

Nature-related risks: a Compendium of Implementation Practices to guide Action by Central Banks and Supervisors

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Foreword



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Over the recent years, the NGFS and its members have highlighted the growing relevance of nature-related risks for the mandates of central banks and supervisors. And as the understanding of the links between the increasing nature degradation,¹ economic activity and the financial system has advanced, attention is progressively shifting from conceptualising these risks to assessing their potential implications in practice.

The *NGFS Conceptual Framework on Nature-related Financial Risks*, published in 2024, established a common structure to support this work. It provided central banks and supervisors with a shared language and analytical approach for identifying, assessing and understanding nature-related financial risks. Yet, as with any emerging area of risk analysis, developing a conceptual foundation is only the first step.

This Compendium reflects the progress made by NGFS members in this regard. It showcases a wide range of implementation practices developed across jurisdictions and institutional contexts, illustrating how the Conceptual Framework can support the consideration of nature-related financial risks. The multiplicity of approaches presented in this publication also highlights an important reality: there is no unique pathway for addressing these risks. Approaches may vary according to institutional mandates, local circumstances and available resources. At the same time, the experiences gathered here demonstrate a growing commitment across the community and suggest an emerging degree of convergence in how nature-related financial risks are understood and approached by central banks and supervisors.

More broadly, and in adequation with the 2026-2027 strategy,² this publication reflects two core strengths of the NGFS: its role as an incubator and its commitment to capacity building.

While important challenges remain, the examples presented in this publication demonstrate the growing ability of central banks and supervisors to analyse these risks in a structured, increasingly sophisticated and policy-relevant manner. They also underline the value of continued collaboration and knowledge sharing across the NGFS community as analytical practices mature. We express our sincere gratitude to all NGFS members who contributed to the surveys, case studies, drafting and review of this publication. We also thank the many experts and stakeholders who shared their knowledge and experience throughout this work. A special thank you goes to the members of the Nature Task Force who coordinated this effort, and to the NGFS Secretariat for its continued support and dedication in advancing the Network's work.

¹ [Seven of nine planetary boundaries now breached – Stockholm Resilience Centre.](#)

² [NGFS Strategy for 2026-2027: From Principles to Practice | Network for Greening the Financial System.](#)

Executive summary

Nature degradation is increasingly recognised as a source of economic and financial risk. Ecosystem degradation can impair economic activity through multiple channels, including reduced water availability, biodiversity loss, soil degradation, and the weakening of natural protection against environmental hazards. At the same time, policy measures aimed at protecting and restoring nature can generate transition risks for firms and financial institutions. Understanding these risks has therefore become an important priority for central banks and supervisors.

In 2024, the NGFS published its Conceptual Framework on Nature-related Financial Risks, providing a common analytical structure for assessing how nature-related physical and transition risks affect the economy and the financial system. This Compendium builds on that framework by documenting how NGFS members are applying it in practice. It reviews 35 nature-risk assessment initiatives across multiple jurisdictions and complements this evidence with six in-depth case studies covering different geographies, ecosystems, analytical questions and policy objectives.

The Compendium demonstrates that central banks and supervisors are increasingly moving beyond conceptual discussions and developing practical tools to assess nature-related risks. While methodologies remain at different stages of maturity, a growing body of evidence shows that nature-related risk assessment is already being operationalised across the NGFS community. What's more, the studies developed and analysed in this Compendium highlight a nascent convergence on the big categories of risks prioritised and on the array of methodologies used.

Key findings

Nature-related risks are material and increasingly measurable

Across jurisdictions and institutional mandates, a relatively consistent set of nature-related risk drivers emerges. Water-related ecosystem degradation is the most frequently assessed source of physical risk. Biodiversity loss,

pollination-service degradation, soil and land degradation, and acute environmental hazards such as floods, storms, heatwaves and wildfires also feature prominently. On the transition side, land-use regulation, pollution-control policies, deforestation-related measures, ecosystem restoration programmes and disclosure requirements are among the most commonly analysed policy drivers.

A recurring finding across the initiatives reviewed is that nature-related risks are highly concentrated in a relatively small number of sectors, including agriculture, forestry, water-intensive manufacturing, energy and real estate. However, because these sectors play a critical role in modern economies and are strongly represented in financial portfolios, risks can become systemically relevant for the broader economy and financial system.

Water-related risks emerge as a particular priority

Water-related ecosystem services appear consistently across the evidence reviewed. Water scarcity, deterioration in water quality, disruption of hydrological systems and water-related regulation generate significant impacts on production, prices, asset values and financial performance.

Several initiatives find substantial exposures to water-dependent sectors within banking systems and economies. The evidence also suggests that water-related degradation propagates far beyond directly affected sectors through value chains and international trade linkages. As a result, water-related risk currently represents the most mature and operational area of nature-related financial risk assessment.

Supply-chain effects significantly amplify direct impacts

Many initiatives show that focusing exclusively on direct exposure can materially underestimate nature-related risk. Economic shocks resulting from ecosystem degradation frequently propagate through domestic and international supply chains, affecting sectors, firms and

financial institutions that are not directly exposed to the original environmental shock.

This finding is particularly evident in analyses of water scarcity, agricultural productivity, pollination decline and ecosystem-service degradation more broadly.

The growing use of input-output models, global value chain analysis and network-based approaches reflects increasing recognition of these indirect transmission channels.

Credit risk is currently the most analyzed financial transmission channel

Most initiatives that progress beyond exposure mapping ultimately translate nature-related risks into traditional financial risk categories. Credit risk is by far the most widely analysed channel. Nature-related shocks can weaken revenues, profitability and asset values, leading to higher probabilities of default, increased non-performing loans and pressure on financial institutions' capital positions.

By contrast, market risk, collateral valuation effects, sovereign risk and broader systemic amplification mechanisms remain less developed areas of analysis and represent important priorities for future work.

Physical-risk assessment is more advanced than transition-risk assessment

The review suggests that methodologies for analysing physical nature-related risks are generally more mature than those used for transition risks. More jurisdictions have produced quantified economic and financial estimates for physical impacts, reflecting the greater availability of data on ecosystem degradation and environmental hazards.

Transition-risk assessment remains constrained by uncertainty surrounding future policy pathways, behavioural responses and the absence of widely adopted nature-related scenarios comparable to those available for climate risks.

Lessons on implementation

The initiatives reviewed reveal a common progression in analytical practice.

Most institutions begin with exposure and dependency mapping using tools such as ENCORE and related databases. As data availability and analytical capabilities improve, institutions increasingly incorporate geospatial analysis, firm-level assessments, econometric methods, macroeconomic modelling and scenario analysis. A smaller subset of initiatives has moved further towards translating economic impacts into explicit financial risk metrics through credit-risk models, capital adequacy assessments and stress-testing approaches.

No single methodology provides a complete assessment of nature-related risks. Existing approaches each capture different dimensions of the problem and should therefore be viewed as complementary rather than competing tools. The evidence reviewed supports a layered approach in which exposure mapping, geospatial analysis, economic modelling and financial-risk quantification are combined according to institutions' objectives, data availability and analytical capacity.

Priorities for future work

Despite significant progress, important challenges remain. Data limitations continue to represent the most significant obstacle to implementation. Nature-related risk assessment is often constrained by insufficient ecosystem data, limited geographical granularity, scarce firm-level information and the absence of broadly accepted ecosystem metrics comparable to climate-related indicators. In addition, current available modelling frameworks still struggle to capture the complexity of nature-economy-finance interactions. This complexity reflects three related challenges present across the initiatives reviewed: the geographical specificity of ecosystem conditions, which sector-level and global datasets and models still struggle to capture; the difficulty of translating nature degradation into quantified economic and financial shocks; and the challenge of modelling the bidirectional relationship between nature and the financial system, in which economic activities both depend on and exert pressure on ecosystem services.

The Compendium identifies several priorities for advancing nature-related risk assessment:

- Improving ecosystem datasets and disclosure information;
- Strengthening the use of geospatial data;
- Developing more standardised ecosystem metrics;
- Expanding macroeconomic and integrated nature-economy modelling;
- Improving quantification of productivity impacts;
- Strengthening integration between climate and nature assessments;
- Advancing scenario design and validation practices;
- Developing more robust nature-related stress-testing frameworks.

Conclusion

The evidence reviewed in this Compendium demonstrates that nature-related financial risk assessment is no longer a purely conceptual exercise. Central banks and supervisors are increasingly developing practical methodologies to identify material exposures, evaluate economic impacts and assess implications for financial stability. While significant gaps in data, modelling and scenarios remain, the experiences gathered across the NGFS community show that meaningful action can already be taken using currently available tools and information. Continued experimentation, methodological development and international knowledge sharing will be essential to support the next stage of progress in nature-related financial risk assessment.

1. Introduction

Despite significant advances in understanding climate and nature interdependencies and related risks, assessing the implications of nature degradation for economies and financial systems remains a major analytical challenge. Nature and the economy are deeply interconnected, and the degradation of ecosystems can affect economic activity and financial stability through a wide range of transmission channels. At the same time, efforts to halt and reverse nature loss are generating new policy, regulatory, and market developments that may themselves create transition risks for firms and financial institutions.

Recognising these challenges, the Network for Greening the Financial System (NGFS) published its Conceptual Framework on Nature-related Financial Risks in 2024.³ The Framework provides central banks and supervisors with a structured approach for analysing nature-related risks through three sequential stages: identifying sources of physical and transition risks; assessing their transmission to the economy; and evaluating their implications for, from, and within the financial system. Its objective is to provide a common analytical structure through which institutions can identify and assess those nature-related risks that are most material to their jurisdictions.⁴

As a follow-up to the publication of the Framework, its implementation was identified as a key priority under the NGFS 2024-2026 work programme. To support this objective, the NGFS documented members' practical application of the Framework and promoted the sharing of experiences across jurisdictions. This work was undertaken through two complementary streams. First, the NGFS conducted member surveys to gather practical examples of nature-related risk assessments across jurisdictions. Then, it supported six case studies designed to address specific nature-related risk questions using the Framework's three-phase analytical logic.

This Compendium consolidates lessons from both exercises. The survey review covers 24 initiatives assessing physical impacts across 13 jurisdictions and 11 initiatives assessing transition impacts across 9 jurisdictions.⁵ These initiatives span a diverse range of analytical approaches, from exposure mapping and geospatial analysis to macroeconomic modelling, scenario analysis, and financial-risk quantification. The survey evidence is complemented by six in-depth case studies focused on Baltic and Nordic countries, Brazil, Chile, France, Germany, and North Macedonia, which illustrate how the Framework can be applied to address specific analytical and policy questions. Figure 1 presents the geographical coverage of the information used in this Compendium.

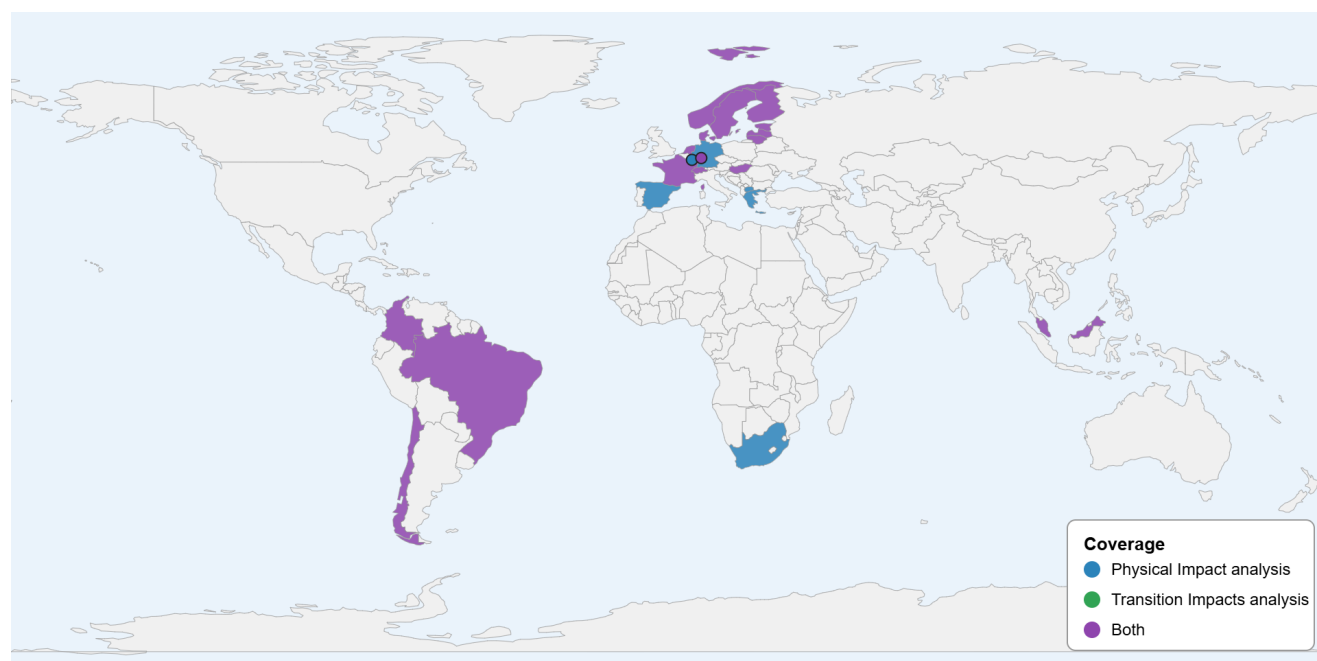
Beyond documenting current practices, the Compendium aims to identify broader patterns emerging across jurisdictions. Although institutional mandates, economic structures, and data availability differ significantly, many initiatives converge on a common set of priorities. Disruptions in water-based ecosystems, biodiversity loss and pollination-service degradation, extreme weather events and acute environmental hazards (floods, storms, heat), and soil and land degradation emerge repeatedly as key sources of physical risk, while land-use regulation, pollution controls, deforestation-related measures, and disclosure requirements are among the most frequently assessed sources of transition risk. Likewise, a relatively small number of methodological approaches, including exposure mapping, geospatial analysis, integrated economic-environmental modelling, and financial-risk quantification, account for a large share of the analytical work currently being undertaken.

3 For more details, see the [Nature-related Financial Risks: a Conceptual Framework to guide Action by Central Banks and Supervisors](#) document.

4 Throughout this Compendium, the terms “physical impacts” and “transition impacts” are generally preferred to “physical risks” and “transition risks”, an intentional choice meant to convey that the evidence gathered allows one to foresee a central scenario in which nature degradation has impacts that are materially different from zero. Accordingly, “impact” is used to denote an estimated consequence that is materially different from zero under the most plausible scenario, while “risk” refers to an assessment that incorporates both the likelihood and the magnitude of potential outcomes.

5 The initiative counts exceed the jurisdiction counts because several jurisdictions contributed more than one initiative, and some jurisdictions contributed to both surveys.

Figure 1 **Coverage of the initiatives reviewed in this Compendium**



The purpose of this Compendium is therefore twofold. First, it demonstrates how the NGFS Conceptual Framework can be used in practice to guide the assessment of nature-related financial risks by Central Banks and supervisors. Second, it provides a practical reference for NGFS members, and external community, by identifying key common sources of physical and transition impacts, providing an analytical review of the methodological approaches currently used, synthesising a set of key lessons learned from the analysis, and stating the current gaps and way forward. The Compendium seeks to help central banks and supervisors identify and draw inspiration from approaches that are most relevant given their policy objectives, analytical capacities, and data availability.

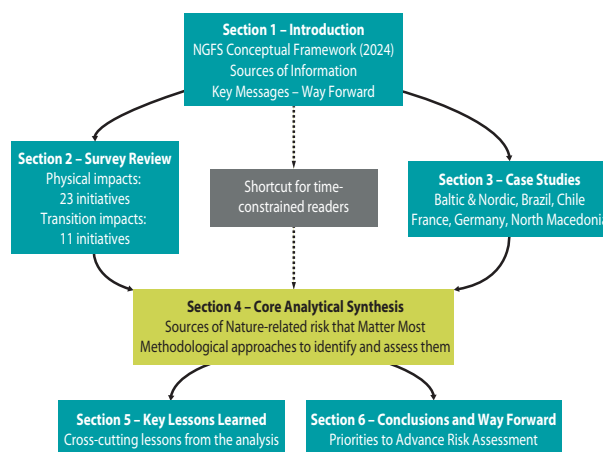
Finally, the evidence presented throughout the report points to a broader conclusion. Central banks and supervisors are increasingly moving beyond conceptual discussions of nature-related risks and developing concrete analytical tools to assess their economic and financial implications. While methodologies remain at different stages of development across jurisdictions, the collective body of work reviewed in this Compendium demonstrates that the operationalisation of nature-related financial risk assessment is already well underway across the NGFS community. This progress should nonetheless be read in light of the scope and limitations of this Compendium:

current practice remains bounded by presently available tools and data, and continues to evolve alongside the broader scientific understanding of nature degradation.

How to Navigate this Compendium and Key Messages

This Compendium is organised into six parts. Sections 2 and 3 document the survey evidence and the six case studies in detail, providing a comprehensive overview of current

Figure 2 **Overview of Compendium Structure**



practice across the NGFS membership. Section 4 draws on this material to synthesise the findings, identifying the most significant sources of nature-related risk and comparing the methodological approaches used to address them. Section 5 distils these insights into a small number of cross-cutting lessons for NGFS members. Section 6 concludes with a brief discussion of the way forward.

To help readers navigate the document, Figure 1 presents the structure of the Compendium and summarises the content of its sections. Readers seeking a concise overview of the Compendium's key findings, without engaging with the full survey and case-study details, may wish to proceed directly to Section 4. Sections 4, 5, and 6 together form the Compendium's core analysis. Sections 2 and 3 supply the underlying evidence – the survey review and the six case studies – but do not themselves interpret it; that interpretive work happens in Section 4, which draws across both evidence streams to identify which sources of nature-related risk are the most commonly assessed and which methodological approaches can be used to assess them. Section 5 then distils this synthesis into the cross-cutting

lessons of greatest relevance to NGFS members, and Section 6 turns those lessons into forward-looking priorities for advancing risk assessment. Read together, d.

Boxes 1 and 2 below provide a short summary of the key messages drawn from the analysis performed throughout this document: Box 1 summarizes the key lessons already evident from the initiatives reviewed, and Box 2 sets out the priorities identified for advancing nature-related risk assessment going forward. These key messages should be read as a reflection of where data and analytical approaches are currently most developed, rather than a definitive ranking of nature-related risks: as data availability and methodologies improve, other hazards, affected sectors, and transmission channels not yet captured here may prove equally or more material. In particular, the prominence of water-related risk in the evidence reviewed likely reflects its visibility as an observable endpoint of nature degradation, and should not overshadow upstream drivers – such as land- and sea-use change, overexploitation, and climate change – where prevention efforts may ultimately be more effective.

Box 1

Key Lessons Learned at a Glance

- **Disruptions in water-based ecosystems are the most consistently identified source of nature-related economic and financial risk.**³ It recurs across more physical-risk initiatives than any other ecosystem service and, owing to the greater availability of measurable data, produces some of the sample's largest quantified figures.⁴
 - **Nature-related risk is highly sector-concentrated but economically pervasive.** Agriculture, forestry, water-intensive manufacturing, and real estate recur as the most exposed sectors across almost every initiative reviewed, yet those sectors are large enough that the aggregate financial system is exposed.
 - **Supply-chain and value-chain effects materially amplify direct impacts.** Assessments limited to direct, sector-based exposure materially understate the magnitude of nature-related risk.
 - **Most jurisdictions remain at the exposure- and dependency-mapping stage; a smaller subset has moved to financial-risk quantification.** ENCORE-based dependency mapping is the most common starting point; few initiatives carry this through to a quantified financial metric.
- .../...

³ This key message is result of the analysis performed on the tools, data, and methodologies currently available to central banks and supervisors, not a comprehensive account of the underlying science of nature degradation. Much of current practice focuses on observable ecosystem-service endpoints – such as water availability – rather than tracing impacts back to their upstream drivers: land- and sea-use change, pollution, overexploitation, climate change, and invasive species, the five direct drivers identified by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). These boxes should therefore be read as a partial and evolving approximation of the underlying science, not a definitive account of it.

⁴ This concentration of supervisory attention is consistent with what firms themselves report: companies disclosing through CDP identify US\$339 billion in potential financial impacts from water-related risks, and report a larger share of revenue vulnerable to water-related transition risk than to any other environmental theme.

- **Credit risk is the most widely analyzed transmission channel of nature-related risks into the financial system.** Default-probability models, non-performing-loan estimates, capital-depletion models, and sovereign distance-to-default calibrations recur across the sample, while collateral, market-risk, and sovereign channels remain comparatively less developed.
- **Physical-risk assessment is currently more advanced than transition-risk assessment.** More initiatives produce financial-loss quantifications or credit-risk estimates on the physical-risk side, reflecting greater data availability than for forward-looking nature-related transition scenarios.
- **Data and scenario limitations remain the primary implementation barrier, particularly for cross-border and emerging-market applications.** Firm-level

data gaps, reliance on international datasets rather than jurisdiction- and location-specific information, and the inherently multidimensional nature of biodiversity, which cannot be readily captured by a single aggregate nature metric comparable to climate's CO₂-equivalent indicator, all hinder the development of more granular assessment.

- **Existing modelling frameworks each capture only part of the picture, pointing toward complementary rather than single-tool strategies.** Static, sector-average tools cannot capture ecosystem tipping points, and biophysical models remain weakly linked to financial analysis – favouring diverse models applied in parallel.

Box 2

Way Forward – Priorities at a Glance

- **Better ecosystem datasets** – expand temporal coverage, local ecosystem features, while maintaining cross-country comparability.
- **Exploit existing disclosure data** – drawing on firm-, facility- and subnational-level environmental information already reported at scale, as a practical complement to new ecosystem datasets and analytical tools.
- **Improve the use of geospatial information** – on assets, economic activities, ecosystem conditions, and environmental hazards.
- **Develop standardized ecosystem metrics** – a common analytical language across central banks, supervisors and the broader financial system, akin to established climate-risk indicators.
- **Advance macroeconomic modelling** – moving beyond exposure mapping to trace how ecosystem degradation propagates through the economy.
- **Better quantification of productivity impacts** – from water scarcity, biodiversity loss, and land degradation.
- **Greater integration of nature and climate assessments** – including joint scenarios capturing feedback loops of physical risks and policy interactions.
- **Develop nature stress testing** – building on progress in the above areas and scenario analysis to translate degradation and policy responses into measures of financial-system resilience.

2. Conceptual Framework Implementation Practices – Survey Review

2.1 Physical impacts

This section presents an analytical review of 24 initiatives assessing the physical impacts of nature degradation, collected through two surveys conducted by the NGFS in 2023 and 2025 and covering 13 jurisdictions.

The initiatives are predominantly drawn from advanced economies with well-developed financial supervisory capacities, including France, Germany, Greece, the Netherlands, Spain, and Switzerland. The inclusion of several emerging economies, namely Chile, Colombia, Hungary, Malaysia, and South Africa, enriches the analysis by capturing perspectives from jurisdictions whose economies and financial systems may be more directly exposed to nature-related risks through agriculture, forestry, water-intensive industries, and commodity-dependent sectors. In addition, the European Central Bank and the European Investment Bank provide euro area-wide and multilateral, portfolio-wide perspectives, respectively.

Across jurisdictions, the physical risks assessed can be broadly grouped into four recurring forms of ecosystem service degradation: **Disruptions in water-based ecosystem services (including water-quality collapse/degradation), Biodiversity loss and pollination-service degradation, Soil and land degradation, and Extreme weather events and acute environmental hazards (floods, storms, heat)**. Disruption in water-related ecosystem services is the most frequently assessed source of risk, followed, separately, by biodiversity loss

and by ecosystem degradation affecting soil quality and land productivity. Several initiatives also examine floods, storms, heatwaves, wildfires, and other hazards linked to the deterioration of ecosystem functions that regulate environmental conditions. While these nature-related physical risks often interact with climate-related physical risks, they remain conceptually distinct insofar as they originate from the degradation of ecosystem services and natural capital rather than from climatic hazards alone.

Although the physical risk sources examined vary across jurisdictions, the methodologies used to identify and assess them can be grouped into a smaller set of more homogeneous approaches. Most initiatives rely on one of four broad approaches: **exposure and dependency mapping, geospatial hazard assessment, macroeconomic and scenario-based modelling, and financial-risk quantification**. Exposure and dependency mapping, particularly through ENCORE-based assessments, remains the most widely used approach. However, an increasing number of jurisdictions are complementing these static assessments with spatially explicit analyses, forward-looking scenarios, and financial-risk models designed to estimate the economic and financial implications of ecosystem degradation.

