




Re-WIRE

Agricultural Resilience:
From cost to investment opportunity

September 2026

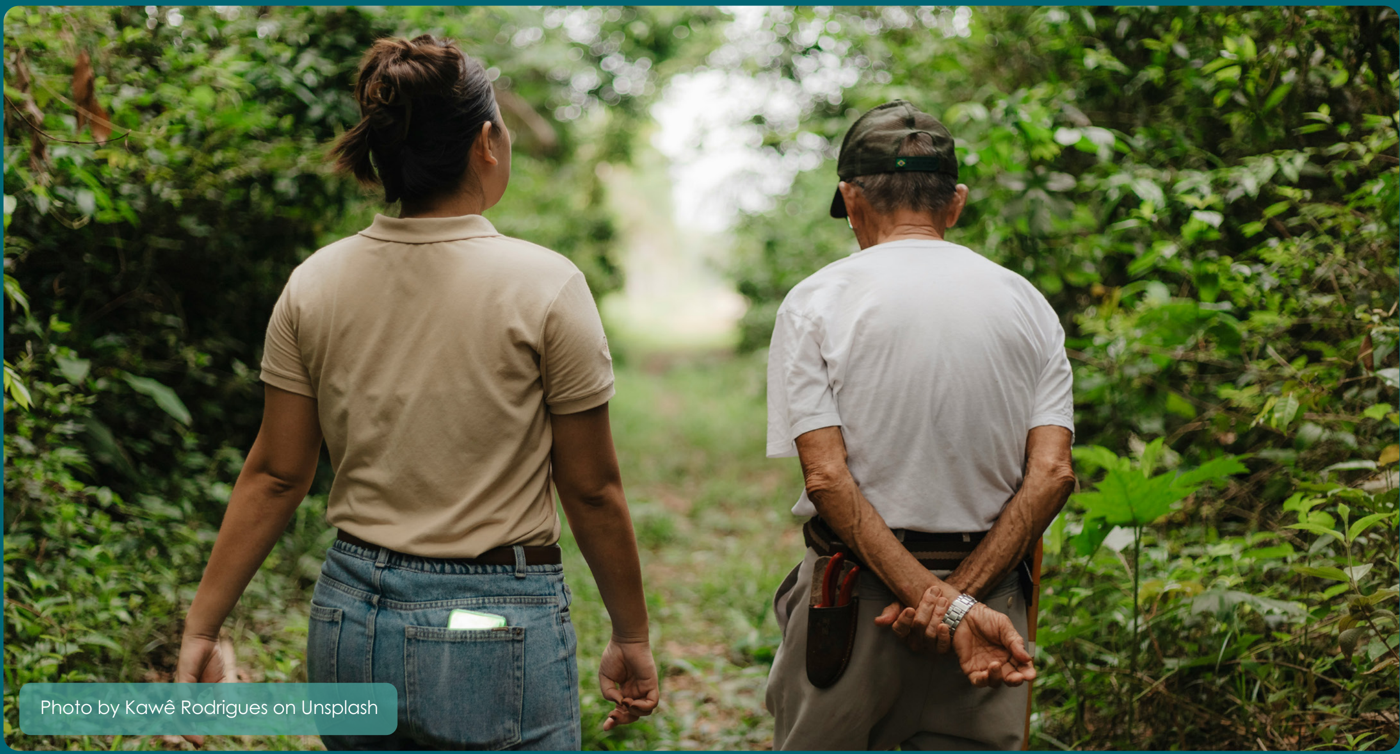
The Food and Land Use Coalition

in collaboration with:

World Business Council for Sustainable Development

SYSTEMIQ

Contents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About Re-WIRE

Re-WIRE is a programme of work delivered by the Food and Land Use Coalition (FOLU) in collaboration with Systemiq and the World Business Council for Sustainable Development (WBCSD), with support from the FOLU Brasil and FOLU China country platforms, to build a shared evidence base to guide investment in making agri-food value chains **R**egenerative, **E**quitable, **W**holesome, **I**nclusive, **R**esilient and **E**conomically viable. FOLU's country platforms enable engagement with business leaders and national policymakers responsible for agriculture, trade and fiscal planning. WBCSD brings a private-sector convening role to this partnership by gathering 50 private sector companies, helping surface the business needs, investment barriers and enabling conditions required to build a stronger case for investing in resilience across food and land use systems. Systemiq leads Re-WIRE's analytical and knowledge generation workstream.

Phase 1 (2025) developed a comprehensive index for agricultural value chains, applied to soy, beef, wheat and cocoa across eight producing countries and consulted 180+ leaders in business and civil society on the framework and its key findings for beef and soy. The first phase identified limited progress in transforming agrifood value chains despite significant and growing risks, alongside strong appetite amongst those consulted to deepen the climate risk analysis and strengthen the commercial case for investment. Phase 2 (2026), of which this paper is the first part, further explores physical risks and the returns to resilience for the world's main oilseed crops, soy, palm, rapeseed and sunflower, starting with the Brazil-China soy corridor. From 2027, Re-WIRE will extend this approach to further crops and geographies and turn the evidence into investable models.

About FOLU

The Food and Land Use Coalition (FOLU) is a global community of Country Platforms (Brazil, China, Colombia, Ethiopia, India, Indonesia, and Kenya), Partners and Ambassadors working to advance secure and resilient food and land use systems enabling people and the planet to prosper. Created in 2017, and guided by equity and sustainability, FOLU forges consensus through evidence-based and people-centred approaches that empower farmers, policymakers, businesses, investors and civil society to unlock collective action at scale.

Learn more at www.foodandlandusecoalition.org/
and follow us on LinkedIn.

About Systemiq

Systemiq is a systems change company that works with businesses, policymakers, investors and civil society organisations to reimagine and reshape the systems that sit at the heart of society - energy, nature and food, materials, built-environment, and finance - to accelerate the shift to a more sustainable and inclusive economy. Founded in 2016, Systemiq is a certified B Corp, and has offices in Brazil, France, Germany, Indonesia, Kenya, the Netherlands, and the UK.

Find out more at www.systemiq.earth or via LinkedIn.

About the World Business Council for Sustainable Development (WBCSD)

The World Business Council for Sustainable Development (WBCSD) is the leading community of around 230 global businesses making sustainability performance a key driver for competitiveness. Established in 1995, WBCSD is a non-profit member-led organization that connects business leaders through all sectors and major economies, and creates the tools and frameworks to scale collective impact, drive cross-sector innovation, and shape an ambitious, enabling policy agenda. We operate from seven offices worldwide — in Geneva, New York, Chicago, Amsterdam, London, Singapore and Wuhan — enabling collaboration across value chains and geographies. Together with our members, we are rewiring economic and financial systems to support the transition to a net-zero, nature-positive, and inclusive future that creates business value.

