Integrating physical **climate and nature risks** into credit decisions

SYSTEMIQ

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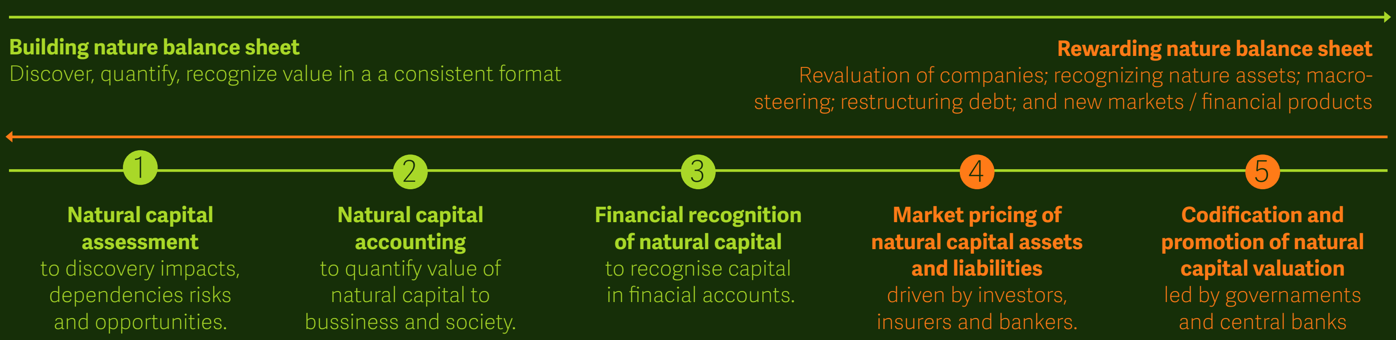
About this report

This report is an extension of Systemiq's work on the Nature on the Balance Sheet Initiative[1]. The initiative sets out a five-action pathway for recognising nature as a driver of value and risk: moving from natural capital assessment to natural capital accounting, financial recognition, market pricing and eventual codification in policy and regulation. Its core message is that natural capital should not sit outside financial decision-making: it should be assessed, valued and recognised in ways that help organisations better protect and restore the natural systems on which economic value depends.

This paper applies that logic to bank credit. It asks how physical climate and nature risks, and the resilience investments that reduce them, can move from portfolio-level assessment into borrower-level credit decisions. Credit integration is part of the shift from building a "nature balance sheet" to financial recognition and pricing.



The report draws on empirical evidence and interviews with banks, development finance institutions, insurers, data providers and regulatory stakeholders. It is written primarily for decision-makers in banks and for regulators shaping the supervisory agenda, but the implications extend to the broader economy. Credit decisions influence whether exposed sectors can access the capital needed to adapt, remain productive and protect or restore the natural systems on which they depend. Borrower-level integration of physical risks is therefore not only a bank commercial issue, but also relevant to real-economy resilience.

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1. A multi-partner effort led by the Capitals Coalition, the Center for Global Commons, the Landbanking Group, and Systemiq.

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Executive Summary

Physical climate and nature risks are credit risks. They include acute and chronic climate hazards such as floods and shifting rainfall patterns, together with nature degradation that weakens ecosystem services such as soil quality. These risks affect borrower cash flows and collateral values, and should sit inside core credit models, not only in portfolio-level assessments. The materiality case is no longer prospective. In 2024, natural disasters cost USD 417 billion globally, 63% of which was uninsured[1], affecting employment and real economy resilience. Agriculture loses around USD 123 billion of production annually due to disasters[2] and a further USD 379 billion due to forest loss[3]. The translation to credit quality is clear: ECB analysis found that 72% of euro area firms are critically dependent on ecosystem services, and these firms account for 75% of corporate bank lending[4].

Materiality is sector-specific, and prioritisation is critical. This paper focuses on agriculture in Europe and Brazil as the starting point, with energy and utility infrastructure as additional illustrations of near-term materiality. Europe and Brazil combine observable exposure in bank portfolios with active supervisory attention. Agriculture is a strong starting point because physical climate and nature risks are visible in yield and revenue impacts. In Europe, the 2022 drought reduced yield by 16% for grain maize, 15% for soybeans, and 12% for sunflowers compared with the previous five-year average[5]. In Brazil, the agricultural sector loses around USD 2.2 billion per year from extreme events[6].

Resilience investments can strengthen credit quality while protecting and restoring natural systems. Agriculture offers evidence that resilience can improve both borrower economics and ecosystem outcomes. For corn in Italy, the share of production area at high or extreme yield loss risk in 2030 could fall from 82% under a do-nothing scenario to 0% with resilience practices in place[7].

The commercial case for integrating physical climate and nature risks into credit decisions has two dimensions: better risk measurement and resilience finance opportunity. If credit models do not reflect material physical climate and nature risks, banks may underprice exposed borrowers, underestimate provisions, and misallocate capital. Better integration allows banks to distinguish borrowers that are merely exposed from those that are genuinely vulnerable. The upside is also becoming clear.

1. Gallagher Re. Natural Catastrophe and Climate Report: 2024
2. FAO. The Impact of Disasters on Agriculture and Food Security 2025.
3. World Bank (2025). Reboot development: The Economics of a livable planet.
4. ECB. The European economy is not drought-proof.
5. European Commission. Drought in Europe August 2022
6. The World Bank. Policy note – Brazil Agricultural Market Insurance Development.
7. Alliance Biodiversity & CIAT. Climate Resilience Platform

Resilience investments can protect assets and stabilise cash flows, creating new financing opportunities that also strengthen portfolios. Nature-related resilience investments, such as agroforestry and soil restoration, can protect and restore natural systems while improving credit quality, creating a feedback loop between lower risk, stronger borrower performance and higher ecosystem value.

Early movers are beginning to turn resilience investment into a lending opportunity. Standard Chartered has structured a USD 435 million sustainability-linked revolving credit facility for agriculture supply chains in South America[8], while Rabobank has committed EUR 3 billion for Dutch farmers transitioning to more sustainable models[9]. The market is still early, but these examples show that financing resilience investments can open new revenue pools.

Banks are advancing on portfolio-level assessment, but most have not translated physical climate and nature risks into borrower-level credit model inputs. There are two levels of integration: portfolio-level risk assessment, including scenario analysis and disclosure, and borrower-level integration, which can range from qualitative overlays to formal credit model adjustments. This paper focuses on the latter. While the economy-level materiality case is clear, bank interviews show that perceived credit materiality varies by institution, reflecting differences in portfolio sector and geographic exposure. As a result, progress has remained concentrated in portfolio-level assessment, driven by regulatory expectations. Some banks have identified material segments or developed risk overlays, but few have changed approved credit model inputs. Even fewer banks interviewed are actively incorporating resilience into credit decisions. This creates an incentive gap: borrowers that invest in resilience do not receive clear credit benefits, and banks risk under-rewarding the very investments that could reduce future portfolio losses.

Physical nature risk lags behind physical climate risk in credit integration, despite its direct relevance to borrower performance and resilience. One reason is data limitation. Nature tools such as ENCORE can identify sector- and country-level dependencies, but often lack the location-specific detail needed for borrower assessment. The challenge is also methodological: nature factors such as soil health and biodiversity can amplify or reduce impacts from physical hazards, while second-order effects through value chains are assumption-heavy and may offset direct impact. These interactions are difficult to estimate in a precise and defensible way in credit models.

8. Standard Chartered (2025). Standard Chartered and COFCO International close USD 435 million Sustainability-Linked Loan with adaptation and social KPIs.
9. Rabobank (2026). Rabobank helps farmers invest in a more sustainable future

Four barriers in data, methodology, regulation and industry coordination explain the credit model integration gap. First, the data foundation remains fragmented and insufficiently granular for borrower-level assessment. Third-party data can help, but reliability remains a concern, as shown by the wide variation in hazard estimates in a benchmarking study of 13 physical risk vendors[10]. Banks also lack consistent, verified information from borrowers on asset type, site locations, production model and resilience measures. Second, banks still lack robust methodologies for translating hazard, exposure, vulnerability and resilience investment into cash flow impact or credit parameters and the empirical link between physical events and actual defaults has not yet been rigorously established. Third, regulatory expectations point toward borrower-level integration but do not yet require model adjustment or define the model pathway. Banks need clarity on evidence thresholds for overlays and formal IRB model changes, including how credible resilience measures can be recognised. Fourth, coordination failures create a first-mover problem. Individual banks lack enough observations to validate risk signals alone, while moving ahead of peers can create near-term commercial disadvantage.

Improving data, credit analytics and supervisory signals are creating momentum for borrower-level integration, while large insurance gaps add urgency. Data and analytics are becoming more decision-useful: hazard and geospatial data are increasingly available through public and commercial sources. Credit rating agency analytics are moving toward end-to-end climate-credit solutions, including Moody's Climate-Adjusted Expected Default Frequency and S&P Global and Oliver Wyman's Climate Credit Analytics. Regulatory pressure is also building. In Europe, the ECB expects banks to consider climate and environmental risks across the credit lifecycle. In Brazil, the BCB's DRSAC framework (Social, Environmental and Climate Risk Document) collects risk information at client and project level, creating a supervisory data foundation that could support future model integration. Insurance protection gaps add urgency: in EU agriculture, only 20 to 30% of climate-related losses are insured, and drought, which drives more than half of climate risk, remains significantly underinsured[11].

Three targeted unlocks can accelerate borrower-level credit model integration on data, methodology and regulatory clarity. All three involve pre-competitive coordination: banks do not need to share proprietary loan data or IRB models, but they should align on data needs, methodological approaches and regulatory asks. But the unlocks alone are not sufficient. Turning their output into changed credit decisions requires two things inside banks: credit practitioners must recognise physical risks as credit risks rather than as an ESG compliance layer, and risk management leaders must actively sponsor the agenda with dedicated resources and a clear governance mandate.

10. Climate Financial Risk Forum and GARP Risk Institute. 2025. A Risk Professional's Guide to Physical Risk Assessments: A GARP Benchmarking Study of 13 Vendors. October 2025.

11. European Commission – EU CAP Network (2023), Insurance and Mutual Funds for Farm Resilience and Adaptation in the EU

Unlock 1/ Build a shared view of which physical climate and nature datasets can support credit decisions, and where gaps remain

Step 1 – Compare datasets and vendors: Banks should confidentially share, through a neutral convener, the types of hazard, exposure, ecosystem-condition and resilience datasets they already use, including commercial vendors, public hazard maps, open-source tools and supply-chain data sources.

Step 2 – Identify data gaps and reliability issues: The review should distinguish data that is useful for portfolio screening from data that can support borrower-level model integration, and identify common limitations such as inconsistent vendor outputs, black-box methodologies, weak resolution or reliance on proxies.

Step 3 – Share borrower-data collection and verification approaches: Banks do not need to share proprietary borrower-reported data, but could share how they collect and verify information on site location, asset characteristics, production models and resilience measures, including how they handle incomplete information, which is often a challenge for SMEs and private borrowers.

Step 4 – Feed the gap analysis into improving public data infrastructure: The resulting gap analysis should be shared with public institutions to guide which data layers need to be built or strengthened for model integration. In Brazil, a practical first step is improving interoperability between AdaptaBrasil, ThinkHazard and the Atlas Digital de Desastres, which are all tools that have been cited by the BCB, while also strengthening regional nature and supply-chain data to support first- and second-order risk assessment.

Potential partners

→ **Banking alliances:** Febraban and the European Banking Federation (EBF) can help coordinate bank input while protecting confidentiality in Brazil and Europe

→ **International conveners:** UNEP FI can provide an international coordination layer, supported by The Science for Evidence-based and Sustainable Decisions about Natural Capital (SELINA) network in Europe for the nature-data dimension

→ **Regulators:** including the BCB and ECB can assess which data sources are credible for supervisory use and support advancement of public data infrastructure and public and private data providers can help develop missing data layers.

Unlock 2 / Share methodological approaches across banking and other credit-relevant sectors

Step 1 – Start with own portfolio materiality assessments: Given methodologies are highly sector- and geography-specific, banks should first identify segments where exposure is material, transmission channels are clear and resilience investments have the potential to reduce risk. Because historical default data may not clearly attribute losses to physical climate or nature risk drivers, initial screening may need to be exposure-based rather than default-based.

Step 2 – Share non-proprietary methodology approaches: Banks with overlapping sector and geography priorities should compare how they address common methodological challenges, such as time-horizon mismatch, feedback loops between physical climate and nature risks, and second-order value-chain effects. On resilience, banks should compare approaches for identifying eligible measures, estimating avoided losses, and translating financial benefits into credit metrics. The goal is to improve approaches without sharing proprietary loan data or IRB models.

Step 3 – Build a collective evidence base for model governance: Banks should work together to test whether and how hazard exposure, borrower vulnerability and resilience measures correlate with credit-relevant outcomes. Individual banks may not have enough observations to validate this alone. A coordinated programme that runs actual default rates from pooled loan books against historical event data could establish whether a statistically meaningful link exists, closing the empirical gap that currently gives rating agencies and supervisors insufficient grounds to require model adjustment. This could generate evidence for bank internal governance and supervisors without requiring banks to disclose sensitive loan-level data.

Step 4 – Draw on adjacent-sector methods through cross-industry sharing: Banks should draw on the insurance industry for methodology learning, including catastrophe modelling and vulnerability functions, and backward-looking claims data. Credit rating agencies may also offer insights as Moody's and S&P have developed methodologies that translate physical hazards into credit parameters. Lastly, Development Finance Institutions (DFIs) and Multilateral Development Banks (MDBs) can contribute practice experience in emerging markets, where they have combined financial and non-financial data linking resilience to borrower capacity. They also lend to commercial banks and have direct interest in improving bank risk management and resilience finance practices.

Potential partners

→ **Banking alliances and industry conveners:** Within banking, Febraban and EBF can coordinate regional participation. While UNEP FI and broader cross-industry groups including the Global Association of Risk Professionals (GARP) and the Climate Financial Risk Forum (CFRF) can support broader risk-practitioner engagement. ICMA could be engaged on the resilience finance dimension to help align definitions and eligibility, building on its work on sustainable bond principles and guidance on nature-related bonds.

→ **Insurers and reinsurers:** They hold the most mature hazard-to-loss methods and backward-looking claims data. Initiatives such as IIGCC's PCRAM include participation from insurance stakeholders and is a potential platform for deeper cross-industry sharing.

→ **DFIs and MDBs:** Existing initiatives, such as the Global Emerging Markets Risk Database (GEMs), already enable anonymised credit default and recovery data sharing amongst DFIs and MDBs. This model could be expanded to include commercial banks.