The reviewed initiatives are analysed below following the three-step structure of the Conceptual Framework. Table 1 provides a summary of each initiative, while detailed descriptions of their scope, methodology, and findings are presented in the Annex.

Table 1 Cross-initiative comparison matrix – physical-risk initiatives

Institution/ Jurisdiction	Source of physical risk	Transmission channels	Methodological approach and data ¹	Key economic sectors affected
European Central Bank – Initiative 1	Ecosystem service exposure (direct & indirect dependencies)	Economic (direct): economic output at risk mostly due to water scarcity and water pollution; Economic (indirect): output at risk due to supply chain water dependency; Financial: share of bank loans exposed (AnaCredit)	Nature Value-at-Risk (NVaR), based on ENCORE, EXIOBASE and AnaCredit data	Agriculture, mining, manufacturing, construction and real estate
Bundesbank (Germany) – Initiative 1	Reduced river navigability due to droughts	Economic (direct): transport-cost increases and productivity losses in logistics-dependent sectors; Economic (indirect/macro): supply chains, producer price index inflation	SVAR model. River level data	Inland-waterway-dependent industry
Bundesbank (Germany) – Initiative 2	Ecosystem service exposure (direct & indirect dependencies), condition of ecosystems (country level)	Nature shock to ecosystem services, sensitivity of firms & supply chains via asset depreciation, change of credit risk of banks in Germany (CET 1 ratio depletion)	EDSI: Modified Merton-model- applied to corporate loans (ENCORE, EXIOBASE, ND-GAIN, AnaCredit, CoRep)	Non-financial firms in exposed sectors with bank-extended loans
Banco Central de Chile – Initiative 1	Forest loss and wildfires affecting timber, pollination, erosion protection Ecosystem Services (ES)	Economic (direct): ecosystem-service loss → forestry/agriculture productivity; Economic (indirect/macro): I-O spillovers	Integrated Economic-Environmental Model linked with spatial land-use and ecosystem-services model	Agriculture; forestry
Banco Central de Chile – Initiative 2	Water scarcity affecting hydropower generation	Economic (indirect/macro): hydropower shock propagation into the broader economy via I-O linkages	New Keynesian model with a detailed electricity-generation sector	Energy (hydropower)
Banco Central de Chile – Initiative 3	Wildfires affecting firms' sales and households' labour income	Economic (direct): income/sales disruption; Financial: loan delinquency and bank balance-sheet solvency (insolvency channel)	Damage functions estimation using Encore and geolocated administrative data	Economic activities with dependency on disrupted ES
Banco de la República (Colombia) – Initiative 1	Rainfall shocks affecting households' and firms' income	Financial: rainfall shocks → credit-risk indicators (default probabilities) at bank-municipality-sector level	Rainfall-shock credit-risk model. Precipitation and credit data	Not defined
Banco de la República (Colombia) – Initiative 2	Reduced precipitation affecting hydroelectric output	Economic (direct): reduced precipitation → lower hydroelectric output → higher firms' costs; Financial: weaker firm income → higher credit risk	Firm-level corporate-impact analysis of hydropower shock	Energy (hydropower generation)
Banque de France – Initiative 1	Disruption to multiple ecosystem services (water cycles, pollination, pest control, invasive-species control)	Economic (indirect/macro): agricultural yield shock → international production-network propagation into agricultural prices → headline inflation (+ 0.5 pp CPI)	Global value chain (GVC) model. Data and plug-on of a standard inflation forecast model: international production-network/trade data	Agriculture (international value chains)

¹ It is worth noting that the data underlying the cases summarised here present various degrees of granularity, which might translate in a different order of spatial magnitude (e.g. km² v. country-level).

Institution/ Jurisdiction	Source of physical risk	Transmission channels	Methodological approach and data ¹	Key economic sectors affected
Banque de France – Initiative 2	Water-related ecosystem degradation affecting value chains	Economic (indirect): value-chain propagation of water-related degradation beyond directly exposed sectors (exploratory, not yet quantified)	ENCORE + EXIOBASE	Sectors depending on or impact freshwater ecosystems; industrial sectors prone to water restrictions
Bank of Greece	Climate-driven biodiversity loss among protected species	Economic (macro): biodiversity loss → estimated GDP losses (willingness-to-pay) under IPCC scenarios	FUND integrated assessment model under RCP2.6/4.5/8.5 scenarios	Economy-wide (national GDP-level, protected-species focus)
Magyar Nemzeti Bank (Hungary)	Drought-driven disruption of surface- and groundwater ecosystems	Economic (direct): input-output modelling → output losses of EUR 6-11.3 billion (4%-7% of GDP); Financial: Non-Performing Loans (NPL) increase from 1% to 3% of corporate loans; sovereign risk (debt-to-GDP rising ~74% → 80%)	ENCORE exposure mapping + input-output modelling + drought scenario analysis	Mostly agriculture and manufacturing (water-dependent sectors)
Bank Negara Malaysia ² – Initiative 1 (TNFD LEAP pilot)	Dependencies on ecosystem services across agriculture/construction value chains	Economic (direct/indirect): multi-service dependency affecting production capacity, operating costs and stability across the value chain; Financial: credit-risk concentration in bank loan portfolios (qualitative)	Firm-level TNFD LEAP pilot. Data: ENCORE; TNFD LEAP framework	Agriculture; construction
Bank Negara Malaysia – Initiative 2	Economy-wide dependency on ecosystem services	Financial (indirect): concentrations of ecosystem-service dependency within bank loan portfolios	Macro-level “ENCORE” assessment. Data: ENCORE	Economy-wide; bank loan-portfolio sectors
De Nederlandsche Bank (DNB, Netherlands) – Initiative 1 (Indebted to Nature – Exposure study, jointly with PBL)	Broad ecosystem-service dependency	Financial: exposure/dependency mapping (no quantified financial-risk impact)	ENCORE	Real estate; distribution; processed food/drink; construction
DNB (Netherlands) – Initiative 2 (TNFD LEAP Pilot)	Broad ecosystem-service dependency + deep dive on ecosystem degradation affecting electric utilities	Financial: exposure/dependency mapping (no quantified financial-risk impact)	ENCORE + WWF Biodiversity Risk Filter	Electric utilities
DNB (Netherlands) – Initiative 3 (scenario study, jointly with PBL)	Global decline in wild pollinators	Economic (direct): agricultural yield/revenue shock → food-processing/retail spillovers	CGE model (MAGNET, NiGEM)	Agriculture; food-processing; retail
DNB (Netherlands) – Initiative 4 (EDSI)	Ecosystem degradation embedded in bank loan-book dependencies	Financial: Merton-based CET1 capital-depletion estimate; correlated credit deterioration across borrowers sharing a degraded ecosystem service	ENCORE + EXIOBASE + degradation index + Merton-based distance-to-default model	Not specified
South African Reserve Bank	Regional degradation of 21 ecosystem services	Economic (direct): sectoral dependency on water-flow regulation/soil quality Financial: credit-risk concentration in bank loan portfolios	Spatially explicit assessment covering 21 ecosystems across regions	Agriculture; mining

² Published and available here: [BNM-WBG-UNDP-leapfornature-26.pdf](#).

Institution/ Jurisdiction	Source of physical risk	Transmission channels	Methodological approach and data ¹	Key economic sectors affected
European Central Bank – Initiative 2	Wildfires, water stress, storms, landslides, subsidence and flooding	Economic (direct): firm-level operational disruption and tangible-asset damage; Financial: firm-level indicators support portfolio-level credit-risk assessment	Geolocated firm-level indicators (postal codes)	Non-financial corporations broadly
Banco de España (Spain)	Ecosystem collapse from extreme rainfall runoff (water-quality collapse)	Economic (direct): property-value and local-economic-activity depression (43% lower housing returns, > €4,000 million losses)	Property-price/asset-pricing analysis. Data: housing-market data	Real estate/housing (Mar Menor area)
Financial Market Supervisory Authority (FINMA, Switzerland) – Initiative 1	Floods, storms and heatwaves affecting Swiss real estate	Economic (direct): per-building Annual Average Loss and extreme-loss estimates for floods/storms/heat; Financial: weakened collateral quality	Geolocated per-building hazard modelling	Real estate/mortgage portfolios
FINMA – Initiative 2	Nature-related dependencies embedded in bond/equity portfolios	Financial: portfolio-level dependency materiality (high-level assessment)	ENCORE applied to listed bond and equity portfolios of large banks and insurers	Bank and insurer bond/equity holdings
European Investment Bank	Counterparty dependency/impact across 21 ecosystem services	Economic (indirect): supply-chain-embedded ecosystem-service pressures <i>via</i> input-output data; Financial: portfolio-wide credit-risk concentration flagging	ENCORE + EXIOBASE + WWF/GLORIA scoring model	Ecosystem-dependent counterparties across the Bank's portfolio

2.1.1 Identifying sources of physical risks: ecosystem services and methodological approaches

A range of methodological approaches exists to identify sources of physical risk, but all of them based on the connection between ecosystem service degradation and the economic activities that depend upon those services. Environmental degradation processes, including both acute hazards and the gradual loss of ecosystem functionality undermine the availability, quality, and reliability of ecosystem services that support economic activities and, consequently, the financial assets and exposures associated with them.

The most widely used approach across the initiatives reviewed is **exposure and dependency mapping using ENCORE (Exploring Natural Capital, Opportunities, Risks and Exposure) or comparable databases**, which

link economic sectors to the ecosystem services on which they depend or which they affect.⁶ Dutch study “Indebted to Nature”, conducted jointly by De Nederlandsche Bank (DNB, the Netherlands) and the Netherlands Environmental Assessment Agency (PBL), applies ENCORE to the national financial sector and finds that over EUR 510 billion (36%) of investments by Dutch financial institutions are highly or very highly dependent on at least one ecosystem service. Swiss Financial Market Supervisory Authority (FINMA) applies the same tool to listed bond and equity portfolios of large banks and insurers to obtain a high-level assessment of the materiality of nature-related dependencies, with an explicit focus on gaining experience and identifying data needs. Magyar Nemzeti Bank (MNB, Hungary) uses ENCORE to match ecosystem services with the impacts and dependencies of Hungarian banking-sector exposures, finding EUR 24.4 billion (43% of corporate lending) and EUR 23.3 billion (41%) exposed to surface- and groundwater-dependent sectors, respectively.

⁶ ENCORE includes, but is not limited to, the following ecosystem services relevant to this compendium: water supply; flood and storm protection; soil quality maintenance; pollination; pest control; water purification; nursery habitat; coastal protection; and water flow regulation.

Bank Negara Malaysia (BNM) applies ENCORE at two levels: a firm-level TNFD LEAP pilot across the construction and agriculture value chains, and a macro-level “ENCORE” assessment of the broader economy and financial system to identify dependency concentrations within bank loan portfolios. The European Investment Bank (EIB) relies on spatially explicit data to apply a similar logic at portfolio scale, combining ENCORE with EXIOBASE and WWF data to separately score dependency and impact for each counterparty across 21 ecosystem services, based on each firm’s sector and country of operation – flagging high risk where high dependency coincides with local ecosystem degradation. Banque de France (BdF) is developing a comparable, still largely exploratory application of ENCORE and EXIOBASE to French freshwater ecosystems, aiming to trace how water-related degradation affects value chains beyond directly exposed sectors, with farming and agrifood identified as the most indirectly exposed. The European Central Bank (ECB) used ENCORE as a basis for a Nature Value at Risk (NVaR) approach that estimates the economic output and loan exposure at risk due to water scarcity and water pollution.

A second cluster of initiatives identifies sources of physical risk through geolocated and spatial hazard modelling.

FINMA is developing a geolocated assessment of the financial impact of floods, storms and heatwaves for every building in the Swiss real estate market, moving from sector averages to site-based hazard data. South African Reserve Bank (SARB) conducts a spatially explicit assessment covering 21 ecosystems across regions, mapping regional vulnerabilities in water availability and soil quality to identify where the financial system’s dependency on surface and groundwater is most concentrated – finding that more than ZAR 1,200 billion in banking assets are issued by activities highly dependent on these services. An ECB task force initiative, to which the Banco de España (BdE, Spain) has participated constructs firm-level physical-risk indicators – NEAR (Normalized Exposure at Risk) and PEAR (Potential Exposure at Risk)⁷ – using geolocated data (postal codes) to assess exposure to wildfires, water stress, storms, landslides, subsidence and flooding for individual non-financial corporations, again moving the level of analysis from sectoral averages to site-based assessment. DNB conducted a LEAP pilot for two own account investment portfolios. Following an ENCORE-based risk screening for both portfolios,

a sectoral deep dive into electric utilities was conducted using publicly available location data for power plants owned by electric utility companies held in the portfolios and the WWF Biodiversity Risk Filter.

A third cluster of initiatives identifies sources of physical risk by embedding ecosystem degradation directly into macroeconomic or general-equilibrium models.

The Bundesbank’s work on the macroeconomic effects of low river levels treats German rivers as transport infrastructure and models how drought-driven reductions in water levels propagate into key macroeconomic variables such as producer price index inflation and manufacturing growth. Banco Central de Chile (BCCh) uses an Integrated Economic-Environmental Model linked with spatial land-use and ecosystem-services modelling (IEEM+ESM) to trace how forest loss and land degradation – associated with wildfires and deforestation – reduce ecosystem-service flows (timber, pollination, erosion protection) and propagate through supply chains into GDP, employment and investment. Another Chilean initiative extends a New Keynesian model with a detailed electricity-generation sector to capture the dependency of hydropower output on water reservoir dynamics.

DNB uses a CGE model to quantify the financial impact of a global pollinator-decline scenario on agriculture, using a productivity shock affecting agricultural production. Banco de la República (BRC, Colombia) pursues two related lines of work: a model relating rainfall shocks to credit-risk indicators at the bank, municipality and sector level, motivated by the observed sensitivity of hydroelectric generation to the 2015-16 El Niño episode; and a firm-level corporate-impact analysis of how reduced hydropower generation under low-rainfall scenarios affects generators’ income statements. BdF uses a global value chain (GVC) model coupled to a standard inflation forecast model to trace how disruptions to four ecosystem services – water cycles, pollination, pest/pathogen control, and the control of invasive species – reduce agricultural yields and propagate through international production networks into agricultural prices, estimating a resulting rise in headline inflation of 0.5 percentage points. The MNB water-risk study combines input-output modelling with an exploratory drought scenario, estimating GDP losses of EUR 6-11.3 billion (4%-7% of GDP) from a severe disruption to surface-

7 European Central Bank. (2023). *Towards climate-related statistical indicators*.

and groundwater ecosystems. The Bank of Greece (BoG) biodiversity study applies the FUND⁸ integrated assessment model to link climate-driven species loss to GDP losses under the IPCC's RCP2.6/4.5/8.5 scenarios, focusing on protected species given data constraints.

A fourth, smaller cluster of initiatives moves beyond exposure or dependency mapping to quantify actual financial-risk metrics. DNB's Ecosystem Services Degradation Sensitivity Indicator (EDSI) is the most developed example: it combines ENCORE dependency scores (enriched with an index of ecosystem degradation by country and linked to EXIOBASE for indirect exposures) with a Merton-based distance-to-default model to estimate the depletion of banks' CET1 capital ratios under a nature shock – explicitly described by DNB as “moving from an ‘exposure’ approach to a ‘financial risk’ approach.” Germany's Bundesbank is applying a comparable EDSI-based methodology to German banks, using AnaCredit loan-level data and covering exposure across all ENCORE ecosystem services rather than water alone, though without EXIOBASE-based indirect exposures or a forward-looking scenario dimension.

Some initiatives also complement this largely static exposure or hazard mapping with forward-looking, scenario-based approaches. This is most explicit in MNB's drought scenario, DNB's pollinator-decline and tail-risk scenarios, BCCh's FOLU and hydropower scenario work, BRC's precipitation-scenario credit-risk modelling, and the BoG's use of IPCC emissions pathways. These approaches are broadly aligned with emerging work on nature scenarios, such as the NGFS Technical Document on Nature Scenarios.⁹

2.1.2 Transmission channels to the economy¹⁰

Building on the sources of physical risk identified above – water-based ecosystems services (including water-quality collapse), Biodiversity loss and pollination-service degradation, Soil and land degradation, and Extreme weather events and acute environmental hazards (floods, storms, heat) – this section traces how each type

of degradation is transmitted into economic outcomes: productivity, output, asset values, and, ultimately, GDP.

Direct transmission channels: ecosystem degradation and hazard exposure

Direct effects arise when firms and households are immediately affected by environmental degradation or physical hazards, resulting in productivity losses, capital damage, and operational disruptions.

A first direct channel relates to **water availability and hydrological systems**, where disruptions in water-based ecosystem services constrain production. Bundesbank shows that reduced river navigability increases transport costs and leads to measurable effects on macroeconomic variables. ECB's NVaR approach shows that surface-water scarcity alone could expose up to 24% of euro area output to risk under a drought event with a 100-year return period. MNB's water-risk study provides another quantified application of this same water-availability channel – the ENCORE-based exposure mapping described above is extended through input-output modelling for scenario analysis, simulating a severe drought shock affecting water-dependent ecosystem services and estimating output losses of EUR 6 to 11.3 billion (4%-7% of GDP) over one year, mainly through contractions in agriculture and manufacturing. SARB provides a further quantified example: its spatially explicit assessment shows heavy sectoral dependency of agriculture and mining on the regulation of water flows and on soil quality, with shocks to water-dependent exports affecting household demand and national economic stability. BRC's two initiatives extend this water-availability channel to hydropower: a firm-level analysis shows that reduced precipitation lowers hydroelectric output and directly affects generating firms' income, while a companion model links rainfall shocks to household and firm income more broadly, with effects varying by municipality and economic sector. BdE's Mar Menor study – reclassified here from an extreme-weather example, since the underlying shock is water-quality collapse from extreme rainfall runoff rather than the weather event itself – shows how the loss of a water-based ecosystem's ecological function depresses local property values and economic activity.

8 Framework for Uncertainty, Negotiation and Distribution. See: [FUND Model](#).

9 NGFS (2023). Recommendations toward the development of scenarios for assessing nature-related economic and financial risks.

10 This transmission-channel structure follows the logic set out in the [NGFS Conceptual Framework on Nature-related Financial Risks](#) (NGFS, 2024, p. 13).

A second direct channel arises from **biodiversity loss and pollination-service degradation**. DNB's CGE-based pollination study shows that a global decline in wild pollinators – a service essential to roughly 75% of food crops – reduces agricultural yields and revenues, generating immediate supply shocks that propagate into food-processing and retail sectors. The BoG's biodiversity study complements this with a macro perspective: using the FUND integrated assessment model, it links climate-driven biodiversity loss among protected species to an estimated economic loss (*via* willingness-to-pay for avoided biodiversity loss) at the level of national GDP, under IPCC emissions scenarios RCP2.6/4.5/8.5. BNM's TNFD LEAP pilot also identifies high firm-level dependencies on multiple ecosystem services – including pollination, soil quality, and water regulation – across the agriculture and construction value chains; because the pilot covers several services jointly rather than isolating biodiversity specifically, its firm-level findings (participating companies reporting that ecosystem-service degradation affects production capacity, operating costs, and stability) are best read as evidence of multi-service dependency rather than a biodiversity-specific channel.

A third direct channel operates through the **degradation of climate-regulation and flood/storm-protection ecosystem services**, whose loss increases the frequency, severity, or damage potential of acute weather-related hazards – floods, storms, and heat – for physical assets. FINMA's Swiss real-estate assessment quantifies the hazard-damage side of this channel through per-building Annual Average Loss (AAL) and extreme-loss estimates for floods (river basins), winter storms, and heat; the assessment explicitly focuses on hazard impact on building values rather than attributing hazards to specific ecosystem-service loss, and does not, at this stage, consider indirect effects. BdE's ECB-aligned Ecosystem Services Indicators initiative extends this hazard-damage channel to non-financial corporations more broadly, using firm-level, geolocated indicators (NEAR and PEAR) to assess operational disruptions and tangible-asset damage from wildfires, storms, flooding, landslides, and subsidence. BCCh pursues a complementary, more granular version of this channel: using geolocated and administrative data, it models damage functions linking the occurrence of extreme weather events to firms' sales and households' labour income, and from there to loan delinquency and bank balance-sheet solvency, focusing specifically on the insolvency channel triggered by these income and expense shocks.

A fourth channel relates to **soil and land degradation** that affects land productivity and resilience, independent of any single acute hazard. BCCh's IEEM+ESM framework identifies this channel at a larger scale: wildfires and deforestation reduce the flow of ecosystem services (timber, pollination, erosion protection), directly lowering productivity in forestry and agriculture before propagating further through the economy.

Indirect transmission channels: supply chains and cross-sector spillovers

Beyond first-order impacts, physical risks can propagate through economic networks, affecting upstream and downstream sectors that are not themselves directly exposed to the initial degradation.

BCCh's Integrated Economic-Environmental Model linked with spatial ecosystem-services modelling (IEEM+ESM) provides the clearest example of this channel: forest loss and land degradation reduce ecosystem-service flows, which the model explicitly traces through supply chains into GDP, employment, and investment effects economy-wide, beyond the forestry and agriculture sectors directly affected. EIB portfolio tool builds in a comparable indirect dimension methodologically, combining ENCORE with EXIOBASE and WWF/GLORIA input-output data so that a counterparty's exposure reflects not only its own direct dependency but also ecosystem-service pressures embedded in its supply chain.

Energy systems provide a further example of indirect transmission, this time quantified at the macro level. BCCh models drought-driven declines in hydropower generation as a shock that spills over into other sectors through input-output linkages, using I-O table data to discipline a New Keynesian model of the broader economy. The BNM TNFD LEAP pilot reinforces the same supply-chain mechanism through its explicit value-chain approach in agriculture and construction, in which participating firms and financial institutions assess how ecosystem degradation at one stage of production affects suppliers and downstream activities.

BdF provides two further examples using global-value-chain and input-output methods. A global value chain (GVC) model traces how disruptions to four ecosystem services (water cycles, pollination, pest/pathogen control, control of invasive species) reduce agricultural yields, propagate through international production networks into agricultural

prices, and ultimately raise headline inflation – a quantified effect of +0.5 percentage points on CPI – illustrating how a sector-specific physical shock can generate broader, economy-wide price pressures. A companion, still largely exploratory initiative on French freshwater ecosystems plans to use ENCORE and EXIOBASE to trace how water-related degradation affects value chains beyond directly exposed sectors, with farming and agrifood identified as most exposed indirectly.

The ECB provides another illustration of the materiality of indirect transmission channels. Linking ENCORE to the multi-regional input-output database EXIOBASE, its analysis shows that around half of the euro area's exposure at risk from the disruption of water-related ecosystems stems from international supply chains. This underscores how the euro area economy's reliance on imported raw materials, goods and services creates vulnerability to supply-chain disruptions, higher costs, or reduced availability of critical resources caused by ecosystem degradation abroad.

Micro, sectoral, and macro perspectives

The initiatives collectively span micro, sectoral/regional, and macro levels, providing a multi-layered view of transmission mechanisms.

At the micro level, BNM's TNFD LEAP pilot, BdE's firm-level NEAR/PEAR indicators, BRC's firm-level hydropower analysis, and EIB's counterparty-level tool show how physical risks affect individual firms' operations, costs, and risk profiles. FINMA's building-level hazard analysis and BdE's Mar Menor property-price evidence illustrate impacts on individual assets and households.

At the sectoral and regional level, initiatives identify concentrations of risk and propagation patterns. The Bundesbank's analysis highlights regional dependence through river transport; DNB's biodiversity-related assessments map sectoral exposure patterns; the SARB adds a spatial dimension by assessing how ecosystem services shape sectoral vulnerabilities across regions; and BRC's rainfall-shock model is explicitly designed at the bank-municipality-sector level. BCCh's land-use mapping further supports regional risk identification by improving data granularity and highlighting ecological hotspots.