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Executive summary

As physical climate and nature impacts on agriculture worsen, standard corporate responses to risk management will face limits. Agri-food companies, farmers and governments are already paying for physical climate and nature impacts on agricultural supply chains. In 2021 and 2022, droughts across Brazil, Argentina and Paraguay cut soy production by over 18 million tonnes, a 9-10% decrease from a region that supplies over half the world's crop,[1] while a heat dome over Western Canada, the world's largest rapeseed producer, cut its rapeseed production by 35%.[2] In shocks like these, most companies respond by accepting higher raw material costs, diversifying sourcing regions, substituting raw materials, reformulating products, or passing costs on to consumers to preserve or expand margins. These are rational responses, but they do not build the resilience of farmland and landscapes to withstand shocks over the long term. Diversification and substitution work while risks are independent and modest, yet available evidence suggests these conditions will not last. The four major oilseed crops, soy, palm, rapeseed and sunflower, supply virtually all the world's edible oil, oilseed-based animal feed and oilseed-based biofuels. Production of three of these four crops is geographically concentrated, and the likelihood of simultaneous shocks is increasing. Simultaneous droughts in the US, Argentina and Brazil, which together produce around 80% of global soy, become 11-16 times more likely under long-term climate trends, and 4-15% more severe.[3] A flood or drought in any one of the US, Brazil or Argentina raises world soybean prices by 1.8 to 5.9%, because buyers shift to the unaffected producers. When all three are hit in the same year, prices rise by 9.5 to 33.2%, Chinese soybean imports fall by around a fifth, and the additional cost to Chinese consumers of soybeans and meat reaches up to 174 billion yuan.[4]

Investments in agricultural resilience could reduce yield losses, but are a fraction of what's needed. Such investments span in-season practice-level adaptations like precision nutrient management, medium-term farm investments such as no-till, and longer-term landscape interventions like watershed restoration (Exhibit 9). Unlike diversification and substitution, these interventions act to reduce crop exposure and vulnerability to climate and nature shocks. Whilst their benefits are expressed today in terms of increased yields, GHG mitigation or nature benefits, there is strong consensus amongst experts and practitioners on their potential to avoid yield losses under climate change and nature loss.[5] Economy-wide returns on adaptation investment in agriculture run at around 27%, but accrue to farmers, governments and whole economies rather than to the companies and lenders with a stake in resilient supply chains. Whilst many leading companies today invest in these measures under a rationale of building supply security, quantifying the return on investment remains a challenge, and investment has not scaled beyond a small group of sustainability leaders.[5] The result is a system that misallocates capital on a large scale: private finance has the capacity to provide around USD 630 billion annually to global food systems,[6] yet only around USD 19 billion is directed toward financing climate mitigation and adaptation.[7] This compares with an estimated combined public-private need of USD 1.1 trillion per year.[8]

Structural barriers and evidence gaps mean risks and returns in agriculture are systematically underestimated. Incentives to quantify the financial impact of physical climate and nature risks to agricultural supply are weak or non-existent. This has not to date been required by regulation, and low insurance penetration in agriculture has meant weak incentives for the (re)insurance sector to build out comprehensive models.[9, 10] Where agrifood companies, banks, insurers or investors seek to quantify the risks, three evidence gaps contribute to their underestimation. Incomplete hazard coverage, limited crop vulnerability data and an absence of financial metrics mean that decision-makers in companies do not see a problem large or near-term enough to act on. Companies relying on standard sectoral crop yield models do not see material yield losses for oilseed crops until the 2050s, far beyond their standard five-to-ten-year planning horizons. As a result, programmes that build agricultural resilience are treated as discretionary sustainability costs rather than as investments that reduce recurring, foreseeable losses under a rapidly changing climate.

Photo by Kawê Rodrigues on Unsplash

To correct their risk baseline and develop a return-on-investment case, agri-food companies, governments and investors need to use probabilistic risk-to-resilience modelling. Catastrophe risk modelling, a widely-used approach in the (re)insurance industry, can quantify the full range of possible losses, including events with no historical precedent, and generate financial metrics for a business case for resilience investment. The Annual Average Loss (what supply disruption costs in an average year) and Probable Maximum Loss (what it costs in a bad year at a defined probability) are established metrics in (re)insurance, risk capital markets and the built environment.[11] They allow investors to assess the return on resilience spending against the losses it avoids. A recent study published by the European Investment Bank and the European Commission applied this approach to European agriculture, and demonstrated that adverse weather already causes an estimated EUR 28 billion in annual average losses to EU crops and livestock. The findings have sharpened how European policymakers, regulators and insurers understand the scale of the exposure they carry.[9] Resilience interventions reduce crop vulnerability. Catastrophe risk models can quantify losses before and after resilience investments, isolating the avoided losses. Comparing the losses avoided against the cost of the intervention therefore gives a return on investment (Exhibit 6).

Better evidence alone is not enough: new investment models are needed to make resilience pay. The returns on agricultural resilience are hard for any single investor to capture. A company that co-funds producers across a sourcing region to adopt conservation tillage or improved irrigation lowers drought vulnerability for every buyer sourcing from that region. Lenders cannot price the benefit either, for different reasons. The benefit appears at landscape level, credit is repriced annually, and unfamiliar practices are underwritten as an added risk rather than a mitigant.[12] Without mechanisms that return part of the benefit to whoever funds it, better evidence could push companies and investors out of at-risk producing regions faster, rather than incentivise investment to build their resilience.

Three gaps must therefore be closed together. The first is evidence, meaning crop vulnerability thresholds, the effect of nature risks on yields, and data on how far interventions avoid losses. The second is return capture, the financing structures, offtake design and public instruments that return part of the benefit to whoever funds it. The third is capability, the skills and worked examples to build a credible ROI case. No single actor can close all three gaps. Because the underlying risk modelling should be a public good, progress depends on private, public and philanthropic partners working together from the outset.

The next Re-WIRE paper applies this approach to the Brazil-China soy corridor. Due January 2027, it will produce a first partial estimate of avoidable losses and return on investment, and a first view of who is best placed to invest and how returns can be captured and shared.

USD 630bn	USD 19bn	USD 1.1tn
Estimated annual private finance capacity for the global food system (2023)	Private sector climate finance flowing to agrifood systems annually (2021/22): roughly 20% of combined private and public flows	Annual climate finance needed for agrifood systems by 2030, roughly 12 times current levels (private and public combined)

1

Physical risks to oilseed crops are likely larger and more correlated than markets assume


Photo by Chamika Jayasri on Unsplash

Re-WIRE's 2026 work focuses on soy, palm, rapeseed and sunflower as a test case for quantifying the returns on resilience. These crops were selected for four reasons:

i. their deforestation exposure,

ii. their materiality and interconnectedness,

iii. their geographic concentration, and

iv. the large volume of existing capital already flowing through these value chains.

First, these crops sit at the heart of the world's most critical deforestation frontiers, which exacerbate physical risks. Soy and palm oil are directly linked to land-use change risks in Brazil, Indonesia, Malaysia and other high-priority landscapes. Deforestation removes a key buffer against climate volatility. Forest loss disrupts rainfall patterns, degrades local hydrology and destabilises soil, which undermines the climate resilience of agricultural production across entire regions.

Second, these four crops are material for human nutrition and animal feed. They underpin the majority of edible oils, oilseed-based animal feed and oilseed-based biofuels and are partially substitutable (Exhibit 1). Under normal conditions, that substitutability is a strength, as a shock to any single crop can be absorbed as buyers shift toward the others.

Exhibit 1

Four crops supply almost all of three major end-use categories

Oilseed crop	Share of global oilseed-based animal feed supply	Share of global edible oils supply	Share of oilseed-based biofuels
Soy	68%	27%	31%
Palm oil	4%	34%	49%
Rapeseed	11%	11%	19%
Sunflower	6%	13%	1%
Four crops combined	90% of global supply	85% of global supply	100% of global supply

Sources: USDA FAS (2025); FAO Food Balance Sheets.