→ **Academic and knowledge partners:** Cambridge Institute for Sustainability Leadership (CISL) could act as a knowledge partner, given its work on physical risk and resilience in credit. The Earth Capital Nexus at the London School of Economics could also be engaged, given its focus on decision-useful analytics for climate- and nature-related risks.

→ **A convening event, such as a Bellagio Center-style working session:** A structured working session could bring the above actors together with supervisors and academic researchers to accelerate convergence on which methodologies can be adapted for bank credit models.

Unlock 3 / Achieve regulatory clarity on physical risk models and resilience recognition

It is important to note that regulatory clarity is necessary but not sufficient. It addresses the financial sector side of the gap, while corporate-facing policy on resilience standards and incentives remains a separate, necessary track that this report does not address

Step 1 – Define specific regulatory asks on an industry-level: Banks should align on a small number of concrete questions for supervisors, rather than asking for broad guidance. These should include: what evidence thresholds are required for risk overlays, collateral adjustments and approved IRB model changes; how incomplete data should be treated; and how credible resilience measures can be recognised in credit assessment and capital treatment.

Step 2 – Develop a shared industry position: Banks should translate these questions into a coordinated industry position rather than approaching supervisors through fragmented individual submissions. A shared position is more likely to generate actionable guidance and reduce first-mover concerns.

Step 3 – Use live regulatory windows in Brazil and Europe: In Brazil, the GRSAC implementation phase creates a near-term window for engagement, with the new format expected to enter into force in January 2027. This creates an opportunity now to clarify how social, environmental and climate risk disclosures could support future credit model integration. In Europe, the EBA Guidelines on ESG Risk Management apply from January 2026, while the EBA Guidelines on Environmental Scenario Analysis are being implemented alongside ongoing EBA and ECB work on credit valuation. These processes provide an opening for industry engagement on evidence thresholds, model governance and the treatment of resilience measures.

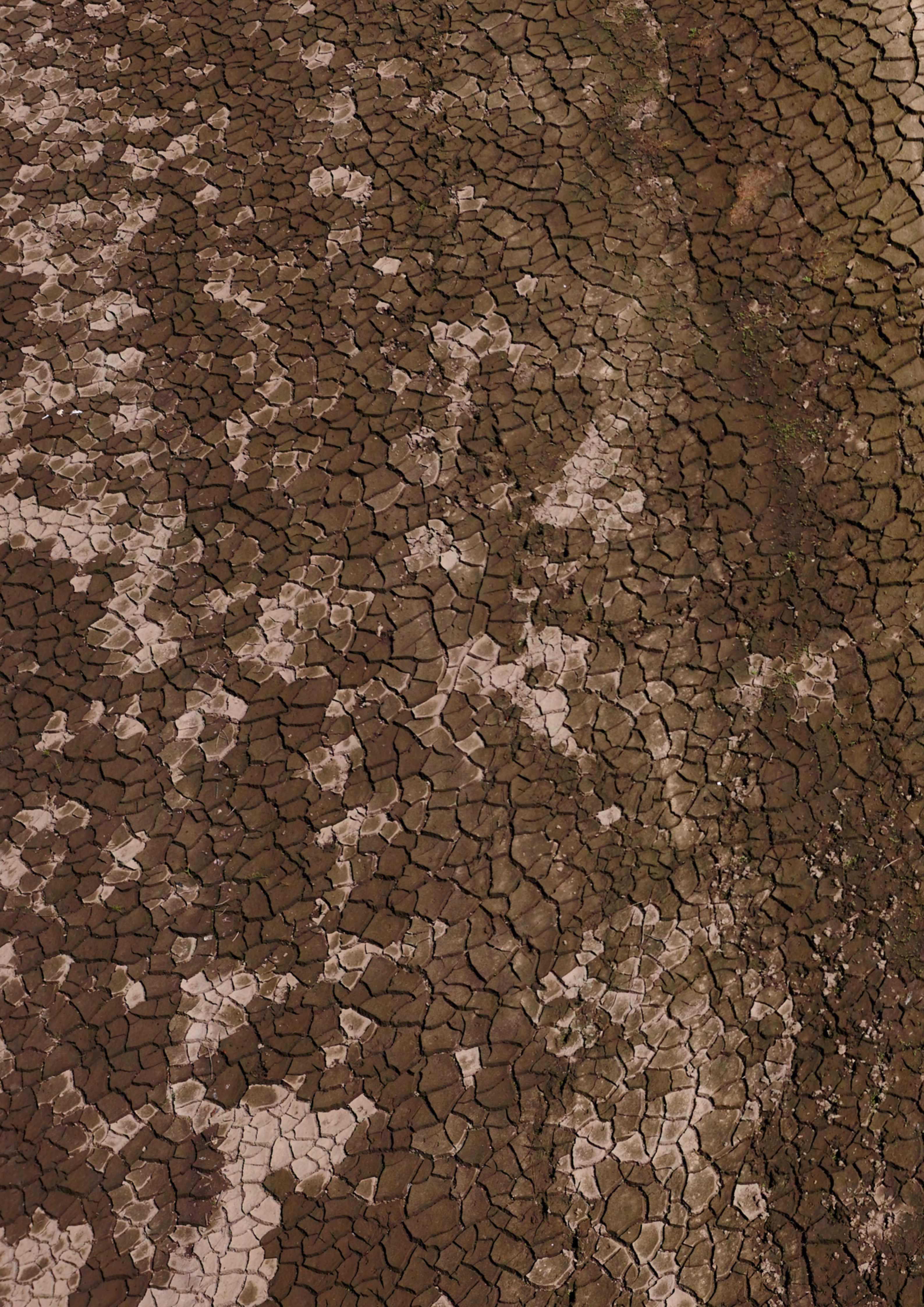
Potential partners

→ **Banking federations and industry conveners:** In Brazil, Febraban holds both the institutional mandate and the direct channel to the BCB and is the natural convener. In Europe, the Climate Financial Risk Forum (CFRF) is well-positioned to coordinate the industry position in EBA and ECB engagement.

→ **Supervisory and regulatory platforms:** The Network for Greening the Financial System (NGFS) could be engaged as a supervisory knowledge partner, given its central bank and supervisor membership and its work on nature-related financial risks and supervision.

→ **International platforms:** The Institute of International Finance (IIF) and Green Finance Institute (GFI) hold the established relationships with supervisors needed to ensure the industry position reaches the right counterparts.

The building blocks exist, the regulatory moment is opening, and the commercial opportunity is real. The question is not whether physical climate and nature risks will be reflected in credit decisions. It is which banks shape how that happens and on whose terms.



CHAPTER 1

Why physical climate and nature risks are fundamentally credit risks and the commercial case for recognising resilience

1.1 The materiality case: physical climate and nature risks belong in credit decisions

Physical climate and nature risks affect borrower income, collateral values and recovery prospects. That makes them financial risks, not only sustainability issues. Resilience matters because it is a critical lever for reducing those risks. The evidence is now strong enough for banks to treat these risks as material, even if impacts vary by sector and geography. Doing so will be critical for the real economy, which needs to incorporate physical risks into the cost of capital.

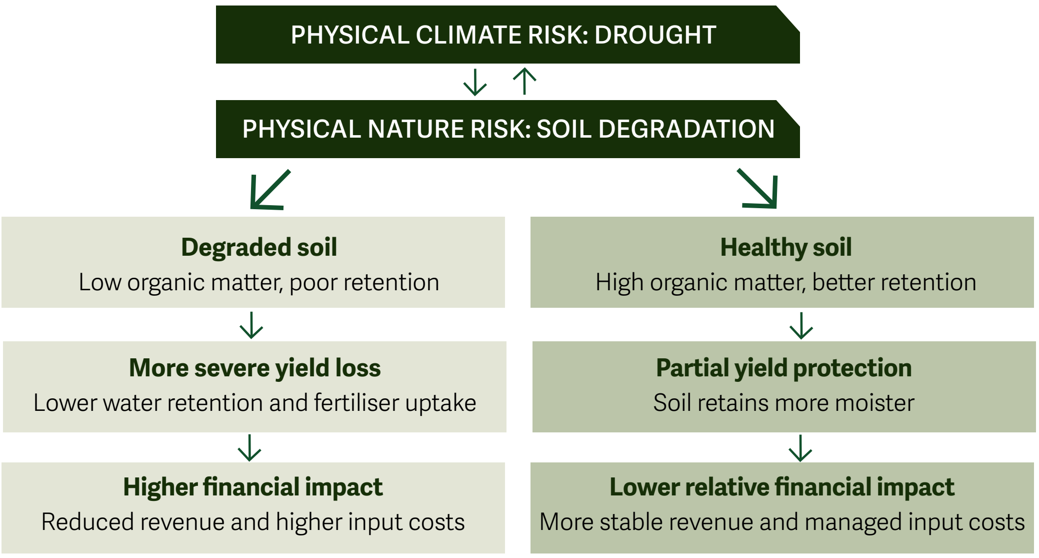
1.1.1 Physical risks are already financially material, affecting economic outputs across value chains

Physical climate and nature risks are increasing in frequency and severity, driven by climate change and ecosystem degradation. The direction of travel is clear: extreme temperature events more than tripled in frequency from 2000-2019 compared with 1980-1999[13]; and billion-dollar disasters now occur every three weeks, compared to every four months 40 years ago[14]. In this report, they are collectively referred to as physical risks, unless specifically distinguished as physical climate risks or physical nature risks.

1. Physical climate risks arise from acute shocks and chronic shifts in climate patterns. Acute risks are event-driven, including floods, storms, droughts, and wildfires. Chronic risks result from longer-term changes, including sustained higher temperatures, sea-level rise, and water stress.

2. Physical nature risks arise when degradation of nature reduces the ecosystem services on which businesses depend. These risks stem from changes in the condition of ecosystems, including declining soil quality, reduced water availability, loss of pollination and biodiversity, forest degradation and loss of natural flood protection.

These risks are closely interlinked and often reinforce each other. rought risk, for example, is shaped not only by rainfall patterns but also by soil condition and water retention, while flood risk depends on precipitation, land use and wetland function. This means that models assessing physical risks separately underestimate high-severity, high-frequency scenarios where extreme climate events interact with ecological tipping points.



13. UNDRR, CRED (2020). The Human Cost of Disaster: An overview of the last 20 years 2000-2010.
14. Economist Impact, Climate Change's Disruptive Impact on Global Supply Chains (2025)

Physical nature risk is economically material, but is less systematically integrated into financial decisions than physical climate risk. Over USD 44 trillion of economic value generation, more than half of global GDP, is estimated to be moderately or highly dependent on nature[15]. Yet the role of natural capital and ecosystem services in economic prosperity has often gone unnoticed, and the World Economic Forum notes that confusion persists on how nature loss relates to prosperity and how businesses should respond[16].

Materiality is already observable in the near-term, not only in long-term scenarios. In 2024, natural disasters cost USD 417 billion globally, 63% of which was uninsured[17]. Agriculture is already losing USD 123 billion of production annually due to disasters[18], equivalent to 5% of global agriculture GDP, while forest loss is linked to USD 379 billion per year of agricultural production losses[19]. These figures show that physical risks are already moving through real economy balance sheets, especially in sectors that depend directly on land, water, and other ecosystem services.

Under business as usual, these impacts are likely to worsen in the medium term as physical risks erode the core drivers of firm performance: physical, natural, and human capital. They can reduce asset productivity, operating costs, and labour output. Extreme heat is projected to drive $560 - 610 bn in annual fixed asset losses for listed companies by 2035[20], while heat stress alone could reduce labour productivity by the equivalent of 80 million jobs by 2030[21].

Materiality is sector-specific, so banks need to prioritise the sectors where risk exposure and resilience potential are clearest. This paper focuses primarily on agriculture, with energy and utility infrastructure used as additional illustrations of near-term materiality. These sectors are selected because physical risks are already affecting core business drivers, including production volumes, asset utilisation, operating costs and revenue stability. Residential and commercial real estate are also material for many banks, but they are not the focus of this paper. Their credit transmission channels are different, driven heavily by property collateral values, housing market liquidity, appraisal methods and mortgage regulation, and therefore require a dedicated framework rather than the corporate cash-flow and sector-lending approach used here.

Agriculture presents a clear near-term case because physical risks already translate directly into yield and revenue impacts. Globally, ~1.7 billion people live in areas where crop yields are 10% lower because of human-induced land degradation[22]. In Europe, the 2022 drought reduced yield by 16% for grain maize, 15% for soybeans, and 12% for sunflowers compared with the previous five-year average[23]. In Brazil, the primary agricultural sector loses around ~USD 2.2 billion per year from extreme events, equivalent to 1% of agricultural GDP[24].

15. WEF (2020). New Nature Economy Report. / 16. WEF (2020). New Nature Economy Report. / 17. Gallagher Re. Natural Catastrophe and Climate Report: 2024 / 18. FAO. The Impact of Disasters on Agriculture and Food Security 2025
19. World Bank (2025). Reboot development: The Economics of a livable planet.
20. WEF (2024) Climate Hazards will slash 7% off corporate earnings annually by 2035, research warns.
21. ILO (2019) Increase in heat stress predicted to bring productivity loss equivalent to 80 million jobs
22. FAO. FAO report: 1.7 billion people experience lower crop yields due to land degradation.
23. European Commission. Drought in Europe August 2022
24. The World Bank. Policy note – Brazil Agricultural Market Insurance Development.

Agriculture exposure differs by crop, hazard, ecosystem condition and production model: above-ground fruit and vegetable crops are highly sensitive to heat, drought and frost; roots and tubers can be more stress tolerant but remain vulnerable during key development stages[25]; and nitrogen-dependent crops such as maize and wheat can face amplified yield risk when drought reduces fertiliser effectiveness and nitrogen uptake[26]. Nature degradation adds a further vulnerability layer, as monocultures are more exposed to soil health decline, biodiversity loss and disease, while diversified cropping systems can improve soil fertility, water regulation, and pest control[27].

Energy and utility infrastructure show that physical risks can affect asset performance and service continuity. These systems are exposed to water availability, heat, storms, wildfires and coastal risk, with climate resilience affecting every segment of the electricity system, from generation potential and efficiency to transmission and distribution, and demand patterns[28]. The 2022 European drought disrupted energy and transport systems: Portugal stored less than half its average hydroelectric energy, Italian power plants generated 40 to 50% less electricity, and low Rhine water levels disrupted coal and oil transport in Germany and the Netherlands[29]. Drought has also affected hydropower output in California, where generation in 2021 was 48% below the 2011 to 2020 average[30].

