameworks."

4. Conclusion and next steps

It is increasingly important to make efforts to assess the risks that can arise from biodiversity and nature loss (physical risks) and the potentially profound socioeconomic changes (transition risks) linked to the need to protect biodiversity. The NGFS (2022b) has recently stated that central banks and supervisors need to make progress in research into the nature and location of these risks, how they interact with other risks (including climate-related risks), and their impact on financial and price stability.

Nevertheless, the complexity of ecosystems and the limited substitutability of natural capital assets make it challenging to assess these risks. Extreme nature-related events triggered by biodiversity loss, or 'green swan' events (e.g. future pandemics), have systemic consequences and can therefore not be measured precisely or be otherwise addressed by financial institutions, central banks or supervisors alone. However, such events also show that not aiming to assess and manage these risks (which will keep increasing, according to scientific evidence) is akin to ignoring significant sources of economic and financial risks. While central banks and supervisors cannot resolve nature loss and its ensuing risks, they have a key role to play in managing them (Bolton et al., 2020a; 2020b) and potentially scaling up sustainable finance to build a nature-positive economy.

In this context, the Taskforce on Nature-related Financial Disclosures (TNFD), recently launched by the NGFS (2022b), should make a significant contribution to mainstreaming the consideration of nature-related financial risks across central banks' and supervisors' activities. Indeed, the Task Force will seek to integrate nature-related considerations into all existing NGFS workstreams. This could support central banks and supervisors to more quickly address three critical challenges they face: (i) to build a scientifically grounded analytical framework to assess the interactions between nature, the macroeconomy and the financial system in a way that is both comprehensive and actionable; (ii) to bridge the likely data gaps that will emerge from such a framework; and (iii) to use this new framework and datasets to align policies with environmental sustainability and inform the assessment of nature-related financial risks (NGFS, 2022b).

Moreover, central banks and supervisors can help build the necessary financial architecture for mobilising investment for a nature-positive economy where this is compatible with their mandates (which can vary across jurisdictions) – as recommended too by the 2022 NGFS-INSPIRE Joint Study Group. This includes considering how central banks' monetary policy operations and non-monetary policy portfolio management should be conducted in the context of biodiversity loss, and how prudential regulation could be mobilised in such a way that it contributes to shifting financial flows towards nature-positive outcomes, thereby strengthening the resilience of the financial system in the face of nature-related risks.

While governments hold primary responsibility for halting and addressing environmental damage including loss of biodiversity and nature, the financial sector also has an important role to play, and central banks and supervisors can actively help it to deliver. Given that remaining within planetary boundaries is an essential condition for human activity to thrive and for financial and price stability to be preserved, tackling nature-related risks falls firmly within the remit of central banks and supervisors.

“While central banks and supervisors cannot resolve nature loss and its ensuing risks, they have a key role to play in managing them.”