Third, oilseed production is geographically concentrated and structurally interconnected, which exposes the system to correlated and compounding physical risks. The top three producing countries account for around 80% of soy, 86% of palm oil and 73% of sunflower production (Exhibit 2).

Exhibit 2

Production is highly concentrated for soy, palm oil and sunflower

Oilseed crop	Share of global production from top 3 producing countries / regions	Main producers
Soy	80%	Brazil • US • Argentina
Palm oil	86%	Indonesia • Malaysia • Thailand
Sunflower	73%	Russia • Ukraine • EU
Rapeseed	60%	Canada • EU • China

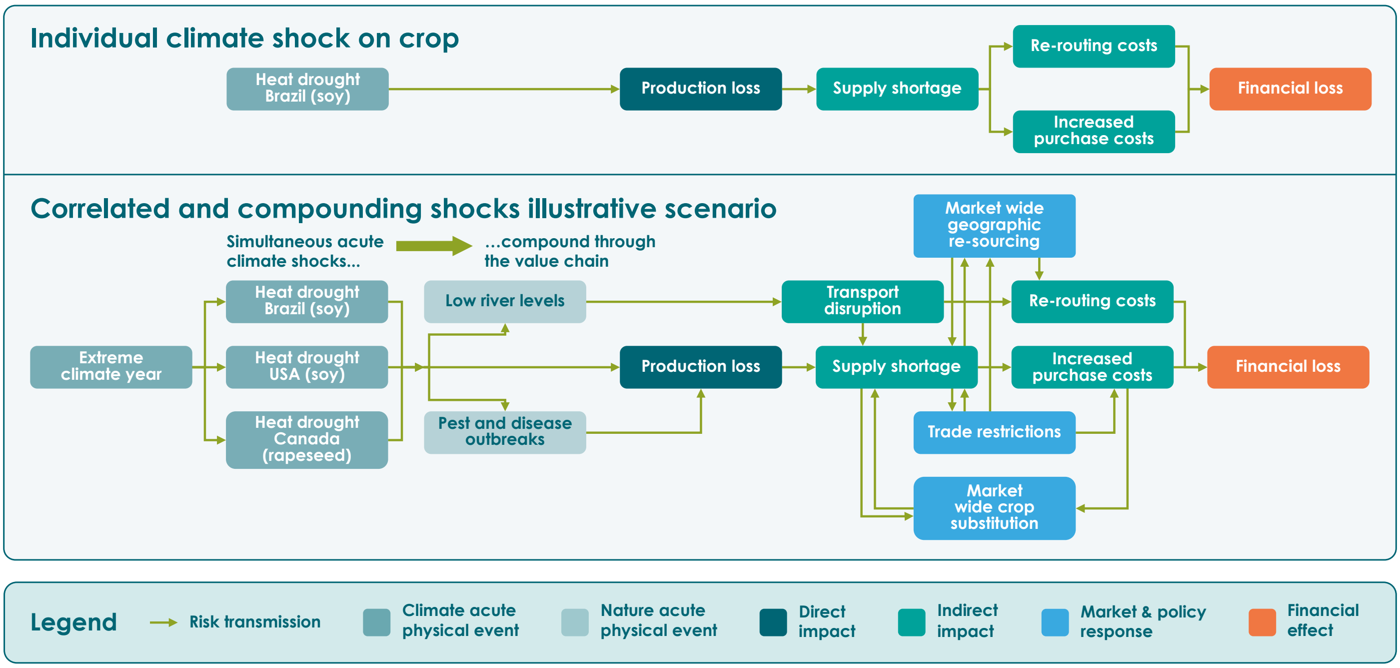
Sources: USDA FAS Oilseeds World Markets and Trade (2025); FAOStat.

Substitution offers a supply chain buffer if shocks are independent of one another, but as the climate changes, these shocks are more likely to happen simultaneously or within a short space of time. The same large-scale atmospheric circulation patterns influence weather systems across several major food-producing regions, significantly raising the probability of simultaneous events such as heatwaves or floods.[13] In 2012, for example, all three major soybean producing regions, US, Brazil and Argentina, were hit by drought and extreme heat in the same year. Global production fell by around 19 million tonnes, the largest annual decline recorded at that point. Buyers could not substitute from unaffected regions and prices reached all-time highs. Under future climate scenarios, long-term trends in mean climate are projected to make this type of simultaneous shock 11 to 16 times more frequent, and 4 to 15% more severe.[14]

Shocks can then compound through the supply chain, for example, acute climate events can amplify pest and disease pressure and disrupt transport and storage infrastructure. In Brazil in 2024, low river levels halted barge transport on key grain corridors, causing supply losses even where harvests had succeeded.[15] Trade policy responses can further compound risks. In 2022, surging global vegetable oil prices from the war in Ukraine led Indonesia to ban palm oil exports, closing off a key substitution channel for buyers already short on other oilseeds.[16] When substitution options narrow, competition for alternative sources drives up costs simultaneously across all oilseeds, spreading shortage and financial loss beyond the regions originally affected. Researchers simulated a 2012-type simultaneous compound shock scenario in US, Brazil, and Argentina and its impact on China, estimating that prices would rise by 9.5 to 33.2%, Chinese soybean imports would fall by around a fifth, and the added cost to Chinese consumers of soybeans and meat could reach as much as 174 billion yuan.[4] Exhibit 3 illustrates how correlated, simultaneous or consecutive shocks compound into losses greater than a single regional event would.

Exhibit 3

While a single regional shock may appear manageable, greater losses are revealed once correlated shocks and compounding impacts are accounted for



Source: FOLU Re-WIRE Analysis. The direct and indirect impacts shown here are sometimes referred to as first-order and second-order effects respectively in credit risk frameworks. The upper panel shows a single regional climate shock causing direct impacts in the form of production loss that lead to indirect impacts in the form of supply shortage and result in financial loss. The lower panel shows a correlated shock year: simultaneous heat droughts across multiple regions compound into direct and indirect impacts at each stage — pest outbreaks and transport disruption amplify production losses, trade restrictions close off substitution channels, and market-wide competition for alternative sources spreads costs and shortage across the entire oilseed system.

Fourth, the large volumes of capital already flowing through these value chains could be redirected towards investments in making agriculture resilient to climate and nature shocks. Analysis of financial flows in the soy Brazil value chain reported in the Food and Land Use Coalition 2025 report "Re-WIRE Agri-Food Value Chains"[17] revealed that USD billions in private sector finance flow each year through loans, forward contracts, bartering or input pre-purchase agreements, and could be made conditional upon more regenerative and deforestation-and-conversion-free (DCF) production. Meanwhile sustainability-linked credit from PRONAF (Brazil's National Program to Strengthen Family Farming) and PRONAMP (Brazil's National program to support medium-sized rural producers) is growing from a tiny base. Expanding the proportion of public and private finance which is conditional on practices that build agricultural resilience would support rural jobs and incomes, food security, agricultural innovation and infrastructure, while reducing exposure to imported fertiliser costs and trade disruptions.