At the macro level, several initiatives explicitly assess aggregate impacts. MNB's drought scenario provides quantified estimates of GDP losses, sectoral output declines, and inflationary pressures; the BoG's biodiversity study estimates GDP-level losses under IPCC emissions scenarios; BCCh quantifies drought-driven hydropower spillovers economy-wide through a New Keynesian model disciplined by input-output data; Banque de France estimates a comparable inflationary effect (+0.5pp CPI) from agricultural ecosystem-service disruptions using a global value chain model, coupled with a standard inflation forecast model; and the Bundesbank modelling links reduced river levels to changes in producer price index inflation. Together, these results indicate that large-scale environmental shocks can materially affect GDP, fiscal positions, and inflation dynamics.

2.1.3 Transmission channels to the financial sector

Direct transmission channels: creditworthiness and asset impairment

The most widely documented channel is the **deterioration of borrower creditworthiness** resulting from physical impacts on firms and households. When ecosystem degradation or environmental shocks reduce revenues, increase costs, or damage assets, repayment capacity weakens, translating into higher credit losses, rising non-performing loans (NPLs), and potential pressure on banks' capital adequacy and solvency.

Several initiatives illustrate this mechanism. MNB's water-risk study provides one of the clearest quantified examples, linking a macroeconomic shock (severe drought leading to disruption of surface and ground water resources supply) to financial outcomes: output losses of up to 7% of GDP are estimated to increase NPLs by EUR 730 million to 1.46 billion (1%-3% of corporate loans). The Bundesbank is applying the EDSI/Merton-model logic to firms borrowing from German banks captured in the AnaCredit register, covering all ENCORE ecosystem services rather than water alone. The ECB mapped its NVaR output-at-risk estimates to euro area bank portfolios using the Analytical Credit Datasets (AnaCredit): around 19% of loans are exposed to surface-water scarcity and 22% to groundwater scarcity, while 12% are linked to risks from degraded water quality.

BRC's rainfall-shock model builds this channel directly into its design, modelling precipitation shocks as a direct driver of credit-risk indicators (default probabilities) at the bank-municipality-sector level; its companion hydropower study traces the same channel at firm level, from reduced generation to weaker firm income to higher credit risk for the firms' lenders. BCCh pursues a closely related version of this channel for extreme weather events specifically: damage functions link the occurrence of extreme weather events to firms' sales and households' labour income, and from there to default decisions and bank balance-sheet solvency. BNM's TNFD LEAP pilot identifies the same channel at a micro level, though only qualitatively: participating firms in agriculture and construction report that ecosystem-service degradation can weaken their financial position, and financial institutions assess this as a source of increased credit-risk exposure, but the pilot does not produce a quantified credit-loss estimate.

A second direct channel arises from **damage to collateral and assets**, especially in real-estate portfolios. FINMA's Swiss real-estate assessment examines how floods, storms, and heat affect property values and physical assets; these impacts weaken collateral quality and increase expected losses in mortgage portfolios, affecting balance sheets through higher loss given default (LGD) and potentially lower capital buffers.

Indirect transmission channels: portfolio-wide and market-wide effects

This channel is distinct from the economic-sector indirect channel above: rather than tracing how a shock propagates from one economic sector to another, it concerns how physical shocks propagate across a financial institution's counterparties and asset holdings, deteriorating credit quality across a portfolio rather than output in a supply chain.

DNB's Ecosystem Services Degradation Sensitivity Indicator (EDSI) shows how ecosystem-service dependencies embedded in a bank's loan book – including dependencies transmitted indirectly through counterparties' supply chains *via* EXIOBASE – can lead to correlated credit deterioration

across seemingly unrelated borrowers when a shared ecosystem service degrades. Methodologically, EDSI adapts the Merton model of credit risk: nature-dependence and degradation indexes shift a firm's estimated distance to default, and this is then translated into an estimate of the depletion of a lending bank's Common Equity Tier 1 (CET1) capital buffer. The EIB's portfolio tool is built for exactly this purpose: by scoring both dependency and impact per counterparty across 21 ecosystem services and sectors, it is designed to flag where portfolio-wide credit risk may be concentrated in specific ecosystem-service exposures, although the Bank has not yet extended the analysis to quantify losses to its own balance sheet. BdE's firm-level NEAR/PEAR indicators support the same portfolio-level use case for supervisors and banks assessing corporate loan books.

A further mechanism is **market risk through asset-valuation effects**. DNB's tail-event scenario study is, among the initiatives reviewed, the only one explicitly considering impacts on non-bank financial institutions: translating macro-financial scenarios into financial-sector impacts, it finds increased market risk for insurers and pension funds alongside increased credit losses for banks. At the time of the survey, DNB's EDSI initiative planned a further, more targeted extension to market risk – revaluing stock and bond prices *via* the Merton model to capture nature-driven equity and bond price.¹¹

A third mechanism is **sovereign risk**, highlighted in MNB's study: the macroeconomic effects of physical shocks (lower GDP, higher expenditure) can deteriorate public finances – MNB's severe drought scenario shows the sovereign debt-to-GDP ratio rising from around 74% to about 80% – potentially weakening investor confidence and generating a feedback loop through sovereign-bank linkages, as institutions holding sovereign bonds face valuation losses. The BoG's biodiversity study is relevant background for this same channel (its GDP-loss estimates could in principle feed a similar sovereign-risk analysis) but the initiative itself stops at the real-economy/GDP estimate and does not extend to financial-sector or sovereign-risk quantification.

¹¹ This DNB Working Paper is now published, see: Gallet, S., Prodani, J. and Rang, K. (2026) *From nature shocks to financial stability Incorporating nature physical risks – in particular water-related risks – into banks' credit risk models and insurers' market risk models*. DNB Working Paper no 857.

Concentration risk

Concentration risk is treated here as a specific form of the indirect/portfolio-wide channel above, rather than a separate transmission mechanism, since the underlying concern in both cases is correlated exposure across a portfolio; it is kept as its own point because the initiatives below focus specifically on how exposures are distributed across a loan book, rather than on how a shock propagates. BNM's ENCORE assessment extends its exposure analysis to the macro-financial level, identifying concentrations of ecosystem-service dependency within bank loan portfolios; MNB's analysis similarly finds that the financial system's exposure to highly nature-dependent sectors (agriculture, forestry, manufacturing) is concentrated enough to generate broader systemic vulnerability even though these sectors represent a limited share of total output. MNB's study also finds that mitigating factors – collateralisation and relatively low exposure to the most vulnerable sectors – can limit transmission in some contexts, suggesting that financial transmission strength depends on balance-sheet structure and risk-management practices as well as shock magnitude.

Micro, sectoral, and macro perspectives

The financial-sector evidence spans multiple levels of analysis. At the micro level, BNM's TNFD pilot, BdE's firm-level

indicators, BRC's bank-municipality-sector model, and the EIB's counterparty tool focus on borrower- or counterparty-level exposures. At the sectoral level, DNB and BdE identify risk concentrations across industries, while MNB and BNM's ENCORE highlight portfolio-level concentration in water- and biodiversity-dependent sectors. At the macro level, MNB's framework shows how physical risks can translate into systemic financial stress through GDP, inflation, and sovereign-risk channels; the BoG's GDP-loss estimate is a potential future input to this macro level but has not yet been extended to a financial-sector application.

2.1.4 Summary of key findings

Table 2 synthesises the preceding analysis into four recurring physical risk channels, tracing each from its underlying ecosystem degradation or hazard through to its economic and financial transmission mechanisms. It is worth noting that these four categories are not drawn from an existing scientific taxonomy of nature degradation; rather, they are an inductive summary of the physical hazards most frequently identified across the 24 initiatives reviewed in this section, grouped by how each is transmitted into economic and financial outcomes.¹² Table 5 in Section 4 reflects this overlap explicitly through its “cross-cutting” category; Figure 1 summarizes methodological pathways rather than risk sources and is not intended to mirror this table's categorisation.

¹² They should be read as a survey-based synthesis of what NGFS members are currently assessing, rather than a definitive or exhaustive classification of nature-related physical risk sources. In particular, pollution and invasive species – two of IPBES's five direct drivers of nature degradation – do not appear as separate categories here because no initiative reviewed identified them as a primary source of risk, not because they were judged immaterial. The categories are also not mutually independent: they interact and are often causally linked – for example, biodiversity loss and land degradation frequently act as upstream drivers of the water-related disruption in the table's first row, which may help explain why water recurs as a transmission channel across nearly every initiative reviewed.

Table 2 **Summary of Physical Risk Channels**

Physical hazard	Key affected sectors	Economic Risk Channel	Financial Risk Channel
Disruptions in water-based ecosystems (including water-quality collapse)	Agriculture, logistics (water transport/navigability), manufacturing, energy/power generation (including hydropower), banking and insurance	Production capacity (input and output), economic resilience, operational stability, supply chains, increase of costs, macroeconomy/GDP losses, decline in property value and local economic activity, trade, economic instability, inflationary pressures, investments	Credit worthiness and credit losses, reduction of revenues, increase of NPLs, potential pressure on capital adequacy and solvency, sovereign/fiscal risk and feedback loops through sovereign-bank linkages
Biodiversity loss and pollination-service degradation	Agriculture, construction, manufacturing, forestry	Supply shocks, construction value chains, agricultural yields and revenues, macroeconomy/GDP losses, investments, trade	Weakened financial positions of firms, market risk, operational risk, credit risk, investment portfolios, asset prices and returns
Extreme weather events and acute environmental hazards (floods, storms, heat)	Agriculture, financial sector, manufacturing, real estate, banking and insurance	Macroeconomy, physical assets' damage, asset prices, repair costs, income disruptions, systemic shocks	Banking and insurance sectors' expected losses with the effect on balance sheets and lower capital buffers, mortgage portfolios/increase of NPLs, collateral quality, credit, market and operational risks
Soil and land degradation	Agriculture, land, forestry, banking and insurance	Land productivity and resilience, ecological risk hotspots, production capacity, supply-chain propagation into GDP/employment/investment	Balance sheets, credit risk, market risk, operational risk, NPLs, portfolio concentration

Read across the four hazard categories, a pattern of sectoral concentration seems to emerge. Agriculture is identified as exposed across all four categories, while manufacturing and the banking and insurance sectors appear across three. This suggests that a relatively small number of sectors may accumulate exposure to multiple forms of ecosystem degradation. Assessing hazards separately may therefore obscure overlapping vulnerabilities within the same sectors, counterparties or portfolios.

2.2 Transition Impacts

This section draws on a stocktake of nature-related risk-assessment initiatives undertaken by central banks, supervisors, and other public authorities. The sample includes nine jurisdictions (Chile, Colombia, France, Hungary, Latvia, Malaysia, the Netherlands, Switzerland, and the European Union/ECB). It combines European experiences (France, Hungary, Latvia, the Netherlands, Switzerland, and the EU/ECB) with perspectives from Latin America (Chile, Colombia) and Southeast Asia (Malaysia).

Most initiatives originate in advanced or upper-middle-income economies with relatively developed supervisory capacity. At the same time, the inclusion of Chile, Colombia, and Malaysia brings perspectives from jurisdictions where the economy and financial system are more directly exposed to nature-intensive sectors such as agriculture, forestry, and commodities. It is also worth noting that, even where jurisdictions have highly exposed, nature-intensive sectors, the specific ecosystem services and policy channels at stake can differ substantially across them. Transmission pathways are inherently local and sector- and geography-specific, rather than uniform within a given sector.¹³

The initiatives also differ in maturity and scope. Some (for example, Latvijas Banka (LB, Latvia), DNB, BdF, and MNB) combine exposure mapping with quantitative economic or financial risk assessment, while others (for example, FINMA, BRC, and BNM) remain at a more qualitative or exploratory stage. A summary of each initiative is presented in Table 3 and a detailed description, including the underlying question, methodological approach, and key results, is provided in the Annex.

13 For instance, Chile's exposure runs through forest ecosystem services – water regulation, carbon capture and storage, pollination and erosion protection – targeted by afforestation and restoration policy under its Nationally Determined Contribution; Colombia's and Malaysia's exposure instead runs through land conversion for commodity production (palm oil, forestry, agriculture), targeted by zero-deforestation and ESG/sustainable-supply-chain due-diligence requirements rather than by ecosystem-restoration policy as such. Even where two jurisdictions share the same broadly defined sector – agriculture appears in all three – the underlying ecosystem service and the specific policy lever differ enough that a single "agriculture is exposed" label understates the range of transition-risk transmission pathways at play.

Table 3 **Cross-initiative comparison matrix – transition-risk initiatives reviewed**

Institution/ Jurisdiction	Source of transition risk	Transmission channels	Methodological approach and data	Exposed sectors
Banco Central de Chile	FOLU policies under the NDC (afforestation, restoration, reduced wildfire-driven forest loss)	Economic (direct): ecosystem-service loss → sectoral productivity; Economic (indirect): input-output spillovers → GDP/employment/investment	Spatial LULC + ES model linked to an integrated economic-environmental model; macro input-output module	Agriculture; forestry
Banco de la República (Colombia)	Zero-deforestation and due-diligence commitments	Economic: not yet modelled beyond compliance-cost exposure	Qualitative/exploratory	Palm oil; forestry; agriculture
Banque de France – NNLT	No Net Land Take land-use regulation	Economic (direct): land-take compliance costs → firm turnover	Geographic land-use + firm-level data; Financial: acknowledged conceptually	Land-dependent sectors
Banque de France – Biodiversity footprint	Biodiversity footprint of financial portfolios (exposure to tightening biodiversity policy)	Loan-portfolio footprint	BIA-GBS/GLOBIO	Sectors with significant impacts on biodiversity
Magyar Nemzeti Bank (Hungary)	Sectoral environmental-impact proxies (exposure to regulatory tightening)	Economic (macro): trading-partner shocks → GDP/output/trade/prices; Financial: NPLs, sovereign risk	Macro-level input-output modelling; financial-risk assessment built on macro analysis	Agriculture, Forestry & Fishing; Manufacturing; Real Estate
Latvijas Banka (Latvia)	ENCORE-based dependency/impact mapping (water, soil, climate regulation)	Economic (direct): sectoral cost/operational exposure; Financial: loan-portfolio exposure share	ENCORE + credit-register loan-level data + national expert survey	Ecosystem-service-dependent loan-portfolio sectors
Bank Negara Malaysia	ESG/sustainable-supply-chain requirements; deforestation due-diligence	Economic (indirect/cross-border): export-market pressure; Financial: credit risk from plantation/agriculture lending	TNFD LEAP Pilot and ENCORE	Agriculture and construction: Palm oil; commodities; plantations
DNB – Indebted to Nature (jointly with PBL)	Biodiversity footprint; protection of biodiversity hotspots; nitrogen measures	Financial: exposure/dependency mapping (no quantified financial-risk impact)	GLOBIO model	Not specified
DNB – scenario study (jointly with PBL)	Four transition-risk narratives (Half-Earth protection, EU deforestation-import tax, ending harmful subsidies, Nitrogen/pollution-control rules)	Economic (indirect/macro): CGE/input-output modelling of transition-narrative scenarios → prices, GDP, sectoral output; Financial: credit losses for banks and market risk for insurers/pension funds under the scenario study's macro-financial scenarios	Exploratory transition-shock scenario analysis	Varies across narratives
Financial Market Supervisory Authority (Switzerland)	Biodiversity-related policy changes abroad (deforestation bans, ecosystem-protection measures)	Economic (indirect/cross-border): supply-chain disruption, higher input costs; Financial: correlated portfolio losses	Portfolio-alignment exercises (qualitative)	Mining; agriculture; energy
European Central Bank (European Union)	EU-wide dependence on imported natural resources/ecosystem services from biodiversity-sensitive regions	Economic (indirect/cross-border): value-chain propagation; Financial: credit, market, operational/legal channels	Portfolio-alignment tools + exposure heatmapping + stress-test scenarios	Ecosystem-dependent sectors across euro-area bank portfolios

2.2.1 Identifying sources of transition impacts: economic sectors affected by policies aimed at protecting, restoring, and/or reducing negative impacts on nature

As a first step, the initiatives reviewed identify and synthesize the sources of transition risk arising from policies aimed at protecting, restoring, or reducing negative impacts on nature. These policies can affect economic activities that depend on ecosystem services or that exert significant pressures on natural capital. **Across the initiatives analysed, transition risks are typically associated with policy responses such as land-use regulation, biodiversity protection measures, ecosystem restoration programs, natural resource management, subsidy reform and economic incentives, or broader environmental regulatory requirements for example related to pollution limits, deforestation and supply-chain.** These domestic and regional policy responses are often anchored in, or aligned with, the broader international policy landscape: MNB's submission, for instance, explicitly situates its nature-related risk-monitoring plans within the evolving Global Biodiversity Framework and related EU legislation, illustrating how global policy commitments can filter down into jurisdiction-specific transition-risk drivers.

A few concrete examples illustrate the range of policies identified as sources of transition risk. Land-use regulation is exemplified by France's "No Net Land Take" objective, which restricts net land conversion and directly affects sectors dependent on land for production or expansion. Forest, land-use and land-use-change commitments under Nationally Determined Contributions, as in Chile, translate into afforestation and restoration targets that reshape land-based economic activity. Nitrogen and pollution-control rules, included in some of the DNB initiatives, constrain agriculture and construction Biodiversity disclosure requirements, such as the EU's Corporate Sustainability Reporting Directive and emerging taxonomies in Malaysia, raise compliance costs and reshape investment allocation across large firms. Deforestation-related due-diligence and zero-deforestation commitments, relevant for BNM and BRC, affect commodity sectors such as palm oil, forestry and agriculture that are often associated with land conversion risks. **Together, these examples show that transition risk sources span direct land- and resource-use restrictions, sector-specific environmental standards, and economy-wide disclosure or taxonomy frameworks.**

Initiatives identify transition risks through the mapping of economic sectors' impacts and pressures on ecosystem services, drawing on ENCORE's (Exploring Natural Capital, Opportunities, Risks and Exposure) paired impact/dependency scores. For example, the Latvijas Banka (Bank of Latvia, BoL) relies on the ENCORE framework to link economic sectors with ecosystem services and identify sectors where impacts and pressures on nature are material – the dimension most directly relevant to transition risk, since it is sectors that degrade ecosystem services which are most exposed to tightening regulation. By combining this information with financial exposure data, these studies identify sectors where environmental regulation or ecosystem restoration policies could generate transition risks. BoL combines granular loan-level data from the credit register with ENCORE to map banks' exposures to sectors whose activities exert significant pressure on ecosystem services such as water availability, soil quality and climate regulation.

Other initiatives focus directly on specific policy frameworks that may generate transition risks

BdF pursues a complementary initiative building on the national "No Net Land Take" objective introduced above – which is targeted for full achievement by 2050, with land conversion reduced incrementally in the interim – by analysing impacts and pressures on freshwater ecosystems and assessing the biodiversity footprint of financial portfolios using the BIA-GBS methodology based on the GLOBIO model.

DNB studies the potential economic and financial stability impacts of four transition-risk scenarios. A "Half-Earth" protection scenario is a global scenario in which 50% of the Earth is categorized as a 'protected area', with protection focusing on areas with the highest biodiversity. An EU deforestation tax scenario aims to disincentivize imports into the EU of products with a high deforestation footprint. The scenario of removing subsidies harmful to biodiversity. And a Dutch nitrogen-reduction measures scenario, in which government measures to reduce nitrogen pollution directly impact either the agricultural or the construction sectors.

BCCh examined transition risks through the implementation of Forest, Land Use and Land Use Change policies included in the Chile's Nationally Determined Contribution. These policies (such as reducing forest loss due to wildfires and expanding afforestation and ecosystem restoration)

affect sectors linked to land use and ecosystem services, particularly agriculture and forestry. The analysis prioritizes ecosystem services closely linked to forest ecosystems, including water regulation, carbon capture and storage, pollination and erosion protection.

The MNB initiative adopts a complementary approach, using sectoral environmental impacts as proxies for transition risks. Sectors with high environmental impacts or strong interaction with natural resources are identified as potentially vulnerable to regulatory tightening or environmental policy adjustments. In this case, Agriculture, Forestry and Fishing, Manufacturing, and Real Estate are highlighted as sectors where transition risks may be particularly relevant.

Across the initiatives, the identification of transition risks is generally based on exposure mapping exercises, which combine information on ecosystem service dependencies and/or impacts with economic or financial data. These analyses allow authorities to prioritize the sectors most likely to be affected by nature-related policies and to identify areas where transition risks may be material for the economy or the financial system.

Some initiatives complement this static exposure analysis with forward-looking approaches. Scenario analysis is used, for example, by DNB and BCCh to explore potential future trajectories of ecosystem service degradation or policy responses and their economic implications. These approaches are broadly aligned with emerging work on nature scenarios, such as the NGFS Technical Document on Nature Scenarios.¹⁴

Several initiatives explicitly incorporate geographical and cross-border dimensions into their analysis, reflecting the fact that local ecosystem degradation can have systemic implications through supply chains and cross-border economic linkages. FINMA's assessment focuses almost entirely on this channel, given that Swiss corporates and financial institutions are highly globally integrated: the analysis examines how biodiversity-related policy changes abroad – such as deforestation bans or ecosystem protection measures in other jurisdictions – can disrupt supply chains, raise input costs for Swiss-financed multinationals, and feed back into Swiss trade and economic activity through correlated losses across globally diversified portfolios. The ECB analysis similarly emphasizes that

nature-related shocks can propagate through EU-wide value chains and the single market, given the bloc's dependence on imported natural resources and ecosystem services from biodiversity-sensitive regions.

Hungary's assessment, while primarily domestic, explicitly considers external transmission channels through international trade, recognizing that environmental shocks affecting trading partners can reduce export demand or disrupt imported inputs. BNM's initiative highlights how international market pressures – including ESG-related sustainable supply chain requirements – affect export-oriented sectors such as palm oil and commodities. By contrast, the BoL, BdF, and BCCh domestic-sector analyses are primarily designed around national exposure mapping, with cross-border linkages acknowledged conceptually but not modelled in detail.

Finally, several studies emphasize the climate-nature nexus, recognizing that climate change and biodiversity loss are mutually reinforcing processes, and that climate mitigation policies and nature restoration strategies may involve both synergies and trade-offs.

2.2.2 Transmission channels to the economy

After identifying the sources of transition risk, the initiatives analyse how these risks may translate into economic impacts. **Transition risk transmits to the economy through two related but analytically distinct channels, which is worth making explicit upfront given how easily they can be conflated with physical risk.** The first is a **pressure-restriction channel**: policies directly restrict, price, or penalize the pressures that economic activities exert on nature – for example pollution limits, deforestation bans, reduction of fossil fuel subsidies, or due-diligence requirements – requiring firms to change practices, incur compliance costs, or scale back nature-degrading activities. The second is an **ecosystem-service-access channel**: policies aimed at protecting or restoring ecosystem services change the availability, quality, or cost of the ecosystem services that economic activities depend on – for example land-use restrictions that reduce the land available for expansion, or afforestation and restoration programs that change the availability of water regulation, pollination or soil fertility. In both channels it is the policy response, not environmental degradation itself, that triggers the change; where a change

14 NGFS (2023). Recommendations toward the development of scenarios for assessing nature-related economic and financial risks.

in ecosystem services results from degradation rather than from a **policy response**, that is physical risk (see the Physical impacts subsection above), not transition risk.

The most immediate impacts occur through these two direct transmission channels. Environmental policies aimed at protecting or restoring ecosystems may impose restrictions on land use, resource extraction or pollution, which can affect production processes, input availability and operating costs. For example, policies limiting land conversion or strengthening environmental regulation may require firms to adapt their production methods, invest in new technologies or reduce resource use. Similarly, policies that restore or protect ecosystem services – such as afforestation, wetland restoration or land-use-change programs – change the availability of services such as water regulation, pollination or soil fertility that sectors such as agriculture, forestry or manufacturing rely on, affecting their productivity as a result of the policy intervention itself rather than of environmental degradation.

Several initiatives explicitly analyse these direct effects. The BCCh integrated economic-environmental modelling framework assesses how changes in ecosystem services associated with forest conservation and restoration policies (ecosystem-service-access channel) influence sectoral productivity in agriculture and forestry. The BdF analyses of land-use regulation and freshwater scarcity examine how environmental constraints (pressure-restriction channel) may affect firms' turnover, input costs or production capacity. The BoL sectoral exposure mapping highlights how firms whose activities most impact ecosystem services may face higher costs or operational disruptions if environmental policies tighten.