References

- Agarwala M, Burke M, Klusak P, Kraemer M, Volz U (2022) *Nature Loss and Sovereign Credit Ratings*. London: Finance for Biodiversity Initiative, SOAS Centre for Sustainable Finance, Bennett Institute for Public Policy at the University of Cambridge, University of East Anglia, Sheffield Hallam University.
- Almeida E and Dikau S (2022) Financial Risks and the Climate-Biodiversity Nexus. [Poster] The Royal Society IPCC AR6 Conference, 11-12 April. London: The Royal Society.
- Basel Committee on Banking Supervision [BCBS] (2022) *Principles for the effective management and supervision of climate-related financial risks*. Basel: Bank for International Settlements.
- Batten S (2018) *Climate change and the macro-economy: a critical review*. Staff Working Paper No. 706. London: Bank of England.
- Bolton P, Després M, Pereira da Silva L, Samama F and Svartzman R (2020a) *The green swan: Central banking and financial stability in the age of climate change*. Basel: Bank for International Settlements.
- Bolton P, Després M, Pereira da Silva L A, Samama F, and Svartzman R (2020b) "Green Swans": central banks in the age of climate-related risks. *Banque de France Bulletin* 229(8).
- Calice P, Diaz Kalan F and Miguel F (2021) *Nature-related financial risks in Brazil*. Policy Research Working Paper 9759. Washington, D.C.: World Bank Group.
- Carbone S, Guizio M, Kapadia S, et al. (2022) *The low-carbon transition, climate commitments and firm credit risk*. SUERF Policy Brief No. 309. Vienna: SUERF.
- Carney M (2022) Climate Policy is Macro Policy: 2022 Paul Volker Lecture at NABE Conference. *Business Economics* 57(2): 43–55.
- Cœuré B (2018) *Monetary policy and climate change*. Speech at the European Central Bank, Frankfurt, 8 November.
- Secretariat of the Convention on Biological Diversity [CBD] (2020) *Global Biodiversity Outlook 5*. Montreal. <https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf>
- Secretariat of the Convention on Biological Diversity [CBD] (1992) *Convention on Biological Diversity*.
- Costanza R, de Groot R, Sutton P, et al. (2014) Changes in the global value of ecosystem services. *Global Environmental Change* 26: 152-158.
- Dasgupta P (2021) *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.
- Díaz S, Settele J, Brondizio E et al. (2019) Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* 366(6471).
- Díaz S, Demissew S, Carabias J (2015) The IPBES Conceptual Framework – connecting nature and people. *Current Opinion in Environmental Sustainability* 14:1-16.
- Dietz S and Neumayer E (2007) Weak and Strong Sustainability in the SEEA: Concepts and Measurement. *Ecological Economics* 61 (4): 617-626.
- EFRA (2022) *ESRS 1 General Principles – Exposure Draft*. Brussels: EFRA.
- ENCORE (2022) Ecosystem services. Web page. <https://encore.naturalcapital.finance/en/data-and-methodology/services>.
- European Banking Authority [EBA] (2022) *The Role of Environmental Risks in the Prudential Framework*. Discussion Paper. Luxembourg: Publications Office of the European Union.
- Finance for Biodiversity (2021) Finance for Biodiversity pledge: Reverse nature loss in this decade. Web page. <https://www.financeforbiodiversity.org/>
- Hassan R, Scholes R and Ash N (2005) *Millennium Ecosystem Assessment*. Inland Press: Washington D.C.
- Herweijer C, Evison W, Mariam S et al. (2020) *Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy*. Washington, D.C.: World Economic Forum.
- Hillebrand H, Donohue I, Harpole W, et al. (2020) Thresholds for ecological responses to global change do not emerge from empirical data. *Nature, Ecology and Evolution* 4: 1502–1509.
- International Association of Insurance Supervisors [IAIS] (2021) *Response to consultation on ISSB exposure draft on climate disclosure*. Press release, 29 July.
- International Financial Reporting Standards [IFRS] (2022) *IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information – Exposure Draft*. London: IFRS.
- International Organization of Securities Commissions [IOSCO] (2021a) *Recommendations on sustainability-related practices, policies, procedures and disclosure in asset management: Final Report*. Madrid.
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] (2019) *Global assessment report on biodiversity and ecosystem services*. Bonn: IPBES.
- Intergovernmental Panel on Climate Change [IPCC] (2021) *Summary for policymakers in climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC*. Cambridge, United Kingdom and New York, USA: Cambridge University Press 3–32.
- Johnson J, Ruta G, Baldos U, et al. (2021) *The economic case for nature: A global earth-economy model to assess development policy pathways*. Washington, D.C.: World Bank Group.
- Kedward K, Ryan-Collins J and Chenet H (2022) *Biodiversity loss and climate change interactions: financial stability implications for central banks and financial supervisors*. Climate Policy 0: 1–19.
- Kedward K, Ryan-Collins J and Chenet H (2020) *Managing nature-related financial risks: a precautionary policy approach for central banks and financial supervisors*. UCL Institute for Innovation and Public Purpose Working Paper. London.
- Kunesch KPMG (2020) *The time has come: The KPMG Survey of Sustainability Reporting 2020*.
- Kraemer M and Volz U (2022) *Integrating nature into debt sustainability analysis*. Finance for Biodiversity and SOAS University of London.
- Monnin P (2022) *Monetary policy operations and biodiversity loss*. CEP Policy Brief. Zurich: Council on Economic Policies.