Oilseeds therefore offer a pragmatic test case. They are vulnerable to risks, commercially material to nationally important food, feed and fuel markets, geopolitically significant, and already supported by extensive public and private capital. If the return on investment on upstream resilience can be demonstrated in this test case, oilseeds could become a template for other agricultural value chains.

2 Re-WIRE's aim: Correcting the risk baseline to unlock capital

Photo by Mapbox on Unsplash

To ‘re-capitalise the upstream’ and get investment flowing to support farm and landscape-level resilience, companies, governments and investors need to adjust their risk baseline and incorporate avoidable losses into their return calculations. For downstream companies, this may also require re-imagining their relationship with upstream suppliers. In a transactional model common to tradeable commodities like oilseeds, companies manage the risk of supply disruption through diversification and hedging. Interviews with corporates in oilseed value chains revealed a widely held assumption that existing approaches are sufficient to manage supply disruptions for the foreseeable future.[5] Current standard sectoral impact models project material yield losses for major oilseed crops only from the 2050s onward. A company managing against a five-to-ten-year horizon has limited reason, on this view, to treat upstream resilience as a near-term capital priority.

Re-WIRE’s hypothesis is that this assumption rests on a flawed foundation: a risk baseline that systematically undercounts the hazards and compounding effects that will impact these supply chains. If governments, investors and companies were to correct their risk baseline, supply disruptions would become a structural feature of the near-term outlook, not a future problem or an exceptional year. Under a corrected risk baseline, the cost of inaction is not a future liability, but becomes a recurring annual loss that is already being absorbed, whether or not it is valued.

The economy-wide returns on investment in climate adaptation in agriculture are high, at around 27%.[18, 19] But those societal returns are largely accruing to farmers, governments and whole economies through avoided losses and stabilised productivity rather than flowing directly to the food companies and lenders with a stake in more resilient supply. In globally traded commodities, the relationship between downstream companies and producers is transactional. The benefits of farm-level resilience for companies are, in theory, improved supply continuity and lower production costs, but without a long-term supply contract these benefits are absorbed by the broader market rather than captured by specific buyers. For individual companies, the return on upstream resilience investment is difficult to capture, predict, or value in advance. For instance, in consultations conducted for this paper, one major food company described how suppliers they had supported to implement regenerative practices maintained supply continuity during a regional drought in 2022 in Spain, while competitors were unable to source the product.[5] The return was supply continuity when competitors could not source, but it depended on a long-term supply contract and could not be predicted with current risk and return tools.

If climate- and nature-related disruptions recur frequently, an intervention that reduces their severity generates a return from recurring avoided cost that can be estimated with a standard payback calculation. It is the same logic that procurement and finance teams already apply to price movements due to other supply chain shocks. Re-WIRE’s aim is to build the evidence base for that calculation: what physical climate and nature risks cost value chain companies, governments and investors, and what resilience interventions would save, whilst acknowledging that evidence is not the sole limitation. Exhibit 4 illustrates how the financial decisions of key actors could change with improved risk and returns evidence.

Exhibit 4

How better risk and returns evidence could shift the investment logic for different actors

Actor	How financial decisions would change
Farmer / farmer organisation ***"It is really, really difficult to try and plan to change our crops or varieties to suit a weather we can't predict... it is becoming impossible to plan for increasingly extreme weather."*** — Rory Lay, livestock and arable farmer, Shropshire, UK, quoted in BBC News (2026)[20]	Better evidence of the returns from resilience practices widens adoption. Better evidence of climate and nature risks could make the income stability and co-investment offered by long-term offtake arrangements, agricultural insurance products and other alternative sourcing models more attractive to farmers, increasing the financial viability of investment in resilience practices and technologies. Farmers that have invested in resilience are better placed to meet offtake commitments when climate events hit. The same evidence could also generate more informed demand for insurance products that many farmers currently do not seek because they lack a clear picture of their own risk exposure.
Input and technology provider	The commercial case for climate-adaptive product lines strengthens when better risk data shows that resilience-enabling technologies reduce loss frequency and severity. R&D investment shifts accordingly, and risk-sharing programmes with growers and buyers become easier to structure.
Agricultural commodity trader, processor, manufacturer and retailer	Traders, processors, manufacturers and retailers move from reactive sourcing (diversifying suppliers, substituting raw materials, or reformulating products due to shocks) to planned investments in upstream resilience with a measurable return. This can be delivered through a variety of mechanisms depending on the appetite of companies to invest directly, use financial intermediaries, or design longer-term supply contracts to support investment.
Lender / development bank	Risk-differentiated lending terms become justifiable once loss data shows resilient farms and value chain companies carry lower climate- and nature-related default risk: preferential rates for resilient borrowers, resilience-linked loan conditions, and blended finance structures where public de-risking uses that same risk evidence to unlock private lending at scale.
(Re)insurer	Insurance penetration in agriculture is low in many countries.[9, 10] Where insurance coverage exists, inadequate risk data leads (re)insurers to underprice agricultural supply chain risks and correct sharply after major loss events, leaving companies to absorb costs or carry risk internally. Better risk data and models would support increased insurance coverage and allow more stable and accurate pricing: preferential premium products for resilient farms and companies with resilient sourcing practices, and resilience-linked parametric insurance products that reward risk reduction rather than correcting for it after a loss event. In many markets this would also generate new demand: companies and governments that can now see their risk exposure become informed insurance buyers, able to seek out coverage they previously had no basis to demand.
Government / policymaker	Better evidence of what resilience investment would save, and over what time horizon, strengthens subsidies as a tool to incentivise resilience investment. It makes the case for redirecting spending from reactive absorption of agricultural losses (e.g., rural credit defaults, disaster relief, insurance payouts) toward prevention: insurance subsidies conditional on resilience interventions, resilience-linked rural credit, and de-risking structures that draw in private capital.

Translating physical risk into financial metrics that enable investment decisions

Two financial metrics allow companies to quantify the financial risk they face and compute ROI[i] from resilience investments. The first is the **Annual Average Loss (AAL)**: what supply disruptions can cost on average this year and in future years. The second is the **Probable Maximum Loss (PML)**: the cost of extreme events at a defined level of probability, such as a drought with 1% or 5% annual probability. These metrics are well-established in the (re)insurance industry and wider risk capital markets, their regulators and standard rating agencies and in other sectors such as civil engineering — but not in agriculture.

Both AAL and PML are typically derived from natural catastrophe risk modelling, a methodology developed in the early 1990s after the unprecedented losses of Hurricane Andrew in 1992, which plunged the (re)insurance industry into crisis and revealed the fundamental inadequacy of pricing exposure to physical risks using historical data alone.[11] Despite the name, catastrophe risk models quantify the entire distribution of risk, from frequent, lower-severity events and the attritional losses they generate, through to rare, high-impact catastrophes.