These direct-effect analyses differ in the question they ask, and the tools used to answer it. The BCCh initiative asks how forest conservation, restoration and afforestation under the Chile's forest, land-use and land-use-change strategy affect productivity in agriculture and forestry; it answers this by linking a spatial Land Use Land Cover and Ecosystem Services model to an integrated economic-environmental framework, projecting changes in water-related services, carbon capture, pollination and erosion protection and translating these into sectoral productivity paths. The BdF initiatives ask, separately, how the "No Net Land Take" regulation affects firms that depend on land conversion, and how water scarcity affects firms'

turnover; the first combines geographic land-use data with firm-level information to estimate land consumption by sector and the cost of compliance, while the second combines firm-level financial data with meteorological data to quantify the turnover impact of water shortages.

The BoL exercise asks which sectors are most exposed to ecosystem-service dependencies that could become costly under tighter environmental policy; and answers this primarily through exposure mapping – combining loan-level or portfolio data with the ENCORE database and a national expert survey – rather than through structural modelling of the cost pass-through itself. **Across these initiatives, the key results point in a consistent direction: agriculture, forestry, construction and land-intensive sectors emerge as the most exposed, with estimated impacts ranging from productivity changes (BCCh) to compliance costs and turnover effects (BdF), to portfolio exposure shares (BoL).**

In addition to these first-order effects, indirect transmission channels may arise through supply chains and value-chain linkages. Shocks affecting one sector can propagate to others if they rely on input produced by affected industries. For example, restrictions on land use or resource extraction may reduce the supply of inputs used by downstream sectors. Some initiatives also recognize that nature-related shocks may propagate through international trade channels, as disruptions in trading partners can affect exports, imports or global value chains.

A smaller number of initiatives go further and explicitly incorporate these indirect, value-chain and cross-border channels, generally as an extension of an already more complex modelling exercise. The BCCh framework's macroeconomic module allows productivity shocks in agriculture and forestry to propagate to other sectors through input-output linkages, so that the framework produces not only sectoral productivity paths but also economy-wide results for GDP, employment and investment under different forest, land-use and land-use-change policy pathways. The DNB initiatives develop exploratory transition shock scenarios in which disruptions to ecosystem services in directly exposed sectors (e.g. agriculture, construction, manufacturing) are allowed to feed through to downstream industries and to aggregate output, providing macro-level results on output and financial-stability implications alongside the sectoral exposure maps.

The MNB initiative, conducted at the macro level due to data confidentiality constraints, incorporates external trade as its main indirect channel: it asks how nature-related shocks affecting Hungary's trading partners could reduce export demand or disrupt imported inputs, and finds that such shocks could affect GDP, sectoral output, trade flows and relative prices. BNM's initiative identifies a comparable cross-border channel, whereby ESG-related sustainable-supply-chain requirements imposed by importing markets create export-market pressure on palm oil and commodity sectors; this is assessed qualitatively, drawing findings from the TNFD LEAP pilot.

FINMA's and the ECB's analyses are framed almost entirely around indirect, cross-border propagation (global biodiversity shocks transmitted through multinational supply chains and the single market), using portfolio-alignment exercises focused on globally diversified holdings (FINMA) and portfolio-alignment tools combined with exposure heatmapping and stress-test scenarios embedded in the ECB's climate stress-testing infrastructure (ECB); both remain at a more qualitative, scenario-based stage rather than producing point estimates.

By contrast, the BoL and BdF initiatives acknowledge supply-chain and cross-border propagation conceptually but do not model it explicitly, remaining focused on direct sectoral exposure mapping. BRC's initiative similarly identifies compliance-cost exposure arising from zero-deforestation and due-diligence commitments but has not yet developed a specified methodology or dataset to model this channel.

Overall, the initiatives highlight that transition risks may affect the economy through a combination of sector-specific adjustments and broader macroeconomic dynamics, including changes in productivity, prices, investment and economic growth.

2.2.3 Transmission channels to the financial sector

In a third step, several initiatives analyse how the economic impacts associated with transition risks may be transmitted to the financial system. These risks typically arise through financial institutions' exposures to firms and sectors affected by environmental policies or ecosystem degradation.

Economic shocks affecting environmentally sensitive sectors can translate into traditional financial risk categories. Declines in firms' profitability or asset values may increase the probability of default on loans, leading to higher credit risk for banks. Environmental policies that restrict resource use or land conversion may also reduce the value of collateral assets, particularly in sectors linked to land use or natural resources. In addition, asset repricing, changes in sovereign risk perceptions or macroeconomic shocks may generate market risk for financial institutions.

Several initiatives analyse these transmission channels by linking financial portfolios to environmentally sensitive sectors. For example, the BoL analysis combines the ENCORE framework with granular loan-level data from the credit register and a national expert survey to examine the share of bank loan portfolios exposed to sectors with strong dependencies on ecosystem services or significant environmental impacts. Similarly, the DNB exposure study used biodiversity footprint, exposure to biodiversity hotspots, and exposure to nitrogen-emitting activities.

Some initiatives go further by attempting to quantify potential financial impacts. The MNB financial risk assessment builds on macroeconomic analysis to estimate the potential increase in non-performing loans resulting from environmental shocks affecting key sectors. The analysis suggests that such shocks could lead to increases in non-performing loans equivalent to roughly 1-3 percent of corporate lending. It also highlights potential concentration risks, as exposures to environmentally sensitive sectors may be concentrated among a limited number of financial institutions. In addition, macroeconomic shocks linked to environmental risks could affect sovereign risk perceptions and bond valuations, creating additional channels of market risk for the financial system.

The ECB analysis takes the most comprehensive approach to quantification among the initiatives reviewed, embedding nature-related risks within the ECB's existing climate stress-testing and scenario-analysis infrastructure. Its central question is how exposed euro-area bank portfolios are to firms highly dependent on ecosystem services, and how biodiversity loss and associated policy responses could affect financial stability; the methodology combines portfolio-alignment tools and exposure heatmapping with stress-test scenarios, and the key result is that a large share of euro-area bank

portfolios is concentrated in ecosystem-dependent sectors, with transition risk materializing through credit, market, and operational/legal channels simultaneously. FINMA's initiative asks a narrower but complementary question (i.e., how exposed are globally diversified Swiss portfolios to biodiversity-sensitive sectors and regions) and answers it through portfolio-alignment exercises rather than stress testing; results remain qualitative, identifying equities and bonds linked to mining, agriculture and energy as the main channels for potential repricing, with systemic risk framed in terms of correlated losses given Switzerland's role as a financial hub.

BNM and BRC are at an earlier stage methodologically: BNM's analysis identifies credit risk from lending to plantations and agriculture and notes the use of taxonomy-based assessments as supervisory tools, while BRC's initiative similarly identifies credit risk and collateral-value channels (including land affected by environmental regulation or Indigenous land rights), though it relies on qualitative/exploratory analysis without a specified dataset, and acknowledges that financial-stability monitoring in this area remains largely framed around climate rather than broader nature-related risk. **Across all initiatives, MNB's NPL estimate (increase in non-performing loans equivalent to 1-3 percent of corporate lending) remains the only initiative in the sample to produce a point estimate of the financial impact of transition risk, underscoring how early-stage quantification of nature-related financial risk still is relative to climate-related financial risk analysis.**

While most initiatives focus on the transmission of economic risks to financial institutions, some also recognize the endogenous relationship between finance and nature. Financial institutions may indirectly contribute to environmental degradation through the activities they finance, thereby potentially increasing future nature-related risks. For instance, analyses linking financial portfolios to sectoral environmental footprints highlight how financing decisions can be associated with pressures on biodiversity or natural capital. BNM's ENCORE

assessment extends this logic to the macro-financial level, mapping how concentrations of bank lending to plantation and agriculture sectors are themselves a source of pressure on ecosystem services, creating a feedback loop in which today's financing decisions shape tomorrow's transition-risk exposure. BoL's loan-portfolio dependency analysis, which combines ENCORE with credit-register data, documents a related two-way relationship: sectors that most depend on ecosystem services are often the same sectors whose lenders' financing decisions determine the pace at which those services are degraded, so that continued financing without regard to environmental footprint compounds exposure to both future policy tightening and physical degradation.

At this stage, most initiatives focus primarily on exposure mapping and risk identification, and relatively few explicitly model contagion or systemic amplification mechanisms within the financial system. However, the concentration of exposures in certain sectors or institutions suggests that nature-related transition risks could potentially propagate across the financial system if multiple institutions are simultaneously affected.

Nature transition risk is sector-concentrated but financially systemic, as banking and investment portfolios are highly exposed to sectors that depend on ecosystems such as agriculture, forestry, mining, food production and construction.

2.2.4 Summary of key findings

Table 4 synthesises the preceding analysis into five recurring transition risk drivers, tracing each from its underlying policy or regulatory driver through to its economic and financial transmission mechanisms. These five categories are not drawn from an existing taxonomy of nature-related transition risk; rather, they are an inductive summary of the policy drivers most frequently identified across the initiatives reviewed in this section, grouped by how each is transmitted into economic and financial outcomes.¹⁵

¹⁵ They should be read as a survey-based synthesis of what NGFS members are currently assessing, rather than a definitive or exhaustive classification of nature-related transition risk drivers.

Table 4 **Summary of policy drivers, affected sectors and financial exposure linked to nature-related transition risks**

Policy Driver	Highly affected Sectors	Financial Risk Channel
Land-use restrictions	Agriculture, real estate, tourism	Credit risk (revenue shocks impairing borrowers' loan-repayment capacity; reduced collateral value of land-linked assets)
Nitrogen or pollution-control rules	Livestock, chemicals, fertilizers	Credit risk (concentration of bank exposure to nitrogen-constrained sectors)
Deforestation regulation and ESG/sustainable-supply-chain requirements	Agriculture, forestry, food processing	Credit risk (plantation and agriculture lending; supply chain exposure)
Protected area expansion	Mining, infrastructure, forestry	Credit risk (increase in non-performing loans and stranded assets); Market risk (sovereign-risk and bond-valuation effects)
Biodiversity disclosure rules	All large firms	Credit risk; Market risk; Operational risk; Legal risk

3. Case Studies

Building on the foundation laid by the Conceptual Framework¹⁶, this section presents six national and regional case studies from Baltic and Nordic countries (Denmark, Sweden, Finland, Norway, Estonia, Latvia, Lithuania), Brazil, Chile, France, Germany, and North Macedonia. All these case studies demonstrate the practical application of the Framework's three-phase logic: identifying risk sources, assessing economic impacts, and evaluating financial transmission. After producing the Conceptual Framework, the NGFS now aims to facilitate its operationalization. These studies serve as a practical guide for institutions seeking to implement nature-related risk assessments within their own jurisdictions.

By moving from theory to practice, these applications provide valuable insights into the specific sources of risk – such as ecosystem degradation, water scarcity, and wildfires – that are most material to different economies. Furthermore, they highlight why central banks and supervisors are increasingly focused on addressing these risks, illustrating how nature loss translates into tangible financial threats, including sovereign credit risk, increased default probabilities in agricultural

portfolios, and liquidity stress for micro-firms. These examples demonstrate how the Framework can be applied as a robust roadmap for identifying and assessing vulnerabilities within the financial system.

While the preceding survey review provided a systematised overview of initiatives across the NGFS community to identify broad trends and common tools, these case studies offer an additional and complementary set of information. They provide tailored deep-dives that test the Framework's logic against granular, location-specific data – ranging from the diverse Brazilian biomes to the industrial sectors of France and the banking system of Germany.

The following pages provide a synthetic overview of each case study, structured around their key features, methodological approaches, and principal findings.¹⁷ These snapshots are designed to facilitate cross-jurisdictional learning by allowing institutions to build on each other's experiences. For a more comprehensive analysis, fuller and detailed versions of these works are available in the appendix.

16 NGFS (2024). Nature-related Financial Risks: a Conceptual Framework to guide Action by Central Banks and Supervisors.

17 **Note on acronyms used in this section:** AnaCredit (the ECB's Analytical Credit Datasets); ANEEL (Agência Nacional de Energia Elétrica, Brazil's National Electric Energy Agency); CMF (Comisión para el Mercado Financiero, Chile's Financial Market Commission); ECI (Ecosystem Condition Index); EDSI (Ecosystem Service Degradation Sensitivity Indicator); EMBRAPA Solos (the soils unit of Brazil's Agricultural Research Corporation); EXIOBASE (a global multi-regional environmentally extended input-output database); FEDS (NASA's Fire Events Data Suite); GLOBIO (the Global Biodiversity Model for Policy Support); IUCN (International Union for Conservation of Nature); MAPBIOMAS (a Brazilian satellite-based land-cover and land-use mapping initiative); ND-GAIN (the Notre Dame Global Adaptation Initiative index); NFC (non-financial corporation); NUTS3 (the EU's Nomenclature of Territorial Units for Statistics, level 3); RAIS (Relação Anual de Informações Sociais, Brazil's annual employer/employment registry); SII (Chile's Servicio de Impuestos Internos, tax authority); VIIRS (Visible Infrared Imaging Radiometer Suite).

3.1 Baltic and Nordic countries (Denmark, Sweden, Finland, Norway, Estonia, Latvia, Lithuania)

Title of the study: Assessing Ecosystem Integrity and its Economic Impact in Nordic and Baltic countries

Key Features

Geographical scope: 83 NUTS3 regions across Baltic and Nordic countries. The Ecosystem Condition Index (ECI; Falsetti *et al.*, 2025) is computed on a 1 km × 1 km grid and aggregated at NUTS3 level.

Risk & sector scope: Nature-related physical risk focused on ecosystem degradation and biodiversity loss affecting agricultural productivity, with macro-financial transmission through lower gross value added. Countries with higher agricultural GVA shares and/or lower agricultural self-sufficiency are more exposed.

NGFS Conceptual Framework scope: Primarily Phase 1 (identify sources of physical risk through location-specific ECI hotspots) and Phase 2 (assess economic risks by linking ECI loss to agricultural GVA). Outputs can be overlaid with financial exposures to inform Phase 3 (risk to, from, and within the financial system), although this remains outside the current scope of the case study.

Study Design and Methodology

The study builds the ECI by combining: (i) Mean Species Abundance (GLOBIO) for animal and plant species; (ii) Forest Landscape Integrity Index (Wildlife Conservation Society); and (iii) threatened animal species (IUCN), using a Leontief-like function. The 1 km grid supports granular hotspot mapping for sectoral and regional diagnostics. The analysis estimates elasticity of agricultural GVA per harvested hectare to ECI loss, controlling for agricultural labour and capital, protected and urban areas, and climate anomalies. Sensitivity analysis using ecosystem-service proxies indicates that results are not driven by any single component or driver.

Output and Key Findings

Main results of the study: ECI results show strong cross-country and within-country heterogeneity: Denmark ranks lowest on average and Norway highest. Hotspots align with intensive agriculture and urbanization (for example, Skane and Sjaelland). Higher ecosystem degradation (greater ECI loss) is robustly associated with lower agricultural GVA per hectare across specifications, indicating that ecosystem integrity supports productivity and that degradation is a material nature-related physical risk to the economy. The study notes this risk is likely underestimated, as future acute ecosystem-condition shocks are not modelled, and emphasizes the growing need for new spatial metrics and ecosystem data.

Most material risk channels and transmission pathways: Physical-risk channel through lower yields and GVA in hotspot regions; transition-risk channel through tighter land-use, biodiversity, and water regulation; macro channel through food-price inflation and trade vulnerability where production gaps are large; financial channel through higher default probability and collateral devaluation in agriculture-exposed portfolios with spillovers across agri-food value chains.

Policy and supervisory relevance: Provides an operational high-resolution framework to identify ecosystem-risk hotspots and monitor conservation/restoration outcomes; supports Phase 1 and Phase 2 applications by translating ecosystem-condition changes into economic effects for agriculture (Sector A, NACE Rev. 2); and creates a practical bridge to Phase 3 by enabling overlays between ECI hotspots and financial portfolios.

3.2 Brazil

Title of the study: Study of the Impacts of Nature Loss on the Brazilian Financial System

Key Features

Geographical scope: Nationwide coverage at the municipal level (c. 5,570 municipalities), spanning all six Brazilian biomes (Amazon, Cerrado, Atlantic Forest, Caatinga, Pantanal, and Pampa).

Risk & sector scope: Exposures of Brazilian economic sectors to nature-related dependencies and impacts, transmitted to the financial system through loan portfolios and weighted by ecosystem conditions at the municipal level.

NGFS Conceptual Framework scope: Phase 1 *via* identification of current exposures to nature-related dependencies and direct negative impacts. Phase 3 through the assessment of materiality from a microprudential perspective, including identification of the most relevant sectors and ecosystems where these sectors and financial institutions operate, together with ecosystem condition.

Study Design and Methodology

The approach has three steps: (i) map direct sectoral dependencies on ecosystem services and impacts using ENCORE, (ii) link sectoral scores to institution-level credit exposures with geospatial allocation to municipalities, and (iii) weight exposures by municipal ecosystem-integrity indicators to produce risk-weighted exposures across nine nature-related risk categories. Exposure location is derived from Banco Central do Brasil (BCB) databases, with subsidiary location from RAIS and power-plant location from ANEEL. Integrity indicators use data and methodologies from MAPBIOMAS (satellite data), the National Water Agency (water quality), EMBRAPA Solos (erosion), and INBrazil's National Institute of Space Research (air quality indicators). Analytical tools include Excel, RStudio, and QGIS.

Output and Key Findings

Main results of the study: Risk-weighted exposures are highest in livestock, grain cultivation, and agricultural support services. Exposures are geographically concentrated in the Atlantic Forest, Cerrado, and Amazon. Large multi-regional institutions hold the largest absolute exposures, while smaller regional and cooperative institutions often show the largest relative concentrations. Biome-level vulnerability differs by dimension (vegetation, water availability, soil quality/erosion, water quality, and air quality).

The study highlights key physical-risk channels through ecosystem services related to rainfall-pattern regulation, water-flow regulation, and water supply, especially for agriculture and livestock under water scarcity, together with dependencies on biomass provisioning, flood and storm mitigation, and local climate regulation under vegetation reduction. These disruptions may increase costs and/or reduce production, with potential implications for rural-credit defaults.

Transition-risk channels are linked to reduced water availability and reduced native vegetation, again with strongest relevance for agriculture and livestock. These stressors can trigger actions aimed at protecting, restoring, or reducing negative impacts on nature, including environmental fines and embargoes, regulatory and policy changes, and shifts in investor sentiment and consumer preferences. The study indicates that these responses may increase costs and/or reduce output in affected sectors, with potential implications for default risk in rural lending.

Policy and supervisory relevance: Supports prioritization of sectors and geographies with concentrated ecosystem dependencies and vulnerabilities, while providing an evidence base for regulatory measures, supervisory actions, and credit policies aimed at reducing nature-related risks and strengthening resilience to ecosystem degradation.

3.3 Chile

Title of the study: Analyzing the direct physical impacts of wildfires in Chile: a firm-level study using administrative data with focus on ecosystem-service dependencies

Key Features

Geographical scope: Urban and rural areas affected by the February 2024 wildfire in the Valparaíso, Viña del Mar, Quilpue, and Villa Alemana corridor in central Chile.

Risk & sector scope: Loss of multiple ecosystem services due to wildfires and direct impacts on firms in nature-dependent sectors, with transmission to the financial sector *via* credit-market channels.

NGFS Conceptual Framework scope: Phase 1 through the assessment of firms' wildfire exposure using ecosystem-service dependencies (ENCORE). Phase 2 by estimating direct wildfire impacts on firm sales and employment in exposed areas. Phase 3 *via* the analysis of transmission of firm-level economic impacts to the financial sector through the credit market.

Study Design and Methodology

The study exploits spatial variation in wildfire exposure using a difference-in-differences event-study approach. Treated firms are identified through geocoded addresses within burned areas defined using wildfire perimeters from NASA's Fire Events Data Suite (FEDS), derived from VIIRS thermal-anomaly data. Administrative data from Chile's tax authority (SII) provide monthly firm sales and employment outcomes, while financial exposures come from the CMF debtor registry. Ecosystem-service dependencies are measured with ENCORE. Spatial overlays are conducted using GIS software, and econometric estimation is implemented in Stata.

Output and Key Findings

Firms located within wildfire perimeters experienced an immediate drop in economic activity, with sales declining by about 10% in the event month. In sectors with stronger ecosystem-service dependencies (ENCORE index > 0.1), the decline deepens to approximately 15%, indicating amplification through ecosystem-service degradation. Employment effects emerge with a lag of around four months, consistent with labour-adjustment frictions. Financial indicators show higher leverage and borrowing among micro firms, pointing to post-disaster liquidity pressure.

The case study identifies wildfires driven by extreme heat and drought as a key physical-risk channel through direct damage to assets, infrastructure, and inventories. It also highlights operational-risk channels through disruption of utilities, transport, and local infrastructure, and a nature-related physical-risk amplification mechanism *via* degradation of services such as hazard regulation and water availability in ecosystem-dependent sectors. Financially, the study indicates increased leverage and liquidity stress, particularly among micro firms relying on bank credit to sustain operations after the disaster.

3.4 France

Title of the study: Assessing the impact of water-stress scenarios on French industrial firms

Key Features

Geographical scope: France.

Risk & sector scope: Water-scarcity risk affecting industrial revenues, with transmission to banks and insurers through financial exposures.

NGFS Conceptual Framework scope: Phase 1: Identification of water-related ecosystem services as priority risk sources and related economic activities (using CDP Water Watch). Phase 2: Estimation of firm-level turnover impacts. Phase 3: Assessment of banking exposure to affected activities using corporate-lending data from AnaCredit.

Study Design and Methodology

The study identifies sectors with high dependency on water in production using CDP Water Watch. For firms in those sectors, water is assumed non-substitutable in the short term, so a 1% decline in water consumption implies a 1% decline in turnover. It then projects water restrictions under an adverse one-year scenario using river-flow data from Meteo-France and computes turnover impacts with Banque de France firm-level data. Finally, exposures of banks and insurers to the most affected firms are assessed.

Output and Key Findings

Estimated turnover losses from water restrictions range from EUR 2 billion to EUR 17 billion over one year, depending on scenario assumptions. For some firms, turnover losses reach up to 17%. On the financial side, the study estimates that 25% of French insurers' assets in French non-financial corporations (NFCs), and 4.5% of French banks' lending to NFCs, are linked to firms whose turnover could fall by more than 5%.

The analysis identifies water scarcity as the central material risk channel for large industrial firms in France, transmitted through water restrictions. The most affected regions are those simultaneously exposed to water scarcity and concentrated industrial activity. Most impacted sectors are those with high water dependence, including petroleum, iron and steel, and plastics manufacturing. The study also notes key limitations and ongoing work to improve methodology, including sectoral coverage gaps (for example, agriculture and energy) and unmodelled impact channels beyond water restrictions.

3.5 Germany

Title of the study: Banks and nature: How strongly does the banking sector in Germany depend on ecosystem services?"

Key Features

Geographical scope: Germany.

Risk & sector scope: Direct and indirect dependencies of Germany's banking sector on ecosystem services through corporate lending, with a deep dive into water-based ecosystem services.

NGFS Conceptual Framework scope: Phase 1 and Phase 3, with a focus on exposure analysis. Direct dependencies of economic activities are identified using ENCORE; indirect dependencies through supply chains are assessed using EXIOBASE; bank exposures to vulnerable activities are calculated using AnaCredit corporate-lending data.

Study Design and Methodology

The study analyses how Germany's banking sector depends on ecosystem services through lending to non-financial corporates, distinguishing between direct and indirect dependencies (the latter transmitted through borrower supply chains). It applies the methodology of Boldrini *et al.* (2023) using AnaCredit, ENCORE (2024 update), and EXIOBASE. The sample covers just below 1,200 banks in Germany¹ and approximately 672,800 non-financial firms, representing around EUR 1.7 trillion in loans. The study also provides a breakdown of dependencies by bank category.

Output and Key Findings

German banks show high direct dependencies on ecosystem services such as soil retention and storm mitigation, underscoring the broad relevance of these services across sectors. Five of the ten most relevant ecosystem services (for both direct and indirect dependencies) are water-supplying or water-regulating services. Water dependence is even more pronounced for indirect dependencies, highlighting the importance of supply-chain effects.

On average, 52.4% of banks' lending volume is directed to firms with high direct dependency on at least one ecosystem service, and 51.9% to firms with high dependency on at least one water-based ecosystem service. The findings point to water-related ecosystem-service degradation as a particularly material source of nature-related risk for the German banking system and support the need to incorporate both direct and indirect dependency channels in exposure assessment.