Highly exposed sectors are core to commercial bank portfolios, making physical risks a credit issue as much as an environmental one. ECB analysis shows that 72% of euro area firms are critically dependent on ecosystem services, and these firms account for 75% of corporate bank lending in the region[31]. Water scarcity is also a material portfolio exposure: the ECB analysed loans from 2,500 Euro area banks to non-financial corporations and found that more than 34% of the outstanding amount, over EUR 1.3 trillion, is to sectors exposed to high water scarcity risk. The implication for banks is direct: physical risks already affect the sectors and geographies that shape loan-book performance.

1.1.2 Real economy losses are impacting credit quality across exposed geographies

Physical risks affect credit quality through cash flow and collateral channels. BIS identifies that physical risks transmit through banks' loan books by damaging borrower assets, reducing income generation, and lowering collateral values[32]. The effects on borrowers can arise through immediate shocks and longer-lasting market effects:

25. IPCC AR6 WGII. Chapter 5: Food, fibre, and other ecosystem products.
26. Flynn et al. (2023), High N availability decreases N uptake and yield under limited water availability in maize.
27. Nature. (2026). Long-term agricultural diversification increases financial profitability, biodiversity, and ecosystem services: a second-order meta-analysis.
28. International Energy Agency. (2021) Climate Resilience.
29. Nature (2024). Direct and lagged climate change effects intensified the 2022 European drought.
30. EIA. (2022). Drought effects on hydroelectricity generation in western U.S. differed by region in 2021.
31. ECB. The European economy is not drought-proof.
32. BIS (2021), Climate-related risk drivers and their transmission channels.

1. First-order effects arise when physical shocks directly damage assets or disrupt operations. These include flood damage to facilities, crop losses from drought and business interruption after wildfire.

2. Second-order effects include value chain and market impacts, such as input cost increases, supply disruption, or reduced demand. In many sectors, second-order impacts may be more persistent than the initial shock because they drive sustained earnings pressure. pressure[33].

Evidence shows that physical risks are already affecting credit quality. World Bank analysis finds that severe disaster episodes have raised system-wide non-performing loans (NPL) by a cumulative 0.6 percentage points after two to three years[34]. At company-level, Moody's downgraded Naked Juice LLC from B3 to Caa1 in 2024, citing climate risk as a key driver. The company sources over 60% of its orange juice from Brazil, which has been affected by severe drought and citrus greening. As a result, Moody's forecasted weaker operating performance and continued negative free cash flow linked to higher procurement costs[35].

The challenge is often more acute in developing economies, where higher hazard exposure can coincide with weaker financial buffers. The same World Bank analysis on NPL shows severe disaster episode effects differ materially by country income group: high-income countries see a cumulative 0.72 percentage point increase three years after severe disaster episodes, while low-income countries see a 5.8 percentage point increase after one year[36].

Europe and Brazil are focus geographies for this paper because they combine high credit exposure with growing supervisory attention. In Europe, ECB analysis shows that physical shocks are already linked to credit outcomes. Its analysis of six flood events since 2018 found that loans to flooded firms had a 0.7 percentage point higher probability of becoming non-performing in the following quarter. For the 2024 Valencia flood, the effect reached up to 2 percentage points over the following two quarters[37]. The ECB also found that adding acute flood risk to stress tests increased Common Equity Tier 1 capital depletion by around 77 basis points[38].

Brazil is a priority geography for this paper because physical risks are already material and the regulator is actively tracking system-wide exposure. Banco Central do Brasil (BCB) analysis, conducted jointly with the World Bank, finds that 46% of corporate credit portfolios in Brazil are concentrated in firms with high or very high ecosystem service dependency, with agriculture and energy among the most

33. S&P Global Ratings (2024), How Climate Scenarios Help Identify Potential Credit Impacts.
34. World Bank. (2023). Banking Sector Risk in the Aftermath of Climate Change and Environmental-Related Natural Disasters
35. Moody's Ratings (2024), Moody's Ratings downgrades Naked Juice's CFR to Caa1 from B3; outlook is stable, Rating Action, 24 July 2024.
36. World Bank. (2023). Banking Sector Risk in the Aftermath of Climate Change and Environmental-Related Natural Disasters.
37. ECB (2025). Integrating climate risk into the 2025 EU-wide stress test: the effects of climate risks for firms
38. ECB (2025). Integrating climate risk into the 2025 EU-wide stress test: the effects of climate risks for firms

exposed sectors. The Cerrado, Mata Atlântica and Pampa biomes, where the largest credit exposures are concentrated, are the ecosystems under most acute degradation pressure. The BCB also states that adverse climate events such as heatwaves, droughts and floods can affect food and energy prices, economic growth and financial-system stability, and has highlighted the May 2024 Rio Grande do Sul floods as a key recent event[39]. Nature risk is not a future exposure for Brazilian banks, it is a present concentration risk embedded in existing loan books.

While the evidence of credit impact is clear, perceived near-term materiality still varies across banks, reflecting differences in sector and geographic exposure. Bank interviews confirm this mixed picture: some institutions see a large share of their loan book as directly dependent on natural capital and increasingly exposed to physical risks and ecosystem degradation, while others view near-term portfolio impacts as more limited, partly because of insurance coverage. Supervisory analysis supports this heterogeneity: ECB stress testing shows that 7% of banks experience capital impacts exceeding 200 basis points, compared with the 77 basis point average[40].

1.1.3 Resilience investments can improve credit performance while protecting and restoring nature

Adaptation and resilience (A&R) measures can reduce downside risk and strengthen borrower operations. Measures such as flood protection, drought-resistant crops and asset hardening can reduce physical damage and protect asset values. Adaptation could reduce cumulative hazard costs for the S&P Global REIT index by USD 45 billion by 2050, including a 59% reduction in flood-related costs and a 5% reduction in extreme heat costs[41].

Resilience investments can create value beyond avoided losses. In agriculture and land-dependent sectors, more than 75% of resilience benefits come from productivity, income and wider economic gains, rather than avoided disaster losses alone[42]. Almost half of WRI's evaluated adaptation investments also generate measurable mitigation co-benefits, reinforcing that the return profile is broader than standard risk-reduction[43].

Nature-based resilience investments can protect and restore natural systems while improving credit quality, creating a feedback loop between lower risk, stronger performance and higher ecosystem value. Measures such as wetlands, agroforestry and soil restoration can reduce physical risk exposure,

39. Banco Central do Brasil. (2023). Report on Social, Environmental and Climate-related Risks and Opportunities
40. ECB. Integrating climate risk into the 2025 EU-wide stress test: the effects of climate risks for firms
41. GIC x S&P Global (2024). Integrating Climate Adaptation into Physical Risk Models
42. World Resources Institute (2025). Adaptation Investment Review - Triple Dividend of Resilience.
43. World Resources Institute (2025). Adaptation Investment Review - Triple Dividend of Resilience.

improve productivity and strengthen long-term asset and collateral resilience. The credit logic is clear: lending that supports resilience can protect borrower continuity, lender recovery value and ecosystem function at the same time.

Agriculture offers evidence that resilience can improve both borrower economics and ecosystem outcomes. In Thailand, a potato pilot across 3,000 farmers that combines soil health and drip irrigation measures resulted in a net increase in farmer income by over 15% over three years while reducing GHG emissions by 20% per tonne[44]. Apollo Agriculture provides an example of resilience-linked lending in practice: it offers Kenyan smallholder farmers improved inputs through a loan repaid post-harvest and uses satellite imagery and AI to assess creditworthiness. Farmers served by Apollo have achieved yields 2.6 times higher than others[45].

CASE EXAMPLES

Resilience investments can shift forward-looking yield-loss risk in exposed agricultural systems.

01 Soybean in Brazil

In Brazil, soybean production covers 110.8 million acres and is already exposed to major climate shocks. In 2021 to 2022, drought caused a 23.8% national yield loss, equivalent to 30 million tonnes or USD 16.3 billion. Without adaptation, 100% of soybean production area could be at high or extreme risk of yield loss by 2030. With resilience practices, this falls to 36%. The most effective measures include conservation tillage, variable-rate planting, and livestock manure application[46].

02 Corn in Italy

Corn covers 1.6 million acres of production area in Italy and faces high drought risk. Without adaptation, 82% of corn production area could be at high or extreme risk of yield loss by 2030. With resilience practices, this falls to 0%. Key measures include crop-residue mulching, adjusted planting dates, conservation tillage, and crop-residue management[47].

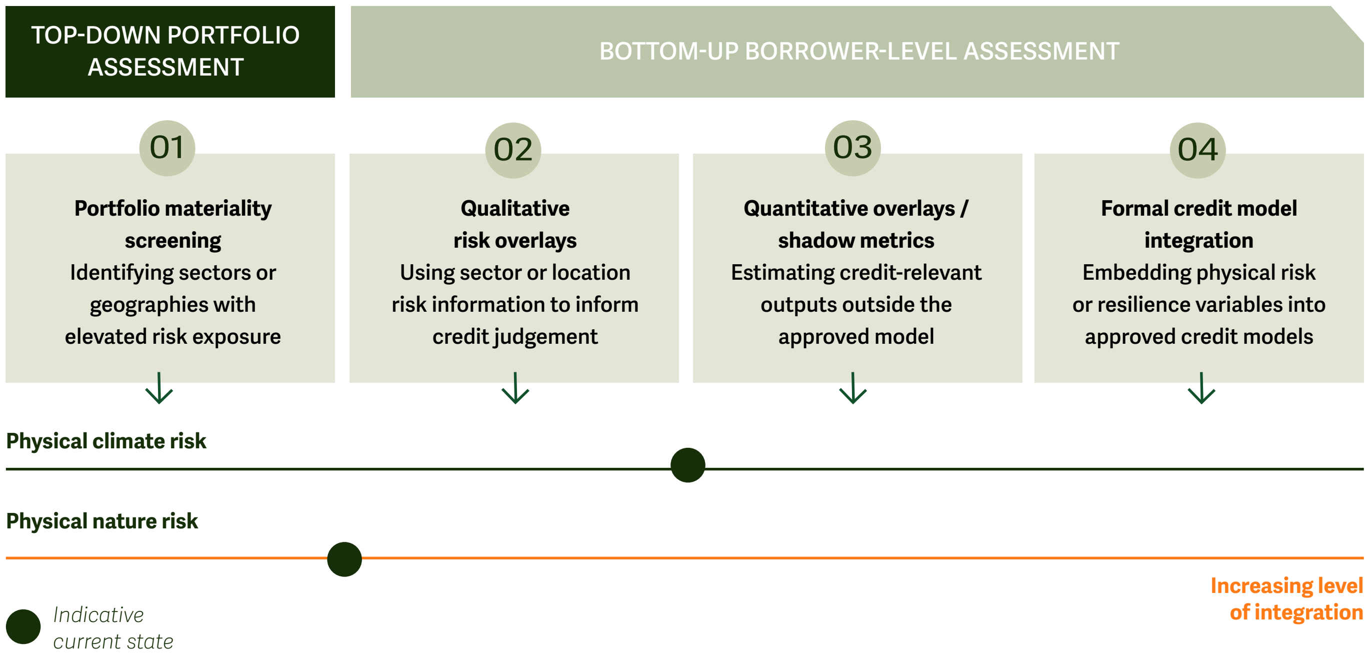
44. Alliance Biodiversity & CIAT. Climate Resilience Platform
45. British International Investment and FMO. 2025. Climate Investment Playbook: A Guide to Climate Adaptation and Resilience Investing.
46. Alliance Biodiversity & CIAT. Climate Resilience Platform
47. Alliance Biodiversity & CIAT. Climate Resilience Platform

Energy and utility infrastructure also show how resilience investment can improve financial performance. Undergrounding transmission and distribution lines can reduce vulnerability to extreme weather and wildfire. Evidence shows that a 10% increase in underground line miles was associated with a 14% reduction in annual interruption duration; while PG&E estimated a 99% reduction in wildfire ignition risk for overhead-to-underground distribution line conversion[48]. The credit relevance is clear: targeted grid resilience investments can reduce service disruption and repair costs, strengthening borrower continuity and asset resilience.

1.2 Banks are starting to respond, but credit model integration remains limited

Banks are increasingly conducting portfolio-level risk identification and assessments, driven by regulatory expectations. However, incorporation into borrower-level decisions remains limited. Where integration is happening, it is typically through overlays or shadow metrics rather than changes to approved credit models.

48. U.S. Department of Energy. 2024. Undergrounding Transmission and Distribution Lines.



HOW ASSESSMENT OUTPUTS MAY BE IMPLEMENTED IN CREDIT DECISIONS

- Automatic credit-policy changes: trigger predefined changes to pricing, covenants, collateral requirements or approval conditions
- Discretionary credit judgement: inform credit officer or risk team judgement, with manual rating adjustments or pricing decisions
- Enhanced monitoring or engagement: strengthen due diligence, client engagement or watchlist monitoring

1.2.1 How risk integration works: from portfolio assessment to credit model integration

Physical risks can be integrated at top-down portfolio-level assessment or bottom-up borrower-level integration, which impacts day-to-day credit decisions. Portfolio approaches such as materiality screening, sector and geography heatmaps, scenario analysis and stress testing help banks identify exposed areas. These tools support disclosure and portfolio steering, but they are only the starting point: the credit question is whether the risk can be evidenced at client level in a way that is decision-useful and auditable. Borrower-level integration goes further, translating physical risks into credit-relevant inputs.

Borrower-level integration can range from qualitative overlays, through quantitative overlays or shadow metrics, to formal credit model integration, reflecting increasing depth of integration. Qualitative risk overlays typically use sector or location information to inform credit judgement.

Quantitative overlays or shadow metrics estimate credit-relevant impacts outside the approved model, such as shadow climate-adjusted PDs. Formal credit model integration embeds physical risk or resilience variables directly into approved PD, LGD, EAD, affecting regulatory capital calculations. Assessment outputs may be implemented as automatic or discretionary changes to pricing, covenants, or collateral requirements, or through enhanced monitoring. In practice, qualitative or quantitative overlays are often discretionary and rely heavily on manual judgement[49].

This paper focuses on building the evidence and methodology needed for formal credit model integration, which is more systematic but faces a higher governance threshold. It changes the regulatory-approved credit model itself, allowing banks to differentiate between individual borrowers. Formal model integration requires evidence that physical risks or resilience investments affect Probability of Default (PD), Loss Given Default (LGD), or Exposure at Default (EAD).

In practice, the path to integration differs across the credit assessment processes banks use. Large banks typically operate two distinct assessment tracks: collective or automated assessments, where scoring models generate ratings at scale across the bulk of the portfolio; and fundamental or judgement-based assessments, used for higher-value or more complex operations, where analysts conduct case-by-case reviews.