Today's corporate climate and nature risk assessments in the agrifood sector are broadly where the (re) insurance industry was before the advent of catastrophe risk modelling. The agrifood sector commonly draws on climate models and sectoral impact models in its physical risk assessments, but these stop short of the probabilistic financial metrics needed to inform investment decisions. Exhibit 5 sets out this distinction, and how catastrophe risk modelling closes that gap.

i Return on Investment

Exhibit 5

Demystifying three different modelling approaches

Type of model	Description
Climate model	**Simulates the physical climate system to quantify future changes in climate variables and hazard frequency or intensity.** Traditional climate models project long-term, chronic changes in temperature, precipitation and seasonal patterns; acute event models simulate individual events such as floods, droughts or heatwaves. Both stop at the hazard level. ***Example:*** *Under a high-emissions scenario, the global climate models assessed by the Intergovernmental Panel on Climate Change (IPCC) project average temperatures in a producing region rising by 2 to 4°C by 2100, with shifts in seasonal rainfall. An acute event model might estimate that a drought of a severity previously expected once in 50 years becomes two to three times more frequent.*
Sectoral impact model	**Estimates the physical impacts of a hazard on a specific system, such as crops, forests or infrastructure.** For example, how much yield loss results from a drought of a given severity. These relationships are often expressed as damage or vulnerability functions, derived from process-based models, field experiments or statistical analysis. Some impact models also translate physical impacts into financial outcomes, such as reduced farm revenue, but typically only for one or a small number of specified hazard or climate scenarios. ***Example:*** *Under the FAO Stratified Societies scenario, irrigated rapeseed and mustard seed yields in Brazil are estimated to decline by 5% by 2050, from 1.84 t/ha in 2012 to 1.75 t/ha.*[21]
Catastrophe risk model	**Integrates climate and sectoral impact models to quantify the full probability distribution of physical and financial loss, from frequent, lower-severity events to rare extremes.** Rather than replaying historical events, it uses stochastic simulation, effectively generating many possible versions of what a year's losses could look like, to model the full range of plausible loss years, including events beyond the historical record. This produces decision-useful metrics, principally Annual Average Loss (AAL) and Probable Maximum Loss (PML), giving a common quantitative basis for pricing risk and allocating capital towards resilience investment. ***Example:*** *Across EU crop production, modelling of drought, frost, hail and excess rainfall estimates annual average losses of EUR 40 billion by 2050, while losses in a catastrophic year with a 2% annual probability could reach EUR 90 billion, under a business-as-usual emissions scenario.*[9]

Catastrophe risk modelling has not yet been applied systematically to agriculture, but a recent study published by the European Investment Bank and the European Commission illustrates its potential. Applying the methodology across the 27 countries of the EU, the report found that EU agriculture already faces an estimated EUR 28 billion in annual average losses to crop and livestock from adverse weather, and a catastrophic year (at 2% annual probability of occurring) estimate of EUR 60 billion. The report attributes much of this EUR 28 billion not to rare catastrophic years but to the steady accumulation of smaller, high-frequency weather events, finding that this pattern of frequent attritional losses is eroding farm margins and reserves across the bloc. The report also found that 70 to 80 percent of those losses are currently uninsured, falling on farmers and governments.[ii, 9] The study has already increased engagement and awareness among policymakers, regulators, insurers and farmers of the scale of the contingent liabilities[iii] and the size of the insurance protection gap. The same methodology applied across the agri-food sector could quantify the expected annual cost from supply disruption that companies, lenders and governments could use as the basis for a standard investment decision.

Three data layers are combined in a catastrophe risk model to generate AAL and PML figures. The first is **hazard**: the frequency, intensity and location of relevant shocks. The second is **exposure**: the value, volume, location, and attributes of assets, crops or supply flows at risk. The third is **vulnerability**: the relationship between a given hazard intensity, the exposure, and the resulting loss. Catastrophe risk modelling conventionally stops here, at quantifying risk.

Agricultural resilience interventions typically reduce the exposure and vulnerability functions, allowing a comparison between expected losses with no action, and avoided losses if resilience interventions are implemented. Re-WIRE proposes that companies and governments should compare these avoided losses against the cost and effectiveness of resilience interventions to estimate the return on investment, an approach we term **probabilistic risk-to-resilience modelling** (Exhibit 6).

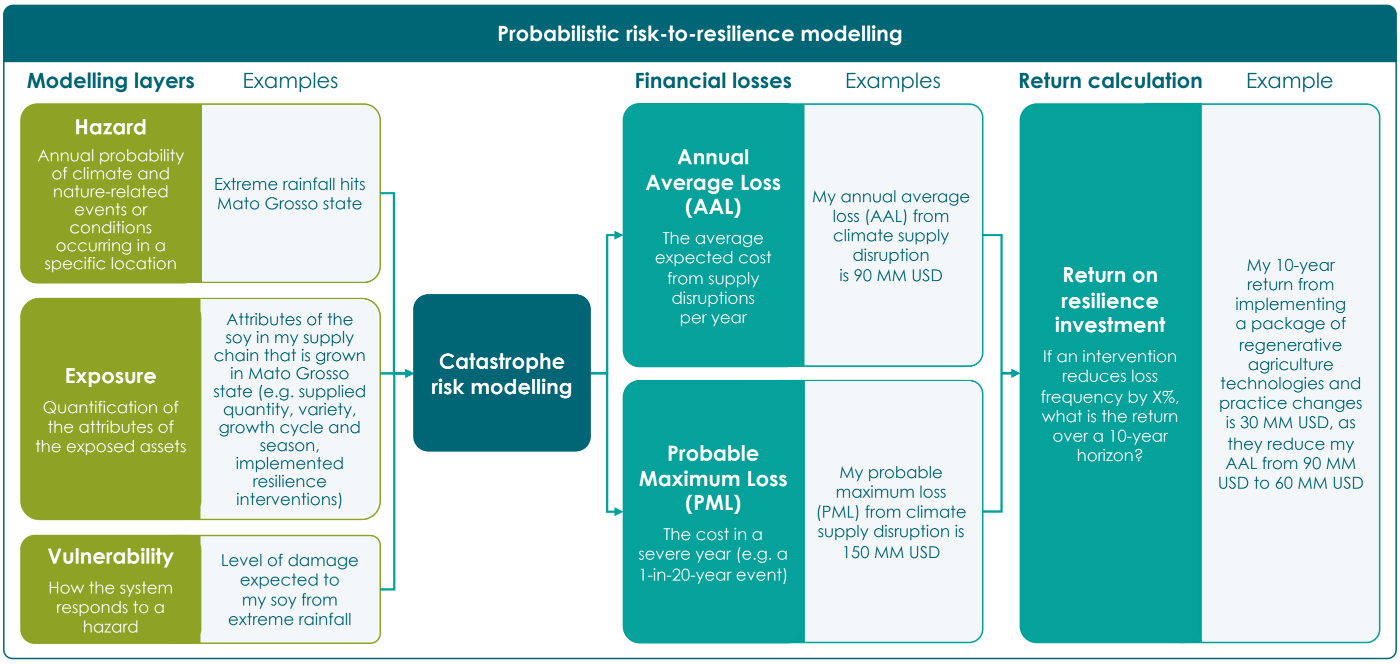
Photo by Ijaz Rafi on Unsplash

ii Where governments run rural credit programmes or agricultural support schemes, as in Brazil, uninsured climate losses flow through to public balance sheets via, for example, loan defaults and disaster relief. In producing countries with less developed agricultural finance systems, those losses fall directly on farmers and rural communities, with consequences for food security, rural incomes and long-term land productivity.

iii These contingent liabilities are the expected financial losses from climate-driven disruptions that have not yet been priced into corporate balance sheets and government accounts.