¹ The German banking sector is dominated by a high number of smaller regional banks.

3.6 North Macedonia

Title of the study: The exposure of the foreign exchange reserves to nature-related risks

Key Features

Geographical scope: Global.

Risk & sector scope: Direct and indirect dependencies of economic activities on ecosystem-service degradation, with transmission to sovereign credit risk.

NGFS Conceptual Framework scope: The study applies all three phases of the NGFS framework: Phase 1: Identification of direct exposure of economic activities to ecosystem services using ENCORE. Phase 2: Identification of indirect exposure through supply-chain channels using EXIOBASE, with explicit attention to overall economic vulnerability. Phase 3: Transmission of nature-related vulnerabilities to credit risk, including implications for sovereign default probability and foreign-reserve portfolio losses.

Study Design and Methodology

The methodology builds on DNB's Ecosystem Service Degradation Sensitivity Indicator (EDSI) framework (Gallet, Hendricks, and Prodani, 2024) and is structured in three analytical steps. First, direct dependencies are derived from ENCORE, translated into numerical scores, and adjusted with the ND-GAIN index. Second, indirect supply-chain dependencies are integrated using EXIOBASE, also adjusted with ND-GAIN as a proxy for ecosystem degradation, with processing implemented in Python. Third, vulnerabilities are translated into credit risk using a Basel IRB and Merton-model setup, with sovereign distance-to-default calibration based on rating-transition matrices and MSCI sub-index volatility.

Output and Key Findings

The study emphasizes transmission from ecosystem-service degradation to sovereign credit risk. A uniform 1% ecosystem-depreciation shock is estimated to increase FX-reserve credit-risk exposure by around 3%. Results also show significant geographic heterogeneity: reserves exposed to countries such as Spain and France show lower sensitivity, while exposures to Korea, China, and Norway show higher vulnerability to nature-related risk. These findings support prioritization of geographies and risk sources in strategic investment or divestment decisions within reserve management.

The analysis does not isolate single ecosystem-risk types; instead, it focuses on the materiality of the transmission channel from nature-related risk to sovereign credit risk at country level, which is the most relevant unit for reserve-allocation and strategic decision-making.

Box 3

Cross-Case Comparison Matrix

Case	Primary Risk Focus	Main Transmission	Data Core	Key sectors affected	Key Result	NGFS CF Phases
Baltic & Nordic countries	Ecosystem degradation & biodiversity loss affecting agriculture	Productivity → GVA → macro spillover → portfolio effects	ECI composite (GLOBIO, FLII, IUCN); spatial NUTS3	Agriculture; agri-food value chains	ECI loss robustly associated with lower agricultural GVA/hectare	1-2 (→ 3)
Brazil	Physical & transition via ecosystem dependencies & impacts	Sector exposures → credit portfolios	ENCORE + municipal geospatial + integrity indicators; Excel/R/QGIS	Livestock; grain; agri-support; biome-concentrated	Risk-weighted concentration by sector, institution type, biome	1, 3
Chile	Wildfire physical impacts amplified by ecosystem services loss	Firm performance → credit/liquidity stress	NASA FEDS; SII admin; CMF registry; ENCORE; Stata	Burned-area firms; ecosystem-dependent; micro firms	Sales ≈10% down (≈15% high-dependency); lagged employment effects	1-3
France	Water stress affecting industrial activity	Turnover shock → bank/insurer exposures	CDP Water Watch; Meteo-France; Banque de France; AnaCredit	Water-dependent industry (petroleum, steel, plastics)	EUR 2-17 billion turnover impact; bank/insurer exposure shares 4.5-25%	1-3
Germany	Banking portfolio dependence on water-related ecosystem services (direct + indirect)	Lending exposure via borrower & supply-chain dependence	AnaCredit; ENCORE; EXIOBASE; bank-category breakdown	Corporate loans to ecosystem-dependent firms; water-dependent	52.4% lending to high-dependency firms; 51.9% water-service dependent	1, 3
North Macedonia	Nature → sovereign credit risk (reserve portfolio)	Ecosystem degradation → sovereign risk → reserve exposure	ENCORE; EXIOBASE; ND-GAIN; Basel IRB/Merton; Python	FX reserve sovereign exposures (country-level)	1% ecosystem shock → ≈3% increase in reserve credit risk	1-3 (3 emphasis)

4. Identification of key sources of nature-related financial risk

This section draws on the sequential logic of the NGFS Conceptual Framework to synthesize the findings of Sections 2.1.1 (Physical Impacts) and 2.2.1 (Transition Impacts), together with the six case studies presented in Section 3. Its purpose is twofold, reflecting the broader objective of the Compendium itself: first, to demonstrate how the Conceptual Framework can serve as a practical guide for conducting analytical work on nature-related risks across NGFS members; and second, to distil practical lessons for members seeking to develop, refine, or expand their own analytical approaches – the latter taken up in full in Section 5.

Two questions guide the synthesis throughout **What patterns emerge across the initiatives reviewed (including in terms of methodological limitations and challenges)?** and For members seeking to replicate or build on this work, which approaches are most useful, in which contexts, and under what conditions? This section addresses these questions in two parts. Part 1 revisits the nature-related risk drivers most frequently assessed across jurisdictions and compares the methodological approaches used to identify, assess, and address them, highlighting their strengths, applications, and limitations while drawing on examples from the initiatives reviewed in Sections 2 and 3. Part 2 provides a concise taxonomy and comparative summary of the methodological approaches, tools, and data sources employed across the initiatives,

helping members identify those most relevant to their own analytical objectives and starting points. Section 5 then distils this material into a set of cross-cutting lessons learned.

4.1 What Sources of Nature-Related Risk are the Most Commonly Assessed, and How Can We Address Them?¹⁸

Across the initiatives reviewed in Section 2 and the case studies in Section 3, jurisdictions repeatedly converge on a small number of ecosystem-service disruptions as their starting point for nature-related risk analysis. These ecosystem services recur because they affect productive activity directly, are difficult to substitute for in the short run, and are frequently the object of both physical degradation and policy-driven change at once. This subsection organizes the discussion around these recurring sources and, for each, compares the alternative approaches that have been used to identify and address it – what each approach delivers, what it requires, and where it runs out of road – so that a member starting this work can see which combination of approaches best fits its own data and institutional context. Table 5 below brings these patterns together at a glance, before the detailed comparison of approaches that follows for each source of risk.

18 The sources of risk discussed in this section reflect those most frequently identified across the initiatives and case studies reviewed for this Compendium – that is, where members have so far concentrated analytical effort and where data is most readily available – rather than a definitive ranking of which sources of nature-related risk matter most in general. Materiality is inherently jurisdiction- and location-specific, and the sample underlying this section remains geographically limited. The risk sources set out in the analysis should therefore be read as those already identified through the evidence gathered to date, leaving room for others to emerge as coverage, data, and analytical practice expand.

Table 5 Risk sources and methodological approaches – where the initiatives reviewed sit¹

	Exposure/dependency mapping	Geospatial/hazard modelling	Macro/scenario modelling	Financial-risk quantification
Water-related ecosystem services	Netherlands (DNB/PBL “Indebted to Nature”); Hungary (MNB); Germany (Boldrini <i>et al.</i>); France (ENCORE + EXIOBASE)	South Africa (SARB); ECB (NEAR/PEAR); France (BdF water-stress turnover model)	Bundesbank; Chile (hydropower); Colombia; Hungary (I-O drought proxy)	Colombia (rainfall-credit PD model; hydropower firm-level study); Hungary (NPL estimate)
Biodiversity loss and pollination-service degradation	Malaysia (TNFD LEAP); Switzerland (FINMA bond/equity)	Baltic & Nordic (Ecosystem Condition Index)	Netherlands (CGE pollinator scenario); Greece (FUND IAM)	France (BdF BIA-GBS/ GLOBIO biodiversity footprint)
Soil and land degradation	France (No Net Land Take, compliance-cost mapping)	Chile (spatial land-use mapping)	Chile (IEEM+ESM); Hungary (sectoral-impact proxy, transition risk)	Brazil (municipal ecosystem-integrity-weighted credit exposure)
Extreme weather events and acute environmental hazards (floods, storms, heat)	–	Switzerland (FINMA per-building); Chile (wildfire event study)	–	Chile (insolvency channel); Switzerland (collateral/ LGD impact)
Loss of multiple ecosystem services	European Investment Bank (portfolio tool); Malaysia (ENCORE); Latvia (ENCORE, water/ soil/climate regulation)	–	France (GVC model, multi-service)	Netherlands (DNB EDSI); North Macedonia (sovereign EDSI variant); Germany (Bundesbank EDSI)

¹ Read across a row to see which approaches have already been applied to a given source of risk in the sample; read down a column to see which sources a given approach has already been used for. Each cell is illustrative, not exhaustive – see the discussion following the table for the full comparison of strengths and limitations.

Water-related disruption and water-use regulation

Why it matters: Water-related ecosystem services give rise to two distinct sources of risk in the sample: degradation of these services drives physical impacts, while policy responses aimed at protecting them drive transition risk. Degradation of these services is the single most frequently assessed source of physical risk in the survey review, though each initiative approaches the topic from a different angle: the Bundesbank traces German banks’ direct and indirect lending exposure to firms dependent on water-based ecosystem services, MNB maps corporate lending exposure to surface- and groundwater-dependent sectors, BRC links rainfall variability to credit risk through hydropower generation, BCCh models the macroeconomic effects of hydropower disruption, and BdE’s Mar Menor study focuses on a localized coastal water-quality collapse. The case studies reinforce this pattern in France, Brazil, Germany, and North Macedonia. Institutions in these countries treat water as a key source of risk because it is a basic input for agriculture, manufacturing, energy, transport, and local services, and because deterioration in water conditions immediately constrains output and raises costs.

Water-use regulation, by contrast, is the transition impact counterpart to this same set of ecosystem services: the DNB’s modelling of a nitrogen scenario and BdF’s exploratory freshwater analysis using ENCORE and EXIOBASE, both of which illustrate how regulatory and policy responses aimed at protecting water resources can generate economic and financial impacts distinct from, but compounding, the physical risks described above.

Comparing approaches. Four broad methodological approaches emerge from the reviewed initiatives, each suited to different objectives and levels of data availability.

- **ENCORE-based exposure and dependency mapping.** Example initiatives applying this framework include the DNB’s *Indebted to Nature* study, MNB’s assessment, and the Bundesbank’s framework combining AnaCredit, ENCORE, and EXIOBASE data.

Strengths: These approaches can be implemented relatively quickly, require limited jurisdiction-specific data collection, and produce results that are readily comparable across countries. They provide a practical entry point for identifying sectors and portfolios potentially exposed to nature-related risks.

Limitations: Lack of geographical/local data, identify potential exposure rather than realised risk, do not quantify economic or financial impacts

unless they are combined with additional data, and rely on sector-level dependency scores that generally do not reflect local ecological conditions or the severity of ecosystem degradation. *Because these scores are taken as common across all firms in a sector just for belonging to it, regardless of country and geographical location, they can overstate risk for firms in relatively low-risk areas within a sector while understating the concentration of risk in specific geographies or among the most exposed firms.*

- **Firm-level geospatial hazard and turnover modelling.** Examples include BdE's NEAR and PEAR indicators and the BdF framework linking hydrological projections, firm-level revenue data, and financial-sector exposures.

Strengths: These approaches generate quantified estimates of economic losses and directly connect ecosystem degradation to identifiable firms and financial exposures. As a result, they provide a much clearer assessment of materiality.

Limitations: They require highly granular data, including firm-level financial information, geospatial asset location data, and detailed biophysical projections. Such datasets are often unavailable or incomplete, even in advanced jurisdictions.¹⁹

- **Macroeconomic and structural modelling.** Examples include the Bundesbank's river-navigability analysis, BCCh's modelling of hydropower-related disruptions, and BRC's rainfall-credit framework.

Strengths: These approaches capture economy-wide transmission channels and trace water shocks through output, prices, credit quality, and broader macro-financial indicators. They are therefore particularly valuable for macroeconomic surveillance and policy analysis.

Limitations: Their implementation requires significant modelling capacity, long historical datasets, and detailed input-output structures. They also sacrifice firm-level granularity in favour of aggregate outcomes.

- **Portfolio-level financial risk quantification.** The most prominent example is DNB's Ecosystem Degradation Sensitivity Indicator (EDSI).

Strengths: EDSI moves beyond exposure mapping by translating ecosystem degradation into prudential indicators such as changes in capital adequacy. This makes it one of the few frameworks designed explicitly for supervisory and financial-stability purposes.

Limitations: It is also the most data- and model-intensive approach reviewed. Implementing it requires combining dependency mapping, geospatial degradation metrics, input-output analysis, and portfolio-level financial data within a coherent modelling framework.

Implications for central banks and supervisors. Water is both the most frequently assessed source of risk in the sample and the one with the most complete methodological ladder, running from immediately replicable exposure mapping through to a working prudential metric (DNB's EDSI). Institutions with limited data can start here with simple exposure mapping; those with richer firm-level or macro data can move toward a quantitative analysis of economic impacts and, ultimately, toward translating those impacts into financial risks.

Biodiversity loss and pollination-service degradation²⁰

Why it matters: Biodiversity- and pollination-related disruption is examined from several distinct angles for physical impacts across the sample: the DNB models a global pollinator-decline scenario and traces it through agricultural and food-processing value chains, Malaysia pilots firm-level, multi-service dependency reporting in agriculture and construction, FINMA assesses financial-sector exposure to biodiversity-related policy tightening abroad, and BoG links protected-species loss to national GDP under alternative climate pathways. The Baltic and Nordic case study takes a more empirical approach, econometrically linking a high-resolution spatial ecosystem-condition index to agricultural output. On the transition side,

19 One exception is the DNB TNFD pilot, that used a fairly simple approach of public location data for powerplants and the WWF risk filter.

20 Like the other three clusters in this part of the analysis, this one is organized around the risk source most frequently isolated as a specific object of study, not a claim that biodiversity's role is limited to pollination: biodiversity also underpins soil fertility/erosion control (Soil, land-use, and land degradation cluster below) and habitat-buffer effects (Acute hazards cluster). Pollination is named in the heading because it is the one biodiversity-linked service an initiative in the sample (the Netherlands' CGE scenario) isolates and quantifies on its own; the other initiatives here – Malaysia, Switzerland, Greece, and the Baltic and Nordic case study – address biodiversity more broadly, *via* species-abundance, habitat/forest-integrity, and protected-species indicators.

the EU's Corporate Sustainability Reporting Directive and Malaysia's emerging Taxonomy for Sustainable Finance focus on the compliance and disclosure consequences of biodiversity-related policy, complementing FINMA's focus on the same underlying service from a cross-border policy perspective.

Comparing approaches. The reviewed initiatives reveal four broad methodological approaches.

- **Ecosystem-condition indices linked to economic output.** The Baltic and Nordic study links a high-resolution Ecosystem Condition Index with regional agricultural output data (combining species-abundance, forest-integrity, and threatened-species data at 1km resolution and aggregated to NUTS3 regions, regressed against agricultural GVA per hectare).

Strengths: This approach produces a statistically robust, interpretable elasticity that is replicable wherever spatial ecosystem data can be matched to sectoral output data. It also provides a practical framework for identifying geographic hotspots and prioritising areas for further analysis.

Limitations: The estimated relationships remain largely correlational rather than fully causal and do not capture ecological tipping points, non-linear dynamics, or cross-border transmission channels. The authors therefore caution that their estimates should be interpreted as conservative lower-bound effects.

- **CGE modelling of ecosystem-service shocks.** The DNB's analysis of a decline in wild pollinators illustrates this approach (global decline in wild pollinators, tracing the shock into agricultural yields and food-processing and retail spillovers).

Strengths: isolates a single, well-defined shock and traces it cleanly through the economy, and also considering possible spillovers *via* input-output linkages.

Limitations: This integrated framework is complex and intensive in the use of both human and computational resources. The analysis remains scenario-based and is not calibrated to an observed event, making results sensitive to assumptions regarding the magnitude and persistence of the shock.

- **Firm-level multi-service dependency pilots.** BNM's TNFD LEAP pilot represents this category.²¹

Strengths: The approach uses real value-chain information and engages directly with firms, helping institutions identify nature-related dependencies and vulnerabilities in practice.

Limitations: Results are primarily qualitative and make it difficult to isolate the effects of biodiversity loss from those of the ecosystem-service disruptions.

- **Macro biodiversity-to-GDP modelling under climate scenarios.** BoG's application of the FUND integrated assessment model to protected-species loss under IPCC RCP2.6/4.5/8.5 pathways provides an example.

Strengths: It offers a macroeconomic estimate that can potentially be incorporated into sovereign-risk analysis and policy discussions.

Limitations: Due to data constraints, the analysis focuses only on protected species and does not directly extend to financial-sector applications.

- **Portfolio-level biodiversity-footprint quantification.** France's Banque de France BIA-GBS methodology, based on the GLOBIO model, converting ENCORE-based dependency scores and a Mean Species Abundance (MSA.km²) impact footprint into a single security-by-security portfolio metric.

Strengths: the only approach in the sample producing a portfolio-level biodiversity metric usable directly in financial-institution reporting.

Limitations: MSA is a coarse, conservation-agnostic metric – an intact desert and an intact rainforest score identically, and broad land-use categories (e.g., intensive and extensive cropland merged into one) can equate a monoculture plantation with an agroforestry farm; GLOBIO was also built for global/regional scenario analysis rather than corporate footprinting, a use its own developers have flagged concerns about.

Implications for central banks and supervisors.

Implications for central banks and supervisors. Because most biodiversity-focused approaches do not yet produce a causal or decision-ready financial-risk estimate – the Baltic and Nordic index is correlational, the Dutch CGE scenario is hypothetical, and Malaysia's and Greece's applications

21 The qualitative nature of the results reflects how Malaysia applied the LEAP framework in this particular pilot, not a limitation of the LEAP methodology itself, which can also support quantitative dependency and impact assessments where firm-level data permits.

are qualitative or narrowly scoped – and because the one approach that does generate a portfolio-level metric, France’s MSA-based biodiversity footprint, carries significant known limitations as a coarse, conservation-agnostic measure, supervisors should treat current biodiversity-risk estimates as indicative screening tools rather than settled or precise risk measures. Where feasible, combining a spatial ecosystem-condition index with sectoral output data, as the Baltic and Nordic study does, is the approach closest to producing a robust, replicable result.

Soil, land-use, and land degradation

Why it matters: Soil degradation and land-use change associated with agriculture, forestry, and other land-intensive activities emerge repeatedly across the initiatives reviewed. These risks feature prominently in BNM’s, DNB’s, and BdE’s work, as well as in BCCh’s modelling of forest loss and wildfires. The Brazil case study provides perhaps the clearest illustration of their financial relevance, showing that risk-weighted credit exposures are concentrated in land-intensive sectors such as livestock, grain cultivation, and agricultural support services, with particularly high concentrations in the Atlantic Forest, Cerrado, and Amazon biomes.

As with other nature-related risk drivers, land-use risks can sit at the intersection of physical and transition impacts – but for land use, this convergence is unusually direct, in that it is often the very same parcel of land that is simultaneously degrading (the physical impact) and subject to conservation, restoration, or land-use policy (the transition impact), rather than the two risk types being borne by different assets or actors. Ecosystem degradation can directly affect productivity through soil erosion, biodiversity loss, or declining water availability, while policy responses such as deforestation controls, conservation targets, land-use restrictions, and forest-restoration requirements can alter costs, asset values, and business models. Consequently, the same geographic area is frequently exposed to both forms of risk simultaneously.

On the transition side, BdF’s “No Net Land Take” objective, BCCh’s Nationally Determined Contribution forest commitments, and Malaysia’s and Colombia’s deforestation due-diligence requirements each focus on a specific land-use policy rather than on degradation itself, though – as Brazil’s case illustrates – the two can act on the same land base at once.

Comparing approaches.

- Integrated economic-environmental modelling linking spatial land-use data to a calibrated macro framework.** BCCh’s IEEM+ESM framework exemplifies a fully integrated approach linking spatial land-use dynamics, ecosystem services, and macroeconomic outcomes, tracing forest loss and wildfire damage through ecosystem-service flows – timber, pollination, erosion protection – into GDP, employment, and investment *via* input-output linkages. **Strengths:** captures both the ecosystem-service-to-productivity link and its economy-wide propagation within a single, internally consistent framework. **Limitations:** is highly data- and model-intensive, requiring both a spatial land-use model and a calibrated computable framework.
- Municipal-level ecosystem-integrity weighting of credit exposures.** The methodology in Brazil’s case study combines ecosystem-integrity indicators with loan-level and municipality-level credit data to identify geographically concentrated exposures. **Strengths:** produces risk-weighted credit exposures by sector, institution type, and biome directly usable for supervisory prioritization, capturing physical degradation and its financial counterpart in one measure. **Limitations:** depends on a wide set of administrative datasets (credit registers, rural-credit systems, satellite land-cover series, water- and air-quality monitoring) that are not equally available in every jurisdiction.
- Land-use policy compliance-cost mapping.** An example is BdF’s analysis of the “No Net Land Take” objective, combining geographic land-use data with firm-level information to estimate compliance costs ahead of the policy’s 2050 target. **Strengths:** quantifies exposure to a specific, dated regulatory target. **Limitations:** is inherently policy- and country-specific, and does not generalize easily to jurisdictions with different land-use regimes.
- Macro input-output proxies where firm-level data are unavailable.** MNB’s use of macro-level input-output modelling to estimate sectoral environmental-impact intensity illustrates an alternative where granular data are unavailable. **Strengths:** usable with only macro or trade data, avoiding firm-level confidentiality barriers. **Limitations:** trades away firm-level precision; the resulting output is a proxy for exposure rather than a direct risk estimate.

Implications for central banks and supervisors. Because physical degradation and transition policy can act on the same land base simultaneously, land-intensive sectoral exposures warrant priority even where only one dimension has so far been assessed. Supervisors with credit-registry data that can be geospatially linked to satellite-based land-cover series can use Brazil's municipal ecosystem-integrity-weighting approach as a template; those without such data can start with MNB's macro input-output proxy, at the cost of firm-level precision.

Acute hazards, hazard-buffer weakening, and cross-cutting disclosure pressure

Why it matters: Floods, storms, heatwaves, droughts, and wildfires are increasingly recognised as material sources of nature-related financial risk. These hazards can be amplified when ecosystem services that provide natural protection, such as wetlands, forests, or coastal systems, become degraded. The reviewed initiatives from FINMA, BdE, BCCh, and MNB all highlight the growing importance of these interactions. In contrast to the previous risk categories, the associated transition pressures often come not from sector-specific regulation but from economy-wide disclosure, taxonomy, and portfolio-alignment requirements. Frameworks such as the CSRD, emerging sustainable-finance taxonomies, and portfolio-alignment exercises increasingly shape how institutions identify, measure, and report nature-related exposures.

Comparing approaches.

- **Per-asset geolocated hazard modelling.** FINMA analysis represents the most granular example reviewed. This initiative build Annual Average Loss and extreme-loss estimates for floods, storms, and heat at the building-level. **Strengths:** By combining asset-level location data with physical-hazard models, the approach directly estimates expected losses and can be incorporated into collateral valuation, mortgage-risk analysis, and insurance modelling. **Limitations:** The methodology relies heavily on external hazard datasets and currently captures only a subset of potential transmission channels.
- **Firm-level event-studies.** BCCh's difference-in-differences analysis of the February 2024 Valparaíso wildfire is an example in which NASA FEDS geocoded fire

perimeters is linked to administrative tax, credit-registry microdata and ENCORE to test whether ecosystem-dependent sectors are more affected.

Strengths: Event-study methods can provide some of the strongest causal evidence available regarding the economic consequences of ecosystem disruption. They allow observed firm outcomes to be directly linked to a specific natural hazard.

Limitations: Their applicability depends on the availability of highly detailed administrative and geospatial data. Findings may also be difficult to generalize beyond the event studied.

- **Macro scenario and stress-testing frameworks for systemic exposure.** Examples include ECB's broader scenario-development work.

Strengths: These approaches are specifically designed to assess systemic vulnerabilities and portfolio-wide impacts. They also provide a structure for incorporating multiple risk channels within a coherent narrative.

Limitations: Most applications remain exploratory and continue to depend on scenario assumptions rather than observed impacts.

- **Sovereign and reserve-portfolio credit-risk translation.** In North Macedonia's case study, the adaptation of the EDSI framework illustrates a novel extension into reserve-management analysis.