This distinction matters for integration. In fundamental assessments, analysts already have discretion to consider climate and nature factors in their credit judgement, making integration through qualitative scorecards or structured checklists a more immediate step. The harder challenge lies in collective and automated assessments, which process the majority of credit volume but depend on robust statistical evidence to justify model changes. Integrating physical climate and nature risks at this scale requires the kind of validated, borrower-level data and methodology that this paper identifies as the current gap.

The Basel credit risk framework shapes how banks can modify formal credit risk models. Basel is the global prudential framework that sets how banks calculate capital for credit risk. Banks follow either the Standardised Approach, using prescribed risk weights, or the Internal Ratings-Based (IRB) approach, where banks may rely on internal estimates of PD, LGD, and EAD, subject to supervisory standards and approval requirements[50]. In practice, the IRB route is mainly available to larger banks with advanced modelling capabilities.

Smaller institutions that rely on standardised models have less flexibility to adjust regulatory capital at a granular level, since risk weights are externally prescribed. However, this does not limit their ability to integrate physical risks into internal credit decisions. Banks using the standardised approach can,

49. UNEP FI / Global Credit Data (2025), Bridging Climate and Credit Risk.
50. Basel Committee on Banking Supervision (2017), Basel III: Finalising post-crisis reforms.

and increasingly do, incorporate climate-adjusted probability of default estimates from external providers into their internal approval, pricing and risk appetite processes. These adjustments do not change regulatory capital requirements, but they can influence which operations are approved, at what terms, and how the portfolio is steered over time. In Brazil, the DRSAC framework already requires social, environmental and climate risk assessment at the individual operation level regardless of the capital approach adopted, reinforcing that risk integration and capital treatment are separate obligations.

THE KEY IRB RISK COMPONENTS ARE PD, LGD, AND EAD:

01 **PD** captures the likelihood of default and is affected by borrower cash flows, earnings volatility and debt service capacity.

02 **LGD** captures expected loss severity if default occurs and is affected by collateral value, recovery prospects, and insurance coverage.

03 **EAD** represents the exposure outstanding at default and can be impacted by facility drawdowns, working capital stress or restructuring needs.

04 **Expected Loss (EL)** can therefore be expressed simply as **EL = PD × LGD × EAD**[51].

The governance and regulatory burden rise as integration moves toward changes in approved credit models. Portfolio screening, scorecards and qualitative overlays generally require internal governance, documentation and clear policies, but not formal supervisory approval. Shadow PDs and model overlays do not require prior supervisory approval, but they face strong audit and prudential scrutiny[52], especially if they influence pricing or provisioning. Formal IRB model changes carry the highest burden because material adjustments to PD, LGD, EAD or collateral methodologies require robust evidence, independent validation and supervisory pre-approval. In the EU for example, this is through CRR Article 143.

51. Basel Committee on Banking Supervision (2017), Basel III: Finalising post-crisis reforms.
52. ECB. (2024). IFRS 9 overlays and model improvements for novel risks.

1.2.2 Banks are progressing on portfolio-level assessment, but not yet on credit model integration

Banks are more advanced in top-down portfolio assessment than in bottom-up borrower-level integration, largely in response to regulatory expectations. Bank interviews suggest that physical climate risk is often framed around reporting and monitoring. Several banks have identified material sectors and geographies for selected physical hazards, but most have not translated these risks into approved credit model inputs or consistent loan-level decision processes. One banking federation reflected that member bank demand remains more focused on reporting topics than on credit decision integration.

Physical nature risk is further behind physical climate risk in credit integration, even though it can directly affect borrower performance and resilience to shocks. Nature risk is sometimes assessed as not material enough to trigger external action or reporting. Banks may consider nature qualitatively in risk assessment, but this is often not visible externally and rarely translates into formal credit model integration.

Regulatory expectations are pushing banks to assess climate and environmental risks, but most requirements still sit closer to disclosure and risk management than model integration. In Europe, transition risk expectations are the most developed, including Pillar 3 ESG disclosures on carbon-related assets and taxonomy alignment[53]. Physical climate risk requirements are also advancing, with EBA disclosure requirements for exposures subject to chronic and acute climate events[54] and ECB expectations to integrate climate and environmental risks into governance and risk management[55]. Physical nature risk is emerging more gradually, with the EBA Environmental Scenario Analysis Guidelines broadening the frame to environmental risks[56].

Brazil's DRSAC framework is more granular than most comparable supervisory instruments reviewed for this paper and represents an underutilised foundation for credit model integration. Unlike disclosure frameworks that operate at portfolio or sector level, DRSAC requires banks to score Social, Environmental and Climate (SAC) risk at the individual credit operation level, linked to unique loan identifiers (IPOC), with physical climate risk mitigants identified and reported at the individual loan level. This creates a data architecture capable, in principle, of supporting borrower-level PD and LGD analysis. The gap is methodological: the BCB defines what must be managed but leaves the translation into credit parameters to bank discretion, and SAC assessment is not compulsory where banks have not yet developed internal policies.

53. EBA. Implementing Technical Standards (ITS) on prudential disclosures on ESG risks in accordance with Article 449a CRR.
54. EBA. Implementing Technical Standards (ITS) on prudential disclosures on ESG risks in accordance with Article 449a CRR.
55. ECB. Guide on climate-related and environmental risks
56. EBA. Guide on environmental scenario analysis.

Systematic integration into borrower-level credit decisions therefore remains at an early stage. Bank interviews show that institutions need a stronger evidence case before changing formal credit models. One bank is currently analysing whether sustainability attributes, combining climate and nature factors, correlate with farmer default rates in agriculture, and whether the effect is material over credit-relevant time horizons. Survey evidence points in the same direction: only 18% of surveyed banks report incorporating climate risk into IRB modelling[57].

Where banks go beyond portfolio screening, credit integration is usually through overlays or shadow metrics rather than formal model changes. Interview feedback suggests that physical risk assessments are often used only in high-risk sectors and as risk overlays or inputs for loan officer judgement, not as systematic calculations inside approved credit models. Some banks are developing proprietary environmental scoring tools for selected sectors, but these approaches are still evolving and are not yet comprehensively integrated into approved credit models. ECB-observed practices are similar, with banks experimenting with climate-informed shadow PDs alongside regular PDs and qualitative sustainability risk scorecards[58].

Recognition of resilience investments is even less developed, creating an incentive problem for banks and borrowers. Adaptation and resilience (A&R) are core levers for reducing physical risk in credit, but banks rarely recognise them systematically in credit decisions. Interviews suggest this space remains nascent. One advanced commercial bank is actively incorporating A&R into credit decisions in agriculture, but the approach remains sector-specific and early-stage. Another commercial bank assesses A&R at credit manager discretion, but without a clear methodology for decision adjustment. Several development finance institutions have recognised resilience in individual transactions, but the approach is deal-by-deal and dependent on qualitative expert judgement. The result is an incentive gap: borrowers that reduce future risk through credible resilience measures have limited ability to access improved credit treatment. This weakens the incentive to invest, even where resilience could reduce future losses and improve portfolio quality for banks.

Overall, risk and resilience investment integration is uneven across banks, with smaller, more concentrated lenders facing higher constraints. Large international banks generally have more internal resources and stronger analytical capacity. Smaller national or regional banks, especially those concentrated in specific sectors or geographies, often have fewer resources to develop the analytics needed for risk integration, while also having fewer diversification options.

57. United Nations Environment Programme Finance Initiative and Global Credit Data. (2025). Bridging Climate and Credit Risk: Current Approaches and Emerging Trends for Climate-Related Credit Risk Assessment Methodologies—Insights from a Global Survey
58. ECB. Guide on climate-related and environmental risks

1.3 Why now: The commercial case for better risk capture and resilience recognition

The case for action is commercial. Physical risks are becoming more measurable, and early movers are starting to turn resilience investments into a financing opportunity. Banks that can distinguish exposed borrowers from vulnerable ones will be better placed to price risk, preserve lending in exposed sectors and originate new resilience financing.

1.3.1 Risk mitigation and resilience opportunity are two sides of the same credit decision

Better borrower- and asset-level risk integration can improve capital planning, portfolio steering, and pricing where appropriate. If credit models do not reflect material physical risks, banks may underprice exposed borrowers, underestimate provisions for emerging losses and misallocate capital[59]. Meanwhile, more granular integration can support better loan assessment, covenant design, client engagement and portfolio concentration management.

Recognising resilience investments is an emerging commercial opportunity, not only a risk management tool. Adaptation and resilience (A&R) measures can stabilise borrower cash flows, protect collateral and improve recovery capacity. These effects matter for credit metrics and long-term portfolio quality[60]. They also create origination opportunity: banks that can identify credible resilience investments can finance borrower adaptation while improving their own risk-return profile. The market is still early, but first movers are beginning to develop resilience finance offerings. This creates an entry point for banks that do not want to miss this emerging revenue pool.

Early bank examples show resilience finance is moving from concept to product offerings, especially in agriculture and energy.

→ **Standard Chartered** has helped define A&R as an investable category through its 2024 Guide for Adaptation and Resilience Finance, developed with KPMG and UNDRR, which maps more than 100 eligible activities[61]. The bank also announced major adaptation finance deals, including facilitating trade in solar modules resistant to tornadoes and storms in 2025[62] and closing a USD 435 million sustainability-linked revolving credit facility for agriculture supply chains in South America in 2026, together with COFCO International[63].

59. WEF (2020). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy
60. The World Bank, The Triple Dividend of Resilience
61. Standard Chartered, KPMG, UNDRR (2024). Guide for Adaptation and Resilience Finance.
62. Standard Chartered (2025). Press release: Standard Chartered scales finance for resilient infrastructure as economic cost of extreme weather hits over $2 trillion.
63. Standard Chartered (2025). Standard Chartered and COFCO International close USD 435 million Sustainability-Linked Loan with adaptation and social KPIs.

→ **Rabobank** has created a EUR 3bn financing package for Dutch farmers transitioning toward more sustainable business models, with lower interest rates and more attractive terms. By early 2026, EUR 1bn had been financed, including investments in land, crop diversification, soil quality, fresh water storage and drainage[64].

→ **Westpac NZ** offers a Sustainable Farm Loan with a 0.20% margin discount for farmers meeting sustainability and resilience standards within two years, including sustainable water management, land management, biodiversity, climate mitigation and climate adaptation[65]. Since June 2023, the bank has provided NZD 3.58bn through the product[66].

1.3.2 Data, analytics, and regulatory tailwinds are supporting credit integration

Data and analytics are becoming more decision-useful, making borrower-level integration more feasible than it was only a few years ago. Hazard, geospatial, satellite and agronomic data are increasingly available through public and commercial sources. AI can also help turn fragmented data into more usable signals. Goldman Sachs and the MIT IBM Watson AI Lab pilots show how AI can address nature data challenges such as coarse resolution, poor reliability and data gaps. For example, deep occupancy modelling improved species occupancy estimate reliability by 27% across 16 species, while the TerraMind foundation model achieved 95% accuracy in peatland identification and detected around 12 hectares of peatland loss from a 2022 wildfire[67].

Public data platforms are creating a stronger baseline for transparent and scalable risk assessment. In Europe, the Common Agricultural Policy (CAP) monitoring system uses Copernicus Sentinel satellite data, geotagged photos and equivalent data to monitor whether farmers fulfil subsidy commitments. This parcel-level infrastructure could potentially be used beyond compliance, creating a foundation for assessing farm exposure and vulnerability[68]. In Brazil, AdaptaBrasil is a public climate risk platform that consolidates and disseminates information on observed and projected climate impacts. It has been cited by the BCB as a tool for extracting data to estimate the effects of extreme events on companies[69].

64. Rabobank (2026). Rabobank helps farmers invest in a more sustainable future
65. Westpac NZ (2023). Westpac NZ launches Sustainable Farm Loan and Sustainable Business Loan.
66. Westpac NZ (2024). Westpac NZ commits to increasing sustainable lending to $9 billion by 2027.
67. Goldman Sachs, MIT-IBM Watson AI Lab. AI for Biodiversity Measurement: Advancing Nature Finance.
68. European Commission. (2022). Commission Implementing Regulation (EU) 2022/1173 of 31 May 2022.
69. Ministério da Ciência, Tecnologia e Inovação (MCTI). (2023). Banco Central cita AdaptaBrasil como ferramenta para análise dos efeitos de eventos.

Commercial agriculture data and analytics providers are narrowing the gap for credit decision-making.

- **Agroclimatica** is designed for banks and financial institutions, providing agricultural climate risk scores and green credit tools, including climate vulnerability and technical A&R measures that can be linked to credit products[70].

- **Agrotools** supports rural financing and insurance through rapid territory-level analysis of socio-environmental risk, land use, productivity and harvest forecasts. It reports more than R$50bn in analysed and monitored operations for banks and more than 200 million monitored over more than a decade[71].

Credit rating agency analytics are moving toward end-to-end climate-credit translation. These solutions are promising because they are framed in the language of credit risk. Although in practice they are more likely to be used as overlays or decision support tools given the proprietary nature and governance requirements of banks' credit models.

- **Moody's Climate-adjusted Expected Default Frequency (EDF)** links climate physical risks to borrower-level financials and adjusted credit metrics. Its methodology projects aggregate climate damages to the borrower-level using Moody's ESG (MESG) scores[72].

- **S&P Global / Oliver Wyman Climate Credit Analytics** translates climate scenarios into company-level financial drivers and credit-relevant outputs. The tool combines S&P climate scenarios, company financials, and hazard data to estimate impacts on production volumes, prices, costs, and asset values, which are then converted into credit scores and parameters[73].

Regulation is pushing banks closer to borrower-level integration, even where expectations remain qualitative. The ECB's Guide on Climate-related and Environmental Risks expects banks to consider physical climate risks across all relevant stages of credit granting, assess how these risks affect borrower default risk, adjust risk classification procedures at least qualitatively, consider these risks in collateral valuation and monitor sector and geographic concentrations[74].

70. Agroclimatica. Company website.
71. Agrotools. Company website
72. Moody's Analytics. (2023) Navigating Climate Credit Risk: Insights from NGFS III for Corporates.
73. S&P Global Sustainable. Climate Credit Analytics.
74. ECB. Guide on climate-related and environmental risks.

The EBA Loan Origination and Monitoring Guidelines provide a complementary foundation by requiring institutions to incorporate ESG factors into credit risk appetite, policies and procedures[75].

Brazil is also building a more granular supervisory foundation that could support future credit decision integration. BCB's CMN Resolution 4,943 requires banks to consider social, environmental and climate risk in the credit granting, classification and monitoring, including due diligence, counterparty classification, and periodic assessment of guarantees and collateral[76]. The BCB's DRSAC reporting framework adds a more granular reporting foundation by requiring banks to collect risk data at client, operation and project levels[77].