Exhibit 6

Probabilistic risk-to-resilience modelling combines the three layers of catastrophe risk modelling to generate loss and ROI estimates



Source: FOLU Re-WIRE Analysis. The examples given are fictitious and illustrative.

Probabilistic risk-to-resilience modelling unlocks a standard, calculable business case for resilience investment: expected losses avoided, priced the way any other cost-saving intervention would be. The remaining question is why this has not yet taken hold across agrifood.

3

Structural barriers and evidence gaps mean risks and returns in agriculture are systematically underestimated

This section considers two sets of reasons why physical risks, and the returns on investment in agricultural resilience, are systematically underestimated. First, structural barriers mean that few companies are incentivised to quantify risks, avoided losses and the returns on resilience investments. Second, even where they do, evidence gaps mean that widely used tools underestimate the true scale of risks and the true value of returns.

The first structural barrier is limited demand for risk quantification. Neither regulators nor investors have historically required companies to quantify and disclose physical climate and nature risk in financial terms. Even voluntary disclosure standards for climate and nature risk have not required a comprehensive quantification of the cost and frequency of risks to agricultural supply. One of the main reasons for this appears to have been the difficulty in carrying out such quantified risk assessments, as well as the lack of robust tools and practical guidance material.[22] Emerging standards are beginning to move further towards requiring quantitative assessments. The ISSB's IFRS S2[iv] requires companies to quantify the financial effect of material climate-related physical risks,[23] and the ISSB is now developing incremental nature-related disclosure requirements.[24] The EU's Corporate Sustainability Reporting Directive (CSRD) is pushing in the same direction. Together, these standards and regulations are increasing pressure on companies to demonstrate that they have assessed material physical risks, yet requirements for quantifying risks and financial effects do not specify standard methodologies and quantification itself can be phased in over time (under CSRD) or replaced with qualitative disclosure where it would involve undue cost or effort (IFRS S2). How much these standards and regulations will change approaches in agriculture depends on methodology guidance, how the requirements are interpreted in practice, and whether companies have the right tools available to quantify risks.

The second structural barrier is a lack of commercial incentive in developing risk quantification tools in agriculture. Catastrophe risk modelling has historically been built to serve the needs of the (re)insurance and wider risk capital markets sectors. In agriculture, where the majority of climate-related losses are uninsured or covered by government mechanisms, the (re)insurance industry has had limited commercial stake in accurately quantifying loss distributions and therefore limited incentive to develop the same modelling infrastructure that it has for the built environment.[25] The low priority given to physical risks in agriculture relative to other sectors is mentioned in the 2025 report by the United Nations Environment Programme Finance Initiative (UNEP FI),[12] which surveyed 32 banks across 5 regions and found that agriculture, forestry and fishing sectors attract the least physical risk attention from financial institutions, despite their high sensitivity to climate.

Three evidence gaps mean that even where companies seek to quantify supply risk in financially meaningful terms, available data and tools are likely to understate risks.

The first is incomplete hazard coverage. Re-WIRE's review of sectoral impact models that project yield changes under climate change found that many incorporate only a limited subset of relevant hazards (Exhibit 8). Most tools perform best for changes in temperature and precipitation, largely due to the availability of data, models and methodologies used by international organisations and academic groups such as the Intergovernmental Panel on Climate Change (IPCC) to project climate change scenarios. Some include drought or selected extreme weather indicators. Very few include a wider set of hazards. For example, most do not fully capture or predict excessive rainfall events.[26] Meanwhile nature-driven risks, such as pollinator loss, soil degradation, watershed disruption, pest and disease pressure, and deforestation-rainfall feedbacks all interact with climate stress to affect yields, but they are absent from standard hazard layers.[27, 28] Forthcoming disclosure standards will require companies to report nature-related risks alongside climate risks, but no combined methodology exists for agricultural supply chains. The UNEP FI report on Bridging Climate and Credit Risk also discusses how current risk assessment models fail to account for climate tipping points, which the authors conclude leads to the underestimation of physical risks, as well as the failure to account for the cascading nature of physical, social and financial impacts.[12]

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In Exhibit 7, we integrate climate and nature hazards into a single risk framework for agricultural production.

Exhibit 7

Against a comprehensive risk framework for agricultural production, sectoral impact models capture only a fraction of the hazards

Risk type	Risk character	Variable	Standard sectoral impact model	Advanced sectoral impact model	Evidence of relevance for oilseed crops
Climate Risks	Chronic changes	Temperature	Yes	Yes	Direct impacts on growth and yield
		Precipitation	Yes	Yes	Direct impacts on growth and yield
		Sea level rise	No	No	Potential for soil salinity increase
	Acute physical events	Cold wave/ freeze	Yes	Yes	Frost at critical growth stages can sharply reduce oilseed yields; 2024 Riverina field reports indicated 20–90% crop losses[29]
		Drought	Partially	Yes	Recurring driver of major soy losses in Brazil - 2021/22 drought in Rio Grande do Sul state cut expected soy production by ~52%[30]
		Heatwave	Partially	Yes	Heat stress during sensitive growth periods e.g. flowering, severely impacts yield
		Extreme precipitation	Partially	Yes	Extreme rainfall can cause waterlogging, reducing soybean yields by up to 80%[31]
		Fluvial flooding	No	No	2025 flooding along Arkansas river basins generated an estimated USD 9.68 million in soybean replanting costs[32]
		Coastal flooding	No	No	A modelled 3-meter storm surge would inundate 48.7% of soybean fields across three coastal counties in North Carolina[33]
		Storms/ cyclones/ tornados	No	No	Hurricane Fiona destroyed 90% of crops in Puerto Rico[34]
		Hail	No	No	Severe hail-induced defoliation can reduce soybean yield by up to 75%, depending on crop growth stage and defoliation severity[35]
Nature Risks	Chronic changes in natural capital	Pest/disease increase	No	No	Potential of increase in certain pests/diseases depending on temperature and moisture conditions
		Pollinator decrease	No	No	Pollinator decline could put ~12% of agricultural output at risk[27]
		Soil degradation	No	No	Amplifies drought impact; salinisation can collapse yield
		Hydrological disruption from deforestation	No	No	Soy & maize lost >USD 1 billion to deforestation-driven rainfall change (2006–19); risks an irreversible tipping point[36]
		Water quality decrease	No	No	Irrigation-water quality decrease, at 5.0 dS/m salinity, can reduce soybean yield potential by 50%[37]
		Water scarcity/ Groundwater depletion	No	No	Water overuse may mean 30-40% of demand for crop irrigation cannot be met for 2025-40 in the MATOPIBA-Brazil region[38]
	Acute nature-related events	Pest/disease outbreak	No	No	Extreme heat and drought can increase outbreak risk in soy, including charcoal rot, nematodes and spider mites
		Wildfires	No	No	Self-reinforcing fire-drought loop disrupts the rainfall patterns that sustain soy production (e.g. Brazil's record 2024 Amazon fires)[39]
		Landslide	No	No	Landslides can locally damage crops and disrupt transport links

Source: FOLU Re-WIRE Analysis, considering standard sectoral impact models such as FAO 2018 - Food and agriculture projections to 2050,[21] and an advanced sectoral impact model informed by the Climate Resilience Platform, an open-source tool for adaptation of climate change developed by the Alliance of Bioversity-CIAT.[40]

The second gap is limited vulnerability data. Vulnerability refers to how much yield loss occurs at a given hazard intensity in a particular location. Understanding crop response to compound stressors, such as drought coinciding with heat at a critical growth stage, or pest pressure interacting with water stress, remains an open research question. In addition, crop responses are non-linear; beyond certain stress thresholds, yields can collapse rather than decline proportionally. Current models also underestimate negative yield impacts more broadly because they do not adequately represent the full range of stress mechanisms that compound conditions create.[41] Closing this gap requires investment in agronomic research that does not yet exist at sufficient scale. Beyond crop-specific responses, vulnerability is shaped by conditions at the farm level that value chain actors can influence. Whether a field is irrigated, how rich the soil is in organic matter, and the variety and timing of planting all affect how much yield loss a given hazard produces.