Strengths: The approach demonstrates how nature-related risks can be translated into sovereign credit-risk metrics and incorporated into portfolio-management decisions.

Limitations: The framework relies on aggregate degradation proxies and does not identify the particular ecosystem services driving vulnerability.

Implications for central banks and supervisors. FINMA's per-building loss estimates show that, where high-resolution hazard data exists, acute-hazard risk can be translated directly into collateral and loss-given-default assessment; where such data is unavailable, BCCh's event-study approach offers a lower-cost alternative for a specific, dateable shock. Supervisors should treat the cross-cutting disclosure, taxonomy, and portfolio-alignment tools discussed here (the EU's CSRD, Malaysia's Taxonomy for Sustainable Finance, Switzerland's and the EU/ECB's portfolio-alignment work) as complements that typically follow once exposure has been mapped through one of the other three approaches, not as substitutes for that underlying analysis.

4.2 Cross-Cutting Lessons on Methodologies: Which is the Right Approach for a Particular Circumstance?

The initiatives reviewed suggest that methodological approaches are generally not specific to a particular source of nature-related risk. While certain methods have been applied most frequently to water scarcity, biodiversity loss, land degradation, or acute hazards, most can be adapted to analyse a wide range of ecosystem-service disruptions. The key distinction is therefore not the type of risk being studied, but rather the analytical question being asked, the data available, and the ultimate policy objective.

A useful way to compare approaches is to follow the same sequence embedded in the NGFS Conceptual Framework: identifying sources of risk based on exposures, quantifying economic impacts and, ultimately, translating those impacts into financial risks.

Identifying Nature-related Sources of Risk based on Exposures

For many jurisdictions, the starting point is to identify where dependencies on ecosystem services and pressures on nature are concentrated.

Exposure- and dependency-mapping approaches, most notably those based on ENCORE and multi-regional input-output databases such as EXIOBASE, remain the most accessible entry point. They have been used across multiple risk categories, including water scarcity, biodiversity loss, land degradation, and broader ecosystem degradation. Their principal advantage is that they can be implemented rapidly using internationally available datasets and produce results that are comparable across jurisdictions. Their main limitation is that they identify potential exposure rather than actual economic or financial losses.

Where asset locations, firm locations, or supply-chain information are available, **geospatial exposure approaches** provide a more refined assessment by incorporating local ecosystem conditions, environmental degradation, or hazard intensity. Examples include the approaches developed by BCB, BdF, BdE, and FINMA. These methods can substantially improve materiality assessments but require considerably more detailed data.

Practical implication: institutions beginning their work will often start with ENCORE-type exposure mapping and progressively incorporate geospatial information as data availability improves.

Quantifying Economic Impacts

Once exposures have been identified, the next analytical challenge is estimating how ecosystem degradation affects economic activity.

Three broad approaches emerge from the initiatives reviewed.

First, **econometric approaches** estimate historical relationships between ecosystem conditions and economic outcomes. Examples include the Baltic and Nordic's case study analysis linking ecosystem-condition indicators to agricultural output and BCCh's wildfire event study. These approaches provide evidence grounded in observed data and often deliver the clearest estimates of materiality. However, they require high-quality historical datasets and may struggle to capture unprecedented future changes.

Second, **input-output and network approaches** trace how shocks propagate through supply chains and production networks. These approaches have been used extensively to analyse water risks, agricultural disruptions, and ecosystem-service degradation. Their main advantage is that they can quantify indirect effects and spillovers across sectors. Their principal limitation is that they often assume relatively stable economic structures and may not fully capture behavioural responses or structural change.

Third, **general-equilibrium and integrated economic-environmental models**, such as CGE frameworks or BCCh's IEEM+ESM platform, provide the most comprehensive representation of economy-wide effects. These models can capture feedback loops, substitution effects, and policy responses, making them particularly useful for scenario analysis. However, they are also the most complex and resource-intensive to implement.

Practical implication: econometric approaches are particularly useful where historical data exist; input-output models provide a practical intermediate step; and integrated economic-environmental models are most suitable where the objective is comprehensive scenario analysis.

Translating Economic Impacts into Financial Risks

A third set of approaches focuses on translating economic impacts into financial-system outcomes.

The most developed area is **credit-risk modelling**. Across the initiatives reviewed, economic shocks have been translated into default probabilities, non-performing loans, capital adequacy effects, and sovereign credit risks through a variety of methodologies, including rainfall-credit regressions, damage-function approaches, Merton-type models, and sovereign distance-to-default frameworks.

A second group consists of **portfolio-risk and capital-adequacy approaches**, such as DNB's EDSI framework. These methods move beyond exposure mapping by estimating the implications of ecosystem degradation for financial institutions' balance sheets and resilience. Their advantage is their direct relevance for supervision and financial stability analysis. Their limitation is that they require several modelling layers and extensive datasets.

A third, less developed area concerns **asset-valuation, collateral, and market-risk approaches**. Examples include FINMA's mortgage-portfolio analysis and emerging work on reserve management and portfolio concentrations. Although promising, these approaches remain less mature and less widely applied than credit-risk methodologies.

Practical implication: institutions seeking to move beyond exposure assessments will generally find credit-risk analysis the most established and transferable next step, while collateral-, market-, and sovereign-risk applications remain important areas for future development.

Overview of Methodological Approaches and Recommendations

The approaches compared above fall into six recurring categories, which differ along two dimensions that matter for a member choosing where to start: the **scope** of the underlying data – a broad, multi-ecosystem-service average (as in ENCORE) versus a narrow, single-service or single-hazard deep dive – and the **type of insight** the approach generates, ranging from a screening-level exposure flag to a quantified financial-risk metric. Table 6 summarizes this taxonomy, together with illustrative initiatives from Sections 2 and 3.

Read across the table, a natural sequencing emerges, consistent with the “**Which Approaches Are Most Useful, and When?**” question: members with limited data typically start in the first row (exposure and dependency mapping); members with richer administrative or geospatial data can move into the second or third rows to obtain quantified, place- or firm-specific estimates; and only a smaller subset of initiatives – generally building on an existing exposure map – reach the fourth or fifth rows to produce a genuinely macro- or prudentially-calibrated metric. The sixth row, portfolio-alignment and disclosure, typically follows once exposure has already been identified through one of the other five approaches, rather than substituting for it.

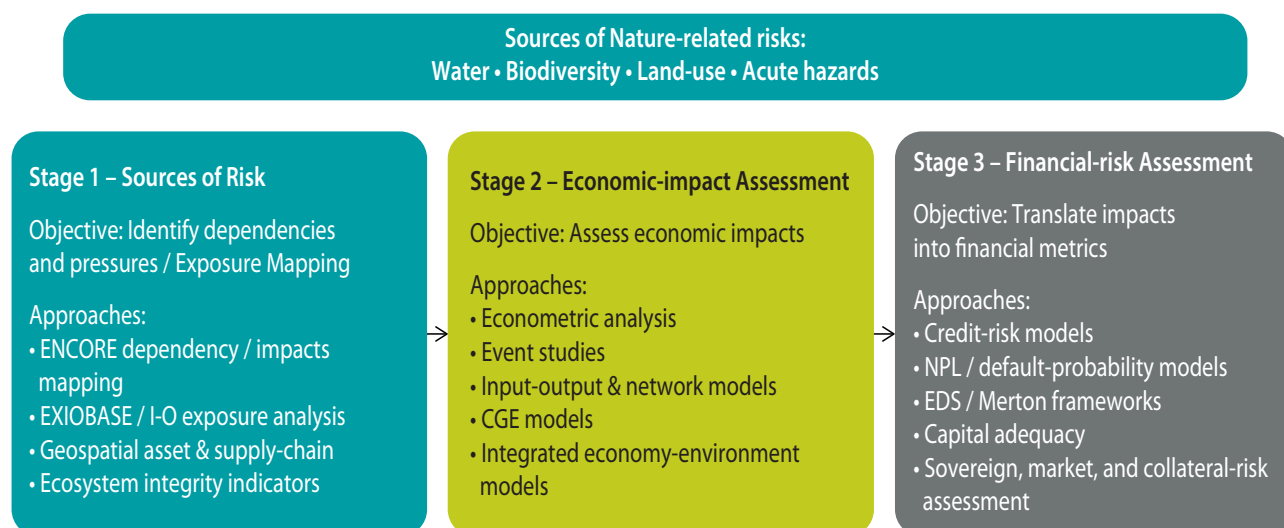
A member choosing where to start should therefore think in terms of which approach fits its available data and institutional capacity, rather than assuming an approach is limited to the source of risk it happens to illustrate here.

Taken together, the evidence suggests that no single methodology is appropriate for all jurisdictions or all analytical objectives. Rather than choosing between competing approaches, most initiatives combine them sequentially. Figure 1 presents the most common progression.

Table 6 **Overview of methodological approaches and data used across nature-related risk initiatives**

Approach category	Scope	Type of insight generated	Core data/tools	Illustrative initiatives
Exposure and dependency mapping	Broad, multi-ecosystem-service, sector-level	Screening-level identification of sectors, portfolios, and counterparties potentially exposed to nature-related risks; high cross-country comparability	ENCORE; EXIOBASE; GLORIA; loan-book and portfolio data	DNB (<i>Indebted to Nature</i> , >€510bn exposure); MNB (EUR 24.4bn/ EUR 23.3bn); FINMA (bond and equity analysis); BNM (ENCORE); EIB portfolio tool; BoL; Bundesbank (Boldrini <i>et al.</i>); BdF (ENCORE-EXIOBASE freshwater analysis)
Geospatial and single-hazard/single-ecosystem-service deep dives	Place-based; focused on a specific hazard, ecosystem, or ecosystem service	Asset-, firm-, or location-level estimates of exposure and severity linked to a specific ecological condition or hazard	Geospatial hazard datasets; building- and postal-code-level data; ecosystem-condition indicators; satellite and administrative data	FINMA (per-building flood, storm and heat analysis); BdE (NEAR/PEAR indicators; Mar Menor); SARB; Baltic and Nordic countries (Ecosystem Condition Index); DNB TNFD pilot
Firm-level administrative event studies and turnover modelling	Firm-, sector-, or event-specific	Quantified impacts on turnover, sales, employment, profitability, or leverage; often provides causal or near-causal evidence	Tax and administrative microdata; credit registries; firm-level financial data; hydro-meteorological data and projections	BCCh (Valparaíso wildfire difference-in-differences analysis); BdF (water-stress turnover model); BRC (hydropower firm-level assessment)
Macro-structural, general-equilibrium, and scenario-based modelling	Economy-wide; multi-sector and system-wide	Estimates aggregate impacts on GDP, output, inflation, trade, employment, and sectoral activity; enables comparison of alternative policy and risk scenarios	Input-output tables; CGE models; SVAR models; New Keynesian frameworks; integrated assessment and scenario models	Bundesbank (river navigability SVAR analysis); BCCh (IEEM+ESM; hydropower model); DNB (scenario study); BdF (global value-chain inflation model); BoE (integrated climate-nature scenario framework); BoG (FUND model); MNB (input-output drought proxy)
Financial-risk quantification (credit, market, and sovereign risk)	Portfolio-, institution-, or balance-sheet-specific	Prudential and financial-stability metrics, including changes in PDs, NPLs, capital adequacy, portfolio losses, and sovereign credit risk	Merton and distance-to-default models; Basel IRB approaches; credit-register data; supervisory and portfolio data	DNB (EDSI); Bundesbank (EDSI); MNB (NPL estimates of EUR 730 m-1.46bn); BRC (rainfall-credit model); North Macedonia (FX-reserve sovereign-risk assessment); BCCh (insolvency)

Figure 3 **Methodological pathways for assessing nature-related financial risks**



5. Key Lessons Learned

Bringing together the sources of nature-related risk and the methodological approaches compared in Section 4, eight cross-cutting messages emerge for NGFS members. These are illustrative of the material reviewed, not an exhaustive list, and members should draw on the underlying evidence in Sections 2 and 3 to identify further lessons relevant to their own context.

Identification of sources of risk

1. **Water-related risks are the most consistently identified source of nature-related economic and financial risks.** They recur across a larger number of physical-risk initiatives than any other ecosystem service (ECB, Bundesbank, MNB, BRC, BCCh, BdF, BdE, SARB) and produce some of the sample's largest quantified figures. Economic effects include output losses of EUR 6-11.3 billion (4%-7% of GDP) under a severe drought scenario in MNB's analysis, up to 24% of euro area output at risk under a 100-year drought event in the ECB's analysis, and EUR 2-17 billion in turnover-at-risk in BdF's analysis. Financial effects include 51.9% of Bundesbank bank lending volume linked to firms with a high dependence on at least one water-based ecosystem service, 22% of ECB loan portfolios exposed to water scarcity, and EUR 24.4 billion and EUR 23.3 billion of surface- and groundwater-dependent lending in MNB's analysis. Members beginning nature-risk work are, in practice, most likely to find usable precedents for water-related risk specifically.
2. **Nature-related risk is highly sector-concentrated but economically pervasive.** Agriculture, forestry, water-intensive manufacturing, and real estate recur as the most exposed sectors across almost every initiative reviewed, yet the same initiatives show this concentration is not narrow in aggregate terms: Bundesbank finds 52.4% of total bank lending goes to firms with high dependency on at least one ecosystem service, the ECB finds that surface water scarcity alone could put up to 24% of euro area economic output at risk, and BCB finds risk-weighted exposures spread across livestock, grain cultivation, and agricultural-support sectors tied to three of the country's largest biomes. A handful of sectors carry most of the risk,

but those sectors are large enough that the aggregate financial system is exposed.

3. **Central banks increasingly include supply-chain effects which amplify direct impacts.** BdF's global-value-chain model finds that agricultural ecosystem-service disruption raises headline CPI by an estimated 0.5 percentage points through indirect input-cost channels, well beyond the direct effect on farms; the EIB's and Bundesbank's use of EXIOBASE to capture indirect, supply-chain-mediated dependencies, and BCCh's input-output linkages within IEEM+ESM, show the same pattern. Assessments that stop at direct, own-sector exposure risk materially understate the true scale of nature-related risk.

Transmission channels and methodologies

4. **Credit risk is the most analysed transmission channel into the financial system.** Across both physical and transition initiatives, credit-risk metrics are the most frequently produced financial output – exposure at risk (ECB: 22% of loan portfolio exposed to water scarcity), default-probability models (BRC), non-performing-loan estimates (MNB), Merton-based capital-depletion models (DNB's EDSI), and sovereign distance-to-default calibration (North Macedonia) – while collateral/asset-impairment and portfolio-wide market-risk channels remain comparatively less developed in the sample.
5. **Physical-risk assessment seems to be currently more advanced than transition-risk assessment.** The physical-impacts survey covers 24 initiatives across 13 jurisdictions, several producing quantified financial-loss or credit-risk figures (MNB's NPL range, BCCh's insolvency-channel estimates, BdE's Mar Menor cost estimates, North Macedonia's sovereign credit-risk sensitivity); the transition-impacts survey covers 9 jurisdictions, and only MNB's sectoral proxy produces a comparable point estimate (a 1-3% NPL impact) – a gap the initiatives reviewed themselves attribute to the greater availability of physical hazard and ecosystem-condition data relative to forward-looking policy-scenario data.²²

²² In addition to data limitation, the difference could possibly also be explained by the lack of clear policies or transition pathways, making it more difficult to identify and/or quantify plausible transition risks.

6. **Most jurisdictions remain at the exposure-mapping stage; a meaningful further group has advanced to quantifying economic impact, but only a handful have carried this through to a financial-risk metric.**

ENCORE-based dependency mapping is the most widely used starting point on both the physical and transition side (DNB, MNB, FINMA, Malaysia, BoL, the EIB, the ECB, Bundesbank, and BdF's exploratory work). A distinct middle group already quantifies economic impact directly – the Baltic and Nordic Ecosystem Condition Index, Chile's IEEM+ESM and Valparaíso wildfire event study, the Netherlands' CGE scenario, Greece's FUND modelling, France's global-value-chain model, and the Bundesbank's river-navigability analysis – but only a handful carry this through to a financial or credit-risk metric: DNB's scenario study and EDSI, Hungary's NPL estimate, North Macedonia's sovereign application, Colombia's rainfall-credit PD model, and Chile's insolvency-channel estimate.

Limitation to current methodologies

7. **Data and scenario limitations remain the primary implementation barrier, particularly for cross-border and emerging-market applications.** Section 2 repeatedly flags the use of domestic macro data due to the impossibility of using firm-level data (which usually is of restricted access), and reliance on international rather than domestic datasets where domestic granularity is unavailable (BNM, BRC). This is consistent with the broader NGFS review of the modelling-tools literature²³, which identifies geospatial-granularity deficits, firm-level microdata scarcity, and the coarseness of standard sectoral classifications (NACE, ISIC) as recurring obstacles to more granular nature-risk assessment. Unlike greenhouse-gas emissions, which can be converted into a single common unit (CO₂-equivalent) to compare very different sources of climate impact, nature-related pressures have no

equivalent common metric, which makes it harder to compare results consistently across jurisdictions.

8. **Existing modelling frameworks each capture only part of the picture, pointing toward complementary rather than single-tool strategies.** The initiatives reviewed demonstrate that no single modelling framework is currently capable of capturing the full complexity of nature-related economic and financial risks. Widely used tools such as ENCORE and EXIOBASE/GLORIA provide valuable insights into dependencies and exposures but rely on largely static, sector-average relationships that cannot fully capture ecosystem degradation dynamics, spatial heterogeneity, or ecological tipping points. Macroeconomic and general-equilibrium models improve the representation of economic transmission channels but often assume relatively smooth adaptation, substitution possibilities, and stable equilibria, making them less suited to abrupt ecosystem disruptions or non-linear ecological change.

The evidence reviewed therefore suggests that future progress will depend less on identifying a single preferred modelling framework and more on strengthening the integration of complementary approaches. In particular, further development of **integrated Earth-economy models** that explicitly connect ecosystem processes with economic outcomes appears especially promising and critical. The limited availability of robust nature-economy models remains a major obstacle to advancing nature-related assessment, making further model development a priority. Recent examples include approaches such as IEEM-ESM and GTAP-InVEST, which seek to bridge biophysical, economic, and policy dimensions within a common analytical framework. While these models remain data- and resource-intensive, they illustrate a potential pathway towards more comprehensive assessments of nature-related risks and their macroeconomic and financial implications.

23 NGFS (2026). Summary Note on the Improvement of Modelling Tools for Nature-related Financial Risk Scenarios.

6. Conclusions and way forward

The implementation practices and case-study applications presented in this Compendium demonstrate the practical value of the NGFS Conceptual Framework as a guide for identifying, assessing, and analysing nature-related financial risks. Across a diverse set of jurisdictions, ecosystems, economic structures, and institutional mandates, central banks and supervisors have successfully applied the Framework's three-phase logic to identify material sources of risk, assess their transmission through the economy, and evaluate potential implications for the financial system.

The review also highlights two important ideas: **i) nature-related financial risk assessment is no longer a purely conceptual exercise and ii) transmission channels linking nature loss to economic and financial outcomes are becoming progressively better understood, but more work in data and modelling is still needed.** Important differences exist in the maturity of analytical approaches. Exposure and dependency assessments based on ENCORE and similar tools have become established entry points for nature-related risk assessment. Geospatial analysis, firm-level studies, macroeconomic modelling, and financial-risk quantification are increasingly complementing these approaches and helping institutions move from identifying vulnerabilities to quantifying materiality. Nevertheless, relatively few initiatives currently provide integrated assessments linking ecosystem degradation to quantified macroeconomic and financial outcomes. Bridging this gap remains one of the most important challenges for future analytical work.

Way Forward

While the initiatives reviewed demonstrate significant progress, they also highlight a number of common challenges that continue to constrain the development of nature-related financial risk assessment. Several priorities emerge for future work.

Better ecosystem datasets: Many initiatives identify limitations in the availability, consistency, and coverage of ecosystem-condition data. While significant advances have been made in developing global datasets on biodiversity,

ecosystem services, water resources, and land-use change, important gaps remain regarding temporal coverage, local ecosystem conditions, and cross-country comparability. Expanding ecosystem datasets and improving their accessibility would strengthen the ability of central banks and supervisors to identify material sources of risk, monitor ecosystem degradation, and assess how ecological changes affect economic and financial outcomes. Joint work with other local authorities (e.g. local environmental agency, space agency/met office, even global NGOs like Global Canopy, Global Forest Watch, CDP) might help to obtain and collect data required.

Better use of existing environmental disclosure: Existing disclosure datasets can complement ecosystem indicators, geospatial information and modelling approaches by providing firm-, facility- and subnational-level information relevant to nature-related risk assessment. Corporate disclosures can provide information on environmental dependencies, impacts, risks and financial effects, while disclosures from cities, states and regions can offer insight into the resilience of shared water, wastewater, transport and energy systems on which economic activity depends.

Improved geospatial information: The review demonstrates the growing importance of geospatial analysis in nature-related risk assessment. Initiatives by BCB, FINMA, BdE, SARB, BCCh, and Baltic and Nordic central banks all illustrate how geographically explicit information can reveal vulnerabilities that remain invisible in sector-level assessments. Improved geospatial information on assets, economic activities, ecosystem conditions, and environmental hazards would allow institutions to identify risk hotspots more accurately and better assess concentrations of vulnerability.

Standardized ecosystem metrics: Unlike climate-risk assessment, which benefits from a relatively small set of widely accepted indicators, nature-related risk assessment currently relies on a broad range of ecosystem-specific metrics and methodologies. The development of more standardised ecosystem-condition indicators and nature-related metrics would improve comparability across jurisdictions, support scenario development, facilitate

supervisory applications, and help establish a common analytical language across the NGFS community.

More macroeconomic modelling: The Compendium shows that most jurisdictions still focus primarily on exposure mapping and dependency analysis. Far fewer initiatives explicitly model how ecosystem degradation propagates through economic activity and affects macroeconomic variables. Expanding the use of macroeconomic, input-output, network, and integrated economic-environmental models would help improve understanding of the broader economic implications of nature loss and strengthen the relevance of nature-related analysis for monetary policy and financial stability.

Better quantification of productivity impacts: Many of the transmission channels identified throughout this Compendium ultimately operate through productivity. Water scarcity, biodiversity loss, land degradation, and ecosystem-service disruption frequently affect the productivity of labour, capital, or land, and thereby influence economic performance. Improving empirical evidence on these relationships will be critical for strengthening the calibration of macroeconomic models, scenario analysis, and financial-risk quantification.

Greater integration of nature and climate assessments: The review repeatedly highlights the close interaction between climate-related and nature-related risks. Climate change can accelerate ecosystem degradation, while ecosystem deterioration can amplify climate-related physical

risks. Likewise, climate and nature policies often generate both synergies and trade-offs. Future work would benefit from stronger integration between climate and nature perspectives, including the development of integrated climate-nature scenarios capable of capturing feedback loops, joint transmission channels, and policy interactions.

Standardizing scenario design: Initiatives reviewed in this Compendium vary substantially in scenario design. The NGFS's Summary Note on the Improvement of Modelling Tools for Nature-related Financial Risk Scenarios (NGFS, 2026) takes up this challenge directly, setting out core scenario-design considerations and recommending a commitment to robust validation – including sensitivity analysis, parallel model comparison, and transparent documentation of uncertainty – as a guiding principle for future scenario work.²⁴

Development of nature stress testing: Several initiatives point towards the increasing use of forward-looking scenarios, stress-testing frameworks, and prudential applications. However, comprehensive nature stress testing remains at an earlier stage of development than climate stress testing. Progress in ecosystem datasets, geospatial information, metrics, scenarios, and transmission modelling should support the development of more robust nature-related stress-testing exercises capable of translating ecosystem degradation and policy responses into measures of financial-system resilience, risk concentrations, and financial-stability impacts.

24 The Summary Note on the Improvement of Modelling Tools for Nature-related Financial Risk Scenarios was published as part of the [NGFS 2026 Nature Package](#).

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<https://www.bafu.admin.ch/climate-and-financial-markets>

Annex 1 – Survey questionnaire

CF Implementation Practices: Is your institution currently conducting, or planning to conduct, any nature-related studies?¹ If the answer is yes, please provide here with the name of the project.

For the purposes of the Framework, climate-related risks are considered to be part of nature-related financial risks, but please include here only those projects that besides climate change also consider broader nature-related risks as part of a more integrated approach. If the focus of the studies is on climate-related risks only, please do not include them in the survey.