1.3.3 Insurance gaps are increasing residual credit risk, strengthening the case for bank action

Banks have historically managed part of physical risk indirectly through insurance and public risk-sharing mechanisms. As Banks have historically managed part of physical risk indirectly through insurance and public risk-sharing mechanisms. As a risk-transfer mechanism, insurance can reduce borrower income volatility, protect recovery capacity and limit loss severity for lenders. In agriculture, insurance and mutual funds are recognised in EU policy as tools for managing production and income risks linked to adverse weather, pests, disease and market uncertainty[78].

The insurance backstop is weakening as losses rise and protection gaps remain large. EIOPA and the ECB note that only around a quarter of natural-catastrophe losses are insured in the EEA, and that insurance is expected to become less affordable as natural catastrophes become more frequent and severe[79]. In EU agriculture, only 20–30% of climate-related losses are insured[80]. Drought is a particular weak spot: it drives more than half of EU agricultural climate risk, yet remains significantly underinsured, with limited or no coverage in many regions[81].

Insurance adequacy is itself a borrower-level credit risk because banks often lack visibility into whether coverage remains available, affordable and sufficient over the life of a loan. Cambridge Institute for Sustainability Leadership (CISL)'s Resilience-Adjusted Credit Risk report distinguishes three

75. EBA. Guidelines on loan origination and monitoring
76. Banco Central do Brasil (2021). CMN Resolution No. 4,943 on Social, Environmental and Climate Risk Management
77. Banco Central do Brasil (2023), DRSAC – Instructions for Completion (Social, Environmental and Climate Risk Disclosure Report)
78. European Commission – EU CAP Network (2023), Insurance and Mutual Funds for Farm Resilience and Adaptation in the EU
79. EIOPA (2024). The supervisory duty to address insurance protection gaps.
80. European Commission – EU CAP Network (2023), Insurance and Mutual Funds for Farm Resilience and Adaptation in the EU
81. fi-compass / European Commission (2025), Financial Instruments for Agriculture: Insurance Market Analysis (EAFRD)

channels: uninsurability, underinsurance, and affordability[82]. It also notes that visibility varies by facility type: project finance is often closely verified, but other secured lending may rely on borrower confirmation, and unsecured lending can leave banks unable to ascertain a borrower's overall insurance position.

Insurance gaps and adequacy risks create credit white spaces where borrower and lender risk can rise sharply. Where losses are uninsured or only partially insured, more residual risk stays on borrower balance sheets, weakening liquidity and repayment capacity. EIOPA states that insurance protection gaps can increase banks' exposure to physical risk and reduce collateral values, creating a direct credit transmission channel[83]. The EU agriculture insurance study also warns that banks may respond by tightening credit conditions or lowering capital allocations to higher-risk areas, leading to a credit drought[84].

The insurance and credit sectors assess physical risk in fundamentally different frameworks. Insurers express risk as a probability of loss and credit rating agencies as the likelihood of rating migration. No established methodology currently bridges the two. This structural incompatibility means that even where insurers have sophisticated hazard pricing, their models cannot be directly translated into credit parameters.

Banks have a commercial opportunity to measure and manage risk and resilience better, rather than retreat from exposed markets and geographies. The strategic implication is not simply to reduce exposure, but to become better underwriters of physical risk. Hazard, vulnerability and resilience analytics can help banks distinguish borrowers that are exposed from borrowers that are genuinely vulnerable. This can help avoid unnecessary credit restrictions or exits, while protecting portfolios and capturing lending opportunities in markets that peers may withdraw from entirely.

82. CISL (2026). Resilience-Adjusted Credit Risk: Operationalising climate adaptation in financial decision-making.
83. European Insurance and Occupational Pensions Authority (2024), Supervisory Statement on Addressing Insurance Protection Gaps
84. fi-compass / European Commission (2025), Financial Instruments for Agriculture: Insurance Market Analysis (EAFRD)

CHAPTER 2

The transmission chain and barriers to credit integration

2.1 Downside integration: How physical climate and nature risks enter borrower assessment

Physical risks enter borrower credit assessment through cash flows and collateral values, driving changes in PD and LGD. Banks can translate these risks through a clear chain that starts with hazard, exposure and vulnerability, applies damage functions, captures second-order effects and converts the result into credit parameters. Three non-exclusive approaches can support this translation: cash flow and financial ratio analysis, structural credit model extensions (Merton-style), and insurance catastrophe modelling.

2.1.1 Physical risks affect PD and LGD most directly

PD and LGD are the main entry points for credit risk model integration, while EAD is typically affected more indirectly.

1. PD is the most intuitive route because physical risks first affect borrower earnings, free cash flow generation, and debt service capacity.
2. LGD becomes relevant where lending is secured and physical risks impair collateral value, reduce recovery proceeds, or weaken the liquidity of pledged assets.
3. EAD may be affected where physical disruption increases working-capital needs, triggers facility drawdowns, or leads to covenant breaches.

Physical risks affect PD primarily by weakening expected free cash flows and increasing earnings volatility.

PD: PHYSICAL HAZARDS AFFECT BORROWER CASHFLOWS, IMPEDING DEBT SERVICE CAPACITY	
Illustrative free cash flow	**Physical risk impacts**
Revenues	↓ Lower output, lower yields, reduced asset utilisation, business interruption, or disrupted market access.
- Cash operating costs	↑ Increased repair costs, substitute sourcing, higher input costs, or higher insurance costs.
+/- Net interest expense	
- Taxes	
+/- Change in working capital	↑ Larger inventory buffers, delayed receivables collection, or need emergency liquidity needs.
- Capex	↑ Where assets need to be repaired, replaced, hardened, relocated, or adapted to maintain future operations.
Free cash flow / Debt service capacity	↓ Overall, the combined effects erode cash availability to service debt, pushing PD higher.

LGD is impacted where collateral values and recovery prospects are weakened.

LGD: PHYSICAL RISKS CAN REDUCE RECOVERY THROUGH THREE MAIN CHANNELS	
Direct physical damage	Acute events such as floods, storms, wildfires or drought can directly damage collateral or pledged assets.
Market value discount	Chronic exposure such as soil degradation can reduce asset value, particularly where land or property becomes less productive or less insurable.
Increased liquidation costs	Area-wide disasters can reduce market liquidity and increase liquidation costs, lowering recoveries even where the asset is not fully destroyed.

2.1.2 A practical four-step transmission chain links hazards to credit parameters

Banks can translate physical risks into credit parameters through a four-step transmission chain. The chain moves from hazard indicators to damage functions, then to second order effects and finally to credit parameter translation. The output can be applied at different levels of integration, from qualitative overlays and manual rating adjustments to shadow PDs or formal PD and LGD model changes.

01 MAP HAZARD, EXPOSURE AND VULNERABILITY Physical risk is a function of three elements: hazards, exposure, and vulnerability.	. **Hazards** can be drawn from public data sources or vendors, and some banks construct physical risk scores internally by combining data from multiple sources. . **Exposure** requires geolocation of borrower assets, production facilities and critical infrastructure. . **Vulnerability** captures why the same hazard can affect borrowers differently, depending on asset characteristics, production model, and resilience measures. . **As an example,** one bank constructed an internal drought risk score by combining water scarcity data from the Aqueduct score with client-level information on water intensity and energy consumption, producing a client-specific view of drought risk.
02 ESTIMATE DAMAGE CURVES Sector-, commodity-, and geography-specific functions estimate how a hazard affects firm production, asset value, or costs.	. These functions may draw on catastrophe modelling, engineering assumptions, academic evidence (e.g. price elasticity and cost dynamics), historical loss data, or expert judgement. . In agriculture, for example, the same drought indicator can lead to different yield impacts depending on crop type and location.
03 CAPTURE SECOND-ORDER EFFECTS Physical shocks affect borrowers through indirect channels, including supply-chain disruption and reduced market demand or access.	. These effects are often harder to model explicitly and may need to be captured through simplified assumptions or overlays. . They matter because in some sectors they can create more persistent earnings pressure than the initial physical damage.
04 TRANSLATE INTO CREDIT PARAMETERS Adjusted cash flow, EBITDA or asset values are mapped into credit-relevant inputs or parameters.	. Borrower financials are translated into PD, LGD, or rating adjustments. . These outputs can be applied at different levels of integration, from qualitative overlays to formal IRB model changes. . Where incorporated into approved IRB models, these changes can affect capital requirements. How banks implement the resulting signal, for example automatic repricing or discretionary repricing, remains a separate credit-policy decision. . The closer the output gets to approved credit model integration, the stronger the evidence, validation and governance requirements become.

The illustrative results show how drought can reduce borrower repayment capacity, while soil quality, a nature factor, can change farm vulnerability and impact recovery. The case study uses CISL / Robeco's drought stress assumptions, combined with additional Systemiq assumptions, to show the transmission pathway from physical risk to borrower credit quality. DSCR is used as a proxy credit metric because it directly reflects a borrower's ability to service debt and is a core input into credit assessment.

Case study: Soil degradation amplifies drought impact on Brazil agriculture (1/2)

01 MAP HAZARD, EXPOSURE AND VULNERABILITY

. **Hazards**: Drought / dry-season extreme weather event. The CISL / Robeco report assumes that a severe drought reduces average yields by 20%, using observations from La Niña periods, but it does not define the drought in terms of a physical hazard indicator or frequency. For credit model integration, banks would need to specify the drought risk more precisely, for example using SPEI or rainfall deficit, as well as frequency such as a 1-in-10 or 1-in-50 year event.
. **Exposure**: Farming companies operating in Cerrado region.
. **Vulnerability**: Clear distinction between farms on degrading land and on healthy soil, citing that effects can be twice as severe in areas with degradation.

02 ESTIMATE DAMAGE CURVES

Applies academic research to yield impact assumptions.

Scenario	Yield impact	Duration
Average impact	-20% yield	Year 1
Farm on degrading land	-40% yield	Years 1-3
Farm on healthy soil	-10% yield	Years only 1

03 CAPTURE SECOND-ORDER EFFECTS

Adds back second-order market and cost effects.

Driver	Assumption
Crop prices	**+40% in year 2**
Fertiliserprices	**+40% in year 2**
Variable costs for degraded land	**Fall to zero in year 2,** due to planting pause
Land restoration for degraded land	Begins halfway through year 3 to resume full production in year 4

Combined financial impact:
drought has opposite valuation effects depending on soil condition

Farming company archetype	Reported financial impact
Degrading land	~16% market value decline vs no drought
Healthy soil	+ 6% DCF imapct (benefitting from crop price increase)

04 TRANSLATE INTO CREDIT PARAMETERS

PD relevance: Discounted cash flow impact can be translated into Debt Service Coverage Ratio (DSCR), a key input for PD.

Illustrative estimation

Assumptions	
Baseline DSCR	**1.375x**
Baseline CFADSmargin (=EBITDA)	**25.4%**
Starting reveneu	**100 index**
Resulting annualdebt service	**18.47**
Debt service	**Held constant**

Illustrative results

Drought weakens repayment capacity across farms, but soil health can reduce cash flow risk: A farm on degraded land becomes not serviceable in Years 1 and 3. A farm on healthy soil sees DSCR fall to 0.88x in Year 1 but then recover to 3.12x in Year 2 as volumes normalise and prices rise[88].

	No drought	**Stress case dedraded**	**Stress case healthy soil**
Pre-drought	1.375x	1.375x	1.375x
Year 1	1.44x	-0.72x	0.88x
Year 2	1.50x	1.47x	3.12x
Year 3	1.57x	-0.14x	1.57x
Year 4	1.64x	1.64x	1.64x

88. Key assumptions: Baseline DSCR 1.375x; Baseline CFADS margin is equal to EBITDA at 25.4%; starting revenue is indexed at 100; debt service is held constant.

2.1.3 Three methodological approaches are relevant to credit model integration

Three methodological approaches can support the hazard to credit translation, and banks are likely to combine them in practice. The approaches differ in intermediate outputs: borrower free cash flow impact, asset-value shock or expected loss. In practice, they should be treated as complementary tools for building the hazard to credit translation, rather than mutually exclusive solutions.

1. CASH FLOW AND FINANCIAL RATIO APPROACH

The cash flow and financial ratio approach is often a practical route for private borrowers, but it is data-intensive and depends heavily on sector and geography assumptions.

1. First, location-specific hazard data are mapped to borrower operations, assets, and collateral exposure.
2. Then, damage functions are used to estimate impacts on company revenue and costs, using historical evidence, academic literature, and sector expertise and judgement.
3. Second-order impacts, including changes in supply chain, input price, and demand effects are also incorporated, often based on assumptions.
4. Finally, adjusted financials, such as EBITDA, free cash flow, or yield losses, are translated into credit-relevant outputs such as PD or LGD.

2. STRUCTURAL CREDIT MODEL EXTENSIONS (MERTON-STYLE)

Structural credit models translate physical risks through asset value. In a Merton-style model, a firm defaults when the value of its assets falls below its liabilities. Physical risk can therefore be modelled as a shock to the firm's asset value or volatility, with the resulting change in asset value distribution translated into a PD adjustment.

Moody's climate-adjusted Expected Default Frequency (EDF) is one example of this approach. It translates climate hazards into borrower-level asset value impacts, then into adjusted default frequency estimates.

STEP 1

Define scenarios and hazards. Moody's uses climate scenarios, including NGFS, MAS and IPCC pathways, to model both acute physical risks and chronic risks.

STEP 2

Estimate aggregate climate damage. High-level models estimate climate-driven damages as a share of global GDP under different warming scenarios, creating an aggregate view of potential physical risk impact.

STEP 3

Allocate damage to the borrower level. Aggregate damages are mapped to the locations of a borrower's most exposed assets using Moody's ESG scores and external data, reflecting operational, supply-chain and market risk exposure.

STEP 4

Translate asset value impacts into credit. The model estimates how comparable events have historically affected asset values, then adjusts the borrower's asset value distribution to produce a climate-adjusted EDF, or PD, over a 1 to 30 year horizon[89].

The Ecosystem Service Degradation Sensitivity Indicator (EDSI) framework, developed by De Nederlandsche Bank, applies a similar asset-value logic to nature risk. It provides a theoretical framework for translating ecosystem service shocks into asset depreciation and credit impact[90].

STEP 1

Assess firm-level nature vulnerability. The framework combines sector-level ENCORE dependencies, EXIOBASE multi-regional input-output data for supply-chain dependencies, and a country-level nature degradation index to reflect where ecosystems are already degraded.