Exhibit 8 summarises our working assessment of the first two gaps across the three layers of catastrophe risk modelling. The ratings reflect the state of tools broadly available, not the frontier of what is technically possible and might be used by progressive companies.

Exhibit 8

Risk data is weak for key hazards likely to become more frequent, and vulnerability data lags across almost all of them

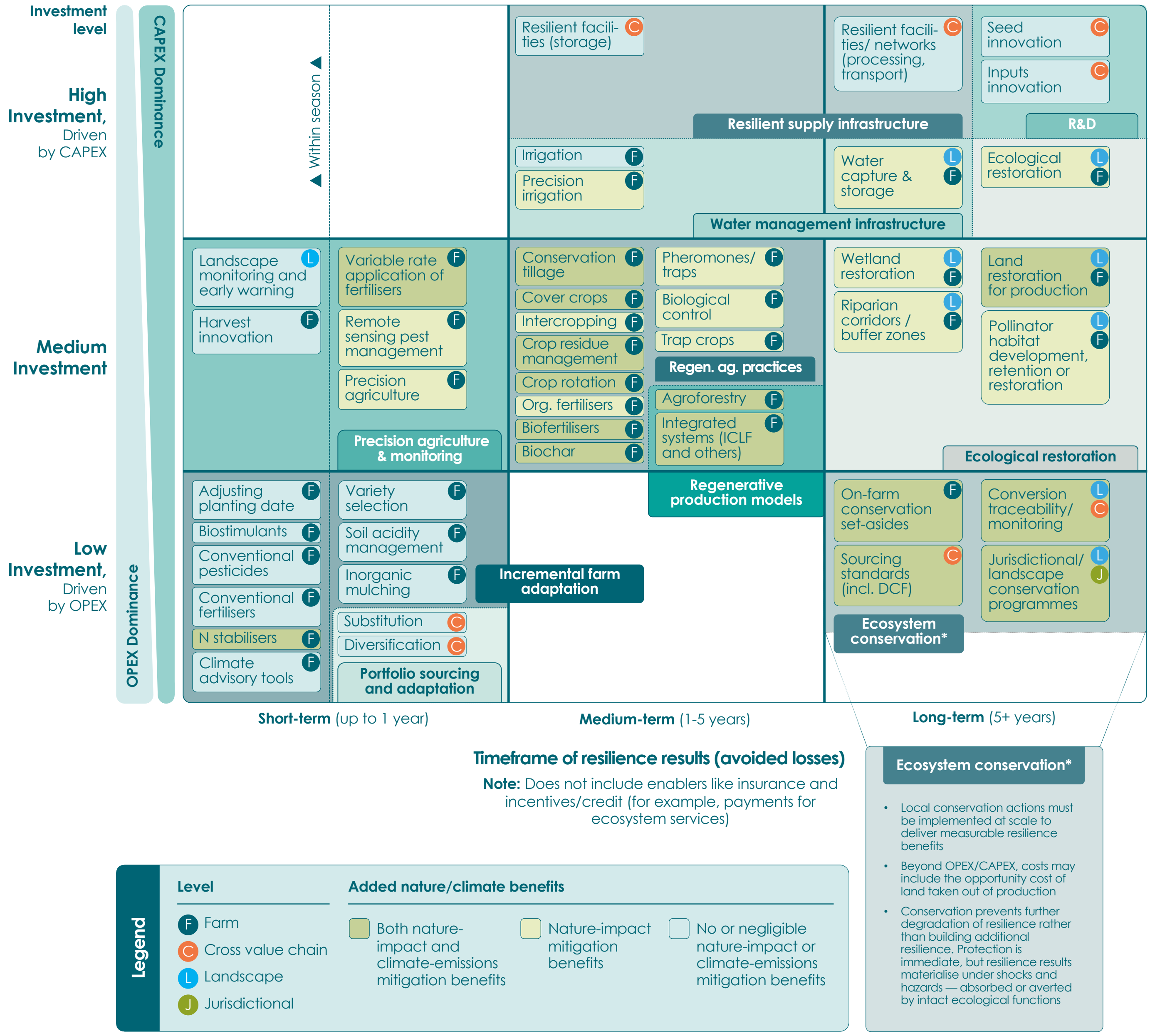
Hazard		Exposure		Vulnerability	
Changes in temperature and precipitation	Strong	Crop area and location	Strong	Crop response functions	Moderate
Frost	Moderate	Production volumes	Strong	Soil and water modifiers	Weak
Extreme rainfall	Weak	Commodity values	Moderate	Farm management data	Weak
Compound events	Weak	Sub-national data	Moderate	Loss and avoided-loss data	Weak
Pests and diseases	Weak	Data interoperability	Weak	Interventions' avoided losses	Weak
Hydrological disruption from deforestation	Weak	Watershed-level data	Weak	Deforestation-rainfall link	Weak

Assessment based on Re-WIRE analysis and published literature on crop model limitations.[14, 26, 27] Strong = well-represented in standard tools; Moderate = available but incomplete; Weak = significant gaps.

The third evidence gap is that most tools do not produce financial metrics. Average yield projections do not produce the probabilistic loss estimates, supply shock frequency distributions and Annual Average Loss figures that would allow companies to understand what climate-driven supply disruptions are likely to cost them in any given year. As a result, those liabilities go unrecognised on corporate balance sheets and in government accounts. The returns side of the equation is equally thin in that data on how much specific resilience interventions reduce loss frequency and severity is largely absent. Available evidence on farm and landscape resilience interventions, covering practices from soil and water management to watershed and habitat restoration, focuses mainly on carbon and nature benefits rather than avoided supply losses. Without evidence of both quantified contingent liabilities and quantified intervention returns, companies cannot estimate whether a given resilience investment reduces risk enough to justify its cost. Exhibit 9 maps farm-, supply-chain-, landscape-, and jurisdictional-level interventions that may build upstream system resilience.

Exhibit 9

System resilience-building interventions can be clustered into archetypes, ranging from low to high CAPEX, and short- to long-term resilience benefits



Source: FOLU Re-WIRE Analysis. The effectiveness, cost and resilience returns of each intervention depend on local soil, climate, ecosystem and management conditions, and on the knowledge farmers hold about what has and has not worked on their land. Farm-level interventions generally have more direct and attributable links to production outcomes, while landscape-level interventions generate shared benefits across multiple farms, communities and supply-chain actors, making attribution and investment coordination more complex. Context-specific investments are needed at both farm and landscape levels to effectively mitigate supply-chain risks. The exhibit is not intended to include enablers like insurance and incentives/credit (for example, payments for ecosystem services) which are essential to implement the interventions listed.