Please, for each project that your institution is currently conducting, or planning to conduct, answer the following questions:

- 1. Risk sources:** As a first step, central banks and supervisors could identify the sources of nature-related risk that are potentially material from a microprudential, macroprudential and/or macroeconomic risk perspective.
 - **Focus of study:** What specific sources (e.g. a specific ecosystem, which segment of the financial sector, which policy focus) of physical and transition risks is your institution interested in?
 - **Exposures to impacts and dependencies:** In this project, are you performing any kind of exposure of impacts or dependencies analysis between economic activities and nature? If so, please explain it briefly.
 - **Prioritization:** In this project, are you doing any kind of prioritization regarding economic activities, ecosystem services, and/or transmission mechanisms on which the analysis is focusing on? If so, please explain it briefly.
 - **Forward-looking dimension (scenarios):** In this project, are you carrying out any sort of scenario analysis to project potential future trajectories in nature degradation and its consequent impacts on economic activities? If so, please explain it briefly.
 - **Climate-nature nexus:** In this project, do you consider nature-related dimensions as part of nature-based solutions to address climate change? If so, please explain briefly.

2. Assessment of economic impacts: As a second step, jurisdictions could assess the potential economic effects and identify material economic risks that can stem from these exposures.

- In this project, is your institution interested in assessing the economic impacts of the previously identified sources of risk? If so, please explain briefly what are the type of economic impacts that your institution is interested in.
- **Direct effects:** In this project, do you consider the direct impacts of nature degradation on economic activities? (e.g., droughts on agricultural and mining firms). If so, please explain briefly the direct impacts on which you are focusing the analysis on. What are the methodological approaches that you are applying for the assessment of those economic impacts?
- **Indirect effects:** In this project, do you consider the potential spillovers *via* the supply chain to other economic sectors? (e.g., increasing wildfires might reduce the supply of wood which is an input to the rest of the firms in the economy). If so, please explain briefly the type of spillovers that you are considering.
- **Micro-macro approaches:** In this project, do you consider micro, macro or both types of effects? Micro level effects relate to how firms and households depend on ecosystem services to sustain their livelihood. Macro level effects relate to implications for prices, productivity, investment, socio-economic changes, fiscal balances and trade and capital flows (in particular, affecting inflation and gross domestic product ("GDP")).
- **Adaptation:** In this project, do you consider any adaptation dimension such as geographical substitution (i.e., reallocation of business and households toward places where ecosystem services are not degraded) or technological substitution (i.e., adoption of new technologies that allow to adapt to the loss of ecosystem services)? Do you consider any kind of conservation or restoration actions (e.g., afforestation, protected areas, etc.)?
- In this project, is there any other dimension of the economic transmission channels that were not properly addressed in the previous questions and that you consider relevant to explain?

¹ For example, studying some possible sources of physical or transition impacts of nature degradation and/or transmission channels to the economic and financial sectors.

3. Assessment of financial impacts: As a third step, central banks and supervisors may want to consider the financial risks that stem from the exposures to sources of physical and transition risks (directly, or more likely, *via* financed activities).

- **Effects on the financial system (transmission from economic risks):** In this project, do you study how economic effects are transmitted to financial institutions *via* their exposure (debt) to affected businesses and households? What transmission mechanisms are you focusing on? (e.g., nature-related risks can lead to the impairment of assets and collaterals; lower corporate profitability and the impairment of insurability, affecting traditional financial risk categories).
- **Contagion:** In this project, do you consider that the effect on individual financial institutions has the potential to spread throughout financial systems and/or create feedback loops to the real economy?

- In this project, is there any other dimension of the financial transmission channels that were not properly addressed in the previous questions and that you consider relevant to explain?

4. Challenges

- What challenges, caveats or issues has your institution faced in the process of working on this project?

5. Additional Information

- General Information: Name of responding person, position and email address.
- Planned timeline: By when are you intending to finalize your study? (ideal timeline from the co-leads' perspective would be 6-8 months).
- Planned further use of the work: How would the resulting outcomes contribute to the research or policy work carried out by your institution? Are you planning to integrate nature-related risks in your operations and supervisory guidance?

Annex 2 – Country initiatives – Physical risk

1. Bundesbank (Germany)

1.1 Macroeconomic effects of low river levels

Summary: This research project explores whether and how the deterioration of natural capital – specifically German rivers – contributes to macroeconomic fluctuations. By treating rivers as a vital transportation infrastructure rather than just an ecosystem, the study identifies the quantitative relevance of hydrological shocks to the broader German economy.

Sources of Physical Risks

- This initiative focuses on shocks to river levels. Physical risks arise from reduced water levels due to droughts. These are often chronic pressures linked to climate variability that progressively impair the functioning of rivers as heavy-load transport infrastructure.

Transmission Channels to the Economic Sector

- **Direct channels:** Reduced river navigability directly constrains the movement of goods, leading to **increased transport costs and delayed supply chains**. This primarily affects industrial sectors reliant on bulk transport, such as manufacturing, chemicals, and agriculture.
- **Indirect channels:** Although not modeled in the analysis increased transport costs and delays could spread through supply chains, affecting a wider range of sectors and potentially leading to broader economic impacts.
- **Level of analysis:** The study focuses on key macroeconomic variables such as producer price index inflation and manufacturing growth.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Not addressed.
- **Contagion/Systemic risk:** While not explicitly modeled as contagion, the study identifies how localized infrastructure can have effects on prices and production across Germany.
- **Endogenous risk:** Not addressed.

1.2 Environmental Degradation Sensitivity Indicator (EDSI) Analysis

Summary: Building on De Nederlandsche Bank's EDSI methodology (see below), this initiative applies a modified Merton model to assess how nature degradation is transmitted from firms to banks, covering the exposure and dependency on a set of ecosystem services available in ENCORE. The analysis observes firms borrowing from banks captured in Germany's AnaCredit loan-level register (2019-23 vintages), tracing how ecosystem-service degradation depreciates firms' assets and reduces their distance to default, and from there estimating the resulting depletion of banks' capital headroom, measured through the Common Equity Tier 1 (CET1) ratio.

Sources of Physical Risks

- Broad degradation across **multiple ecosystem services**.

Transmission Channels to the Economic Sector

- **Direct channels:** exposure and dependencies are captured *via* ENCORE at the level of individual firms; the initiative does not model indirect, supply-chain-mediated spillovers, and takes a micro rather than macro approach.

Transmission Channels to the Financial Sector

- **Financial risk channels:** The initiative focuses on the sensitivity of corporate credit to nature-related risk, transmitted *via* asset depreciation in firms and the probability of default for banks exposed through AnaCredit-covered lending.

2. De Nederlandsche Bank (the Netherlands)

2.1 Indebted to Nature

Summary: This exploratory study identifies the extent to which Dutch financial institutions are exposed to risks stemming from biodiversity loss. Using the ENCORE framework, it revealed that over **€510 billion** of investments are highly or very highly dependent on at least one ecosystem service.

Sources of Physical Risks

- This exploratory study, conducted with the Netherlands Environmental Assessment Agency (PBL), identifies the extent to which Dutch financial institutions are exposed to risks stemming from **biodiversity loss and the degradation of ecosystem services**. It is a general exposure mapping that could be used to identify relevant sources of risk.

Transmission Channels to the Economic Sector

- **Direct channels:** The loss of ecosystem services affects those sectors that are highly dependent on them, ultimately leading to an impairment of assets and collateral or lower profitability.
- **Indirect channels:** The analysis only considered first-order dependencies.
- **Level of analysis:** Sectoral.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Mentions market risks, credit risk, liquidity risk, and operational risk as traditional risk categories that could be affected by the impairment of assets and collateral or lower corporate profitability, as well as more general macroeconomic deterioration.
- **Contagion/Systemic risk:** Over €510 billion of investments of Dutch financial institutions are highly dependent on at least one ecosystem service, indicating potential systemic vulnerability. Mentions that financial risks can lead to macroeconomic deterioration.
- **Endogenous risk:** Analyses the impact of financial institutions on ecosystems, recognizing and mentioning a feedback loop between financial agents, the financial sector, and environmental pressures.

2.2 TNFD Pilot and Assessment (Electric Utilities)

Summary: Assessing nature-related vulnerabilities for own-account investments, with a deep dive into electric utilities. This pilot applied the TNFD LEAP approach to identify sources of nature-related risks, followed by a deep dive into the electric utilities subsector using coordinates of company assets. Among other things, it highlights that even low-carbon options like hydropower are highly dependent on nature.

Sources of Physical Risks

- Physical risks arise from ecosystem degradation affecting, in particular, mass stabilization, surface water, groundwater, and flood and storm protection. **Electric utilities are particularly exposed**, with **water scarcity and land degradation** impacting power generation.

Transmission Channels to the Economic Sector

- **Direct and indirect channels:** Reduced water availability affects electricity generation capacity and reliability.
- **Level of analysis:** Sector screening, followed by asset-level analysis (power plants linked to companies) for electric utilities.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Exposure through investments in electric utilities.

Endogenous risk: Not explicitly considered.

2.3 The economic and financial stability repercussions of nature degradation for the Netherlands: Exploring scenarios with transition shocks

Summary: This study is a first exploration of the potential economic and financial-stability impacts of five tail-event scenarios reflecting strong measures taken suddenly in response to nature degradation. The study considered four transition-risk scenarios and one physical-risk scenario (pollination decline).

Sources of Physical Risks

- Four transition-risk scenarios (a global “Half-Earth” protection scenario, an EU tax on imports linked to deforestation, the removal of subsidies harmful to biodiversity, and Dutch nitrogen-reduction measures) and one physical-risk scenario (a global decline in wild pollinators).

Transmission Channels to the Economic Sector

- **Direct and indirect channels:** Direct economic effects are analyzed for each scenario using computable general equilibrium models (for the Half-Earth, pollinator-decline, and deforestation-tax scenarios) or input-output models (for the harmful-subsidies and nitrogen scenarios); in every scenario, indirect, economy-wide spillovers from the initial shock are also captured, with scenario-specific price and, in some cases, technological-substitution parameters built in.

- **Level of analysis:** The analysis is macro, quantifying effects on prices, GDP, and sectoral output.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Economic impacts are translated into financial impacts for Dutch financial institutions using the resulting macro-financial scenarios, focusing on the two largest risk categories for the Dutch financial sector: increased credit losses for banks and increased market risk for insurers and pension funds, estimated only for scenarios with a significant macroeconomic impact and not yet broken down by economic sector.

2.4 Ecosystem Services Degradation Sensitivity Indicator (EDSI)

Summary: Developing a capital-based sensitivity indicator to show how much a bank's capital buffer is lost due to a specific nature shock. The EDSI integrates ecosystem dependencies with supply-chain data.

Sources of Physical Risks

- Broad degradation across **multiple ecosystem services** such as water provision, soil quality, and climate regulation.

Transmission Channels to the Economic Sector

- **Direct channels:** A shock on ecosystem services **depreciates the assets** of firms that rely on those services, impacting their balance sheets.
- **Indirect channels:** Disruptions propagate across the economy through **multi-regional supply chains** and sectoral interdependencies.
- **Level of analysis:** **Micro and sectoral**, mapping embedded exposures along value chains.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Translates sectoral vulnerabilities into financial exposures; asset depreciation leads to an increase in **expected losses (EL)** and **Risk-Weighted Assets (RWA)**.
- **Contagion/Systemic risk:** The indicator quantifies the depletion of the **CET1 capital ratio**, identifying which banks are most sensitive to localized nature degradation.

3. Financial Market Supervisory Authority (Switzerland)

3.1 ENCORE-based Dependency Assessment

Summary: This project applies the ENCORE tool to listed bonds and equity portfolios to gain experience in identifying nature-related dependencies, focusing on physical risks.

Sources of Physical Risks

- Degradation of ecosystem services – **regulating, provisioning, and habitat health**.

Transmission Channels to the Economic Sector

- **Direct channels:** Sectors face increased **operational risks** and reduced production efficiency due to reliance on ecosystem services flows.
- **Level of analysis:** Map of **sectoral exposure** for large bank and insurer portfolios.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Financial institutions are exposed through **portfolio concentration** in nature-dependent sectors like agriculture and mining.

3.2 Physical Risk Impact on Swiss Real Estate

Summary: Geolocated assessment for the financial impact of natural hazards (floods, storms, heat) on the entire Swiss real estate market, aiming to model impacts for every building in the country.

Sources of Physical Risks

- **Acute physical hazards**, specifically **floods (river basins), winter storms, and heatwaves**.

Transmission Channels to the Economic Sector

- **Direct channels:** Physical damage to buildings reduces **asset values** and triggers high repair costs and income disruptions (e.g., lost rent).
- **Indirect channels:** Reduced economic activity in affected regions due to infrastructure damage.
- **Level of analysis:** **Micro (physical infrastructure-level)** hazard modeling for every building in Switzerland.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Physical damage translates into **mortgage risk** through collateral devaluation and increased loss given default (LGD).
- **Contagion/Systemic risk:** Provides a macro view to identify regional clusters of systemic vulnerability in the real estate market.

4. Banque de France

4.1 NGFS Conceptual Framework applied to Freshwater Ecosystem Services

This is a joint Banque de France/ACPR bulletin applying the NGFS Conceptual Framework to freshwater ecosystems in France – an ongoing project, subject to changes in scope – identifying France’s main dependencies and impacts on freshwater using ENCORE and a literature review. It covers water-related ecosystem-service degradation in France (water regulation, purification, and availability), with a planned focus on the impact of water shortages on firm turnover.

The planned analysis will assess the impact of water shortages on firm turnover in France, computed using firm-level and meteorological data, and will also assess impacts in terms of value-added shocks. It also plans to use ENCORE and EXIOBASE to describe the impacts of water-ecosystem degradation on value chains *via* a literature review, with farming and agrifood identified as the sectors most at risk indirectly. Both micro and macro effects, and their interaction, are planned to be assessed.

A quantitative assessment is planned of the transmission of administrative water-use restrictions to non-financial corporations’ sales, then to probability of default, and finally to banks’ corporate credit risk, alongside a qualitative, literature-review-based assessment; contagion/systemic-risk effects have not yet been assessed and remain pending a literature review. *(As of the survey response, this initiative is largely at the planning stage – its evidentiary weight should be calibrated accordingly.)*

4.2 Global Value Chain Model for Agricultural Nature Risk

This is a literature-review and model-based study of the macroeconomic materiality of nature-related risks for France, focused on agriculture. It quantifies how disruptions to four ecosystem services – water cycles, pollination, natural pest/pathogen control, and control of invasive alien species – affect agricultural yields, prices, and headline inflation, *via* a global value chain (GVC) model.

The study uses agro-economic literature to translate four natural hazards into agricultural-yield shocks, converted into agricultural-productivity shocks within the GVC model; the GVC model then tracks the transmission of these shocks across international production networks into agricultural prices and economic welfare, with a standard inflation-forecast model translating this into a quantified CPI effect of +0.5 percentage points. The analysis is macro only; no micro-level effects are considered.

The financial sector is not addressed in this initiative (survey response: not applicable, for both financial-risk channels and contagion/systemic risk).

5. South African Reserve Bank

5.1 Spatially Explicit Assessment

Summary: Mapping regional vulnerabilities to identify financial system dependencies on specific ground and surface water ecosystems, i.e., assessing the direct exposure of sectors to nature shocks by weighting dependencies against spatially-explicit ecosystem vulnerability.

Sources of Physical Risks

- **Water scarcity, soil degradation, erosion, and biodiversity loss,** focusing on the regulation of water flows.

Transmission Channels to the Economic Sector

- **Direct channels:** Heavy sectoral dependence of **agriculture and mining** on water flow maintenance and soil quality, affecting primary productivity.
- **Indirect channels:** Shocks to exports impact household demand and national economic stability.
- **Level of analysis: Spatially explicit assessment** covering 21 ecosystems across regions.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Financial exposure arises through **lending to vulnerable sectors**; more than **ZAR 1,200 billion** in banking assets are issued by activities highly dependent on surface or ground water.

6. Banco de España (Spain)

6.1 Mar Menor Study

Summary: Quantifying the “macro-critical” economic destruction and wealth loss (losses in housing wealth and regional income) triggered by Europe’s largest salt-water lagoon ecosystem collapse.

Sources of Physical Risks

- **Water ecosystem collapse** and water-quality failure (harmful algal blooms) driven by acute runoff from extreme rainfall and flooding.

Transmission Channels to the Economic Sector

- **Direct channels:** Declines in **property prices**; the return on housing investment was **43% lower** in affected areas.
- **Indirect channels:** Collapse of lagoon health impacts broader **tourism revenues** and regional income, with a total loss of over **€4,000 million** in housing.
- **Level of analysis: Micro (property-level)** data used to show how degradation is capitalized into assets.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Banks face risks through **reduced collateral values** in mortgage portfolios and undermined creditworthiness of borrowers.
- **Contagion/Systemic risk:** Lower house prices reduce **recovery rates** when loans fail, undermining the overall soundness of bank balance sheets.

7. Banco Central de Chile

7.1 IEEM+ESM Framework

Summary: This initiative focuses on physical risks stemming from forest loss and land degradation in the FOLU (Forestry and Land Use) sector. It models both the direct effects of ecosystem service changes and the indirect spillovers into the broader economy.

Sources of Physical Risks

- **Forest loss and land degradation**, closely associated with **wildfires** and deforestation, which reduce water flow maintenance, pollination, and erosion protection.

Transmission Channels to the Economic Sector

- **Direct channels:** Changes in ecosystem service flows; e.g., forest loss reduces timber production and decreases agricultural productivity *via* **pollination failure**.
- **Indirect channels:** Primary sector shocks propagate through supply chains to other sectors, influencing **GDP, employment, and investment**.
- **Level of analysis: Sectoral (micro) and macro levels**, integrating spatial modeling with economy-wide accounts.

7.2 Water Scarcity and Hydropower Generation Model

Summary: This initiative extends a New Keynesian model with a detailed electricity-generation sector supplying power through three alternative technologies – thermal (fossil fuels), hydropower, and non-conventional renewable energy – to trace how water scarcity affects electricity generation and, from there, the broader economy. Hydropower generation is modelled as explicitly dependent on water reservoirs, whose dynamics follow a law of motion driven by current storage, water use, and rainfall-driven inflows.

Sources of Physical Risks

- **Droughts** reduce hydropower output directly.

Transmission Channels to the Economic Sector

- **Direct channels:** altering the electricity-generation mix and prices.
- **Indirect channels:** price and supply changes then propagate into other sectors through input-output linkages used to discipline the model, since electricity is a widespread input used with varying intensity across the economy.
- **Level of analysis:** Sectoral (micro) and macro levels, The analysis is macro, run under alternative drought and fossil-fuel-price scenarios, and does not consider adaptation (geographical or technological substitution).

7.3 Bank Exposure to Climate Stress Scenarios

Summary: This initiative quantifies the exposure of Chilean banks to climate- and nature-related stress scenarios using geolocated and administrative data. It estimates damage functions linking the occurrence of extreme weather events to firms' sales and households' labour income, and from there to loan delinquency and bank solvency. The analysis relies on existing NGFS scenarios rather than constructing its own.

Sources of Physical Risks

- Extreme weather events, through their impact on firms' sales and households' labour income.

Transmission Channels to the Economic Sector

- **Direct channels:** Damage functions relate the occurrence of extreme weather events to income and expense shocks for firms and households, with a focus on the insolvency channel.
- **Indirect channels:** Not considered (partial-equilibrium analysis).
- **Level of analysis:** Micro (individual firm and household probabilities of default), aggregated to assess the impact on banks' balance sheets.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Losses in firms' sales or households' labour income caused by extreme weather events trigger default decisions, affecting banks through their exposures to different industries and geographical areas; the focus is on bank solvency.
- **Contagion/Systemic risk:** Not addressed.
- **Endogenous risk:** Not addressed.

8. Banco de la República (Colombia)

8.1 Rainfall-Shock Credit Risk Model

Summary: Drawing on the Peruvian experience, this initiative aims to assess the resilience of the Colombian financial system to heavy or low rainfall shocks. It develops a model relating rainfall shocks to credit-risk indicators at the bank, municipality and economic-sector level, in order to forecast their evolution under different precipitation scenarios.

Sources of Physical Risks

- Heavy or low rainfall shocks affecting the income of households and firms.

Transmission Channels to the Economic Sector

- **Direct channels:** Precipitation shocks affect household and firm income, with effects expected to vary by municipality and economic sector.
- **Indirect channels:** Not addressed.
- **Level of analysis:** Bank-municipality-sector level; macroeconomic variables such as GDP and inflation are intended to be included.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Rainfall shocks are modelled as drivers of credit-risk indicators (probabilities of default), under future precipitation scenarios.
- **Contagion/Systemic risk:** Not addressed.
- **Endogenous risk:** Not addressed.

8.2 Hydropower Generation and Rainfall Study

Summary: This initiative analyses the potential impact of high and low rainfall on Colombia's hydropower sector and quantifies the resulting losses for the financial system through microeconomic transmission channels. The focus on hydropower reflects data availability and the sector's observed sensitivity during the 2015-2016 El Niño episode, when hydroelectric generation contracted by 6.1% (2015 relative to 2012 levels).

Sources of Physical Risks

- Precipitation variability affecting water availability for hydroelectric generation.

Transmission Channels to the Economic Sector

- **Direct channels:** A model relating hydropower plants' generation to precipitation projects output under low-precipitation scenarios; the decline in generation is then mapped onto the income statements of the firms owning the plants.
- **Indirect channels:** Not addressed.
- **Level of analysis:** Micro (firm-level corporate impact analysis).

Transmission Channels to the Financial Sector

- **Financial risk channels:** Lower income weakens firms' ability to cover their financial expenses, raising credit risk for the banks exposed to them.
- **Contagion/Systemic risk:** Not addressed.
- **Endogenous risk:** Not addressed.

9. Bank Negara Malaysia

9.1 TNFD LEAP Pilot

Summary: This pilot applies the TNFD LEAP approach to two significant value chains in Malaysia. It encourages participating firms and financial institutions to conduct qualitative assessments of how their operations are exposed to nature shocks.

Sources of Physical Risks

- Ecosystem services from ENCORE.

Transmission Channels to the Economic Sector

- **Direct channels:** Firm-level operational risks and production capacity shocks stemming from identified high dependencies on nature.
- **Indirect channels:** Ecosystem degradation at one stage of production affects suppliers and stability across the entire value chain.
- **Level of analysis:** Micro (firm-level) and sectoral, identifying risks across entire value chains.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Exposure of financial institutions to sectoral risks via lending to these specific value chains.

9.2 ENCORE Assessment

Summary: This is a macro-level ENCORE analysis of the broader Malaysian economy and financial system. It identifies potential concentrations of dependencies on ecosystem services within bank loan portfolios.

Sources of Physical Risks

- General ecosystem dependencies.

Transmission Channels to the Economic Sector

- **Direct channels:** Potential systemic disruptions to business continuity if dependencies are geographically or sectorally clustered.
- **Level of analysis:** Macro-level ENCORE analysis of the broader economy and financial system.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Identification of portfolio concentration risks in nature-dependent sectors like plantations and commodities.
- **Contagion/Systemic risk:** Highlights how widespread dependencies increase the National Financial System's vulnerability to systemic shocks.

10. Magyar Nemzeti Bank (Hungary)

10.1 Water Risk Study

Summary: This exploratory scenario study maps the financial risks from disruptions to surface and groundwater ecosystems. It found that a severe drought could lead to substantial GDP losses and an increase in non-performing loans.

Sources of Physical Risks

- **Severe drought** and disruption to water ecosystems (surface and groundwater).

Transmission Channels to the Economic Sector

- **Direct channels:** Negative productivity shock; massive contractions in agriculture and manufacturing.
- **Indirect channels:** Large GDP losses estimated between €6 to €11.3 billion (4%-7% of GDP) and inflationary cost-push pressures.
- **Level of analysis:** Macro-level scenario analysis using input-output modeling.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Borrower distress translates into an estimated increase in NPLs of 1%-3% (€730M-€1.46B).
- **Contagion/Systemic risk:** High concentration risk, as five banks hold over 50% of instruments linked to high-risk sectors. Severe GDP shocks could increase the sovereign debt-to-GDP ratio to 80%, raising sovereign credit risk.