STEP 2

Translate ecosystem shocks into asset value impacts. The estimated nature-related shock is applied to firm asset values.

STEP 3

Estimate changes in default risk. The asset value shock is fed into a Merton-style model to estimate the drop in distance to default, recalculating asset values relative to liabilities and revaluing PD and LGD.

STEP 4

Aggregate impacts at bank level. Firm-level credit impacts are aggregated to assess changes in an institution's prudential ratios, notably CET1.

89. BIS (2025) Incorporating physical climate risks into banks' credit risk models.

90. Gallet, S., Hendricks, A. and Prodani, J. (2024), The Ecosystem Service Degradation Sensitivity Indicator (EDSI): A New Framework for Understanding the Financial Risk Repercussions of Nature Degradation.

The main limitation of EDSI is that it is less granular than borrower-level credit assessment requires. It uses hypothetical shocks and sector-level ENCORE dependency scores that do not include a geographic component, meaning banks would need to enrich the framework with asset-level and location-specific data.

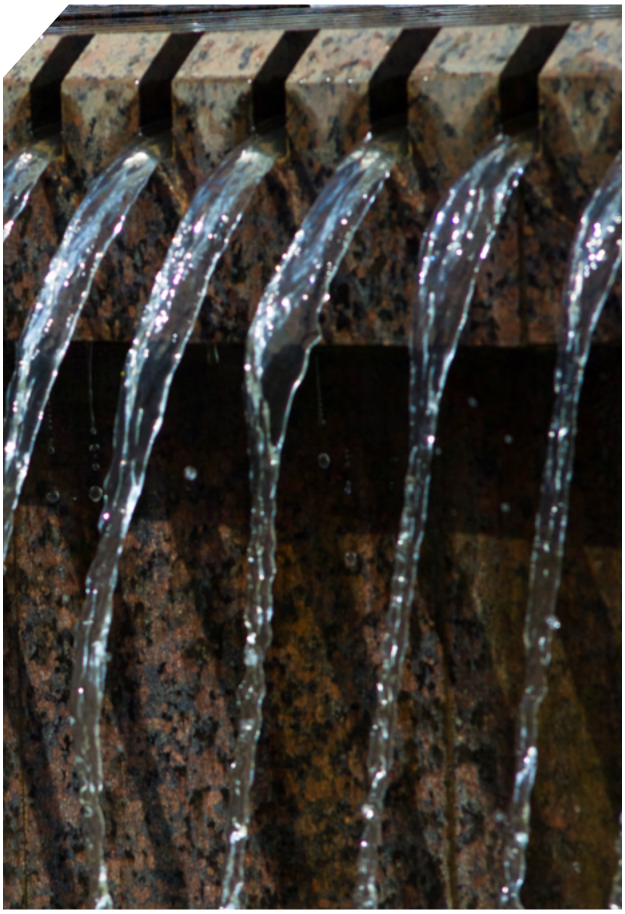
3. INSURANCE CATASTROPHE MODELLING

Insurance catastrophe modelling provides a forward-looking view of expected and tail event losses. Catastrophe models combine hazard, exposure and vulnerability, often using large stochastic event sets, to estimate metrics such as Annual Average Loss (AAL) and Probable Maximum Loss (PML). These outputs have the potential to help banks understand the scale and distribution of physical risk in asset-heavy, location-specific sectors such as agriculture, energy, and utilities.

The value of catastrophe models is that they go beyond historical observations. Catastrophe models use stochastic event sets: large collections of statistically representative synthetic events based on the joint distribution of location, intensity and spatial extent. This allows models to estimate risk across a plausible range of event frequencies and severities[91].

Catastrophe models are also useful because they can capture spatial correlation. For banks, this matters because physical shocks can affect multiple borrowers at the same time. For example, a flood model can estimate not only whether two locations are exposed to flooding, but the likelihood that both are affected by the same event. This is directly relevant for portfolio concentration risk.

However, catastrophe model outputs do not translate directly into PD or LGD. AAL and PML can help estimate expected physical loss and tail risk, but banks still need a credit translation layer that connects physical losses to borrower cash flows, collateral impairment, and default risk.



91. Climate Financial Risk Forum and GARP Risk Institute. 2025. A Risk Professional's Guide to Physical Risk Assessments: A GARP Benchmarking Study of 13 Vendors. October 2025.

2.2 Upside integration: how resilience could be reflected in credit decisions

Capturing the downside is only half of the credit case. Resilience investments can reduce borrower vulnerability, stabilise cash flows, and protect collateral, giving borrowers a different forward-looking risk profile than their historical performance alone would suggest. Banks that can identify and recognise that difference are better underwriters and can open new origination opportunities in the process. This also matters for preserving access to finance: resilience recognition creates a channel for banks to finance the investments that improve borrower quality and portfolio resilience, rather than simply excluding vulnerable segments.

2.2.1 Case study: Irrigation system against water scarcity – Brazil coffee production

The illustrative results show how irrigation can improve borrower repayment capacity by reducing water-deficit vulnerability and increasing farm cash flow. The case study draws on Voltolini et al[92], which evidences the yield differences between rainfed and irrigated coffee systems, and applies Systemiq cash-flow and debt ratio assumptions to show the transmission pathway of resilience investment. According to our illustrative estimation, irrigation could generate up to USD 226.5k of net annual cash-flow uplift for a 50ha arabica coffee farm in Cerrado Mineiro and improve DSCR from 1.375x to 1.89x in the best-case scenario. This could support lower PD risk, while higher land productivity may also create a potential LGD benefit through stronger collateral value.

92. Voltolini et al., 2025. Agronomic Performance of Irrigated and Rainfed Arabica Coffee Cultivars in the Cerrado Mineiro Region.

01

MAP HAZARD, EXPOSURE AND VULNERABILITY

. **Hazards**: Seasonal water deficit during the dry months (April to October) can lead to evapotranspiration exceeding precipitation across 21 ten-day periods.
. **Exposure**: 50 ha Arabica coffee farm in Cerrado Mineiro, a major Brazilian coffee region exposed to recurring water stress.
. **Vulnerability**: Irrigation system type is a key factor: Rainfed systems are more vulnerable to yield loss from water deficit, while drip or centre-pivot irrigation reduces this vulnerability.

02

ESTIMATE DAMAGE CURVES

Direct yield impact from resilience
Increase from 36 to 50 bags/ha, equivalent to ~39% increase or +700 bags per year for a 50 ha farm.

Processing yield benefit
Improved from 557 L/bag to 537 L/bag, meaning less harvested coffee volume is needed to produce one bag.

SYSTEMIQ MODELLING

Assumptions
Coffee price = USD 375/bag; irrigation CAPEX = USD 300k; annual maintenance = 12% of CAPEX or USD 36k /year.

Illustrative net annual cashflow
+USD 225.6k /year for a 50ha farm.

03

CAPTURE SECOND-ORDER EFFECTS

Potential LGD channel
Irrigation could improve land productivity and the value of pledged farmland, creating a potential LGD benefit through higher collateral recovery.

Evidence direction
In areas of intensive agriculture in Brazil, the presence of irrigation or the technical infrastructure required for installation can increase market value. In some regions, the difference between rainfed and well-developed irrigated land can be as much as 20-50%, depending on the crop and income generated.

04

TRANSLATE INTO CREDIT PARAMETERS

PD relevance: Higher net free cash flow would improve DSCR ratio, a core input to PD. The following estimation illustrates potential impact.

Assumptions	
Baseline DSCR	**1.375x**
Baseline CFADS margin	**30%**
Implied baseline annual debt service	**USD 147.3k**
Irrigation financing	**5-year debt; 10%**
Implied debt service on irrigation CAPEX	**USD 79.1k**

Illustrative results
Irrigation improves cashflow and brings DSCR up from 1.375x baseline to 1.89x.

	Before irrigation	After irrigation
Gross revenue	USD 675k	USD 937.5k
CFADS	USD 202.5k	USD 429.0k
Annual debt service	USD 147.3k	USD 226.4k
DSCR	1.375k	1.89x[94]

93. Investidor Rural, 2026. Valorização de terras agrícolas no Brasil: variáveis de valorização para 2026.
94. Key assumptions: Baseline DSCR 1.375x; Baseline CFADS margin 30%; Implied baseline annual debt service USD 147.3k; irrigation financing by 5-year debt at 10% interest rate.

Key metrics for linking resilience to credit decisions

The case studies above illustrate the credit transmission pathway for resilience, but translating this logic into systematic credit decisions requires a defined set of metrics. Banks need indicators that are measurable at the borrower level, linkable to specific resilience measures, and expressible in the language of credit parameters. The table below sets out a practical starting framework, organising metrics by credit channel and resilience type.

CREDIT CHANNEL	METRIC	WHAT IT CAPTURES	RESILIENCE LINK
PD - cash flow	Debt Service Coverage Ratio (DSCR)	Borrower ability to service debt from operating cash flows	Resilience measures that stabilise or increase revenue (e.g. irrigation, drought-resistant crops) improve DSCR and reduce PD
PD - earnings volatility	Revenue-at-risk under hazard scenario	Cash flow loss under a defined physical stress event (e.g. 1-in-10 year drought)	Measures that reduce yield sensitivity to hazard events lower revenue-at-risk and compress earnings volatility
PD - operational continuity	Days of business interruption per hazard event	Expected downtime from physical shocks	Asset hardening, flood protection and backup systems reduce interruption duration and frequency
LGD - collateral value	Loan-to-value ratio under physical stress	Collateral impairment under hazard scenario	Resilience infrastructure (e.g. irrigation systems, drainage) can increase or protect land and asset values under stress
LGD - recovery prospects	Collateral liquidity discount in stressed markets	Marketability of pledged assets post-event	Assets with resilience credentials retain liquidity in stressed conditions; unprotected assets face deeper discounts
LGD - insurance adequacy	Insured share of expected loss	Proportion of physical loss covered by insurance	Adequate and maintained insurance coverage reduces residual loss on bank in default scenarios

No single metric is sufficient on its own, and the relevant set will vary by sector, geography and hazard. For agriculture, DSCR and revenue-at-risk are strong entry points. For secured infrastructure lending, collateral impairment and insurance adequacy carry more weight. The value of this framework is not comprehensiveness but consistency: if banks agree on a core set of credit-relevant resilience metrics, even at sector level, it becomes possible to compare borrowers, build an evidence base for model validation, and engage supervisors with concrete, auditable outputs rather than qualitative assertions.

2.2.2 Insurance offers a precedent for recognising resilience as a risk differentiator

Insurers already operationalise resilience measures through sector-specific underwriting conditions. Through policy requirements and coverage conditions, insurers assess whether clients have credible protections in place before deciding whether to insure, restrict coverage, reduce claims or decline cover. In agriculture, US crop insurance rules reduce indemnity where farmers do not follow recognised "good farming practices," including prudent agronomy, pest and disease control, and accepted production methods[95]. In energy, insurer guidance is explicit. SCOR's renewable energy underwriting handbook sets out expectations: wind projects should maintain lightning protection and solar projects in hail-prone areas should use hail-rated panels[96]. HSB Munich Re highlights vegetation control, surge protection, and elevation and drainage for ground-mounted PV installations[97]. The lesson for banks is clear: insurers have already developed practical, sector-specific views on which protections could reduce loss.

Insurance vulnerability functions provide a second precedent because they quantify the financial difference between protected and unprotected assets. A vulnerability curve describes the relationship between hazard intensity and loss. Swiss Re states that vulnerability modeling combines exposure data with asset characteristics and protection measures, drawing on claims information, damage observations, expert opinion and engineering judgement[98]. Protection can be reflected in several ways: reducing hazard intensity at the asset, such as flood defenses lowering flood depth, lowering physical susceptibility, such as lightning protection, decreasing operational loss or improving salvage and recovery. This provides a useful starting point for banks seeking to differentiate borrowers by resilience measures, not only hazard exposure.

Public examples show that resilience measures can materially reduce expected losses. In the French Meadows wildfire resilience insurance project, ecological forestry reduced expected annual wildfire loss by 44%, with reductions ranging from 10% to 84%[99]. FM reports a similar operational resilience effect for flood risk: facilities with well-organised flood emergency response plans sustain nearly 70% less damage and resume operations sooner than locations without adequate plans[100]. These examples show that resilience can change the expected loss profile in measurable ways.

Insurers already have a quantitative method for distinguishing protected from unprotected risk. While insurance metrics such as AAL and PML do not translate directly into credit parameters, banks can adapt their underwriting logic and vulnerability methods into credit-relevant measures of resilience.

95. USDA Risk Management Agency. Good farming practices protect your investment in crop insurance.
96. SCOR. (2017) Risk control practice: Guidance occupancy: Renewable Energy (Engineering / Property).
97. HSB Munich Re. Underwriting and loss control considerations for solar photovoltaic system.
98. Swiss Re. NatCat Modelling Engine.
99. Nature. Wildfire resilience insurance: quantifying the risk reduction of ecological forestry with insurance.
100. FM. Creating a flood emergency response plan.

2.3 Why integration is still limited and the barriers to scaling

Four barriers limit the scaling of physical risk integration into credit decisions. Banks need borrower-level data that is granular and reliable, verifiable methodologies that translate hazards into credit impacts, regulatory clarity on acceptable model treatment, and stronger internal and industry alignment. These barriers are connected: weak data limits methodology, weak methodology limits regulatory acceptance, and regulatory uncertainty reinforces first-mover concerns.

2.3.1 Data constraints limit borrower-level assessment

Banks often lack the hazard and exposure granularity needed for borrower-level credit decisions. ECB good practice analysis shows that many institutions can allocate exposures to regional units, but not to asset-level or client-level geo-coordinates. For corporate borrowers, headquarters location is not enough. Banks need the location of production sites, collateral, facilities and critical infrastructure to understand where value is actually exposed[101]. Interview insights suggest that this constraint tends to be sharper in emerging markets, where data infrastructure is often less complete, less standardised and harder to verify.

The other core data barrier is that many borrowers, especially SMEs, do not hold verified location-level information that determine their exposure and vulnerability. At minimum, scalable borrower-level integration requires verified data on site location, asset characteristics, production model and resilience measures. For flood risk, for example, relevant vulnerability indicators include building type and ability to withstand damage. Bank interviews suggest that this is difficult for private SMEs, where borrower-supplied data can be incomplete, inconsistent or hard to verify. Where precise data is unavailable, banks may need to establish a hierarchy of proxies, such as municipality-level exposure, farm registries, satellite data or sector averages.

101. European Central Bank. 2026. ECB report on good practices for climate and nature-related risk stress testing. ECB Banking Supervision, May 2026.