While these evidence gaps exist, the pursuit of perfection should not hinder progress. Building the evidence base for nature-risk quantification or crop vulnerability thresholds works on multi-year academic timeframes and is not yet coordinated around a shared, applied purpose. Companies, banks and governments should not wait for perfect evidence before building the demand and capability to use it. The study by the European Investment Bank and European Commission referenced in Section 2 shows that such analysis can advance progress based on available data today.

4 Better evidence alone is not enough: new investment models are needed to make resilience pay

Addressing the structural barriers and closing data gaps described above would allow companies, investors and governments to calculate a return on investment from specific resilience interventions and build a standard business case for action. However, a structural challenge remains. Individual downstream companies have perhaps the biggest stake in resilient supply yet lack reliable mechanisms to capture the returns on farm-level resilience investment. Consider a company that funds producers in a landscape to implement practices such as conservation tillage, cover cropping and improved irrigation. This reduces drought vulnerability across a producing region, but the benefit flows to all buyers sourcing from that region. With supply contracts for oilseed crops rarely exceeding 18 months, returns from farm-level investment (e.g. improved supply continuity and avoided procurement cost) accrue to the open market rather than to the company that paid for the interventions. Furthermore, farm-level practices deliver most value when adopted widely across a landscape. Limited adoption therefore also caps returns as farm-level resilience depends on the resilience of the surrounding system.

Investors and lenders face a related but distinct problem. A bank benefits when a borrower's resilience investment lowers the probability of future crop failure, so in principle it should price credit accordingly. In practice, it usually cannot. The benefit shows up mostly at landscape level, contingent on adoption by neighbouring farms in which the lender has no stake, so the risk reduction attributable to any single loan is small and hard to isolate. Agricultural credit is also typically written and repriced annually, on cycles too short to capture a resilience investment's multi-year payback. Lenders default to underwriting on current, conventional risk categories, which often treat unfamiliar practices as an added risk rather than a mitigant. What value chain companies can provide that investors cannot is a way to convert that diffuse, multi-year benefit into a specific, near-term, contracted cash flow. A long-term offtake commitment gives a lender a defined repayment stream to lend against, in place of a probability of reduced risk that may or may not materialise for that farm, in that season. Without a value chain company underwriting the demand side in this way, investors are financing the same return that companies are trying, and failing, to capture on their own — real at the system level, but not attributable, contractible or recoverable by any single actor.

While not yet mainstream, emerging models show promise in addressing these challenges. The use of financial intermediaries, public and philanthropic de-risking, insurance products, multi-buyer co-investment programmes, longer-term offtake contracts and cross-supply chain data-sharing mechanisms have all enabled the returns on resilience to be captured by governments, investors or downstream companies.

When buyers, producers and financiers invest in the same production system at scale, individual efforts stack, overall system resilience rises, and each actor draws a return from that shared resilience. Enabling mechanisms such as insurance, sourcing standards, incentives and credit are critical to overcoming coordination and risk-sharing barriers and driving collective investment at scale. Governments in both producing and importing markets can accelerate this by strengthening traceability, investing in public data to correct risk baselines, and aligning policy signals and public finance to de-risk private sector investment. Without these enablers, better evidence risks driving commercially rational but systemically damaging responses. For example, companies may diversify and relocate sourcing away from at-risk producing regions faster, rather than invest in strengthening their resilience in place.

This point has important implications for how the probabilistic risk-to-resilience modelling and quantification proposed in this paper should be developed and funded. The objective is not simply to produce better risk information, but to translate that information into system resilience investment. That requires private, public and philanthropic partners from the outset to fund the scale and public-good nature of the underlying risk modelling, and to build the governance structures and financing mechanisms through which a shared risk baseline becomes common ground for coordinated investment.

5 Conclusions and next steps

Re-WIRE argues that agricultural resilience remains underfunded because physical climate and nature risks, and the returns from reducing them, are not yet translated into the financial metrics that shape capital allocation. This paper finds that risks in oilseed value chains are likely larger, more correlated and more imminent than current baselines suggest, and that probabilistic risk-to-resilience modelling can help quantify expected losses, severe-loss scenarios and the value of resilience interventions.

But better modelling alone will not move capital at scale. Progress depends on closing three distinct but interdependent gaps: **evidence**, to quantify risk and avoided losses credibly; **return capture**, so that actors investing in resilience can capture sufficient financial value; and **capability**, so that governments, companies and financial institutions can incorporate these insights into real investment decisions.

Re-WIRE's foundational approach is that the system should not wait for perfect evidence before building the demand and capability to use it. Using the best available evidence, Re-WIRE aims to demonstrate the financial value of resilience today, while identifying the scientific, modelling and market gaps that most constrain investment and helping partners close them over time.

Photo by Ataberk Güler on Unsplash

Evidence

The evidence needed to price agricultural climate and nature risk, and the returns from resilience investment, does not yet exist as a sufficiently complete or shared asset. Catastrophe risk modelling provides a proven architecture for translating physical risk into financial metrics. It combines three layers: the hazards that may occur, the assets or production exposed to them, and the vulnerability of those assets to different levels of stress. In agriculture, however, important gaps remain within those underlying layers. These include crop vulnerability thresholds, the impacts of nature and soil degradation on yields, compound and correlated hazards, and evidence of how far specific resilience interventions reduce losses. As a result, even where modelling capability exists, the underlying evidence is often too incomplete to generate robust estimates of expected losses and avoided losses. Closing these gaps will require coordinated investment in scientific research, data infrastructure and modelling. Re-WIRE aims to identify the evidence gaps most material to financial decision-making, demonstrate how available data can already be translated into risk-and-return metrics, and help shape future research and modelling around the needs of capital providers.

Return capture

Better evidence is necessary but not sufficient. In many agricultural value chains, the actors paying for resilience do not reliably capture the financial benefits they create. A buyer may invest in more resilient production, for example, but the resulting improvements in supply continuity can accrue to other buyers or to the wider market. Investment therefore requires mechanisms that allocate costs, risks and returns between farmers, buyers, lenders, insurers and governments. These may include longer-term offtake arrangements, resilience-linked credit, guarantees, blended finance, insurance products, public incentives and pre-competitive co-investment. Re-WIRE aims to identify the financing and commercial archetypes best suited to specific crops and geographies, and test how better risk-and-return evidence can strengthen their economics.

Capability

Even where evidence and financing mechanisms exist, many decision-makers lack the tools, incentives and experience to translate them into investment decisions. Procurement teams, lenders, governments and companies need to understand how physical risk affects future losses, how resilience changes that exposure, and how these effects can be incorporated into standard ROI, credit and capital-allocation processes. This is a translation and capability gap, not simply a data gap. Re-WIRE aims to develop worked examples, ROI cases and practical decision frameworks that demonstrate how avoided losses and resilience benefits can be incorporated into financial decisions, while building demand among the institutions capable of moving capital at scale.

The next Re-WIRE paper will illustrate these three gaps further with a worked case: Brazil-China soy. Due January 2027, it aims to produce a first partial estimate of avoidable losses and ROI on available data, and a first view of who is best placed to invest and how returns can be captured and shared.

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