- Network for Greening the Financial System [NGFS] (2022a) *Capturing risk differentials from climate-related risks. A Progress Report: Lessons learned from the existing analyses and practices of financial institutions, credit rating agencies and supervisors.*
- Network for Greening the Financial System [NGFS] (2022b) *Statement on Nature-Related Financial Risks.*
- Network for Greening the Financial System [NGFS] (2021) *Progress report on the Guide for Supervisors.*
- Network for Greening the Financial System [NGFS] and International Network for Sustainable Financial Policy Insights Research and Exchange [INSPIRE] (2022) *Central banking and supervision in the biosphere: an agenda for action on biodiversity loss, financial risk and system stability.*
- Pörtner H, Scholes R, Agard J, et al. (2021) *IPBES-IPCC co-sponsored workshop report on biodiversity and climate change.* Bonn and Geneva: IPBES and IPCC.
- Safiullah M, Nurul Kabir M and Dulal Miah M (2021) Carbon emissions and credit ratings. *Energy Economics* 100(105330).
- Schnabel I (2022) *A new age of energy inflation: climateflation, fossilflation and greenflation.* Speech at the European Central Bank. Frankfurt, 17 March.
- Setzer J and Higham C (2022) *Global trends in climate change litigation: 2022 snapshot.* London: Grantham Research Institute on Climate Change and the Environment, London School of Economics.
- Stockholm Resilience Centre (2022) *Planetary boundaries.* Web page.
- Steffen W, Richardson K, Rockstrom J et al. (2015) Planetary boundaries: Guiding human development on a changing planet. *Science* 347: 1259855–1259855.
- Svartzman R, Espagne E, Gauthey J et al. (2021). *A 'Silent Spring' for the financial system? Exploring biodiversity-related financial risks in France.* Banque de France Working Paper no. 826. Paris: Banque de France.
- Swiss Re Institute (2020) *Biodiversity and Ecosystem Services: A business case for re/insurance.*
- Van Toor J, Piljic D, Schellekens G, et al. (2020) *Indebted to nature. Exploring biodiversity risks for the Dutch financial sector.* Amsterdam: De Nederlandsche Bank; Planbureau voor de Leefomgeving.
- World Bank and Bank Negara Malaysia (2022) *An exploration of nature-related financial risks.* Kuala Lumpur.
- World Economic Forum (2021) What is 'nature positive' and why is it the key to our future? Blog post, 23 June. <https://www.weforum.org/agenda/2021/06/what-is-nature-positive-and-why-is-it-the-key-to-our-future/>
- World Wide Fund for Nature [WWF] (2020) *Living Planet Report 2020: Bending the curve of biodiversity loss.* Almond R, Grooten M and Petersen T (Eds). Gland, Switzerland: WWF.
- Xiao Y, Xiao Q and Sun X (2020) Ecological risks arising from the impact of large-scale afforestation on the regional water supply balance in Southwest China. *Scientific Reports* 10: 4150.

About the authors

Elena Almeida Policy Analyst – Sustainable Finance at Grantham Research Institute on Climate Change and the Environment, LSE.

Simon Dikau Research Fellow – Sustainable Finance at Grantham Research Institute on Climate Change and the Environment, LSE.

Nick Robins Professor in Practice – Sustainable Finance at Grantham Research Institute on Climate Change and the Environment, LSE.

Jeanne Stampe Green Finance Resource Lead at the Monetary Authority of Singapore & Senior Fellow at the Centre for Sustainable Finance at SOAS, University of London.

Romain Svartzman Senior Research Economist with the Climate Change Centre (Financial Stability Division) of the Banque de France.

Thomas Viegas Manager at the Bank of England.

Ulrich Volz Professor of Economics and Director of the Centre for Sustainable Finance at SOAS, University of London & Visiting Professor at the Grantham Research Institute on Climate Change and the Environment, LSE.

Acknowledgements

The authors acknowledge comments from one anonymous referee. The authors are responsible for any remaining errors or omissions.

Disclaimer

The views expressed in this briefing paper are those of the authors and do not necessarily reflect those of the authors' host institutions, or those of the series editors or their host institutions.

Briefing paper series editors

Dr Simon Dikau: S.Dikau@lse.ac.uk
Professor Nick Robins: N.V.Robins@lse.ac.uk
Professor Ulrich Volz: uv1@soas.ac.uk

Find out more about their work at www.lse.ac.uk/granthaminstitute/research-areas/sustainable-public-and-private-finance/ and www.soas.ac.uk/centre-for-sustainable-finance/.

Editing and production

Georgina Kyriacou (Managing Editor), Natalie Pearson and Zoe Kay, with support from Sophie Scharlin-Petee.

About INSPIRE

The International Network for Sustainable Financial Policy Insights, Research, and Exchange (INSPIRE) is a global research network and designated research stakeholder of the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) in its work to manage climate risk and mobilise finance to support the transition to a sustainable economy. The INSPIRE secretariat is co-hosted by the Grantham Research Institute on Climate Change and the Environment and the ClimateWorks Foundation, and is guided by an Advisory Committee who provide domain expertise independently but in close interface with the work priorities of the NGFS. Philanthropic support for INSPIRE is provided by ClimateWorks Foundation.

www.inspiregreenfinance.org/