Physical climate data is more mature than physical nature risk data. Hazard data for floods, drought, heat and storms is increasingly available at meaningful resolution, while nature risk assessment remains less developed. Biodiversity and ecosystem-service risk are inherently spatial, but many widely used tools remain too high-level for borrower-level credit integration. ENCORE is a useful starting point for identifying sector-level dependencies and adds country- and sector-level supply chain exposure. However, banks still need location-specific details and borrower vulnerability data for credit assessment[102]. This does not mean physical climate and physical nature risks should be treated separately. The practical entry point is the climate-nature nexus. Agriculture illustrates this: drought risk is not only a climate hazard, but also shaped by soil health.

Even where data exists, reliability is a concern and banks lack clarity on which indicators are decision-useful. A benchmarking study of 13 physical risk vendors found a large spread in hazard estimates, with some assets assessed as highly exposed by one vendor and not exposed by another[103]. This creates a practical risk that banks select indicators or vendors that generate weak credit signals. Banks need to know which metrics best predict borrower financial performance for a specific crop, region or value chain, and interviews suggest that this is not yet well established. This is particularly challenging where indicators rely on proxies or vendor methodologies that are not sufficiently standardised or validated for model use. The issue is therefore not only data availability, but confidence in decision-useful information: banks need governance processes to assess source quality.

Public data platforms are improving, but remain insufficient for borrower-level credit integration. Public platforms are valuable because they improve transparency for supervisors and accessibility for banks. In Brazil, the BCB has used publicly accessible climate data, such as AdaptaBrasil and ThinkHazard, in its own risk analysis. This provides a useful starting point, but the granularity of the data still falls short of what is needed to differentiate between individual borrowers.

2.3.2 Methodological gaps limit translation into credit parameters

The core methodological gap is converting hazards into first and second-order effects in a defensible way. Bank interviews highlighted that the impact pathways are highly sector- and region-specific and remain largely assumption-driven. Second-order effects, which could offset each other, are difficult to model: in agriculture, for example, a physical shock may reduce production volumes but increase market prices, making the net impact on borrower revenues hard to estimate. The UNEP FI / GCD survey similarly identifies the lack of methodology to map climate risk drivers to financial risk drivers as a key remaining gap[104]. Without this bridge, physical risk analysis remains a screening tool rather than a driver of PD or LGD.

103. Climate Finance Risk Forum. (2025) A Risk Professional's Guide to Physical Risk Assessments.
104. UNEP FI / Global Credit Data (2025), Bridging Climate and Credit Risk.

Physical nature risk assessment creates a scale problem because the relevant data does not sit at one level. Some inputs need to be assessed at farm-polygon or asset level, but there are also interactions occurring at landscape or biome level. This differs by type of risk: soil health may be highly farm-specific, while water and biodiversity risks often depend on wider ecosystem condition. As a result, banks cannot rely on a single generic nature indicator; they need risk-specific transmission chains and clear rules for where the assessment boundary should sit.

Physical climate and physical nature risks should not be treated as separate data tracks, as they interact and create feedback loops. Assessment methodologies therefore need to capture the relationships between physical hazard and nature-related vulnerability or resilience factors, including ecosystem tipping points. Some banks are exploring framing nature risk as vulnerability or resilience modifiers that amplify or reduce physical climate impacts, rather than as standalone risks.

Credit tenor is structurally short relative to the horizon over which physical risks materialise. Most lending is priced and reviewed over one to five years, while physical climate and nature risks unfold over ten to thirty years. This mismatch limits the incentive for banks to price resilience today, since the credit relationship may end well before the risk being priced would materialise.

Resilience investment recognition is less developed than downside risk integration. Bank interviews reveal the lack of a scalable approach for identifying which measures materially reduce risk, evidencing their impact and monitoring residual risk. The main challenge is a counterfactual problem: banks need to understand what would have happened without the resilience measure and how much loss the measure avoided. This is difficult because comparable backward-looking data is limited and often held by insurers. It is further complicated by the fact that resilience strategies are highly context-specific. A measure that reduces risk in one geography, sector or production system may not work in another. Without a credible baseline and local evidence of effectiveness, resilience investment recognition remains qualitative and difficult to scale.

2.3.3 Regulation points toward credit integration, but does not provide model guidance

Regulators increasingly expect banks to consider physical climate and environmental risks in credit processes, but do not yet require systematic model integration. European and Brazilian regulators expect banks to consider these risks in credit granting, classification, monitoring and risk management. However, they do not prescribe how banks should translate hazards or resilience into credit parameters. Banks therefore retain discretion over whether and how to reflect these risks in credit models.

Published methodological support is limited, leaving banks to develop approaches independently. Supervisors provide limited guidance on how to quantify hazards, damage functions, second-order impacts or resilience benefits. BIS identifies this as a core barrier, noting the absence of generally accepted industry models for incorporating physical risk factors into credit risk, despite the need for such models in capital requirements, loan loss provisions and loan pricing[105].

Changes to approved credit models face a high supervisory bar under the Basel framework. The Basel framework does not provide a dedicated capital treatment for climate or nature factors. Any risk or benefit must flow through existing channels such as PD, LGD, EAD or collateral value. For IRB banks, there is conceptual flexibility to reflect physical risk or resilience within existing modelling architecture, but banks must provide robust evidence linking these factors to approved credit parameters, which are subject to supervisory approval. Smaller banks that rely on standardised models face limited options because regulatory risk weights are fixed.

Resilience recognition faces a regulatory asymmetry. Supervisors increasingly encourage banks to identify and integrate downside risk, at least qualitatively, but provide less guidance on how credible resilience investments could be recognised. In principle, resilience benefits could flow through the same IRB channels, but in practice, banks are struggling to define eligible measures, estimate avoided losses and assess residual risk for regulatory approval. The EU has opened a narrow potential channel for upward revaluation through CRR3 property collateral valuation. Overall, this creates an uneven incentive: banks are pushed to recognise downside risk, but have less clarity on how to recognise borrowers that reduce that risk through credible measures.

2.3.4 Industry misalignment and internal bank barriers slow integration

At the industry level, banks face a first-mover problem when pricing physical risks ahead of peers. More risk-sensitive pricing can create a near-term commercial disadvantage if higher spreads or tighter terms push exposed clients toward less advanced competitors. Bank interviews suggest that institutions with stronger analytics capabilities see market alignment as a constraint: without peers moving in parallel, it can be difficult to reclassify borrowers even where the risk case is increasingly understood.

Capital uncertainty compounds the incentive problem. More conservative physical risk estimates may increase provisions or risk-weighted assets under existing prudential frameworks. In the absence of consistent supervisory expectations or market standards, individual banks have limited basis for moving first.

Internal alignment is also a material barrier. Banks typically organise credit risk management across three layers: the front office originates loans, risk team sets policies, and audit provides assurance.

105. BIS (2025) Incorporating physical climate risks into banks' credit risk models.

Embedding physical risks into credit decisions requires coordination across these lines, as well as support from sector experts, sustainability, data and governance functions. Bank interviews suggest that sustainability teams are often more aware of the need for integration, but translating the issue into credit language and socialising it across the bank takes time. For resilience investments, several banks indicated that assessment often remains with the front office on a case-by-case basis rather than being systematically assessed by credit risk teams.

A further internal barrier is the absence of active CRO sponsorship. Physical risk integration requires changes to credit policies, approved models and resource allocation. Decisions that sit with risk management leaders, not with sustainability or ESG functions. Where that leadership is absent or passive, integration stalls at the portfolio screening and disclosure layer: sustainability teams may be aware of the issue but lack the authority to mandate model changes, reallocate analytical resources or drive buy-in across the front office and the board.

Internal buy-in depends on strong evidence that physical risks are material for near-term credit outcomes. Severe physical events can be low frequency, which makes it harder to build proof points of immediate credit impact. Reflecting physical risk in credit decisions may imply higher spreads or tighter terms, which can create resistance from internal teams and require sustained advocacy, training and senior sponsorship. Until impacts are clearly linked to material near-term earnings, some banks may continue to treat physical risks as scenario analysis, disclosure or reputational issues rather than day-to-day credit decision risks, particularly in the current political environment. Resilience recognition can help shift the conversation: if resilience investments can demonstrably reduce PD or LGD, banks can move from penalising exposed borrowers to financing and rewarding risk reduction.

From a development finance perspective, better risk analytics can create access to finance concerns. More granular physical risk assessment may lead banks to reduce lending or raise prices in vulnerable sectors or regions, including agriculture, where lending is already conservative. This is an active concern for development finance institutions, and reinforces that downside integration needs to be paired with resilience investment recognition and financing solutions that help borrowers reduce risk rather than simply absorb higher costs.

Without a complementary real-economy policy track, tighter credit terms alone can produce adverse distributional outcomes, burdening the most exposed borrowers with higher costs while leaving their underlying vulnerability unchanged.

CHAPTER 3

What needs to happen next to accelerate progress

This chapter presents three unlocks that can address the four connected barriers identified in the previous chapter. The first unlock focuses on creating a shared view of data needs and gaps, and applying that to strengthen public data infrastructure. The second focuses on methodology sharing and collective evidence-building within banking and across insurance, DFIs and MDBs. The third focuses on achieving regulatory clarity. Coordination is embedded across all three because the first-mover problem can only be reduced if banks move together.

The industry is not starting from zero: existing initiatives provide building blocks across data, methodology, and regulatory dialogue. OS-Climate and PhysRisk support open-source physical climate risk analytics for bottom-up calculations across large numbers of individual assets. A-Track also provides relevant building blocks for nature integration, including work on biodiversity information pathways and natural capital assessment and accounting. The Institutional Investors Group on Climate Change's (IIGCC) Physical Climate Risk Appraisal Methodology (PCRAM) 2.0 provides practical guidance for integrating physical climate risk into investment appraisal and asset value assessment, particularly for real assets and infrastructure. The European Banking Federation (EBF) C-ESG Risk Roundtable supports banking peer and supervisory exchange on physical risk, while the International Association of Credit Portfolio Managers (IACPM) provides forums for credit portfolio managers on ESG topics. However, most initiatives remain stronger on portfolio assessment, disclosure and broad ESG risk management than on borrower-level credit model integration.

The next phase should focus on targeted, pre-competitive action rather than broad new workstreams. Agriculture in Brazil and Europe could be the first proof point because it combines strong credit relevance, active supervisory attention and relatively tractable data infrastructure. A successful proof point would build momentum and create a replicable pathway for other exposed sectors and geographies.

Data	Building a decision-useful data foundation and surface gaps
Methodology	Share methodological approaches across banking and other credit-relevant sectors
Regulations	Achieve regulatory clarity on physical risk models
Industry Coordination	Increased coordination is embedded across all three unlocks

Unlock 1 / Build a decision-useful data foundation and surface gaps

Banks and regulators need a shared view of which physical climate and nature data can support credit decisions, and where the gaps remain. The objective is not to create a single dataset for all banks, but to clarify what minimum inputs are needed for portfolio materiality screening, borrower-level overlays, quantitative shadow metrics and eventual model integration. This should cover hazard and ecosystem exposure data, supply-chain exposure and dependency data, and borrower-reported vulnerability information.

The near-term output should be a shared data gap analysis, starting with agriculture in Brazil and Europe. This would distinguish datasets that are already useful for borrower-level integration. It should also identify what data is commonly unavailable, where proxies are needed, and where public data infrastructure needs to be improved so banks and supervisors have a transparent, verifiable baseline.

STEP 1 / COMPARE THE DATASETS AND VENDORS BANKS ALREADY USE

Banks should confidentially share, through a neutral convener, the types of datasets and vendors they currently use for hazard, exposure, vulnerability and resilience assessment. This should include commercial physical risk vendors, public hazard maps, open-source tools, ecosystem-condition datasets and supply-chain data sources. The comparison should also identify which inputs banks view as sufficient for different use cases: materiality screening, qualitative overlays, quantitative shadow metrics or formal model integration. CISL's Resilience-Adjusted Credit Risk report provides a useful reference point, identifying potential sources such as Jupiter Intelligence, XDI, Moody's RMS, Environment Agency flood maps, CDP supply-chain data and input-output models.

STEP 2 / IDENTIFY COMMON DATA GAPS AND RELIABILITY ISSUES

The shared review should identify which hazards, ecosystem indicators and borrower attributes are commonly unavailable or require proxies, and how this constrains the level of integration banks can credibly pursue. Where data exists, banks should assess common limitations, such as significant inconsistencies across vendor estimates, black-box methodologies, or inconsistent resolution.

STEP 3 / SHARE APPROACHES TO BORROWER-LEVEL DATA COLLECTION AND VERIFICATION

Banks do not need to share proprietary borrower data, but they should share how they collect, verify and use it for exposure and vulnerability assessment. This includes data on company site and asset location, production models and resilience measures. The goal is to understand which information is often incomplete and develop acceptable proxies, especially for SMEs and private borrowers where data availability and verifiability is cited as a common challenge during interviews.

STEP 4 / FEED THE GAP ANALYSIS INTO IMPROVING PUBLIC DATA INFRASTRUCTURE

The output should be used to guide public institutions and data providers on which data layers need to be built or strengthened. Public data infrastructure matters because it creates a more transparent baseline for regulatory assessments and a level playing field across banks. In Brazil, a practical starting point is improving interoperability between AdaptaBrasil, ThinkHazard and the Atlas Digital de Desastres, so that forward-looking climate risk indicators, global hazard screening and historical disaster records can be combined to better support borrower-level assessment. For physical nature risk, this should ideally include regional ecosystem-condition and supply-chain data to support first and second-order effects estimation. Country-level input-output tables are useful for screening, but regional tables would help banks assess how ecosystem degradation in production regions transmits through companies and value chains. Brazil is a clear example: degradation in key agricultural biomes such as the Cerrado can affect both local farmers and wider companies whose supply chains depend on their production.

Partners needed

→ **Banking federations:** Febraban in Brazil and the EBF in Europe can coordinate participating bank inputs while protecting confidentiality, and translate the data gap analysis into supervisory and public-data priorities.

→ **Conveners:** UNEP FI can provide an international coordination layer. The Science for Evidence-based and Sustainable Decisions about Natural Capital (SELINA) network could be engaged on the nature dimension in Europe, given its focus on improving the use of biodiversity, ecosystem condition and ecosystem service information in decision-making.

→ **Central banks and supervisors:** The BCB and ECB should help assess which public or commercial data sources are credible enough for supervisory use. Both are already pushing banks toward more granular climate and environmental risk assessment. In Brazil, where the BCB has already referenced public data sources for climate risk analysis, it could also play a direct role in addressing interoperability gaps across public-data platforms.