11. European Central Bank (European Union)

11.1 Nature Value-at-Risk study

Summary: This study moves from dependency mapping to a risk-based assessment of the euro area economy and banks, applying the nature value-at-risk (NVaR) framework, which links biophysical shocks to ecosystem services with sectoral-production functions.

Sources of Physical Risks:

- All ecosystem services are assessed, but water-related risks, including flood protection, surface water and groundwater scarcity, and water quality, emerge as the most material for the euro area economy.

Transmission Channels to the Economic Sector

- Surface-water scarcity alone could expose up to 24% of euro area output to risk under a drought event with a 100-year return period.
- Agriculture emerged as the most exposed sector, with potential output losses of up to 30% under a 25-year drought scenario and 38% under a 100-year event.
- Other sectors, such as manufacturing, mining, water supply, construction, publishing, and accommodation and food services, also showed high vulnerability, with more than 20% of their output at risk even under moderate drought conditions.

Transmission Channels to the Financial Sector

- Mapping these results to euro area bank portfolios using the ECB Analytical Credit (AnaCredit) dataset (for December 2022) revealed that around 19% of loans are exposed to surface-water scarcity and 22% to groundwater scarcity, while 12% are linked to risks from degraded water quality.
- The most affected loan exposures were in real estate, manufacturing, wholesale and retail trade, mining and construction.

11.2 Ecosystem Services Indicators

Summary: A project by an ECB task force to produce physical risk indicators for financial institutions based on their exposure to non-financial corporations.

Sources of Physical Risks

- **Wildfires, water stress, storms,** landslides, subsidence, and flooding.

Transmission Channels to the Economic Sector

- **Direct channels: Firm-level operational disruptions** and damage function on tangible assets of non-financial corporations.
- **Level of analysis: Micro (firm-level)** indicators using geolocal data (postal codes) to move from sectoral averages to site-based assessments.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Quantification of **exposure at risk** in financial portfolios using indicators like **NEAR** (Normalized Exposure at Risk) and **PEAR** (Potential Exposure at Risk).
- **Contagion/Systemic risk:** Identifies systemic vulnerabilities where shocks are likely to amplify across production networks and financial holdings.

12. Bank of Greece

12.1 Economic Losses from Climate-Driven Biodiversity Loss

Summary: Conducted as part of the update of the study “The environmental, economic and social impacts of climate change in Greece” (LIFE-IP AdaptInGR project), this initiative estimates the economic losses from biodiversity loss caused by climate change in Greece. Owing to data limitations, it focuses on protected species.

Sources of Physical Risks

- Climate-driven biodiversity loss, measured as the decline in species richness among protected species.

Transmission Channels to the Economic Sector

- **Direct channels:** Following the FUND integrated assessment model (Tol 2002; Anthoff and Tol 2008) and its extension by Brooks and Newbold (2014), two functions are applied: the first links temperature change to the pace of species loss; the second links the change in species richness to economic losses, measured as individuals’ willingness to pay to avoid biodiversity loss. Results are expressed in terms of GDP under three IPCC scenarios (RCP2.6, RCP4.5 and RCP8.5).

- **Indirect channels:** Not addressed.
- **Level of analysis:** Macro (national GDP).

Transmission Channels to the Financial Sector

- **Financial risk channels:** Not addressed; the initiative is limited to real-economy (GDP) effects.
- **Contagion/Systemic risk:** Not addressed.
- **Endogenous risk:** Not addressed.

13 European Investment Bank

13.1 Biodiversity Risk Assessment Tool for Counterparties

Summary: The EIB has finalised a biodiversity-risk assessment tool that provides a portfolio view of nature-related risks across its counterparties, identifying high-risk concentrations and exposed sectors. Built on public databases (ENCORE, EXIOBASE, WWF), the tool assesses dependency and impact separately. It currently covers the part of the portfolio for which sufficiently granular information is available, excluding financial institutions, sovereigns and sub-sovereigns.

Sources of Physical Risks

- Dependency on ecosystem services, assessed for each counterparty and each of its sectors of activity (based on revenue/asset splits) across 21 ecosystem services, combined with the state of each ecosystem service in the counterparty's country or region of operation.

Transmission Channels to the Economic Sector

- **Direct channels:** Where a counterparty is highly dependent on an ecosystem service that is degraded in its country of operation (e.g. water filtration), the tool flags a very high risk of financial impact; this is an exposure assessment, without quantification in financial terms.
- **Indirect channels:** Supply-chain effects are partially captured, to the extent that they are embedded in the underlying sources (ENCORE, EXIOBASE, GLORIA).
- **Level of analysis:** Micro (counterparty level), aggregated to a portfolio view.

Transmission Channels to the Financial Sector

- **Financial risk channels:** Not yet analysed; the tool identifies concentrations of counterparty-level risk across the portfolio but does not yet quantify effects on financial institutions.
- **Contagion/Systemic risk:** Not addressed.
- **Endogenous risk:** Not addressed.

Annex 3 – Country initiatives – Transition risks

1. Latvijas Banka (Latvia)

Sources of transition risks

- Dependence of economic activities on ecosystem services and the impact of economic sectors on natural capital. To identify potential sources of transition risk, the analysis focuses on **economic sectors that both depend strongly on ecosystem services and have significant impacts on ecosystems and natural habitats**.
- The study combines granular loan-level data from the Latvijas Banka Credit Register with the ENCORE database, which maps economic sectors to their dependencies on ecosystem services and their impacts on natural capital.
- The assessment shows that **a large share of the corporate loan portfolio is exposed to sectors whose activities depend on ecosystem services** such as water availability, soil quality, and climate regulation. **These dependencies indicate potential vulnerabilities if environmental policies aimed at protecting ecosystems impose stricter requirements or increase production costs for firms operating in these sectors.**
- In addition to the ENCORE framework, the analysis is complemented by a survey of environmental experts, which provides Latvia-specific assessments of how different economic activities affect natural habitats. This approach allows **identification of sectors that are likely to face the strongest adjustment pressures if biodiversity protection or ecosystem restoration policies are strengthened.**

Transmission channels to the economic sector

- **Direct channels: firms' dependence on ecosystem services.** Economic activities rely on natural capital for inputs such as water resources, soil fertility, flood protection, and climate regulation. When ecosystems degrade or environmental policies tighten to protect them, firms may face higher production costs, reduced productivity, restrictions on resource use or land use, and potential disruptions in economic activity. These direct effects can influence firms' revenues and profitability, which in turn affects their capacity to service debt and invest.

- **Indirect transmission may occur through supply chains and sectoral linkages**, as environmental shocks or regulatory changes affecting one sector can propagate to others – e.g., restrictions on resource extraction or land use can affect industries that depend on those inputs.
- **However, the Latvian analysis mainly focuses on direct sectoral exposure, rather than modelling detailed supply-chain spillovers.** The approach is primarily sectoral and micro-level, focusing on the relationship between economic sectors, ecosystem services they depend on, and their environmental impacts. While the broader macroeconomic implications are acknowledged, the analysis is mainly designed as a risk-identification and exposure-mapping exercise rather than a full macroeconomic modelling framework.

Transmission channels to the financial sector

- **Nature-related risks affect financial institutions mainly through their lending exposures to firms in environmentally dependent sectors.** If ecosystem degradation or environmental policies affect firms' profitability or asset values, this may translate into traditional financial risks for banks, including credit risk (borrowers' reduced repayment capacity), collateral value declines, and higher default probabilities. The Latvian central bank therefore examines the share of bank loan portfolios exposed to sectors with strong dependencies on ecosystem services and those with significant environmental impacts.
- **The study also examines the reverse relationship – i.e., the impact of bank-financed economic activities on ecosystems.** By linking loan portfolio exposures to sectors with significant environmental impacts, the analysis highlights how the financial system can indirectly contribute to pressures on biodiversity and natural capital.
- **The Latvian assessment primarily focuses on exposure mapping and risk identification, rather than modelling systemic contagion or feedback loops within the financial system.** The objective is to provide an initial understanding of how biodiversity loss and ecosystem degradation could translate into financial risks through banks' lending portfolios.

2. Banque de France

Sources of transition risks

- [Initiative 1 – evaluation of the dependencies and impacts of the French financial system on biodiversity using sectoral exposure analysis]. To estimate the environmental footprint of financial institutions and their exposure to transition risks, the analysis relies on the **BIA-GBS biodiversity footprint methodology**, based on the GLOBIO model. This allows the estimation of impacts on biodiversity in terms of Mean Species Abundance (MSA.km²). The methodology links financial securities to their issuers and assigns ecosystem-related dependencies and impacts to financial portfolios.
- [Initiative 2 – examining transition risks associated with **land-use regulation**, particularly the French “No Net Land Take” (NNLT) policy adopted in 2021]. This policy aims to halt net land take by 2050 and halve land conversion by 2031. Using detailed geographic data on land use across mainland France and firm-level information, the study estimates land consumption by economic sector and evaluates the economic cost of complying with the regulation. This cost depends heavily on each sector’s capacity to adapt to tighter land-use constraints.
- [Initiative 3 – focus on freshwater ecosystems] Highlight the main economic dependencies and environmental pressures affecting freshwater ecosystems in France and the potential transition risks associated with **water scarcity and environmental regulation**.

Across these initiatives, the main ecosystem services identified as material include water provision and regulation, mass stabilization and erosion control, flood and storm protection, and climate regulation. **Sectoral impacts are also linked to land-use pressures and industrial activities such as chemicals production, dairy processing, and energy-related sectors.**

Transmission channels to the economic sector

- Direct channels: **policy and regulatory changes aimed at protecting ecosystems, such as restrictions on land use or water withdrawals**. For example, the NNLT law creates adjustment costs for sectors that depend heavily on land conversion or urban expansion. At the microeconomic level, these shocks can affect firms through higher input costs, reduced productivity, constraints on land or water use, and declines in turnover. Some analyses quantify the impact of water shortages

on firms’ turnover, combining firm-level data with meteorological information.

- Indirect channels: nature-related shocks may propagate across the economy through **value chains and international production networks**.
- The initiatives combine microeconomic and macroeconomic approaches: micro-level analysis of sectoral dependencies on ecosystem services, sectoral and value-chain analysis of exposure to environmental constraints, and macroeconomic modelling of impacts on prices, productivity, and inflation.

Transmission channels to the financial sector

- **Mapping exposures between economic activities and ecosystem services, rather than modelling full financial transmission channels.** However, future work aims to analyze how environmental shocks could affect the financial system through traditional risk channels (e.g., restrictions on water use could reduce firms’ sales, which may increase their probability of default and translate into higher credit risk for banks through their corporate lending exposures).
- **At this stage, contagion effects across financial institutions are not explicitly modelled.** Potential systemic implications of nature-related risks may be explored through literature reviews or future analytical work.
- **The biodiversity footprint analysis highlights how financial institutions contribute indirectly to environmental pressures through their financing of economic sectors with high impacts on biodiversity.** By linking financial portfolios to the environmental footprints of issuing firms, the analysis provides an indication of the environmental pressures associated with financial exposures, particularly in sectors linked to land use and industrial production.

3. Banco Central de Chile

Sources of transition risks

- Transition risks are analyzed in the context of **policy-driven land-use and ecosystem management changes linked to Chile’s Forest, Land Use and Land Use Change strategies under its updated NDC**. The analysis focuses on the economic implications of implementing nature-based policies including reducing forest loss from wildfires by 25%, afforestation of 200,000 hectares, and restoration of 200,000 hectares.

- The study evaluates how these policy measures affect ecosystem services and economic activities using an integrated modelling framework combining Integrated Economic-Environmental Modelling with spatial Land Use Land Cover and Ecosystem Services Modelling. It estimates changes in ecosystem service flows, including water-related ecosystem services, carbon capture and storage, pollination, and erosion protection, and assesses how these changes interact with economic production systems.
- Priority is given to ecosystem services closely linked to forest loss and land-use change. These ecosystem services represent key channels through which nature-related policy measures may influence productivity in sectors such as agriculture and forestry.

Transmission channels to the economic sector

- Direct impacts of ecosystem degradation and **restoration policies on economic activities**. For example, forest loss reduces timber production in the forestry sector and lowers agricultural productivity through changes in pollination and erosion protection services. Conversely, restoration and conservation measures can improve ecosystem services and increase productivity in these sectors.
- Potential spillovers across sectors through the framework's macroeconomic module. Changes in ecosystem service flows affecting sectors such as forestry and agriculture can propagate to other parts of the economy through **production linkages and broader macroeconomic adjustments**.
- The analysis integrates both sectoral (micro) and macroeconomic perspectives. At the micro level, the model assesses how changes in ecosystem services affect sectoral productivity, particularly in agriculture and forestry. At the macro level, it evaluates how these productivity changes influence broader economic variables such as GDP, employment, investment, and productivity.
- **The framework is forward-looking and projects alternative scenarios associated with the implementation of the forest, land-use and land-use-change policies, assessing both ecosystem dynamics and macroeconomic trajectories under different policy pathways.**
- The analysis explicitly incorporates **conservation and restoration measures**, including afforestation and ecosystem restoration, which correspond to the policy actions evaluated in the study.

Transmission channels to the financial sector
Not studied.

4. Magyar Nemzeti Bank (Hungary)

Sources of transition risks

- **Sectoral environmental impacts are used as a proxy for transition risk.** It reflects the possibility that regulatory tightening, climate policies, or environmental degradation may impose adjustment costs on firms operating in environmentally intensive sectors.
- The analysis identifies Agriculture, Forestry and Fishing, Manufacturing, and Real Estate activities as key sectors where the banking system may be particularly exposed to environmental transition risks, given their strong interaction with natural resources and environmental regulation.

Transmission channels to the economic sector

- Effects of environmental regulation or ecosystem degradation on sectoral production and economic activity. The study assesses **how nature-related shocks affecting ecosystem services could influence GDP, sectoral output, trade flows, and relative prices, creating cost pressures in affected sectors.**
- Supply-chain spillovers are not explicitly modelled within the domestic economy, but the analysis considers **external transmission channels through international trade**, recognizing that shocks affecting Hungary's trading partners may reduce demand for Hungarian exports or disrupt imported inputs, thereby transmitting nature-related risks to domestic sectors.
- The assessment is conducted primarily at the macro level, due to confidentiality constraints in the banking data.

Transmission channels to the financial sector

- The financial risk assessment builds on the economic risk analysis to **examine how environmental shocks could translate into financial vulnerabilities in the banking system.** The analysis estimates that nature-related shocks could increase **NPLs** by between EUR 730 million and EUR 1.46 billion, corresponding to approximately 1-3% of corporate lending.
- The transmission mechanism operates primarily through **declines in corporate output and profitability**, which weaken borrowers' repayment capacity and increase credit risk for banks. Mining and Quarrying and Agriculture, Forestry and Fishing are the most directly affected due to their dependence on natural resources.

- Potential systemic vulnerabilities related to **concentration risk** (more than 50% of financial instruments linked to high- or very high-risk sectors are held by five banks, increasing the potential for risk amplification within the financial system).
- **Market risk channels** (macroeconomic shocks linked to environmental risks could increase Hungary's sovereign debt ratio (towards 77-80% of GDP) and lead to **sovereign rating pressures or declines in government bond prices**). Given the significant holdings of government securities by Hungarian financial institutions, such developments could propagate nature-related shocks to the financial sector through interest rate and valuation effects.

5. De Nederlandsche Bank (the Netherlands)

Sources of transition risks

- [Indebted to Nature – exposure study] Considered as source of transition risk the biodiversity footprint, activities in biodiversity hotspots (vulnerability for new protected areas); and exposure to nitrogen-emitting activities. GLOBIO model is used to calculate the biodiversity footprint as a consequence of changing land use and greenhouse gas emissions.
- [Scenario study] Includes four transition-risk scenarios: a global "Half-Earth" protection scenario, an EU tax on imports linked to deforestation, the removal of subsidies harmful to biodiversity, and Dutch nitrogen-reduction measures.

Transmission channels to the economic sector

- [Scenario study] The uncertainty associated with nature-related risks and the exploratory methodologies applied in this study makes it challenging to provide a concrete estimate of the economic impacts. The study therefore stresses that the results are preliminary and largely a methodological contribution. It presents the impact on output and prices for each of the scenarios considered.

Transmission channels to the financial sector

- [Scenario study] The study measures the effects on credit losses for Dutch banks and weighted average loss on the market value of assets for insurer and pension funds based on the calculated macroeconomic impacts.

6. Bank Negara Malaysia

Sources of transition risks

- Policy and regulatory responses to deforestations, biodiversity loss, and land-use change, particularly in sectors such as palm oil, forestry, and agriculture. Measures have included more stringent sustainability standards, zero-deforestation commitments, and biodiversity protection policies.
- Malaysia's economy and financial systems is highly exposed to nature-impacting sectors (e.g. agriculture, commodities, and plantations), which rely heavily on ecosystem services such as soil fertility, rainfall patterns, and pollination.
- Increasing pressure from international markets (i.e. ESG requirements, sustainable supply chain regulations) are affecting export-oriented industries.
- Malaysia has committed to the development of climate and nature-related taxonomies (e.g. value-based Intermediation and Climate Change and Principle-based Taxonomy) to classify environmentally harmful vs sustainable activities.

Transmission channels to the economic sector

- Transition policies (e.g. land-use restrictions or sustainability certification requirements) are increasing production costs and reducing output in key sectors such as palm oil and logging.
- Export competitiveness may be affected by global sustainability standards, leading to reduced demand for non-compliant goods.
- Sectoral shocks may propagate through value chains, affecting manufacturing, trade, and rural livelihoods.
- Future work (supported by the WB) is exploring how environmental constraints and policy shifts impact GDP, sectoral output, and long-term growth.

Transmission channels to the financial sector

- Financial institutions are exposed to borrowers in high-impact sectors (e.g. plantations, agriculture), increasing credit risk under transition scenarios.
- Repricing of assets linked to environmentally sensitive activities may lead to valuation losses.
- Supervisory tools (e.g. climate risk stress testing and taxonomy-based assessments) have been helping identify concentration risks.

- Two-way relationship: financial flows into agriculture and commodities can exacerbate environmental degradation, increasing systemic exposure to nature-related risks. Potential systemic risk arises from concentrated exposures in a few key sectors central to Malaysia's economy.

7. Financial Market Supervisory Authority (Switzerland)

Sources of transition risks

- Global policy responses to biodiversity loss, including carbon pricing, ecosystem protection, and sustainable finance regulations are affecting multinational corporates.
- Switzerland's financial sector has significant international exposure, including investments in sectors with high biodiversity impacts (e.g. mining, agriculture, energy).
- Growing investor and regulatory pressure for biodiversity disclosure and alignment with frameworks such as TNFD or EU CSRD. Corporates depend on global value chains that may be affected by ecosystem degradation in other regions.

Transmission channels to the economic sector

- Transition risks primarily arise through international channels, as Swiss corporates and investors are highly globally integrated.
- Policy changes abroad (e.g. deforestation bans, biodiversity regulations) may disrupt supply chains and increase input costs.
- Multinational corporations headquartered or financed in Switzerland may face operational and compliance costs.
- Reduced productivity in ecosystem-dependent sectors globally can feed back into Swiss trade and economic activity.
- Scenario-based approaches emphasise global biodiversity shocks and their macroeconomic spillovers.

Transmission channels to the financial sector

- Swiss financial institutions (banks, asset managers, insurers) face exposure to biodiversity risks through globally diversified portfolios.
- Transition shocks may lead to asset repricing, especially in equities and bonds linked to high-impact sectors.
- Portfolio alignment exercises have been assessing exposure to biodiversity-sensitive sectors and regions.
- Risks are amplified by Switzerland's role as a global financial hub, increasing systemic exposure to external nature-related shocks.

- While contagion is not always explicitly modelled, systemic risks may emerge through correlated losses across globally exposed institutions.

8. Banca de la República (Colombia)

Sources of transition risks

- Policy responses have been to deforestation, biodiversity protection, and land-use regulation, particularly in the Amazon and other ecologically sensitive regions.
- There is high economic dependence on natural capital, including agriculture, mining, and forestry.
- Exposure to international environmental policies are affecting commodity exports (e.g. sustainability requirements for coffee, oil, and minerals).
- There has been an increased focus on biodiversity conservation and ecosystem restoration in national policy frameworks (e.g. NBSAP and integration of nature into NDC).
- Colombia faces significant ecosystem dependencies (e.g. water regulation, soil quality) that underpin economic activity.

Transmission channels to the economic sector

- Environmental policies (e.g. restrictions on deforestation or mining) may reduce output in key sectors.
- Ecosystem degradation (e.g. loss of forests, water stress) can directly affect agricultural productivity and energy generation (e.g. hydropower).
- Regional economic disparities may widen, as nature-dependent regions are more vulnerable to transition shocks.
- Supply chain disruption may affect manufacturing and exports.
- Scenario analysis explores how biodiversity loss and conservation policies affect macroeconomic stability, including GDP and employment.

Transmission channels to the financial sector

- Banks are exposed to borrowers in agriculture, mining, and energy sectors highly sensitive to nature-related transition risks.
- Credit risk may increase due to declining profitability and asset stranding in environmentally constrained sectors.
- Financial institutions may face losses due to asset repricing and reduced collateral values (e.g. land affected by environmental regulation, land with customary Indigenous Peoples rights).

- Supervisory initiatives increasingly incorporate environmental risk considerations into financial stability monitoring though these risks are still very focussed on climate.
- Systemic risk could emerge from correlated exposures to nature-dependent sectors, particularly given the concentration of lending in these areas.

9. European Central Bank (European Union)

Sources of transition risks

- Ambitious EU-wide biodiversity and environmental policy frameworks, including the EU Biodiversity Strategy for 2030, the European Green Deal, and the Nature Restoration Regulation impose stricter requirements on land use, ecosystem protection, and restoration.
- Regulatory developments such as the EU Taxonomy for sustainable activities, Corporate Sustainability Reporting Directive (CSRD), and emerging nature-related disclosure frameworks, increase compliance costs and reshape investment flows.
- The EU economy and financial system is significantly exposed to sectors with high ecosystem dependencies and impacts (i.e. agriculture, forestry, fisheries, construction, and energy).
- There has been increasing market and investor pressure to align with biodiversity goals, including divestment from environmentally harmful activities and reallocation toward sustainable sectors.
- As EU firms depend on imported natural resources and ecosystem services from biodiversity-sensitive regions globally, there is greater exposure to cross-border supply chain.

Transmission channels to the economic sector

- Environmental regulations (e.g. restoration obligations, pesticide restrictions, land-use constraints) may increase production costs and require a change in business models, particularly in agriculture, forestry and infrastructure development.
- Corporates dependent on ecosystem services (e.g. pollination, water availability, soil quality) may face productivity losses due to ecosystem degradation or policy-induced changes.

- Transition policies may lead to structural shifts across sectors, with declining output in high-impact industries and growth in sustainable activities.
- Nature-related shocks can propagate through EU-wide value chains and the single market, amplifying macroeconomic effects across EU Member States.
- Scenario analysis (including ECB) evaluates the macroeconomic impacts of biodiversity loss and ecosystem service disruptions on GDP, inflation, and productivity.
- There have been effects on trade: stricter environmental standards may affect competitiveness and imports/exports, particularly for commodities linked to deforestation or biodiversity loss.

Transmission channels to the financial sector

- Financial institutions in the EU are significantly exposed to nature-related risks through lending and investments in ecosystem-dependent sectors. The ECB analysis shows that a large share of euro area bank portfolios is exposed to firms highly dependent on ecosystem services, increasing vulnerability to transition shocks.
- Transition risks can materialise through: (i) increased credit risk (borrowers facing higher costs or reduced revenues), (ii) market risk (repricing of securities linked to high-impact sectors), and (iii) operational and legal risks (due to new disclosure and compliance requirements).
- The ECB stress testing and scenario analysis frameworks incorporate nature-related risks, assessing how biodiversity loss and policy responses affect financial stability. Portfolio alignment tools and exposure mapping (similar to “heatmapping”) are used to identify concentrations in high-risk sectors and regions.
- There is a clear two-way relationship between finance and nature: (i) financial institutions are exposed to biodiversity risks and (ii) financing activities can contribute to ecosystem degradation, creating feedback loops.
- Systemic risk considerations: (i) high correlation of exposures across large EU banks may amplify shocks; (ii) cross-border financial integration increases the potential for contagion across member states; (iii) while still an emerging area, ECB work acknowledges that widespread exposure to nature-sensitive sectors could pose systemic risks under severe transition scenarios.



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