→ **Public and private data providers:** Data providers should be involved both as subjects of the assessment and potential partners in developing the additional data layers. The aim is not to replace commercial analytics, but to identify where public datasets can provide a common baseline and where private providers can add decision-useful granularity.

Unlock 2 / Share methodological approaches across banking and other credit-relevant sectors

Banks need methodologies that translate physical risks into borrower financials and credit parameters in a transparent and defensible way. The priority is not to develop one generic model, but to test specific hazard-sector-geography combinations with a strong climate-nature nexus where transmission channels are clear, data is relatively available and resilience measures can plausibly reduce risk.

The immediate output should be a sector-specific methodology playbook for priority use cases, starting with agriculture in Brazil and Europe. This should cover downside risk integration and resilience recognition: how physical risk affects borrower financials, PD, and LGD; and how credible resilience investments can reduce vulnerability. The two should be developed together because resilience recognition can turn a conversation about tighter pricing, which may see bank internal opposition, into a commercial opportunity. A methodology developed for a specific sector and geography could become a replicable proof of concept that other exposed sectors can build on.

STEP 1 / START WITH BANKS' OWN PORTFOLIO MATERIALITY ASSESSMENTS

Banks should first identify where they have material exposure to sectors and geographies with clear physical risk transmission channels and meaningful A&R potential. The starting point may need to be exposure-based rather than default-based. As noted by CISL, low observed climate-related bad debts and classification or attribution challenges are barriers: losses or defaults may be recorded under broad categories such as operational or market issues rather than climate-related credit losses[107].

STEP 2 / DEVELOP SHARED INDUSTRY METHODOLOGY APPROACHES WITHOUT SHARING PROPRIETARY MODELS

Banks with overlapping priorities should share high-level, non-proprietary outputs from their materiality assessments, such as priority hazards and crop-region pairs for agriculture. This would first help establish whether a given risk is material, creating a larger evidence base than any single bank can build alone. Then, banks should compare how they address common methodological challenges, such as time-horizon mismatch, feedback loops between physical climate and physical nature risks, and second-order value-chain effects. On resilience, banks should compare approaches for identifying eligible measures, estimating avoided losses, and translating financial benefits into credit metrics. This approach allows banks to learn from each other and sharpen methodology while preserving proprietary model architecture.

107. CISL (2026). Resilience-Adjusted Credit Risk: Operationalising climate adaptation in financial decision-making.

STEP 3 / BUILD A COLLECTIVE EVIDENCE BASE FOR MODEL GOVERNANCE

A critical output should be evidence that physical risk and resilience investment correlate with credit-relevant outcomes. Individual banks rarely have enough observations to validate this alone. For example, physical nature risks often operate at a landscape level, affecting multiple farms simultaneously. Combining data across banks could allow for a more complete understanding of these risks than assessing at the individual plot level alone. A coordinated programme could use anonymised portfolio observations and case-study reconstruction to test the extent to which hazard exposure and resilience measures are associated with changes in borrower financials. This would generate evidence for bank internal governance and supervisors without requiring banks to disclose sensitive loan-level data.

STEP 4 / DRAW ON ADJACENT-SECTOR METHODS THROUGH CROSS-INDUSTRY SHARING

Banks should draw on insurance, credit rating agency and DFIs' / MDBs' experience. Insurers and reinsurers hold damage-function and vulnerability estimation expertise, as well as backward-looking claims data that can help assess the financial effect of hazards and resilience measures. Credit rating agencies already translate climate hazards into credit-language outputs, such as asset-value shocks and adjusted default risk. DFIs / MDBs can contribute practical experience from emerging markets, where they have combined financial and non-financial data to link resilience to borrower repayment capacity. These organisations are particularly relevant as they lend to commercial banks and have a direct interest in improving bank risk management and resilience finance practices.

Partners needed:

→ **Banking federations and industry conveners:** Within banking, Febraban and EBF can coordinate regional participation. While UNEP FI and broader cross-industry groups including the Global Association of Risk Professionals (GARP) and the Climate Financial Risk Forum (CFRF) can support broader risk-practitioner engagement. ICMA could be engaged on the resilience finance dimension to help align definitions and eligibility, building on its past work on sustainable bond principles and guidance on nature-related bonds.

→ **Insurers and reinsurers:** They hold the most mature hazard-to-loss methods and backward-looking claims data. Initiatives such as IIGCC's PCRAM include participation from insurance stakeholders and is a potential platform for deeper cross-industry sharing.

→ **DFIs / MDBs:** Existing initiatives, such as the Global Emerging Markets Risk Database (GEMs), already enable anonymized credit default and recovery data sharing amongst DFIs and MDBs. This model could be expanded to include commercial banks, or be used as a platform for broader approach sharing on physical risk methodologies, including how resilience investments could be recognised in credit.

- **Academic and knowledge partners:** CISL could be a knowledge partner, given its work on physical risk and resilience in credit. Its Banking Environment Initiative convenes banks to co-produce applied research and industry collaboration, while its Centre for Sustainable Finance works with banks, insurers and investors on sustainable finance tools. The Earth Capital Nexus at the London School of Economics could also be engaged, given its focus on decision-useful analytics for climate- and nature-related risks.

- **A convening event, such as a Bellagio Center-style working session:** A structured working session could bring the above actors together with supervisors and academic researchers to accelerate convergence on which methodologies can be adapted for bank credit models.

Unlock 3 / Achieve regulatory clarity on physical risk models

Regulatory clarity addresses one side of the integration gap. Prudential regulation alone cannot resolve the underlying vulnerability of exposed borrowers. Corporate-facing policy, including resilience standards, fiscal incentives and codified adaptation taxonomies directed at borrowers, is a necessary complement that sits outside the scope of this paper.

Banks need clearer supervisory signals on how physical risks can be reflected in credit models. The Basel framework does not prohibit integration: risks and resilience benefits can, in principle, flow through existing credit channels such as PD, LGD, EAD and collateral value. The issue is that current expectations are stronger on governance and risk management than on methodology. Banks are expected to consider physical and environmental risks in credit processes, but they lack clarity on which approaches are acceptable, what evidence is required, and how resilience measures could affect capital treatment.

Regulatory clarity should be developed alongside the data and methodology work. Early engagement is more effective because supervisors can shape approaches before banks invest in methods that may later prove difficult to validate or approve. The outputs should also inform each other: data-gap analysis should guide methodology development, and methodology pilots should sharpen regulatory asks. The near-term output should be a shared industry position on regulatory asks related to model treatment and evidence thresholds supported by practical use cases from agriculture in Brazil and Europe.

STEP 1 / DEFINE INDUSTRY CONSENSUS ON SPECIFIC REGULATORY ASKS

Banks should avoid broad requests for guidance and instead align on a small number of concrete supervisory asks. These should include: what are the evidence thresholds needed for physical risk integration in risk overlays, collateral adjustments and approved IRB model changes; and how credible resilience measures can be recognised in credit assessment and capital treatment. Banks also need clarity on how to treat data that is incomplete.

STEP 2 / DEVELOP A SHARED INDUSTRY POSITION AND POTENTIAL ENGAGEMENT OPTIONS

This means outlining possible approaches for supervisory dialogue and producing a shared industry position statement. A well-prepared industry group with concrete asks is more likely to generate actionable supervisory guidance than a single-bank submission. Early regulatory engagement does not require a complete methodology, it requires a clear articulation of the problem and specific asks.

STEP 3 / USE LIVE REGULATORY WINDOWS IN BRAZIL AND EUROPE

In Brazil, the GRSAC implementation phase creates a window to clarify how social, environmental and climate risk information could support future credit model integration. The new format enters into force in January 2027 for S1 and S2 institutions and will require banks to report credit exposures by biome and disclose physical climate risks at portfolio level. Design decisions are being made now and engaging during implementation is likely to be effective.

In Europe, two binding EBA guidelines are now in active implementation. The EBA Guidelines on ESG Risk Management, in force from January 2026, require physical climate risks to be embedded into credit scoring, rating models and collateral valuation, where material. The complementary Guidelines on Environmental Scenario Analysis specify how IRB banks must incorporate physical risks into credit stress testing. Both are live obligations. The EBA is also simultaneously reviewing its credit risk rulebook and has signalled in its April 2026 response to the European Commission's competitiveness consultation that IRB model approval processes are being streamlined[108].

Partners needed

- **Banking federations and industry conveners:** In Brazil, Febraban holds both the institutional mandate and the direct channel to the BCB through the GRSAC implementation process and is the natural convener. In Europe, the Climate Financial Risk Forum (CFRF) is well-positioned to coordinate the industry's position in EBA and ECB engagement.

- **Supervisory and regulatory platforms:** The Network for Greening the Financial System (NGFS) should be engaged as a supervisory knowledge partner, given its central bank and supervisor membership and its work on nature-related financial risks and supervision.

- **International platforms:** The Institute of International Finance (IIF) and Green Finance Institute (GFI) hold the established relationships with supervisors needed to ensure the industry position reaches the right counterparts.

108. EBA Response to the European Commission's Targeted Consultation on the Competitiveness of the EU Banking Sector, 17 April 2026, pp. 23–24.

Conclusion

The partners exist, the regulatory moment is opening, and agriculture in Brazil and Europe provides a strong proof point to start.

The question is not whether that foundation will be built. It is who builds it, and on whose terms.

The gap this paper has documented has two dimensions. For many credit officers, loan originators and project evaluators, it remains a gap in awareness: physical climate and nature risks are still encountered as sustainability obligations rather than as factors that directly affect PD, LGD and debt service capacity. For institutions that have moved past that threshold, it is a gap between what banks increasingly know and what their credit processes currently reflect. Closing it requires borrower-level model integration that is granular, evidence-based and defensible within model governance, and that no single institution can deliver alone.

The commercial case for banks runs in both directions. Banks that measure physical risks more precisely can avoid misclassifying exposed borrowers, reduce unexpected provisions and preserve lending capacity in sectors where less prepared competitors may retreat. Those that can identify and measure credible resilience investments can also open new origination opportunities, develop differentiated products and support borrowers in reducing the risks that would otherwise weaken future credit quality.

For regulators, the risk of inaction is a financial system that carries physical risk exposures it cannot yet measure or capitalise against. Banks are already developing internal approaches, but without a common evidence base or clear supervisory signal on what constitutes acceptable practice. Physical risks that are not reflected in borrower-level assessment do not disappear; they accumulate in loan books, provisions and collateral valuations until they materialise as unexpected losses. Early regulatory engagement can shape a market that is already moving, rather than trying to correct one that has diverged. This report focuses on the regulatory and credit model pathway. It does not address the real-economy policy track needed to change borrower-level vulnerability directly.

For insurers and development finance institutions, collaboration creates value on both sides. Banks can learn from insurers' catastrophe and vulnerability modelling expertise, while insurers benefit from a larger evidence base on how physical risks and resilience measures affect firm-level performance and asset quality. DFIs / MDBs bring practical experience from emerging markets, where they have extended resilience financing to borrowers. They also lend to commercial banks, giving them a direct interest in helping banks improve physical risk management. Collaboration can happen without sharing proprietary data or methodology. It requires contributing to an anonymised evidence-building exercise with potential output for model validation.

The three unlocks create the conditions for borrower-level integration. But turning those conditions into changed credit decisions requires two things inside banks. Credit officers, loan originators and project evaluators must recognise physical risks as credit risks, not as an ESG layer added to the credit process. And risk management leaders must actively sponsor the agenda, allocating dedicated resources and embedding physical risk assessment in credit policy rather than leaving it to sustainability functions. The will to act collectively across banks, regulators and industry bodies is what determines whether the three unlocks deliver at the pace the moment requires.

Case study calculation notes

2.1.1 Soil degradation amplifies drought impact on Brazil agriculture – CISL / Robeco

The case is based on the CISL and Robeco farming archetype, which uses a normalised base case of 4.5% annual revenue growth from 2023 to 2031 and a 25.4% EBITDA margin from 2024 to 2031. The stress case provides different revenue growth and EBITDA margin pathways for farms on degraded land and farms on healthy soil.

The illustrative DSCR calculation uses the following simplifying assumptions. Pre-drought revenue is indexed to 100. The baseline DSCR is 1.375x. EBITDA is used as a proxy for cash flow available for debt service. Annual debt service is held constant at 18.47, calculated as baseline CFADS of 25.4 divided by the baseline DSCR of 1.375x. DSCR is calculated as:

1. BASELINE CASE, NO DROUGHT

Year	Revenue index	EBITDA margin	EBITDA / CFADS	Debt service	DSCR
Pre-drought	100.0	25.4%	25.4	18.47	1.375x
Year 1	104.5	25.4%	26.5	18.47	1.44x
Year 2	109.2	25.4%	27.7	18.47	1.50x
Year 3	114.1	25.4%	29.0	18.47	1.57x
Year 4	119.3	25.4%	30.3	18.47	1.64x

2. STRESS CASE: FARM ON DEGRADED LAND

Year	Revenue index	EBITDA margin	EBITDA / CFADS	Debt service	DSCR
Pre-drought	100.0	25.4%	25.4	18.47	1.375x
Year 1	60.0	-23.3%	-14.0	18.47	-
Year 2	84.0	32.4%	27.2	18.47	1.47x
Year 3	60.1	-5.0%	-3.0	18.47	-
Year 4	118.9	25.4%	30.2	18.47	1.64x

3. STRESS CASE: FARM ON HEALTHY SOIL					
Year	**Revenue index**	**EBITDA margin**	**EBITDA / CFADS**	**Debt service**	**DSCR**
Pre-drought	100.0	25.4%	25.4	18.47	1.375x
Year 1	90.0	18.1%	16.3	18.47	0.88x
Year 2	140.0	41.2%	57.7	18.47	3.12x
Year 3	114.1	25.4%	29.0	18.47	1.57x
Year 4	119.2	25.4%	30.3	18.47	1.64x

2.2.1 Irrigation system against water scarcity – Brazil coffee production

The baseline 50ha farm is assumed to produce 36 bags per hectare under rainfed conditions. After irrigation, production increases to 50 bags per hectare. Across 50 hectares, this creates an annual production uplift of 700 bags. At an assumed coffee price of USD 375 per bag, gross revenue increases from USD 675,000 to USD 937,500. Maintenance cost is assumed at 12% of capex, equal to USD 36,000 per year. This gives a net annual cash-flow benefit of USD 226,500.

The DSCR calculation uses the following additional assumptions. Baseline CFADS margin is 30%. Baseline DSCR is 1.375x, implying existing annual debt service of USD 147,300. Irrigation capex is assumed to be financed through five-year debt at a 10% interest rate, adding USD 79,100 of annual debt service. Total annual debt service after irrigation is therefore USD 226,400.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